FAO SOILS BULLETIN

27

organic materials as fertilizers

FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS ROME

FOREWORD

FAO wishes to thank all participants in this Expert Consultation on Organic Materials as Fertilizers for their expert contributions and support and in particular the Swedish International Development Authority (SIDA) which has provided generous financial assistance for its organization.

Over the past two decades FAO has increasingly assisted its member countries in the improvement of soil fertility. Emphasis has been placed on the use of mineral fertilizers because they have been found to produce quick and positive results. On the other hand it is known that optimum results in yield and soil fertility can be obtained by using balanced proportions of inorganic and organic fertilizers. Yet, within recent years interest in the use of organic materials in agriculture has lagged, even in countries with a long tradition of organic manuring, largely due to the relative ease of handling and applying mineral fertilizers.

A new and serious situation has now developed. Mineral fertilizers are in short supply, with a threefold increase in price within a period of about two years. This has placed mineral fertilizers out of reach of the farmers in a large number of developing countries and at a time when there is an ever increasing need to step up food production.

Under these circumstances developing countries in particular are aware that it is now urgent to take a hard look at the resources of organic materials available to them and the processes of organic decomposition taking place under traditional systems of agriculture, which could be mobilized as sources of organic fertilization.

During 1974, resolutions have been put forward at the Session of the FAO Committee on Agriculture, the Commission on Fertilizers, the FAO Council and recently at the World Food Conference endorsing initiatives in the better use of organic materials as fertilizers as a promising means of increasing soil fertility and food production.

In the framework of FAO's mandate the main purpose of this Consultation has been to compile as much information as possible on the use of organic materials as fertilizers and to make recommendations for follow-up activities at the international and national level in the field of practical application, research and extension.

The consultation has received technical contributions from leading experts in the subject matter from 15 countries, and it is hoped that the outcome will have a far reaching and useful impact. It should also serve as a starting point for sound and balanced developments for the improvement and maintenance of soil fertility.

Edouard Saouma
Director
Land and Water Development Division

CONTENTS

I. INTRODUCTION

The FAO/SIDA Expert Consultation on Organic Materials as Fertilizers was held in Rome from 2 to 6 December 1974.

The Consultation recommends that FAO conveys to the Swedish International Development Authority (SIDA) the recognition and gratitude of the participants for naving made possible, through their contributions, the organization and success of the Consultation.

In order to simplify the presentation of this report the Conclusions and Recommendations of each of the four Working Groups will be presented as:

A. Report of the Working Group on Research Aspects

B. Report of the Working Group on Practical Aspects

C. Report of the Working Group on Training and Extension

D. Report to the Chairman: Nitrogen Fixation by Legumes

II. REPORTS OF THE WORKING GROUPS - THEIR CONCLUSIONS AND RECOMMENDATIONS

A. REPORT OF THE WORKING GROUP ON RESEARCH ASPECTS

1. CONCLUSIONS

The necessity to increase world food production to feed the rapidly expanding population calls for an integrated approach by governments and international agencies. The world comprises a system of interacting socio-ecological regions and the problem of world food production can only be solved by intensive cooperation among these regions.

Therefore, scientists engaged in applied and fundamental research in agriculture must cooperate together and work as a team in solving problems. The present problem is the use of organic materials as fertilizers, motivated by the high price and shortage of inorganic fertilizers, but scientists must keep in mind the overall needs for research in order to find solutions to the problems that will face world agriculture now and in the future.

The plant is the basis for food production, but plant production is, and will remain, dependent on the soil. The production of food from the soil is regulated by man, and thus it follows that the interactions between the inorganic and organic constituents in the soil as well as the interactions of these two with applied mineral fertilizers must also become as much as possible susceptible to regulation by man. The production potential of soils can be increased further by adding various organic wastes of man and animals.

2. RECOMMENDATIONS

The following recommendations are differentiated between short term and long term research. Short term research should be sponsored mainly by FAO, and long term research by national Governments in cooperation with international and other agencies.

Local legislation for the collection and utilization of organic materials should be drafted with reference to the results of research to be carried out in the areas designated, especially for long term research.

2.1 Short Term Research

In order to obtain fruitful results for the extensive use of organic materials as fertilizers within 3 to 4 years, short term research should be carried out on the following problems:

2.1.1. Economics of the use of mineral fertilizers in combination with various dosages of organic materials from rural and city waste, including studies leading to efficient methods for producing bio-gas as a by-product (see Guideline 3.1.1).

2.1.2 Management of harvest residues and green manures in relation to cropping patterns and systems (see Guideline 3.1.2).

2.1.3 Nitrogen fixation (see Guideline 3.1.3).

2.1.4 Efficient methods of production of compost with the correct properties from different sources of organic material (see Guideline 3.1.4).

2.1.5 Recycling of plant nutrients in soils from different sources of organic materials, especially as related to the balance of nitrogen and phosphorus (see Guideline 3.1.5).

2.1.6 Safe handling, storage and application of animal, human and other organic wastes (see Guideline 3.1.6).

2.1.7 The socio-economic implications involved in the results of research (see Guideline 3.1.7).

2.1.8 The environmental implications resulting from the results of research (see Guideline 3.1.8).

2.2 Long Term Research

2.2.1 The characterization of soil organic matter and its dynamics in relation to soil productivity.

2.2.2 The long term effect of soil organic matter on the yield potential of soils, especially in sub-tropical and tropical climates.

2.2.3 The selection of naturally occurring, and the breeding of new legumes which can fix nitrogen efficiently and quickly for use as food and animal fodder.

2.2.4 The possibilities of finding organic industrial waste products which may be used as a base for slow releasing N-fertilizers and for other agricultural and industrial purposes.

2.2.5 The effects of constituents of soil organic matter on plant production.

2.2.6 The evolvement of new varieties of plants to improve soil organic matter status and utilization of mineral nutrients.

2.2.7 The evolvement of very quick growing trees and shrubs to supplement and conserve other resources of organic materials currently used as fuel, shelter and other purposes.

2.2.8 The association between trees and crops.

3. GUIDELINES FOR RESEARCH

3.1 Short Term

3.1.1 Regarding 2.1.1 above:

3.1.1.1 Compatibility of different wastes on different soils to obtain data for the possibilities of land disposal.

3.1.1.2 The toxic constituents of wastes to be considered are:

(a) heavy metals

(b) additives to animal feeds

(c) polycyclic aromatics

(d) others

for decisions as to their suitability for use in agriculture.

3.1.2 Management of harvest residues and green manures as related to cropping systems.

3.1.2.1 Comparisons between intercropping and mono cropping systems with a view to improvement of soil fertility and conservation.

3.1.2.2 Studies on the management of harvest residues in relation to soil tillage. Comparisons of zero/minimum tillage with mulch versus ploughing and incorporation of vegetative matter in the soil.

3.1.2.3 Possibilities of combining fodder and green manuring.

3.1.2.4 Assessment of the economics of mineral fertilization in combination with crop rotation with legumes, especially pulses and fodder legumes.

3.1.2.5 Studies on the economics of mineral fertilization in combination with green manure.

3.1.3 Nitrogen fixation

Because the basic technology for utilization of the nitrogen fixing systems is best developed for the legume system, short term research objectives are confined to this system. Four major areas of research are identified.

3.1.3.1 The development of suitable inoculant strains. Some progress can be made using imported prepared inoculants or inoculants made with bacterial strains suitable to the legume species to be used, on the basis of experience elsewhere. However, experience in the developed countries forecasts the need for host-cultivar/bacterial strain screening if maximum utilization of this technology is to be achieved. Further selection of strains on the basis of the effects of local soil environments will also be necessary.

3.1.3.2 Establishment of inoculation requirements in the regions. The delineation of areas within the region in which inoculation is required to ensure nodulation, or to maximize nitrogen fixation by the various legumes to be utilized, is seen as an important regional research responsibility.

3.1.3.3 Inoculation methods. The adaptation of existing inoculation techniques, or the development of new ones suited to regional or local needs is a further important research activity. It may be necessary to pay special attention to particular problems related to persistence of the rhizobia in soils under the rigorous conditions of the tropics.

3.1.3.4 Other factors influencing nodulation. Interactions between nodulation and nitrogen fixation in specific management systems involving various soil conditions and fertilizer practices (N.P.K. and minor elements) will need to be studied locally.

3.1.4 Studies on the efficient methods of production of compost with optimum properties from different sources of organic material.

3.1.5 Studies on the recycling of plant nutrients in soils from different resources of organic materials, especially in connection with the balance of nitrogen and phosphorus.

3.1.5.1 Extensive research work should be carried out on the nitrogen transformations in soils including biological nitrogen fixation, nitrogen in precipitation, mineralization, nitrification, denitrification, fixation in organic matter and clay minerals, resulting after addition of different organic materials. These investigations should include use of nitrogen-15 (N-balance).

3.1.5.2 The turn-over of phosphorus should follow including transformation in available form, and fixation by formation of insoluble salts after addition of organic material.

3.1.5.3 The recycling of other nutrients such as potassium, calcium, magnesium and minor elements should be favoured in special cases.

3.1.6 Studies on the safe handling, storage and application of animal, human and other organic wastes.

3.1.6.1 Determine the most effective methods of handling, storage and application of waste; (1) to avoid hazards from pathogenic organisms, toxic substances to man and animals and permanent damage to land for food production; (2) to retain maximum nutrient content; (3) and at lowest cost in land utilization.

3.1.7 Social and economic implications

3.1.7.1 In the use of organic materials as fertilizers specific local economic and social constraints on agricultural development must be identified. This requires close contact between research bodies and farmers, directly and through the agricultural extension services.

3.1.7.2 The acceptability to farmers of different practices must be assessed in the light of the economic and social pressures bearing on their decisions. Particular attention must be paid to labour requirements of alternative practices.

3.1.7.3 The likely impact of possible solutions on society and the economy must be assessed. Technically feasible alternatives should be subjected to social-cost-benefit analysis to determine socially optimal investment patterns.

3.1.8 Impact on the environment

3.1.8.1 The avoidance in handling, storage and application of human and other organic waste of a deterioration in the quality of the air, water and soil environment.

3.2.2 Long term effect of soil organic matter on yield potential of soils, especially in sub-tropical and tropical climatic conditions.

Similar experiments as mentioned in 3.2.1

3.2.3 To select natural occurring and to breed new legumes which can fix nitrogen very efficiently and very quickly as food and feedstuff. Breeding of new legumes. Relatively few of the legumes occurring naturally are utilized in agriculture. Some may be suitable to meet specific agricultural requirements. Others may provide genes for the breeding of entirely new types of plants.

3.2.3.1 It is necessary first to identify areas lacking suitable forage or crop legumes or in which yields are insufficient. In the latter case it is further necessary to establish that improvements cannot be effected by agronomic, microbiological or management means. Specifications for selection or breeding objectives can then be drawn up with regard to the local environment and the agronomic characteristics required.

3.2.3.2 Selection and breeding programmes must pay attention to compatibility for nodulation and nitrogen fixation with the naturally-occurring rhizobia of the area or in their absence, with readily-available cultures for use in inoculants.

3.2.3.3 Research of this type should be conducted in cooperation with the proposed inoculant centres, FAO and other agencies and with suitable centres of research in plant-breeding and agronomy.

3.2.3.4 The extensive plant introduction and exploration programme of FAO will provide a valuable source of legumes for breeding or selection.

3.2.4 To explore the possibilities to find out organic industrial waste products which may be used as a base for slow releasing N-fertilizers and for other agricultural and industrial purposes.

3.2.4.1 Use of industrial, lignin containing waste products.
3.2.4.2 Use for production of biogas.
3.2.4.3 Use for other industrial purposes like wallboard, petroleum-like materials, hydrogen for ammonia production etc.

3.2.5 Studies on the possible effects of constituents of soil organic matter on plant production.

3.2.5.1 Studies on the influence of constituents of soil organic matter on the metabolic pathways in plants.

3.2.5.2 Studies on the effect of constituents of soil organic matter on checking the incidence of plant diseases.

3.2.6 Studies to evolve new crop varieties to improve soil organic matter status and utilisations of mineral nutrients.

3.2.6.1 Studies to evolve such varieties which not only give higher yields of grains but also produce larger amounts of roots which may eventually contribute to the formation of soil humus.

3.2.6.2 Studies to evolve short season varieties of cereals in the semi-arid areas in order to make incorporation into soil of straw by ploughing-under easier and safer.

3.2 Long Term Research

3.2.1 Characterization of humus dynamics in the course of transformation of crop residues, green manuring, cattle manure and of products from urban wastes during the year mainly growing season (well characterized soils of different types with the main crops by means of pot and field (long-term) experiments) in relation to:

3.2.1.1 Yield and quality (determination of dry matter, N, P and other elements, free aminoacids, protein, soluble sugars) of crop.

3.2.1.2 Characterization of humic systems with standardized methods.

3.2.1.3 Functions and availability of nitrogen from added organic materials during humus dynamics (partly use of 15 N-labelled organic material and 15 N-labelled fertilisers).

3.2.1.4 Influence of rotting organic materials on nitrification and urease activity, alterations of the ratio of NH_4+ and NO_3- in soil (important for leaching of NO_3-) (partly use 15 N-labelled materials).

3.2.1.5 Leaching of nitrogen from soil by precipitation and irrigation without and with added organic materials (partly use of 15 N-labelled material).

3.2.1.6 Influence of organic materials on symbiotic and nonsymbiotic nitrogen fixation.

3.2.1.7 Microbial activity in soil; determination CO_2 - production and dehydrogenase-activity (partly use of 14 C - and 15 N-double-labelled materials).

3.2.1.8 Soil structure; determination of stability of crumbles, of evapotranspiration and of cation exchange capacity.

3.2.1.9 Influence of addition of different quantities of nitrogenous mineral fertilizers including urea in combination with organic materials in the investigations from 2.1.1. up to 2.1.8.

Special remarks:

a. Evaluation of results of paragraph 2.1 with multifactorial analyses for recommendations of the use of organic materials as fertilizers in case of plant production at other places with similar conditions.

b. All experiments have to be made according to standardized procedures. This includes also analysis, computerized registration of initial measured values and their evaluation.

c. Such a multiregional research problem with vast benefits for practical purposes can be realised only by cooperation of international institutions with local institutes of countries in different regions especially with tropic and subtropic, arid and semiarid climatic conditions through a centralised, correspondingly equipped and staffed research institute as it has been demonstrated in the case of the variety programme in a relatively short time after the establishment of CYMMIT or IRRI.

3.2.6.3 Studies concerning the efficient use of deep rooted plants in the rotation in order to improve the recovery in the deeper horizons of mineral elements lost by leaching. Pidgeon peas, for instance, seem to be of special interest in this regard.

3.2.6.4 Studies to evolve such plant varieties which have inherent character of utilizing more soil organic nitrogen.

3.2.7 Studies to evolve very quick growing trees and shrubs to conserve other organic materials currently used as fuel and for other purposes.

3.2.8 Studies of association between trees and crops

3.2.8.1 Cropped fields in tropical regions are rarely entirely cleared of trees. This may create a microclimate favourable for crops by decrease of wind speed and potential evapotranspiration. Moreover trees take part of their nutrients from the deep layers of soil. The soil surface layers progressively grow rich at the expense of deeper layers through annual addition of organic matter. Yields of crops are generally increased around the tree provided the shading during the rainy season is light enough. A typical example of this is given by Acacia albida in the Sahelian Zone. This system of association between trees and crops could be extended to other species and provide similar benefits through reduction of leaching losses and continuous additions of organic matter from the tree leaves. Such trees should be self pruning and provide only light shade. Experiments should be undertaken in that field.

Special statements:

1. Cooperation with FAO Fertilizer Programme Projects

All field experiments conducted with organic materials as fertilizers should make use of the above mentioned research proposals. Personnel should be prepared to participate.

2. FAO's Computerized Soil Data Processing System

Results of experiments with organic fertilizers should be included in this system. Cooperation is recommended with the group working on characterization of humic systems (see 3.2.1).

B. REPORT OF THE WORKING GROUP ON PRACTICAL ASPECTS

1. CONCLUSIONS

The present world shortage and sudden increase in price of raw materials for the production of energy has resulted in a shortage and increased costs of chemical fertilizers.

It is now of the utmost importance and urgency to increase utilization at agricultural, municipal and certain industrial organic wastes 1/ as sources of plant nutrients, particularly of nitrogen. Consequently it is imperative that developing countries should immediately organize and adopt adequate and safe methods for the collection, processing and utilization of their organic waste materials.

Whereas there are abundant supplies of these materials in some countries, there are shortages in others, such as those in the arid tropics. Where there are shortages, reliance will have to be placed on processed or composted materials supplemented by the more efficient use of inorganic fertilizers.

In any case it is particularly important that the Government of developing countries should promote the utilization of organic materials in combination with inorganic fertilizers to the best advantage and thus ensure an adequate and integrated nutrient supply system at the lowest possible cost. This would entail, through extension and rural guidance activities the dissemination of recommendations as to the correct amounts and proportions of organic and inorganic materials to be applied to the land in order to attain adequate crop yields.

2. RECOMMENDATIONS

2.1 Development of Mixed Farming

In developing countries more productive and efficient farming systems are being developed. In this task the integration of animal husbandry, forage crops and mixed cropping should form a prominent part of the development process wherever feasible. That is, mixed farming is the best way of ensuring a continuous supply of animal and plant organic wastes for application to the land as fertilizer.

Continuing and intensified research will be needed to achieve the best results but such research should be oriented not only to technical feasibility, but also to the socio-economic problems involved so as to ensure the best chance of acceptance by the farming community as a whole.

There are already well known and proven practices in many areas which could be extended on a wider scale. It is important that teaching and extension work in these aspects be given priority and be intensified at all levels.

2.2 Conservation, Distribution and Utilization of Organic Sources of Manure

There are substantial losses in the collection, processing, storage, transportation and application of organic manures. Organic materials are in general more bulky than chemical fertilizers. Except for materials which can be grown on the spot and incorporated in the soil or used as mulch, the bulk of organic manures have to be transported to the fields. Therefore Governments and FAO should provide a new impetus

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1/ See Annex at end of this paper

to the improvement of rural transport. Due to the present energy situation, this effort should be directed wherever possible to non-fossil energy sources, such as draft animals. Such a policy would also act as a spearhead for the development of mixed farming, which would help to accumulate organic sources of fertilizers.

There are still substantial quantities of animal manures which are not used, or at least not used where they are wanted. Concentration of these manures in the right place can be achieved under semi-nomadic conditions by improvised fencing-in of animals over a few days. In areas of settled farming cattle can be kept at least overnight in temporary sheds or fenced pits, thus mixing solid and liquid wastes with straw bedding. This is a simple way of achieving humification and anoerobic fermentation by the trampling of the animals' hoofs.

2.3 Energy Sources and Crop Residues

The production and utilization of crop residues differs widely from country to country. In developing countries these cellulose type wastes are not processed industrially, but are used to provide shelter, as fuel for heating and cooking, and as rough fodder for animals. Thus, contrary to common belief developing countries do not generally have an abundance of cellulose wastes, either for fuel or for composting.

Thus, it is recommended that national Governments should initiate the planting of suitable species of trees and other crops for use as sources of energy on marginal and community lands. The species selected should be quick growing and adapted to the environment. FAO could help by making available basic data for this purpose.

There are some areas in the humid tropics where surplus maize stover is available, and if conditions are favourable, it may be used for mulching.

There are vast quantities of cotton stocks which have to be burnt annually to control pests and diseases. Research should be initiated to find new ways of controlling pests and diseases without burning so that this material could be utilized as a source of organic fertilizer or mulch.

In arid areas, tree plantations should be established to act as wind-breaks, as a source of energy, as an influence on the micro-climate, and as a means of conserving organic matter in the soil.

The best possible use should be made of slaughterhouse wastes, firstly for animal nutrition and then for use as organic fertilizer.

2.4 Refuse Composting

The domestic refuse of large towns should be collected and processed - if possible together with sewage sludge - at decentralized composting plants on the outskirts of the town. The residues of these composting plants may be transported to a central processing point (for incineration, recycling) with the same vehicles.

Small urbanized communities should be organized in groups of communities of from 4 to 10 000 inhabitants. Their refuse, including night soil or sewage sludge should be processed by one composting plant. Technology should be reduced to a minimum, but would include reduction in size, mixing and screening. If necessary magnetic separation could be employed.

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ANNEX

Classification of Wastes

1. **Solid waste**

   1.1 Domestic waste, garbage etc.)

   1.2 Commercial waste) Municipal waste

   1.3 Industrial waste)

   1.3.1 Organic waste

   Food processing industry, etc.

   1.3.2 Inorganic waste

   Metal processing industry, etc.

2. **Liquid waste**

   2.1 Municipal waste water

   Sanitary waters etc.

   2.2 Industrial waste water

   Organic or inorganic waters

   After primary, secondary, or tertiary treatment:

   2.3 Effluent

   2.4 Sludge

Municipal waste in the forms of compost, effluent, and sludge, are compatible with crops and may be used as fertilizers provided that adequate treatment and monitoring is used to ensure quality and to safeguard health.

Inorganic industrial waste is generally not suitable for agricultural use and can be dangerous.

Organic industrial waste often has an unbalanced ratio of plant nutrients and thus additives may be necessary to meet crop requirements.

Waste with toxic and noxious ingredients in quantities that present a significant hazard to human and animal health, crop growth and the environment must be excluded.

C. REPORT OF THE WORKING GROUP ON TRAINING AND EXTENSION

1. CONCLUSIONS

The Expert Consultation recognizes the dependence of farmers in tropical and sub-tropical areas on the use of organic materials as fertilizers and sources of energy. In order to ensure that the best use is made of the materials available and to popularize and gain acceptance of the necessary techniques, it is now necessary to develop and intensify teaching and extension work at all levels in this field. This needs in turn more attention to man-power planning, particularly in the recruitment and training of field staff. Areas of concentration are needed in the use and development of root nodule bacteria (Rhyzobium), legumes, compost and the conservation, transportation and application of manures derived from animal wastes.

2. RECOMMENDATIONS

2.1 It is recommended that national Governments initiate, develop and improve teaching and extension ability in the following fields:

2.1.1 Organic matter

Organization of seminars and training courses at the national level.

2.1.2 Rhizobium

Prevision of the trained man-power necessary.

2.1.3 Manures and composts

Development of national programmes to promote more and better use of manures and composts.

2.1.4 Bio-gas

Studying of the promising bio-gas projects in India with a view to developing similar plants in other suitable areas.

2.1.5 Publications and Extension Aids

Intensification of the production of publications, extension literature and visual aids, particularly for use at the farm level.

2.2 It is recommended that FAO organize activities in the following fields in cooperation with other organizations:

2.2.1 Soil organic matter

Seminars on the use of organic materials as fertilizers, and training courses in soil organic matter.

2.2.2 Composts and manures

A roving seminar on composting and the use of composts from various organic materials such as animal wastes, night soil and city wastes which are adapted to local needs.

2.2.3 Rhizobium and legumes

2.2.3.1 Strengthening of activities in demonstration and related programmes on the use of Rhizobium and legumes within the framework of the FAO Fertilizer Programme and the FAO/UNDP projects. These programmes should be expanded to include organic materials.

2.2.3.2 Seminars on the application of Rhizobium in agriculture.

2.2.3.3 Appointment of an expert to coordinate FAO activities in Rhizobium/legume work with a view to increasing food and fodder production.

2.2.4 Research and Fellowships

Encouragement of international agencies and research foundations to support research grants and fellowships on soil organic matter in universities and colleges.

2.2.5 Publications and Extension Aids

2.2.5.1 Making available the results of this Expert Consultation as soon as possible and in as many copies as possible.

2.2.5.2 Placing high priority on the provision of additional publications and allied literature on the use of organic materials as fertilizers to all interested countries.

2.2.5.3 Compiling lists of existing publications on organic matter and updating publications on legumes in agriculture.

2.2.5.4 Publishing a book on soil organic matter - its nature and role in soil fertility in the tropics and sub-tropics.

2.2.5.5 Appointment of a consultant for 6 months to produce extension and training material.

D. REPORT TO THE CHAIRMAN: NITROGEN FIXATION BY LEGUMES

Nitrogen Fixation by Legumes: Report by the UNEP consultants to the London meeting following meetings with FAO representatives in Rome
2 - 6 December 1974

1. INTRODUCTION

The lack of plant-available nitrogen frequently limits the amount and quality of food produced in many areas of the world. Atmospheric nitrogen fixed by nodulated legumes is incorporated into plant proteins which serve as sources of food for humans and livestock, and also enriches the soil with nitrogen for subsequent crops.

The technology for making use of the root nodule bacteria (Rhizobium spp; rhizobia) is well established in some developed countries. However, there has been little use or adaptation of this technology in the developing countries owing to a deficiency of trained personnel and the absence of requisite technical centres. It is stressed that the technology is basically simple (although needing skilled surveillance), requires only modest capital investment and may quickly lead to marked benefits.

FAO is currently involved in agricultural development projects using legumes, in many developing countries of Asia, Africa and Latin America. Results are frequently frustrated by failure of nodulation in the field. This may be due to: (a) the inability to supply good quality inoculants at experimental sites; (b) to the use of unsuitable types of inoculants (poorly adapted bacterial strains for example); or (c) to inadequate experience in the area of symbiotic nitrogen fixation of the local personnel involved; (d) possible unfavourable soil conditions or poor management.

It has been recommended that UNEP, in cooperation with other agencies, will sponsor the establishment of microbiological Resources Centres (MIRCEN) in some developing countries and that nitrogen fixation, by nodulated legumes, is to be one of the topics selected for study and application.

The following paragraphs suggest action in which some immediately urgent problems can be dealt with and identifies some of the ways in which FAO could be involved in the programme suggested by the UNEP consultation in London on 26-29 November 1974. This proposed that centres of technical skills related to the agricultural applications of nodulated legumes be established in the MIRCENs.

2. PRACTICAL APPLICATIONS

A. Immediate. Pending the establishment of the above-mentioned MIRCENs and in order to ensure the success of existing and projected work in FAO programmes involving nodulated legumes in Africa, Asia and Latin America, it is proposed that holding and distribution points for inoculants be established. These points should be located close to international airports in countries with minimal import/export barriers. Locations could be related to institutions involved in related aspects of agricultural development and technical assistance, with special reference to seed and fertilizer centres. They should be stocked with inoculants of high quality, imported from suitable sources by refrigerated air cargo and chosen with regard to the requirements of nearby FAO programmes. Distribution to workers in the field should be by insulated container, by the fastest practicable method (courier, if necessary). Before and after distribution inoculants should be stored under refrigeration.

B. Coordination. Many agencies and instrumentalities (international, and national) undertake programmes related to crop and forage legume nodulation and soil fertility. These should be listed in an inventory as a preliminary to coordination of FAO activities. This inventory could be prepared by FAO personnel or by a consultant contracted for the purpose. A plan for coordination should be prepared also. The appointment of a person with experience of legume bacteriology and soil fertility within FAO, responsible for coordination of FAO work and of the work of the proposed centres and with other bodies should be considered.

C. The Regional Production of Inoculants. For many practical reasons, inoculants to be used for legumes in research and ultimately in agricultural production, should be produced in the countries concerned. As a step towards this objective, for developing countries, it has been proposed that inoculant production be established in centres suitable for the major developing regions of the world and that these centres be designated as MIRCENs. Production and quality control would be based on a soundly maintained culture collection as described in the report of the London meeting. Initial action towards the objectives of the centres would be the appointment of a task force including FAO representation on location to advise in the terms set out on p. 13 of the report of the London meeting. Implementation of other action suggested in that report would then follow. It is recognized that patterns of development of this proposal will need to be adapted to regional needs, especially in Latin America, where some centres of technical skill already exist.

D. Regional Centres for Advisory and Technical Services relating to the use of Legume Inoculants

It is envisaged that MIRCENs involved in the production of legume inoculants would also be responsible for: (a) the production of advisory bulletins etc. for use within countries of their regions; (b) the publicizing of the benefits obtainable through proper use of nodulated legumes by the use of demonstration field plots, etc. in coordination with such ongoing projects as the FAO Fertilizer Projects; (c) advising Government Ministries of Agriculture and other national instrumentalities within their regions on the application of inoculation and nodulation technology; (d) coordinating the nodulation work with other aspects of plant production such as mineral nutrition and the control of pests and diseases of legumes; (e) cooperation with FAO projects in plant introductions, genetic resources and development of pasture and grain legumes.

E. Programme of demonstration and related extension services. Use of rhizobia within the ongoing FAO Fertilizer Projects, plant introduction programmes and project of development of pasture and grain legumes.

3. TRAINING

A. For establishment of centres of technical skill relating to the use of nodulated legumes

The report of the London meeting (pages 14-15) forecasts the necessity of training for three levels of staffing. Firstly, a senior professional and then one or two assistant professionals would need to be trained for each centre. This training would probably involve periods of study or experience at suitable laboratories in developed countries such as the U.K. or Australia. In Latin America, study in Uruguay, Brazil, or CIAT, may be adequate for the assistant professional levels. Shorter courses of intensive training specific for the work of the centres is also proposed. The training of technicians could be undertaken within the centres, using locally recruited personnel.

B. The Use of the Centres for Training within the Regions. The centres are to be seen as providing facilities for many aspects of the training of personnel for the extension of legume nodulation technology to the countries of the regions (see p.16 of the report of the London meeting).

C. Fellowships etc. For the support of this training, consultation between ICRO/ Unesco and FAO is to be undertaken. Some resources are already available and their utilization needs to be worked out (see p.15 of the report of the London meeting).

4. RESEARCH

The proposed centres for legume nodulation technology must have a research component if they are to be fully utilized in the purpose of developing national programmes within the regions. Four major aspects of research are identified.

A. The development of suitable inoculant strains. Some progress can be initiated using imported prepared inoculants or inoculants made with bacterial strains suitable to the legume species to be used, on the basis of experience elsewhere. However, experience in the developed countries forecasts the need for host-cultivar/ bacterial strain screening if maximum utilization of this technology is to be achieved. Further selection of strains on the basis of the effects of local soil environments will also be necessary.

B. Establishment of inoculation requirements in the regions. The delineation of areas within the region in which inoculation is required to ensure nodulation, or to maximize nitrogen fixation by the various legumes to be utilized, is seen as an important regional research responsibility.

C. Inoculation Methods. The adaptation of existing inoculation techniques, or the development of new ones suited to regional or local needs is a further important research activity. Special attention may be necessary to special problems related to persistance of the rhizobia in soils under the rigorous conditions of the tropics.

D. Other factors influencing nodulation. Interactions between nodulation and nitrogen fixation in specific management systems involving various soil conditions and fertilizer practices (N.P.K. and minor elements) will need to be studied locally.

5. FURTHER IMPLEMENTATION OF THE REPORT OF THE LONDON MEETING

The above paragraphs identify some of the most urgent areas in which FAO could be involved in the initial implementation of this report. However, it is necessary that there be further consultation between UNEP, FAO and Unesco representatives to take further action in consultation with major centres of agricultural research. This is particularly true in the areas of administration in which the scientific consultants have little experience in relation to the working of the UN agencies. In the areas of training and fellowships, it is desirable that consultations include representatives of Unesco and FAO on both scientific and practical aspects of the programme.

A. USE OF ORGANIC MATERIALS AND GREEN MANURES AS FERTILIZERS IN DEVELOPING COUNTRIES

by

Ambika Singh*

Prior to the introduction of mineral fertilizers, about 130 years ago, manures and composts were practically the only outside sources of nutrients to crops. The importance of legumes in building up and conserving soil fertility has also been recognized since the beginning of agriculture. The organic manures and green manures were mostly used till the early 60's in the soil fertility programmes of developing countries. In these countries consumption of fertilizers noted some increase in the mid '60's when the transition from traditional agriculture to modern agriculture started, in most of them. With developed countries leading the way, global interest in the use of organic manures waned considerably. Now the supply position of fertilizers has changed considerably. High fertilizer prices, the farm energy hunger and acute fuel shortage justify intensive attention to the problem of utilizing in a better manner rural wastes to meet the fuel and fertilizer requirements of farmers in these countries. Even in developed countries organic wastes are still important sources for the supply of nitrogen in crop production as will be evident from the estimates worked out by Aldrich (1972) of the University of Illinois, U.S.A.

Table 1. Major Sources of Nitrogen for Crop Production in U.S.A.

Source	Million tons per year	Percentage
Release from soil organic matter	20	37
In livestock manure	10	18.5
Fixed by soil organisms (22.5 kg per hectare)	10	18.5
Added in rainfall (5.6 kg/ha)	5	9.0
Fertilizers (estimated for 1970)	7	13.0
Human waste (0.022.65 kg N/person/day)	2	4.0
Total:	54	100.0

As most of the plant nutrients are needed by animals and human beings also, a continuous flow of these takes place from soil to plants and from plants to animals and from animals to human beings. In this process an uncontrolled cycling of these nutrients goes on in nature. If left uncontrolled enormous losses and leakages take place and substantial amount of nutrients which could have been utilized are wasted. The earth is like a spaceship where nutrients and energy are limited. The only outside source of energy is sun. The mankind has learnt that in future the resources of the planet have to be conserved, utilized and recycled. This global view of limits to growth has to be taken into account in our planning process. All the urban and rural wastages have to be recycled in an efficient manner, minimizing the leakages and losses.

* Dr., Assistant Director-General, Indian Council of Agricultural Research, Krishi Bhavan, New Delhi, India

The combined use of organic manures and fertilizers for increasing agricultural production and maintaining soil fertility and decreasing pollution hazards by properly conserving urban and rural wastes for manure making will require much greater attention of the government and public of developing countries than it has received hitherto.

Important manurial resources available locally for conservation into indigenous manures may be enumerated as follows:

(i) Urban solid wastes, viz. garbage, night soil, sludge, slaughter house wastes like blood, hoofs, horns.

(ii) Cattle-shed wastes, cattle dung, urine, sheep and goat droppings, litter and spoiled fodder.

(iii) Wastes and by-products of agriculture including forestry, animal husbandry and fisheries.

(iv) Urban liquid wastes, i.e. sewage, sullage, human urine.

(v) Farm and crop wastes, weeds, sugarcane trash, water hyacinth.

(vi) Night soil and urine in villages.

(vii) Green manure.

(viii) Industrial wastes, factory effluents.

(ix) Dead cattle wastes.

Potential for Organic Manures in Developing Countries

Reliable statistics needed for calculating the potential for producing organic manures in developing countries are missing. In India the programmes for effective utilization of local manurial resources have been implemented during earlier plans. Certain model values have been taken into consideration for calculation. Based on the available statistics IBRD has attempted an estimate of the total availability of organic manures. The data presented in Table 2 have been calculated on the basis of various publications, especially Garg et. al. (1971) as well as the FAO Production Yearbook 1971 and IBRD's Trends in Developing Countries (1973). The developing countries' total for human excrement is based on the Indian calculation of 0.0047 metric tons N/person/year, 0.0011 metric tons P_2O_5/person/year, 0.0010 metric tons K/person/year, multiplied by a total population estimate for 1971 and 1980. Cattle estimates are based on Indian figures of 8.6 metric tons/cow/year excrement (liquid and solid) x number of cattle in developing countries (FAO Production Yearbook, 1971, p. 303) x the respective percentages of N, P and K of .0029, .0008 and .0023, likewise based on Indian findings. Assuming that cattle production will rise at least as rapidly as human population growth rates, the 1980 estimated cattle population was based on the human growth factor of 1.25. All other categories are based on a similar methodology, i.e. an extrapolation of Indian findings.

Table 2. Total annual production of soil nutrients (N, P, K) through organic wastes in the developing world, 1971 (actual) and 1980 (estimated)*

Source		(million metric tons of nutrients) N	P	K
Human:				
	1971	12.25	2.87	2.61
	1980	15.26	3.57	3.25
Cattle:				
	1971	17.80	4.91	14.12
	1980	22.25	6.14	17.65
Farm Compost:				
	1971	9.54	3.34	9.54
	1980	11.93	4.18	11.93
Urban Compost:				
	1971	0.48	0.38	0.57
	1980	0.60	0.48	0.71
Urban Sewage:				
	1971	1.43	0.29	0.86
	1980	1.79	0.36	1.08
Other: **				
	1971	6.63	4.44	11.35
	1980	8.29	5.55	14.19
Total:	1971	48.13	16.23	39.05
	1980	60.12	20.28	48.81

* Excludes Central America and Oceania, includes Socialist Asia.

** Bone meal, poultry litter, bagasse, sheep/goat litter, oil cake, press mud. (Several other sources were not included due to small potential for all developing world.)

While reviewing the potential worked out by the IBRD it appears that figures for cattle waste are on higher side. In my personal judgement in place of 8.6 metric tons/animal/year of excrements (liquid and solid) a more conservative figure of 5.5 metric tons/animal/year could be taken. If we calculate on 5.5 metric tons basis the figure for N, P and K from cattle waste will be

	N	P	K
1971	11.38	3.14	9.03
1980	14.23	3.93	11.29

On this basis the total annual production of nutrients in the developing countries will be as follows:

Total	N	P	K
1971	41.71	14.46	33.96
1980	52.10	18.07	42.45

I would urge this consultative group to go into details of these calculations. If need be a working group should be constituted to work out in detail the potential and the availability categories of these sources for developing countries.

As indicated by the IBRD study the values given in the above table are the raw output. The actual amount which could be utilized will depend on several factors, e.g. ease of collection amount collated, cost of collection handling, methods of conserving and application.

Therefore the degree to which the potential presented in Table 2 could economically be harnessed could not be predicted with certainty. Furthermore in case of human excrement and urban sewage calculation for N production has to be reduced to 0-50 % depending on the method of processing. Other adjustments have to be made to account for losses in nitrogen in processing.

The FAO Fertilizer Review 1971 has given the fertilizer consumption in developing countries during the year 1970-71. This value is 13.2 metric tons of N, P and K. Thus, the total production of major soil nutrients in organic manures that is available for utilization is about 6.8 - 7.8 times larger than the consumption of chemical fertilizers during 1970-71.

Economic Value of Organic Manures

IBRD has also made a calculation of the value of N, P and K found in wastes of the developing countries as compared to chemical fertilizer at 1973 world prices (f.o.b.) of chemical fertilizers and these are given in Table 3.

Table 3. Value of N, P and K found in wastes of the developing world as compared to chemical fertilizers (at 1973 world f.o.b. prices)
(in million US $)

	N	P	K	Total
1971	9 626	4 058	2 499	16 183
1980	12 024	5 070	3 124	20 218

It may be noted here that the individual farmer pays local prices which are higher than the world prices because of transport, storage and commercial costs. The values given in Table 3 are based on the world f.o.b. price of urea at US$ 70-105 per metric ton, which means a price of 155-233 US$ per ton of pure N. In the calculation the average value has been taken as US$ 200/metric ton. P_2O_5 value is based on triple superphosphate (46 % P_2O_5) at US$ 120 per metric ton which means US$ 250 per ton of P. The value of potassium chloride (62% K) at US$ 40 per metric ton which means US$ 64 per metric ton of K.

The cost of production of organic manures varies very widely and depends on the method of processing. In India very labour-intensive methods are used. The price works out to approximately US$ 1.00 per metric ton of processed urban compost. The total cost of processing the Indian potential for urban compost would come to 8 million US$. At 1973 world prices the total expenditure that would be required to purchase fertilizers with equivalent nutrient content to that amount (N, P and K only) at world prices would equal 23.8 million US$.

Bio-gas Plants based on Animal and Human Wastes

As a result of the research work done at the Indian Agricultural Research Institute, New Delhi, a design was perfected to produce methane gas from animal wastes. The process reduces loss of organic matter through decomposition and stops nitrogen losses and provides cooking gas. Improvements have been made in the design by various individuals and organizations, namely the Ramakrishna Mission, Khadi and Village Industries Commission and the Planning Research and Action Research Institute, Lucknow (India). The size of these plants vary from those capable of generating 60 cft. (1.7 m^3) of gas per day (the smallest economic size) or 100 cft. (2.6 m^3)/day (the generally acceptable size for an average family of five possessing at least three head of cattle) to 3 000 cft. (85.2 m^3)/day size (the largest sized plant) with about 20 varying sizes in between. The present cost of the smaller sizes, through varying from type to type, is reported to be in the neighbourhood of 270 US$.

In the production of gas from cowdung losses of organic matter and nitrogen are reduced. Data in Table 4 give the amount of manure obtained when one ton of fresh dung is processed by the traditional Indian method and through a gas plant (fresh dung 1 000 kg and 0.25 % nitrogen).

Table 4. Manure obtained when one ton of fresh dung is processed by the traditional Indian methods and through a gas plant (fresh dung), 1 000 kg at 0.25 % nitrogen)*

		Traditional method	Obtained through gas plant
(A)	Organic matter - loss by decomposition	500 kg	270 kg
(B)	Nitrogen - loss by decomposition	1.25 kg	Nil
(C)	Final manure quantity	500 kg	730 kg
	Quality - N % on dry basis	1.0 %	1.3 %
(D)	Additional advantage	-	2 000 cu.ft. gas for cooking

* Garg, A.C. et al. (1971)

To avoid indiscriminate dumping of night soil and its unhygienic handling on farms in the raw conditions, the Central Public Health and Engineering Research Institute (CPHERI), Nagpur, India, has been working on night soil digestion. Digestion of the night soil would give inoffensive sludge undiminished in its fertilizer value and gas which may be profitably used in the rural areas, either for heating or for generating electric power. The characteristics of night soil are different from those of cow dung. Cow dung is poor in nitrogen and phosphorus compared to night soil. Also the destruction of volatile solids added to the digester are both lesser for cow dung than for night soil. The composition of night soil and cow dung are given in Table 5.

Table 5. Composition of night soil and cow dung

Characteristics	Night soil	Cow dung
Moisture content of raw material, percentage	85–90	74–82
Total solids, percentage	10–15	18–26
Volatile solids as a % of total solids	80–88	70–80
Total nitrogen as N % on dry basis	3.0–5.0	1.4–1.8
Total phosphorus as P_2O_5	2.5–4.4	1.1–2.0
Potassium as K_2O% on dry basis	0.7–1.9	0.8–1.2

Pilot plant studies at CPHERI in 230 cft. digester (6.5 m^3) for a period of over a year have yielded the essential design criteria. It also revealed that night soil can be digested without any fly or odour nuisance in an unheated open tank with manual stirring. The digester volume required per person reduces as the water temperature increases. The essential design criteria for night soil digester are given in Table 6.

Table 6. Design criteria for night soil digester

Digester capacity (m^3/100 persons)	3 - 6
Volume of dilution water required per volume of raw night soil	2 - 3
Gas yield (m^3/100 persons)	3
Calorific value (K.cal./m^3 of gas)	5558
Approx. H.P. generated per 100 persons	2.0
Manurial value (% on dry basis)	
Nitrogen - N	3.0 - 5.0
Phosphorus - P_2O_5	2.0 - 4.4
Potash - K_2O	0.7 - 1.9

The gas produced from the digestion of night soil is very similar to that from sewage sludge digestion containing on an average 65 percent methane and 34 per cent carbon-dioxide, and 1 per cent remaining gases.

Digested night soil can be dried on simple sand beds much more easily than raw night soil. During dry season with ambient day time temperature of 37°C, the moisture of digested night soil came down from 95 to 20 per cent in 10 days. It is estimated that a family of four can get 70 - 90 kg of manure (rich in nitrogen and phosphorus) per year with a light musty odour.

Night soil digester needs to be desludged once in a week or two. The sludge can be spread on a sludge drying bed of about 3 - 5 m^2 for 100 persons where it can dry and be removed for use as manure. The supernatant which comes out daily can be disposed of in soak pits or in sub-surface disposal fields such as the ones used for septic tanks. The supernatant can also be treated in small oxidation ponds or used on land after dilution.

Raw night soil contains disease producing bacteria, pathogens, viruses and helminthic parasites. At a detention period of 25 days, it was found that 90 - 95 % of helminthic ova were destroyed. The estimated capital cost excluding land cost for night soil digester with gas collection and sludge drying bed for a population of 100 will be about 3 200 US$. To treat the effluent from the drying bed and the supernatant from the digester in an oxidation pond the estimated cost will be 530 US$.

A full scale night soil digester exists in Ernakulam in Kerala State, India, capable of serving 20 000 people. One of the best village set ups for night soil digestion can be seen at Koroda Gram Panchayat in Maharashtra State of India where latrines were constructed in such a way that the night soil can be directly taken to a centrally located digester. The gas obtained from the digester was being used for running pumps lifting water and also for street lighting. Presently the gas is not being utilized since electricity is available in this village. The supernatant liquid from the digester is mixed along with garbage of the village and the compost is utilised for fertilizing the agricultural land.

From laboratory investigations, digestion of a mixture of cow dung and night soil was found to give better gas yield than either of the materials alone. The night soil digester gas has a higher methane content than cow dung gas and hence a higher calorific value.

Wherever village latrines have not come up a programme of extending the habit of depositing the excreta in a small hole and covering it could be taken up. To start with this programme may be introduced among school children.

Some Problems in the Utilization of Cattle Dung as Manure

Cattle dung is used in India and Pakistan as fuel. Dung cakes are made, dried and burnt for cooking purpose. In order to dissuade farmers from using cow dung for cake making, provision of alternate fuel is necessary. It is very important that while taking up the popularization of cow dung gas plants on a large scale, arrangements are made for promoting the cultivation of quick yielding fuel trees in order to cater to the fuel needs of landless labourers and the poor farmers who do not have farm animals of their own. Community gas plants alone can help poorer sections. If this is not done, the establishment of biogas plants by the well-to-do sections of rural community using the subsidy and credit arrangements now being made by the Government will add to the misery of poor people.

Intensive research is necessary for the choice of suitable species of quick growing fuel trees, shrubs for different agro-climatic regions in the developing countries where potential organic manures are used as fuel. Some of the following quick growing species of trees/shrubs have been identified in India suitable for its different agro-ecological regions.

Name of the region	Name of trees/shrubs
1. North-western Region	Quercus incana, Grewia oppositifolia, Acacia catechu, Dendro-calamus strictus, Albizzia lebbek
2. Indo-Gangetic Plains	Acacia arabica, Dalbergia sissoo, Tamarix articulata, Acacia auriculiforms, Morus alba
3. Central Zone	Cassurina equisetifolia, Acacia arabica, Pongamia glabra, Cassia siamea, Albizzia lebbek, Eucalyptus spp., Tamarindus indica, Acacia auriculiformis, Morus alba, Dendro-calamus strictus
4. Coastal Zone	Eucalyptus spp., Cassia siamea, Acacia auriculiformis
5. North-eastern Zone	Dendro-calamus and Bambusa species, Albizzia lebbek, Eucalyptus spp., Acacia auriculiformis

Work on (i) selection, assessment and breeding of fast growing fuel trees, (ii) introduction and evaluation of different exotic fuel wood species suitable for different regions, (iii) standardization of propagation techniques, (iv) plant population, (v) agro-techniques including micro-, macro-nutrient needs, soil moisture requirement of the different species identified, (vi) pests and diseases affecting them, need to be taken up on a priority basis by developing countries. Forestry departments in their universities may be strengthened to take up these problems.

The other problems related with the use of wastes are lack of their acceptance in some countries, resistance in the utilization of urban waste, public health problems like fly and rat breeding, certain diseases, parasites and noxious odour. But all these problems are surmountable by vigorous extension effort. Certain problems regarding proper waste disposal will need research efforts also. Such research programmes will require coordination of agricultural, environmental and public health problems.

Green Manures and Grain Legumes

The symbiotic genus Rhizobium commonly associated with the Leguminosae has been recognized for its contribution to the nitrogen fertility of soil. Most of the members of family leguminosae are widely distributed in tropics and sub-tropics. Analyzing the floristic composition of the natural vegetation of any part of developing countries, you will find a herb, shrub or tree belonging to three sub-families (Mimosoideae, Caesalpinioideae and Papilionaceae).

Green manuring (ploughing under a crop for the purpose of improving the soil) with leguminous crops was the practice which departments of agriculture used to advocate till recently for adding fixed nitrogen to the soil. This was a good practice in extensive agriculture when one crop growing season was utilized for providing fertility and the other to raise crop for economic gains.

Reviews by Scherbatoff (1940) and Joffe (1955) indicate that in tropical climates in which most of the developing countries are situated, green manuring benefits only one single following crop, the effect being primarily due to mobilization of nutrients and not to improvements in the nitrogen and organic matter contents of the soil.

The author's earlier work on green manuring for wheat and sugarcane (Singh, 1963, 1965-a) gives a basis for apportioning the gain from green manuring over the yield of the same crop after fallow to two effects, designated here as 'legume effect' and 'green matter effect'. Data on the yield of sugarcane or wheat crop grown after the following four treatments have been collected from the results of experiments carried out at different parts of India.

1. Monsoon fallow

2. Green manuring with sunn (*Crotalaria juncea*) for sugarcane, and with guar (*Cyamopsis tetragonoloba*), dhaincha (*Sesbania aculeata*) or sunn for wheat, for assessing the overall effect of green manuring.

3. Green manure crop grown, but all the above-ground parts removed for assessing legume effect.

4. Plot kept fallow in monsoon, and green material from treatment 3 ploughed-in for assessing green matter effect.

Data in the following two tables show the type of results obtained in sugarcane.

Table 7. Yield of sugarcane following incorporation of different parts of the Sunn Plant (Jullundur, India, 1953-57)

Treatment	Yield of cane in quintals per hectare					Mean yield as per cent of control
	1953-54	1954-55	1955-56	1956-57	Mean	
Control:						
No green manure (monsoon fallow)	634	529	247	353	441	100
Sunn tops only, ploughed in	764	699	282	376	530	120
Sunn roots only, ploughed in	698	703	306	427	534	121
Sunn whole plant, ploughed in	829	765	389	482	616	140

Table 8. Amount of dry matter and nitrogen turned in for different parts of the Sunn Plant (Jullundur, India) (average of three years)

Yield and composition	Control (monsoon fallow)	Whole plant	Tops only	Roots only
Total dry matter (kg/hectare)	-	7 793	6 690	636
Total nitrogen (kg/hectare)	-	111	99	3.6
Nitrogen in dry matter of above ground part (per cent)	-	1.64	1.52	-
Nitrogen in dry matter of roots (per cent)	-	0.56	-	0.36
Nitrogen in sugarcane leaves (per cent)	1.32	1.47	1.42	1.36

These data show that the 'legume effect' and the 'green matter effect' are each responsible for about half the overall benefit from green manuring.

Experiments designed to measure the increase in the yield of sugarcane treated after (i) with whole sunn crop ploughed-in and (ii) burnt in situ also confirmed this surmise (Singh, 1965-b).

Whether the green matter was ploughed in or its ash was applied, the yield of sugarcane remained almost unaffected. The increase is therefore not due either to organic matter or its nitrogen content.

According to this observation, the 'legume effect' appears to be more important. Experimental data on paddy crop gave similar indications.

On the practical side, one may suggest on the basis of these findings that introduction of other legumes for fodder in place of green manure and application of inorganic nitrogen to the main crop will be more remunerative in sugarcane and wheat rotations.

The author with the help of his graduate students studied the effect of growing three forage legumes, berseem, senji (*Melilotus indicus*) and peas on the yield of maize crop and the effect of growing moong (*Phaseolus mungo*), urad (*Phasiolus aurius*), lobia (*Vigna catjung*) and guar (*Cyamopsis tetragonoloba*) for fodder and grain on the yield of tall wheat. Some relevant data of the legume-maize sequence are given. Data on wheat pertained to tall wheat and are not much relevant.

Table 9. Amount of nitrogen in the biomass of different legumes per hectare

Rabi Legumes	Per cent N		N in kg/ha		
	Roots	Stubbles	Roots	Stubbles	Biomass
Berseem (*Trifolium alexandrianum*)	2.73	1.80	64.7	24.7	89.4
Senji (*Melilotus indica*)	2.24	1.53	43.2	9.9	53.1
Pea (*Pisum sativum*)	2.54	1.12	19.6	1.1	20.7

It is clear that berseem, senji and pea left in soil 89, 53, 21 kg of nitrogen per hectare. In order to assess the aggregate effects of legumes on the yield of maize, legume effects were calculated and are given below:

Table 10. Kilogram of maize grain produced over fallow plots by different legumes

Rabi Legumes	Kg of grain / ha	
	1965	1966
Berseem	1 710	2 220
Senji	1 160	1 190
Pea	590	890

In the context of today's agriculture we cannot afford the practice of green-manuring but certainly we can grow one fodder or grain legume in multiple cropping sequence involving two or three crops. We have several rotations in which such legumes fit well. The price of grain legumes is very high. The dietary requirements of the developing countries also dictate to grow more legumes. The shortage of fertilizers could to some extent be taken care of by the residual nitrogen left in the soil. The legumes can be planted in sequencial cropping. They can be fitted in inter-cropping with crops like sugarcane, cotton and pigeon peas. Growing orchards offer opportunity for growing several legumes. Even in fully established orchards several fodder legumes could be fitted. The plantation crops also offer opportunities for multi-layer cropping where legumes could be fitted.

Diversities and adaptability of cultivated legumes in developing countries is remarkable. The data on the cultivation of these crops in developing countries are given in Table 11.

Table 11. Area under pulses in developing countries (1972)*

Name of the crop	Area in 1 000 hectares			
	Africa	Latin America	Near East	Far East
1. Dry beans	2 714	6 405	151	7 184
2. Dry broad beans	463	316	213	-
3. Dry peas	523	144	7	952
4. Chick peas	563	245	259	9 235
5. Dry cow peas	4 848	7	9	33
6. Pigeon peas	147	50	-	2 390
7. Lentils	245	42	370	895
8. Vetches	25	-	250	-
9. Lupins	2	5	5	-
10. Other unspecified pulses	1 783	72	153	3 249
Total	11 315	7 286	1 417	23 938

* FAO Production Yearbook, 1972.

Available literature to indicate the ranges in total nitrogen content in several leguminous crops have been collected and are given in Table 12.

Table 12. Yield and nitrogen content of some legumes

Legumes	Dry matter (kg/ha)		Nitrogen (kg/ha)	
	Tops	Roots	Tops	Roots
Sweet clover - fall of seeding year (Willard 1927)	9 923	1 291	152	17
Sweet clover - maturity in 2nd year (Willard 1927)	10 875	694	155	8
Soybeans - straw + beans (19.3 bu/A) (Norman 1944)	6 205		99	
Soybeans - straw + beans (20.4 bu/A) (Weber 1966)	5 795		201	
Soybeans - straw + beans (65.6 bu/A) (Weber 1966)	12 275		387	
Alfalfa - fall of seeding year (Fribourg and Johnson 1955)	1 384	838	43	21
Ladino clover - fall of seeding year (Fribourg and Johnson 1955)	2 458	592	74	15
Vetch - winter cover - tops and roots (N.C. Agron. Res. Rept. No. 12, 1954)	2 985		120	
Austria winter peas - winter cover - tops and roots (N.C. Agron. Res. Rept. No. 12, 1954)	1 994		76	
Crimson clover - winter cover - tops and roots (Willard 1927)	2 538		113	

The total nitrogen contained in single crops of legumes range from a few kg/ha to as high as 300 to 400. Not all of this nitrogen comes from fixation and only a part of it may be made available to crop which follows.

Two aspects of biological nitrogen fixation need mention here. Firstly fixation process is growth dependent. Nitrogen is fixed and used only when it is needed for the growth of bacteria and/or the host plant. Secondly, fixation is inhibited by the presence of available inorganic nitrogen. When mineral nitrogen is present in the soil and is available for use by bacteria and/or host plant, the inorganic nitrogen is first used and the fixation process functions only to supply the deficit of nitrogen need.

Because of these two factors, the increase in the yield of subsequent crop after growing a legume for grain or green manuring varies very widely. Field experiments under different growth conditions of the host plant and under different level of soil nitrogen availability are needed to work out the amount of nitrogen which will be available for the subsequent crops.

Summary

Organic manures and green manures have been used in the soil fertility programmes of developing countries in the past. Even in developed countries they supply sizable percentage of the total need of nitrogen in crop production. Lack of reliable statistics and research data makes it difficult to estimate the potential for organic manures in developing countries. But on a conservative estimate waste materials of animal, plants and human origin can supply 6 - 8 times more nutrients than the consumption of chemical fertilisers during 1970-71 by these countries. The economic value of wastes of the developing world has been estimated at 16 183 millions of US$ at 1973 world f.o.b. prices of fertilizers. Not only major nutrients like N, P and K but methane gas could also be obtained from wastes. Recent work in India pertinent to other countries has been reviewed. The most important problem in the utilisation of organic waste is the supply of fuel for cooking and in this context plantation of quick growing plants on community and waste land offer

some solution. Vigorous extension work and coordinated research programme are needed for the solution of agricultural, environmental and public health problems arising in the use of waste materials as nutrients and energy sources.

Mode of action of green manures in tropics and the possible utilization of legumes in rotations has also been briefly surveyed. Field experiments under different growth conditions of hostplants and under different levels of soil nitrogen availability should be initiated to work out the amount of nitrogen which will be available for subsequent crops.

Summary of Discussion

The paper introduced the scope of the subject and pointed out that organic manures had been widely used in the soil fertility programmes of developing countries up to the early 1960's. After that consumption of mineral fertilizers progressively increased as traditional forms of farming had to give way to more intensive systems, and interest was lost in the use of organic fertilizers. Now the situation had changed drastically due to the high price of mineral fertilizers, fuel and farm energy in general, and it was now necessary to concentrate on the development and better utilization of organic sources of fertilizers and farm energy. A description of cheap and efficient farm energy, or bio-gas plants developed in India for use at the farm and village level ellicited considerable interest and favourable comment, particularly as to the simple design, low capital and running costs possible in India compared to the design, manufacturing and running costs of similar plants in the U.S.A. and other developed countries.

REFERENCES

1. Aldrich, S.R. (1972) in Fact from Environment, American Potash Institute, Atlanta (U.S.A.), p. 12
2. Anon (1954) N.C. Agron. Res. Rept., No. 12
3. Anon (1971) FAO Fertilizer Review, Rome
4. Anon (1972) FAO Production Yearbook, 26, Rome
5. Anon (1973) Trends in Developing Countries, IBRD, New York
6. Fribourg, H.A. and I.J. Johnson (1955) Agron. J., 47, 73
7. Garg, A.C. et. al. (1971) Organic Manures, Indian Council of Agricultural Research, New Delhi, Tech. Bull. (Agric.) No. 32
8. Joffe, J.S. (1955) Advances in Agronomy, 7, 142
9. Norman, A.G. (1944) Proc. Soil Sci. Soc. Am., 8, 226
10. Scherbatoff, H. (1949) Soils & Fert., 12, 155
11. Singh, A. (1963) Empire J. Expt. Agric., 13, 205
12. Singh A. (1965-a) Post Grad. School J. Indian Agric. Res. Institute, New Delhi, 3, 16
13. Singh, A. (1965-b) Expt. Agric., 1, 209
14. Voorhoeve, J.J.C. (1974) Organic Fertilizers for Underdeveloped Countries, Draft Mimeographed Copy (personal communication)
15. Weber, C.R. (1966) Agron. J., 58, 43

B. SPECIFIC EFFECTS OF SOIL ORGANIC MATTER ON THE POTENTIAL OF SOIL PRODUCTIVITY

1. BIOCHEMISTRY OF SOIL ORGANIC MATTER

(A Review)

by

W. Flaig

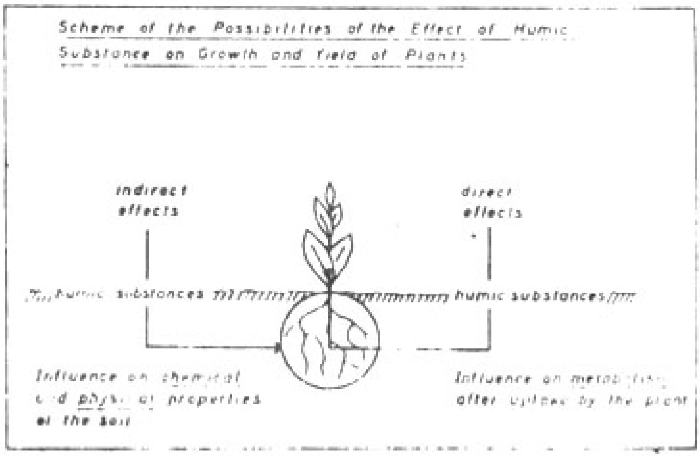
1. Principle considerations about biochemistry of soil organic matter and the utilization of organic materials as fertilizers.

1. The percentage of minerals as nutrients for plants in crop residues and excrements of animals and man is relatively low. Therefore much weight must be transported to fertilize the fields.

   The main constituent of dry organic materials is about 50 % carbon. This can be diminished by composting, whereby no losses of mineral nutrients occur. After composting – processes of biochemistry of soil organic matter – less weight is to be transported on the fields.

2. The rate of composting of organic materials such as straw is in some cases very low. Therefore, mineral forms of nitrogen must be added. During composting gaseous nitrogen losses occur. About 90 % and more of nitrogen in the transformed organic materials are bound in organic form. This organic bound nitrogen is an advantage for plant production, because it serves as a slow release nitrogen fertiliser. It has been proved by experiments with nitrogen-15 that about 50 % of nitrogen in plants is obtained from organic bound nitrogen of soil organic matter and the other half from mineral fertiliser.

Fig. 1



3. The organic material itself and its decomposition products formed during humification have influence on :

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* Institute of Soil Biochemistry, Forschungsanstalt für Landwirtschaft, Braunschweig-Völkenrode, 3300 Braunschweig, Bundesallee 50, Fed. Rep. of Germany

3.1 physical properties of soils
3.2 chemical reactions going on in the soil
3.3 plant metabolism after uptake by the roots.

About the problems of the change of physical properties of the soil and the influence on the course of chemical reactions in the soil by soil organic matter as indirect effects many publications have been written and are therefore not discussed here. Also many references will be made to the contributions of other authors. By this type of changes the environment of roots, the gas exchange, the water household, the sorption capacity, the complex formation with heavy metals and some other properties can become more favourable for plant growth. Therefore yield will be increased.

A favourable influence of fractions or of some defined compounds from humus on plant growth after uptake by the roots as direct effects has up to now been established exactly only in laboratory experiments. But also in field experiments many observations have been made which support these results. Later on more will be mentioned about this direct biochemical effect of humus constituents on plant growth. This effect should be more elucidated as there are some chances that it will perhaps become interesting for practice. In order to influence plant growth through the addition of organic materials, such as stable manure, it is necessary to add tons per ha. The mentioned components of humus have an effect in kg per ha. It is known that some of these components increase root growth and therefore a higher amount of material for humification would possibly be produced.

2. Humification process and formation of humic substances

Some processes during humification of dead plant material will be summarized in the following scheme.

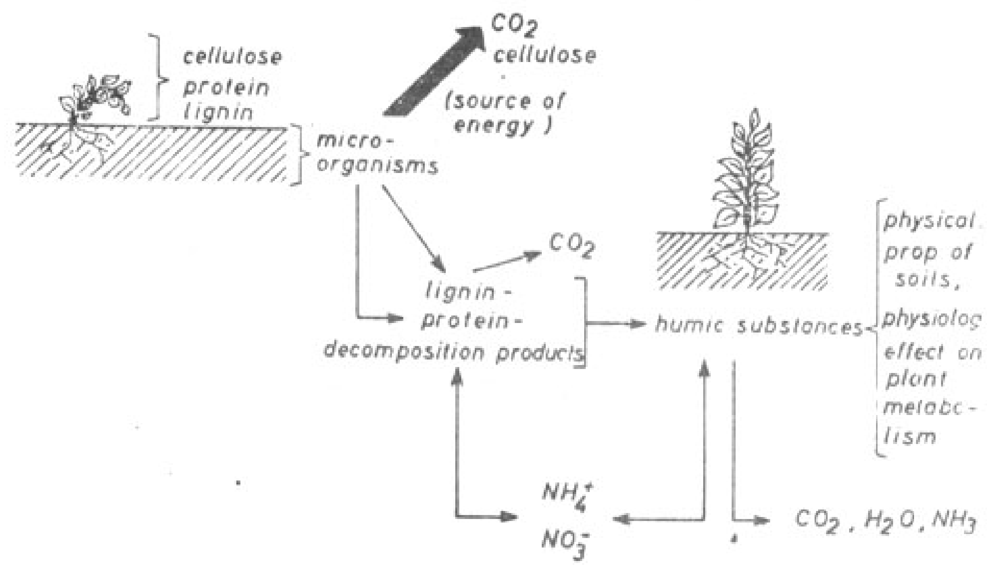


Fig. 2: Scheme of formation of soil organic matter

The main constituents of the plants are cellulose proteins and lignin. The cellulose is used by the microorganism mainly as a source of energy and degraded to carbondioxide. A part of the cellulose as well as the protein serve for formation of the mass of microorganisms.

Lignin is decomposed relatively slowly. Its transformation products react with the decomposition products of proteins to form humic substances. Humic substances have an influence on the physical properties of the soil. They are an important factor for stabilization of soil structure. Moreover they can have a partial effect on the plant metabolism after uptake by the roots.

Soil organic matter itself is not stable, it finally decomposes to carbon dioxide, water and ammonia. The nitrogenous organic compounds in soil are slow releasing nitrogen sources for plant production (See also: PRIMAVESI 1968, SWABY 1968). (Reviews: ALLISON 1973, DUBACH and METHA 1963, FLAIG 1958, 1966, 1970, 1971, KONONOWA 1966, SCHNITZER and KHAN 1972.)

3. Special investigations with straw

The most intensive studies on the processes of humification have been made with straw, a plant material which is relatively rich in cellulose and lignin and poor in protein (BARTLETT and NORMAN 1938; BARTLETT, SMITH, BROWN 1937; BROADBENT 1954; FLAIG, SCHOBINGER and DEUEL 1959; KAILA 1952; KONONOWA 1966, et al. 1973; MAEDER 1960; MOHTADI 1962; PHILLIPS 1934; REINHARDT 1961, SCHOBINGER 1958, SMITH, STEVENSON, BROWN 1930, SPRINGER and LEHNER 1952 a, b; WAKSMAN, TENNEY and DIEHM 1929; with labelled material e.g.: FÜHR et al. 1964, 1965, 1966, 1968; GUCKERT et al. 1971; JANSSON 1968; JENKINSON 1966, a-d, 1968, 1971; MARTIN et al. 1974; MAYAUDON et al. 1958, 1959 a,b, 1960, 1961, 1963; OBERLÄNDER, 1968; SAUERBECK 1968 a-c et al. 1968, 1970; SCHARPENSEEL, 1960 a, b, 1970 et al. 1962, 1964; SIMONART et al. 1958 a, b, 1959, 1966, 1968; SÖRENSEN 1963, 1966).

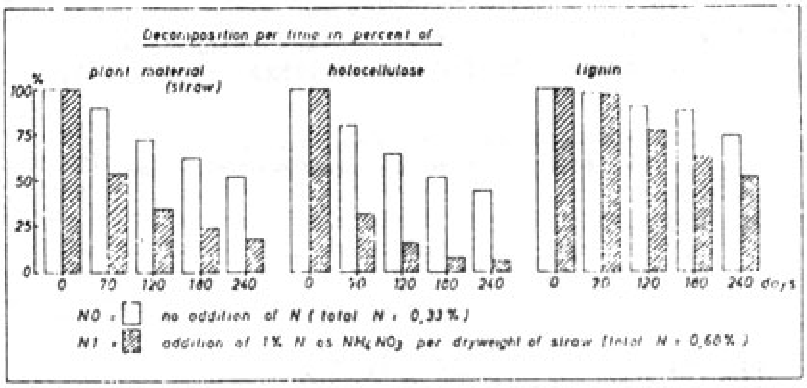


Fig. 3: The decomposition of plant material (straw), of holocellulose and of lignin in per cent during rotting time (MAEDER, 1960)

Since the content of available nitrogen may be a limiting factor for the activity of the microorganisms and therefore also for the rate of humification, the addition of nitrogen to low nitrogen residues accelerates decomposition.

From the figure can be seen that an addition of 1 per cent nitrogen in the form of ammoniumnitrate per dry weight of straw accelerates the bio-chemical degradation of plant materials. The degradation of holocellulose is faster than that of lignin by addition of available nitrogen (MAEDER, 1960).

The quotient of the amount of the cellulose remaining after a given time without addition of nitrogen divided by the amount of the cellulose remaining with addition of nitrogen increases more rapidly than that of lignin (Fig. 4). This means that the degradation of cellulose is accelerated much more than that of lignin by added nitrogen (FLAIG, 1962). Thus curves are characteristic for different decomposing materials, conditions and addition of nitrogen.

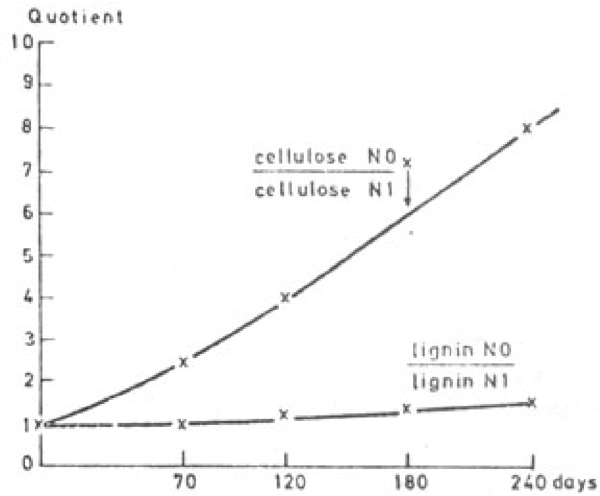


Fig. 4: Acceleration of the degradation of cellulose and lignin of rye straw by addition of nitrogen during 240 days. N 0 = no nitrogen added; N 1 = 1 % N as NH_4NO_3 per dry weight of straw (according to **MAEDER** 1960)

The products formed during degradation of lignin are dark coloured and have physico-chemical properties (spectra, solubility, cation exchange capacity) which are comparable to those of humic acids (FLAIG 1964; FLAIG, SCHOBINGER and DEUEL 1959). The products formed from lignin decomposition have a methoxyl content which is higher than that of humic acids from manures or composts (**NEHRING** and **SCHIEMANN** 1952 a, b).

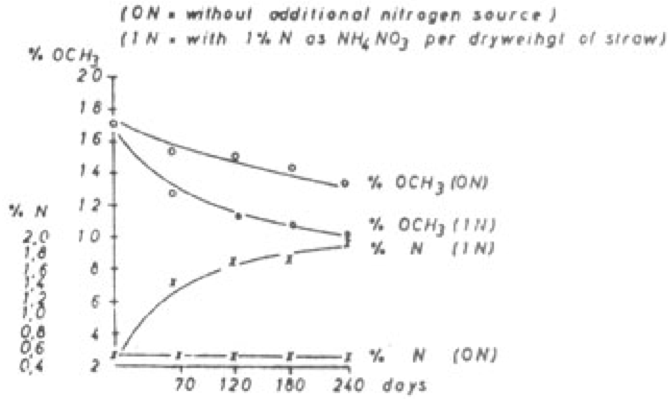


Fig. 5: Alterations of the content of nitrogen and methoxyl of the lignin fractions of straw during humification.

If one isolates the lignin fractions from rotted straw with sulphuric acid, the content of methoxyl groups decreases and the nitrogen content increases concurrently with the time of rotting (BARTLETT 1939; BARTLETT and NORMAN 1938; BROADBENT 1954; FLAIG 1960 a; FLAIG, SCHOBINGER and DEUEL 1959; NEHRING and SCHIEMANN 1952 a, b; RITTER, SEBORG and MITCHELL 1932; STÖCKLI 1952; WAKSMAN and SMITH 1934). This suggests that the cleavage of the methoxyl group proceeds the introduction of nitrogenous groups (FLAIG 1960 b).

The fixed nitrogen becomes partly less available for microorganisms by these procedures.

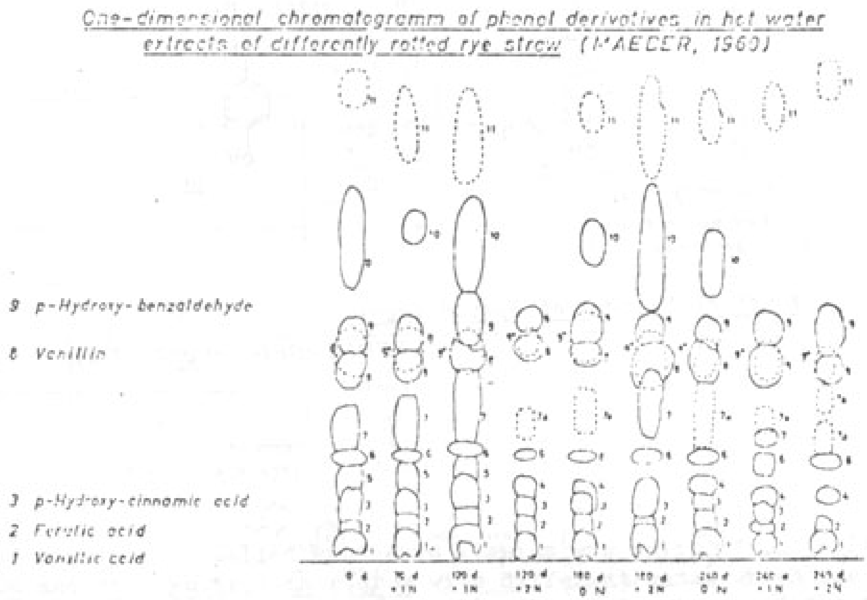


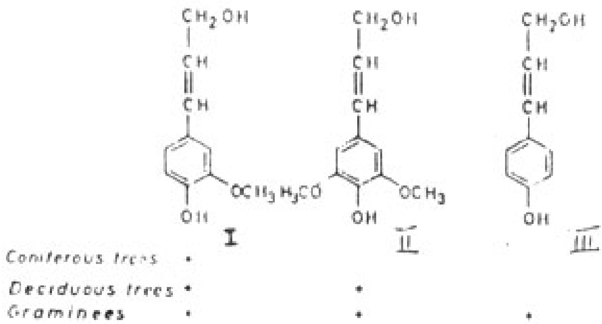
Fig. 6: Lignin degradation products isolated from rotted straw

In water extracts of rotted straw guaiacyl components such as ferulic acid, vanillic acid or vanillin or p-hydroxybenzoic acid and its aldehyde could be identified even during a rotting time of 240 days (MAEDER 1960). Lignin degradation products were also isolated by investigations of other humified materials (JACQUIN 1963; BRUCKERT, JACQUIN and METCHE 1967). Syringic acid was isolated only from soils and peat.

4. Biochemical degradation of "synthetic lignins"

The lignin content is between 10–30 % according to species of plant. Therefore, lignin may be supposed to be one of the most important initial materials for formation of humic substances.

Monomers of different Lignins



Structure Scheme of Spruce Lignin

(FREUDENBERG et al 1964,1968)

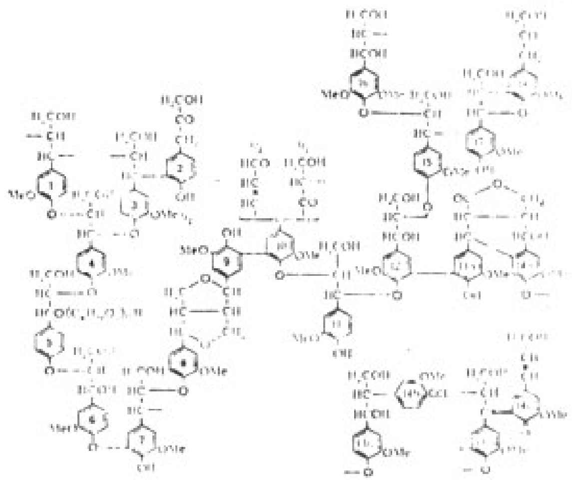


Fig. 7: Structure scheme of lignin

To recapitulate, the structure of lignin according to Freudenberg (1968) will be briefly reported. Coniferous lignin is formed by the condensation of coniferyl alcohol. The lignin of deciduous trees is a polymerisation product of two monomers, graminaceous lignin consists of the three monomers: coniferyl (I), sinapyl (II) and p-coumaryl alcohol (III). For structure schemes of lignins compare also (GLASER and GLASER, 1974; NIMZ, 1974).

The microbial degradation of the single carbon atoms in the molecule of lignins can only be investigated when these are labelled.

For this purpose extensive studies have been made (HAIDER, LIM and FLAIG, 1964; HAIDER 1965; LIM 1965; FLAIG and HAIDER 1968; HAIDER and MARTIN 1968). Variously labelled lignin monomers have been polymerised by Freudenberg's mushroom phenol oxidase method (1962, 1964 a, b) and different types of lignins have been synthesized. In this way we have been able to elucidate single steps of lignin degradation during humification (summarised in: MARTIN and HAIDER, 1971). According to FREUDENBERG (1964 a, b) and KRATZL et al. (1957) these "synthetic lignins" are identical in their physical properties and chemical composition with those isolated from plants.

Table 1: Carbonidioxide released from variously labelled synthetic lignin by the activity of fungi (according to HAIDER 1965, HAIDER and MARTIN 1968)

Organism	Pleurotus ostreatus			Stachybotrys chartarum
Incubation time	10 days			28 days
Polymers from	Coniferylalcohol (labelled)	Coniferyl- (labelled) + p-Coumaryl- + Sinapylalcohol	Sinapyl- (labelled) + Coniferyl- p-Coumarylalcoh.	Coniferyl- (labelled) + Coumaryl- + Sinapylalcohol
$-O^{14}\underline{C}H_3$	4,5*)	3,8	7,0	13,2
$-CH=CH-^{14}\underline{C}H_2OH$	4,4	4,5	8,4	19,2
$-CH=^{14}\underline{C}H-CH_2OH$	2,6	2,5	-	-
$-^{14}\underline{C}_{1-6}$-Ring	14	22	-	9,7

All values in percent of added activity

The carbon atoms of variously labelled synthetic lignins are split off in cultures of Pleurotus ostreatus and Stachybotrys chartarum with different rates which can be followed by determination of active carbondioxide. Generally the carbon atoms of the methoxyl groups and carbinol carbon atoms are split off faster than the other carbon atoms. In the first 10 days a strong cleavage of the aromatic ring occurs in the culture of Pleurotus ostreatus. After 14 days however, it decreases and the percentage of the cleavage of the carbon atoms of the alcoholic and the methoxyl group increases. However, in case of Stachybotrys chartarum after 28 days the values for released labelled carbondioxide caused by ring cleavage were lower than by degradation of the carbinol group in the side chain and by the cleavage of the methyl ether group. Phenoloxidases are activated by phenol carboxylic acids.

5. Transformations of lignin degradation products

Phenol acrylic and phenol carboxylic acids have been identified as lignin degradation products with low molecular weight. The same substances could also be isolated from humified plant material (MAEDER 1960; FLAIG 1962) from peat (BELAV, 1967; SÜCHTIG and MACIAK, 1971) or from soils (BRUCKERT, JACQUIN and METCHE, 1967; SCHNITZER 1972 and others).

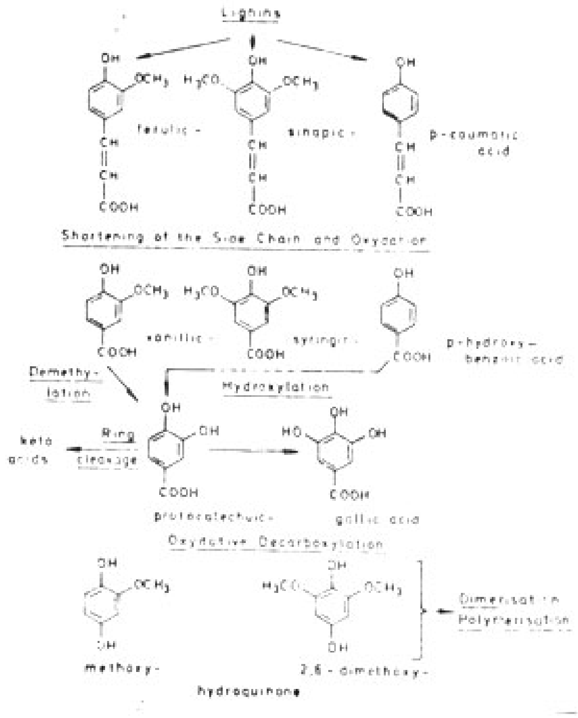


Fig. 8: Transformation of lignin degradation products

The most substantial transformations of lignin degradation products are:

1. The shortening of the side chain of phenol acrylic acids and formation of phenol carboxylic acids.

2. Demethylation of phenol ether to phenol carboxylic acids with hydroxyl groups in ortho-position (i.e. transformation of vanillic acid to protocatechuic acid).

3. Hydroxylation of phenol carboxylic acids to such acids with hydroxyl groups in ortho-positions (i.e. p. hydroxy benzoic in protecatechuic and gallic acid).

4. The oxidative decarboxylation to hydroquinone derivatives (i.e. transformation of vanillic acid in methoxy-hydroquinone).

5. The cleavage of the ring in the case of phenol carboxylic acids with hydroxyl groups in ortho-position to aliphatic keto-acids.

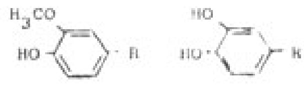
6. Dimerization and polymerization reactions.

These compounds participate in formation of humic substances as well as they have an influence on plant metabolism after uptake by the roots.

6. Participation of "synthetic lignins" and their degradation products in biosynthesis of humic substances.

Some fungi synthesize humic acid-like polymers in the culture solution or in their mycelium. By investigations with labelled compounds it is possible to determine to which extent the carbon atoms either of labelled "synthetic lignins" or of added phenolic lignin degradation products are included in this biosynthesis of humic substances.

Table 2: Participation of carbon-14 from synthetic lignins or from phenolic degradation products in formation of humic acid-like polymers in cultures of fungi (according to HAIDER and MARTIN 1967, 1968)

Stachybotrys chartarum, 4 weeks				Epicoccum nigrum, [illegible] weeks				
Synthetic lignin Coniferyl (labelled) + p-Coumaryl- + Sinapylalcohol				 R = -CH=CH-COOH				
	$^{14}CO_2$	Humic acids of Solution	Humic acids of Mycelium		$^{14}CO_2$	Humic acids	$^{14}CO_2$	Humic acids
$-O^{14}\underline{C}H_3$	13,2	9,6	4,9	$-O^{14}\underline{C}H_3$	58,4	9,8	-	-
$\overset{1}{-CH}=\overset{2}{CH}-{}^{14}\overset{3}{\underline{C}H_2}OH$	19,8	4,6	3,1	$\overset{3}{-CH}=\overset{2}{CH}-{}^{14}\overset{1}{\underline{C}OOH}$	-	-	54,8	1,3
				$-CH={}^{14}\underline{C}H-COOH$	45,6	6,8	52,1	6,2
$-{}^{14}\underline{C}H=CH-CH_2OH$	[illegible],7	10,7	14,6	$-{}^{14}\underline{C}H=CH-COOH$	14,7	15,5	-	-
$-{}^{14}\underline{C}_{1-6}$-Ring	9,6	21,6	17,6	$-{}^{14}\underline{C}_{1-6}$-Ring	6,6	41,0	6,5	46,0

All values in percent of added activity.

In the cultures of Stachybotrys chartarum humic acids can be precipitated by mineral acids after separation of mycelium or isolated from the mycelium by extraction with dilute sodium hydroxide. In case of Epicoccum nigrum the humic acids were obtained by precipitation with acid after separation of the mycelium by centrifugation. Both strains form the humic acid-like polymers from aliphatic carbon sources. The dark coloured polymers do not differ very much in their properties from humic acids isolated from soils or peat. It is known that both strains synthesize phenols in their metabolism (MARTIN, RICHARDS and HAIDER 1967; HAIDER and MARTIN 1968).

Furthermore, it could be demonstrated that the presence of phenolic lignin degradation products in the culture solution increased the quantity of humic acids remarkably.

In case of addition of "synthetic lignin" as well as ferulic acid or caffeic acid the values of the labelled carbondioxide indicate that the carbon atoms of the methoxyl, carbinol, or carboxyl group, take part much more in the release of carbondioxide than in the formation of humic acids.

Furthermore, it could be shown that the shortening of the side chain of phenolacrylic acids occurs mainly at the double bond. The formed C_2-degradation products, oxalic or glyoxylic acid are easily available for microorganisms. For this reason the radioactivity of released carbondioxide is high and that of humic acids low, when ferulic acid was labelled at the carbon atom 2. The most important fact for formation of humic substances is the relatively high activity of humic acids after addition of ring labelled compounds. The aromatic parts of lignin or its phenolic degradation products participate in the formation of humic acids.

The numbers indicate that also degradation products with one carbon atom in the side chain may have taken part in the formation of humic substances. This may be concluded by the fact that in the case of added compounds with carbon atoms labelled in 1-position i.e. coniferyl alcohol, respectively 3-position i.e. ferulic acid the values of activity are higher in the humic acids than by addition of compounds labelled in one of the two other carbon atoms of the side chain.

These experiments demonstrate that lignin or its phenolic degradation products take part in the formation of humic acids, after several chemical transformations, considerably. After addition of 14C-labelled glucose or cellulose to a soil several phenols could be isolated from the extracted humic acids by reductive cleavage after a time of 2 or 3 weeks. The phenols contained a remarkable part of activity and were synthesized by microorganisms (FUSTECMATHON et al. 1973).

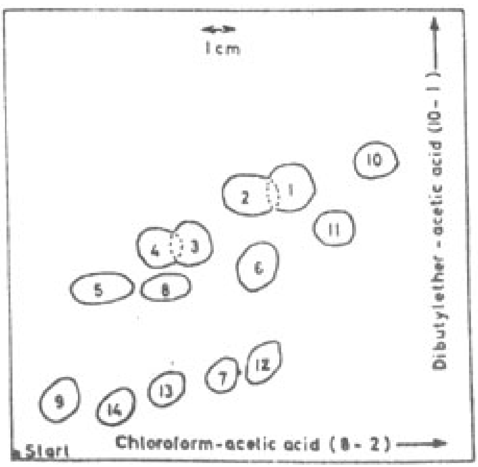
For some further discussion it shall be mentioned that the total nitrogen content of the microbial synthesized humic acids ranges between 6 and 7%. The quantity of a – NH_2 – nitrogen is mor than half of total N after a short time of cultivation and decreases with time to a fifth.

7. Participation of microbial synthesized phenols in biosynthesis of humic substances

By the work of BURGES, HURST and WALKDEN (1963, 1964) or MORRISON (1963) and FARMER and MORRISON (1964) it is known that besides the phenolic compounds which can be derived from lignin, also phenols derived from flavonoids or synthesized by microorganisms are important initial material for the formation of humic substances. These authors isolated by reductive or oxidative cleavage of humic acids, also compounds which belong to 1,3-di – or 1,3,5 – triphenols, and cannot be derived from lignin or its degradation products. Another method to determin aromatic constituents is the oxidation with potassium permanganate after methylation of the humic fractions (KHAN and SCHNITZER, 1971).

The participation of phenols of resorcinol type in the formation of humic substances has been demonstrated (HAIDER and MARTIN, 1967, 1968, 1970; MARTIN and HAIDER, 1969, 1971; MARTIN, RICHARDS and HAIDER, 1967).

For instance Epicoccum nigrum forms dark coloured substances with properties which are comparable with those of the humic acids (FILIP, 1974). From these different resorcinol derivatives could be identified after reductive cleavage.



Phenols recovered after Na-amalgam reduction of E. nigrum humic acid. Two dimensional thin layer chromatogram on silica gel (GF) plates. Spots located with diazotized sulfanilic acid reagent or with ultra-violet light. Phenols identified as follows: 1 = Orsellinic acid; 2 = 2,4-dihydroxy benzoic acid; 3 = 2,4-dihydroxy toluene; 4 = Orcinol; 5 = 3,5-dihydroxybenzoic acid; 6 = 2,4,5-trihydroxy-toluene; 7 = 2,3,5-trihydroxy-toluene; 8 = Protocatechuic acid. Found only when caffeic acid was present in culture solution; 9 = 2,4,6-trihydroxybenzoic acid; 10 to 13 = Unidentified, yellow-orange or pink-violet color with reagent. 14 = Unidentified. Located with ultraviolet light.

Fig. 9: Two dimensional thin layer chromatogram of phenols after reductive cleavage of humic acids from culture of Epicoccum nigrum with Na-amalgam (MARTIN et al. 1967).

But it should be mentioned that other micro-organisms synthesize still other phenoles (Summary: MARTIN and HAIDER, 1971).

Some more phenolic intermediates could be isolated from the culture media of Epicoccum nigrum.

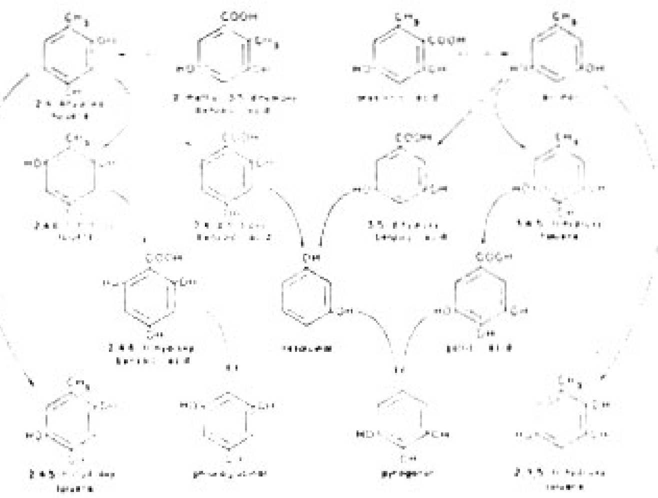


Fig. 10: Synthesis and transformation of phenols by microorganisms (Epicoccum nigrum) (HAIDER and MARTIN, 1967).

Summarizing all results it can be established that orsellinic acid was identified; this is formed through the acetate-malonate metabolism of organisms. 3,5-dihydroxytoluene (orcinol) is formed by decarboxylation. By oxidation 3,5-dihydroxy-benzoic acid is formed, by decarboxylation resorcinol, but it is seldom found. From 3,5-dihydroxytoluene (orcinol), 6-methyl-hydroxy-hydroquinone (2,3,5-trihydroxytoluene) and 4-methyl-pyrogallol (3,4,5-trihydroxytoluene) furthermore gallic acid are formed by hydroxylation. Presumably, pyrogallol is formed by the decarboxylation of gallic acid.

Cresorsellinic acid, which could also be identified, may be formed through the aliphatic acid metabolism. By similar reactions as in the case of orsellinic acid, 2,4-dihydroxytoluene, 2,4-dihydroxybenzoic acid and also resorcinol are formed. The hydroxylation of 2,4-dihydroxytoluene leads to 2,4,6-trihydroxytoluene and 5-methyl-hydroxy-hydroquinones (2,4,5-trihydroxytoluene).

In the culture solution of the fungus also substances such as p-hydroxy-benzoic, protecatechuic, gallic and p-hydroxycinamic acid could be identified in small amounts. These acids are formed through the carbohydrate metabolism by the reaction of phosphornolpyruvic acid with erythrose-4-phosphate to shikimic acid and then by some further metabolic pathways. In culture solution no methoxyl derivatives such as vanillic or syringic acid could be found.

The 5- and 6-methyl-hydroxydroquinons (2,4,5- and 2,3,5-trihydroxytoluene) as well as pyrogallos and its methyl and carboxyl derivatives are responsible for the formation of the higher molecular weight nitrogenous humic acids like substances in the culture media of Epicoccum nigrum, because they react with amino acids under these oxidazing conditions. Resorcinol derivatives do not form this type of nigrogenous compounds.

In this connection it must be mentioned that hydroxyhydroquinone is formed by the enzymatic oxidation of different lignin degradation products in microbial cultures from protocatechuic acid by decarboxylation and furthermore by oxidation of this acid in the presence of phenol oxidases (FLAIG and HAIDER 1961; HAIDER, LIM and FLAIG, 1964).

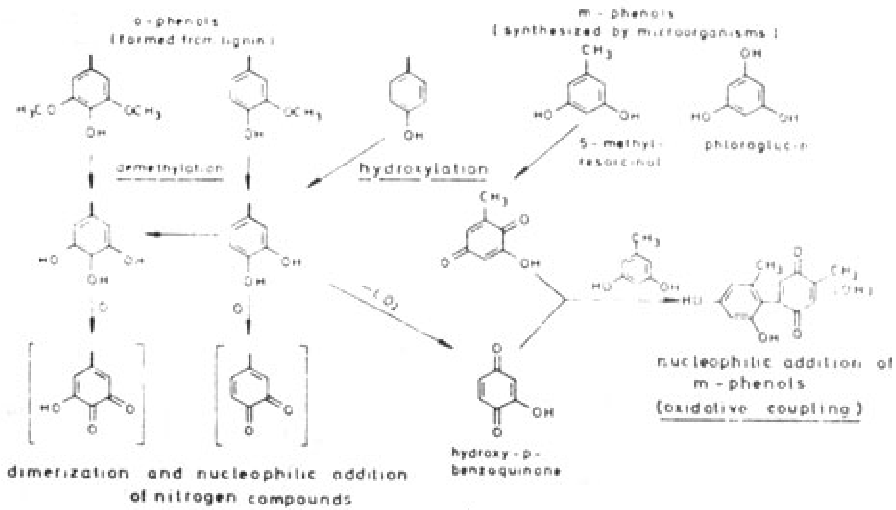
These derivatives of polyphenols can be oxidised to quinones in the culture media at pH-values of 6 to 8, whilst this is not the case with derivatives of resorcinol and phloroglucinol.

This means that generally compounds which are able to form quinones would be important for the formation of nitrogenous humic substances.

8. <u>Different reactivity of phenols participating in humic substances formations</u>

Among the identified phenols isolated after oxidative or reductive cleavage of humic acids, or isolated from soils or synthesized by microorganisms, there exist two types of phenolic compounds which are of interest in studies about the structure and therefore also of the chemical and physical properties of humic acids.

In the following scheme the different reactions are mentioned:



<u>Fig. 11:</u> Transformation of polyphenols under oxidizing conditions

After demethylation of lignin degradation products with side chains of 1 or 3 carbon atoms different phenols are formed which possess two or several hydroxyl groups in o-position. Dimerisation and polymerisation occur during oxidation. Many microbial synthesized phenols have two or three hydroxyl groups in m-position.

By hydroxylation also phenols are formed with OH-groups in o-position.

The compounds with OH-groups in o- or m-position differ widely in their reactivity. Catechol, pyrogallol, hydroxyhydroquinone derivatives add nucleophilicly derivatives of resorcinol and phloroglucinol (MUSSO <u>et al.</u> 1965) as well as proteins or their products of hydrolysis during oxidation to quinonoid intermediates. Phenols with OH-groups in m-position do not. Phenolcarboxylic acids are transformed by decarboxylation to hydroquinone derivatives and by further oxidation to quinones.

The differences in reactivity are important with respect to the function of nitrogen in the molecule of humic acids. The oxidative coupling leads to ramification and increases aromaticity.

9. <u>Degradation of straw by different types of microorganisms</u>

Further experiments have been made about the decomposition of lignin containing material such as sterilized wheat straw:

(a) by pure cultures of soil fungi of different systematic groups, which synthesize phenols in their metabolism, and

(b) by pure cultures of basidiomycetes which do not synthesize phenols

Both types of fungi degrade lignin.

Table 3: Phenol synthesizing soil fungi and Basidiomycetes not phenol synthesizing (GRABBE and HAIDER, 1971)

Lignin Decomposing, Phenol Synthesizing Soil Fungi		Lignin Decomposing Basidiomycetes without Microbial Phenol Synthesis
Preussia fleischhakii (A)	Phialophora cyclaminis (F.i.)	Lentinus edodes
Pyrenochaeta sp. I (F.i.)	Humicola grisen (F.i.)	Hypholoma capnoides
Sordaria verruculosa (A)	Hormiactis candida (F.i.)	Polystictus versicolor
Chaetomium piluliferum (A)	Stachybotrys chartarum (F.i.)	Agaricus bisporus
Sporarmia aemulans (A)	Mammaria echinobotryoides (F.i.)	Cantharellus aurantiacus
Cladorrhinum sp.III (F.i.)	Epicoccum nigrum (F.i.)	Bjerkandera adusta
Doratomyces nanus (F.i.)		

A = Ascomycetes F.i. = Fungi imperfecti

In total 19 strains were investigated.

The results are:

1. By the action of fungi with and without biosynthesis of phenols the general observations were made:

   1.1 The lignin degradation after 4 months was between 25–45 % in both cases.
   1.2 The methoxyl content of the isolated lignin fractions decreased between 50–60 % in both cases afterwards.
   1.3 In the high molecular weight fractions of lignin and humic acids a remarkable amount of nitrogen (which was added as asparagine) was fixed which can be hydrolized by 6 N HCl to 30–40 %.

2. In the case of not phenol synthesizing strains the production of humic acids was lower.

3. The chemical structure of phenols in the humic acids was different.

   3.1 In the case of fungi which synthesize phenol, lignin derived and microbial synthesized phenols are found by two dimensional thin layer chromatography with Silica Gel Merck after reductive cleavage with Na-amalgam of humic acids fractions and fractions of rotted lignin. This means that humic acids are formed not only by condensation of lignin derived but also microbial synthesized phenols. It seems furthermore that also degraded lignin reacts with microbial synthesized phenols.

   3.2 In the case of fungi which do not synthesize phenols only lignin derived phenolic compounds are found in the humic acids fractions by thin layer chromatography.

4. Spectrographic measurements indicate that humic acids formed during rotting of straw in the presence of phenol synthesizing fungi are more similar to those isolated from soils than the others.

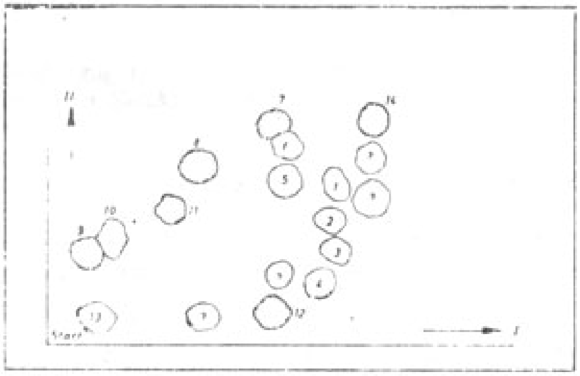


Fig. 12

Two dimensional thin layer chromatogram on silicea gel (GF)-plates. Spots located with diazotized sulfanilic acid reagent or with ultra violet light.

Phenols identified as follows: 1 - vanillic acid: 2 - vanillin; 3 - syringic acid; 4 - syringic aldehyde; 5 - cumaric acid; 6 - p-hydroxybenzoic acid; 7 - orsellinic acid; 8 - orcinol; 9 - phloroglucinol; 10 - methylphloroglucinol; 11 - pyrogallol; 12 - 2,3,5-trihydroxybenzoic acid; 13 - gallic acid; 14 - 6-methylsalicylic acid. (In the picture lignin derived phenols are shown full surrounded, phenols derived from fungal metabolism are punctated).

10. Influences of clay minerals on microbial synthesis of humic substances

The interest in this subject increased in the last few years, the problem is summarized by FILIP et al. (1971) i.e.

The effect of addition of montmorrilonite to culture solution of fungi has also been investigated in the case of Epicoccum nigrum in connection with the formation of humic substances (summary, FILIP et al. 1971). These investigations were made with this fungus because by former investigations it was known which phenolics are formed by this fungus in its metabolism and which transformations had to occur when humic substances are formed as reported above.

The dark coloured humic acid-like substances have been compared with humic fraction from soil and model substances (FILIP et al. 1974).

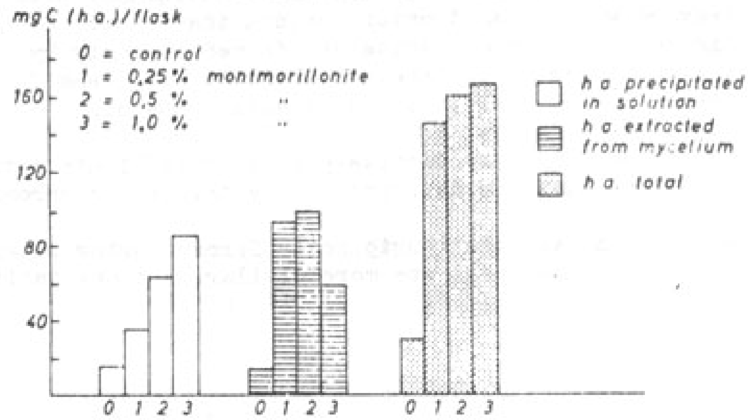


Fig. 13: Formation of humic acids dependent on the quantity of added montmorillonite (FILIP et al. 1972 a)

The addition of montmorillonite has also an effect on the quantity of humic acids. The humic acids are taken as g carbon/vessel of culture.

The humic acids which could be precipitated with mineral acids from a nutrient solution, increase with the quantity of montmorillonite. Humic acids which can be extracted from mycelium by alkaline extraction do not follow exactly the same tendency. If one adds different types of humic acids and also those which can be isolated from mycelium with sulphuric acid after hydrolysis, in total an increase of the weight of humic acids can be observed by increasing the quantity of montmorillonite added.

This effect could not be observed by addition of kaolinite or quartz. Only some types of microorganismsshowed similar behaviour. In some cases the effect was larger in shake cultures than in the stand cultures (FILIP et al. 1972 a, b). Some observations lead to the conclusion that alterations of the concentrations of the low molecular weight substances cause this effect.

11. Participation of nitrogenous substances in the formation of humic substances

Finally the distribution of nitrogen in humic acids was determined mostly by hydrolysis with 6N HCl (BREMNER, 1965). Depending on the environmental conditions during the formation the nitrogen content of humic acids is between 1-5 per cent.

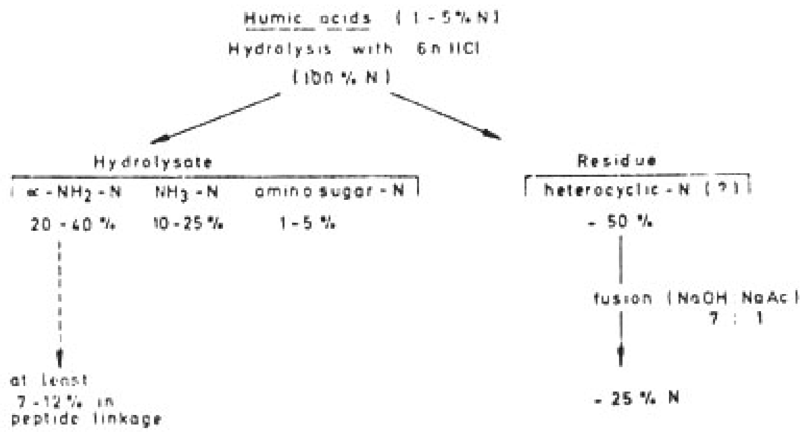


Fig. 14

The nitrogen content of humic acids was determined by different methods as:

20 – 40 % as α–NH_2–N

10 – 25 % as NH_3–N

1 – 5 % as amino-sugar. At least 7-12 % of α–NH_2–N is in the peptide bondings. About 50 % nitrogen remains in residues and is supposed to be bound to a large extent in heterocyclic form. In fusion with a mixture of sodium hydroxide and sodium acetate up to 25 % N can split off again (FLAIG and BREYHAN, 1956).

The content of hydrolysable α-amino-nitrogen of the lignin fractions decreases during the humification of plant material, although the percentage to total nitrogen increases. This can be explained in two ways. Either nitrogen as amino acids or peptides continues to condense with the degraded lignin during humification, or the peptide chains are increasingly decomposed by the microorganisms. There is the possibility that both of these latter nitrogen reactions occur simultaneously.

Only the hydrolysable nitrogen is source of available nitrogen for the nutrition of organisms. In this connection it may be remembered that humus can also serve as a slow release nitrogen

…lizer (FLAIG and SÖCHTIG, 1967). Experiments with N^{15} labelled mineral nitrogen fertilizer have shown that approximately 50–60 % of the uptaken nitrogen comes from the mineral nitrogen fertilizer and 40–50 % from the nitrogen of soil organic matter, as mentioned above.

12. About the linkage of amino acids, peptides and proteins in humic acids

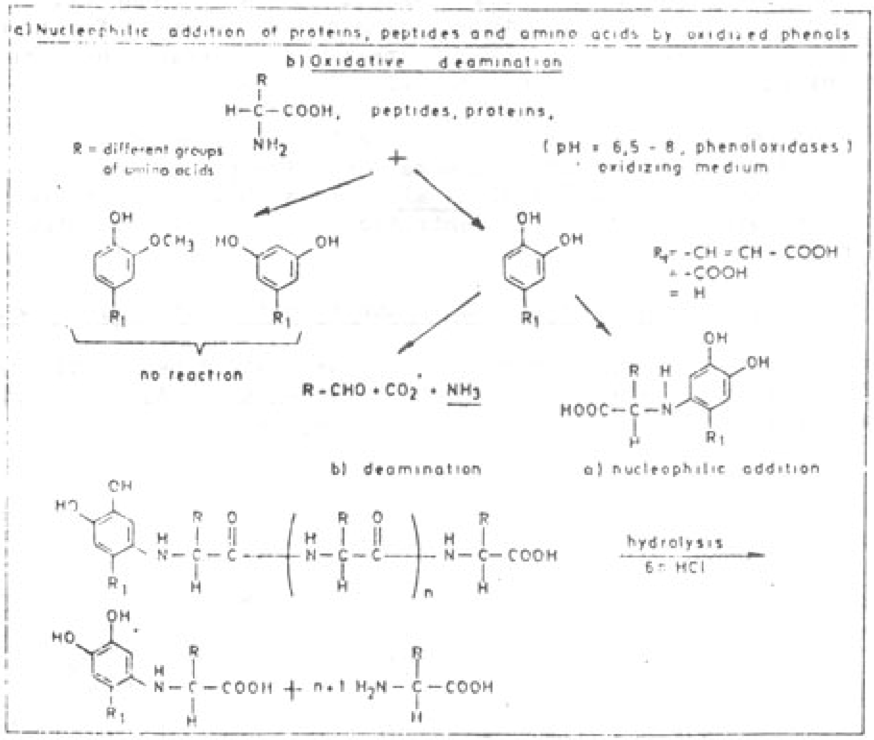


Fig. 15: Reactions of proteins, peptides and amino acids with phenols in oxidizing medium.

Extensive studies have been made with labelled amino acids about the possible linkage of proteins and of their products of hydrolysis to phenols during oxidation (HAIDER, FREDERICK and FLAIG 1965). Some lignin degradation products or some phenols of microbial origin can add nitrogenous compounds derived from proteins at variable rate and in different amounts during oxidation in the presence of phenoloxidases. Summarizing, it could be established that guajacol and resorcinol derivatives however do not add amino acids in a pH-range of 6.5 to 8.0.

The rate of nucleophilic addition (a) is the highest in the case of catechol and hydroxyquinone derivates. Addition by pyrogallol derivatives occurs also to a smaller extent, depending on the chemical constitution of the derivatives. By means of labelled compounds it could be established that the amino acids are added intact. An addition also occurs with peptides and proteins.

Furthermore, during oxidation in the presence of phenol oxidase and nitrogen compounds, catechol derivatives polymerize to nitrogenous polymers which have properties comparable to those of humic acids. In contrast the polymers of guajacol derivatives do not contain nitrogen (FLAIG and HAIDER 1961 b).

After nucleophilic addition the amino acids cannot be hydrolized from the corresponding addition products by 6N hydrochloric acid. In case of addition products formed with proteins and peptides, all the amino acids could be hydrolized with the exception of the N-terminal amino acids in which the amino groups have reacted with the oxidized phenol (HAIDER, FREDE-RICK and FLAIG 1965; HAIDER and MARTIN 1970). Therefore, not all non-hydrolizable nitrogen is bound in humic substances in heterocyclic form as is often supposed.

By oxidative deamination (b) the amino acids are transformed into ammonia, carbondioxide and in a carbonyl compound; this reaction occurs mostly contemporarily.

If both reactions, addition and deamination, occur together, more than 1 Mol oxygen is uptaken (HAIDER, FREDERICK and FLAIG 1965). One molecule quinone gives one addition product but deaminates several mols of amino acids.

13. Stabilization of amino sugars

Very recently work has been carried out with labelled glucosamine, chitosan (polyglucose-amine) to show that these substances are stabilized by nucleophitic addition on phenols in oxidizing medium.

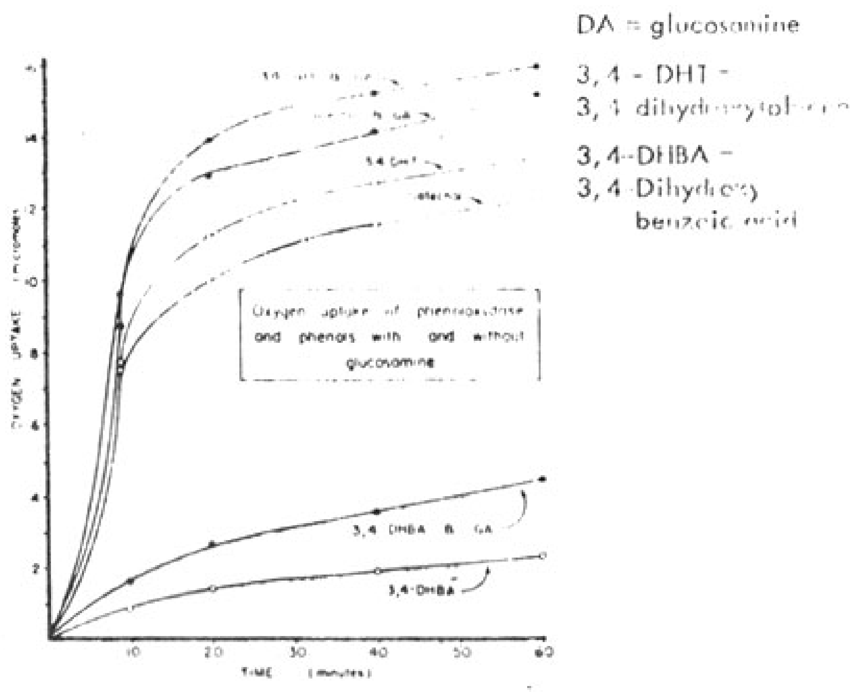


Fig. 16: Oxygen uptake in reaction mixtures as phenol oxidase and phenols with and without glucosamine (BONDIETTI, MARTIN and HAIDER, 1972)

Model substances have been prepared by shaking of phenolics with hydroxy groups in ortho position in the presence and absence of glucosamine at pH 8.0. The oxygen uptake in the presence of glucosamine and chitosan was higher than without glucosamine. This means that reaction between glucosamine and the phenols occur. Experiments about humic acid like polymers with ^{14}C-labelled glucosamine or chitosan have shown that the glucosamine in these polymers is more or less stabilized.

14. Stability of microbial synthesized polysaccharides

Some of the organic soil constituents contribute to a larger extent to soil structure by interaction with the inorganic soil colloids such as clay minerals and amorphous sesquioxides. Among them there are more or less linear mixed polymers of saccharides with uronic acids of relatively high molecular weight. The complexes between the organic high molecular weight substances and the inorganic soil colloids contribute to a favourable soil environment for plant growth.

The mentioned polymers are mainly synthesized by microorganisms. In connection with the use of organic materials as fertilizers it is interesting to know the stability of these polymers against microbial attack and their possible transformation in humic substances. MARTIN et al. (1974) investigated the rate of decomposition of carbon-14 labelled microbial polysaccharides in soil and the distribution of the residual carbon-14 in various humic fractions.

Table 4: Distribution of activity of carbon-^{14} labelled microbial synthesized polysaccharides in Greenfield sandy loam after 2 and 16 weeks (MARTIN et al. 1974)

Polysaccharide from:	Percentage ^{14}C distribution: CO_2 released		Humic acids		Fulvic acids		Humins		Total	
After weeks	2	6	2	6	2	6	2	6	2	6
Leuconostoc dextranicus⁺	70	85	4	4	10	8	10	6	94	103
Azotobacter indicus	52	68	6	3	18	7	13	27	89	105

+ Based on total activity added

15. Summary of comments on the biochemistry of formation of humic substances

The basic research work about chemical composition of humic substances in regard to their phenolic and nitrogenous structure units is summarized in figure 17.

The depicted scheme concerns mainly the biochemical problems of formation of humic substances and therefore does not give a complete information about other processes which occur during humification. The scheme shows that there are two essential sources of phenols for the formation of humic substances in nature.

1. The formation of phenols from lignin occurs mainly by biochemical degradation, whereby the cleavage of C—C bonds, of ether linkages and of the aromatic ring plays an important role. By this the structure of the lignin molecule is disrupted. Larger or smaller degradation products are formed which contribute to the composition of humic substances by reactions with nitrogenous compounds in all phases of the degradation. Methylether cleavage plays an important role for nitrogen fixation.

2. The microbial synthesized phenols of mainly resorcinol and phloroglucinol type contribute to the composition of humic acids by oxidative coupling as well as after transformation by hydroxylation to phenols oxidizable to quinones and by reactions with nitrogenous compounds.

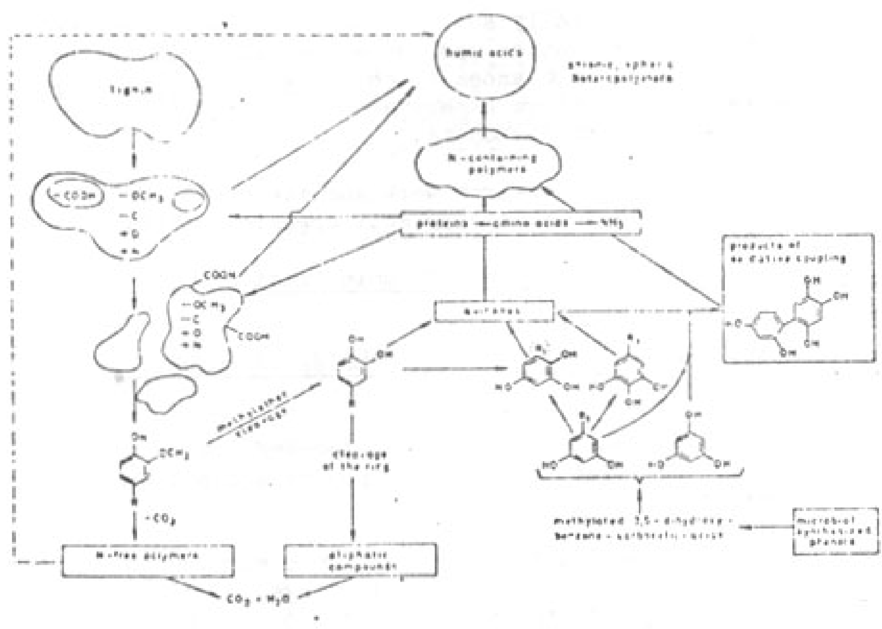


Fig. 17: Contribution of phenolic and nitrogenous structure units to chemical composition properties of humic substances

It is not known how far nitrogen-free polymers containing lignin degradation products with methoxyl groups participate in the formation of humic substances. They are available for the microorganisms as a carbon source.

Aromatic compounds with hydroxyl groups in o-position derived from lignin or microbial synthesized phenols disappear from the equilibrium of compounds which exists during the formation of humic substances by cleavage of the benzene ring and formation of aliphatic acids.

Many questions will remain to be answered; it is not known to which extent the high molecular or the low molecular weight fractions of lignin or its transformation products participate in the formation of various groups of humic substances conventionally defined as fulvic acids, hymatomelanic acids, humic acids and humins. Furthermore, it is not yet clear which of the condensation products of phenolic and nitrogen containing compounds are the most stable under soil conditions. For soil productivity the availability of the organic bound nitrogen is important.

Basic research work about nitrogen fixation and about nitrogen release from soil organic matter is necessary to understand these processes in connection with their importance of crop production. This concerns also the experiments with ^{15}N.

In respect to some physical properties of humic substances, it could be mentioned that in the course of the mentioned reactions, the formation of heterocyclic compounds may occur which possibly contribute to the colour, an essential property of humic substances. The reactions have been discussed which lead to the formation of higher molecular weight substances like humic acids which are anionic, spherical shaped heteropolymers (FLAIG and BEUTELSPACHER, 1968).

16. About the possible effect of humus constituents on plant metabolism and yield

Another part of studies about biochemistry of soil organic matter is the investigation of the influence of fractions of humus or of defined compounds isolated from the organic part of the soil on plant growth and yield.

In general all kind of physiologically active substances have an effect on metabolism in very small traces. Their investigation was therefore difficult in the past. But an elucidation of the action of organic substances of soil organic matter on plant metabolism can be anticipated, because more sensitive experimental techniques have become available and the compounds can be labelled with carbon-14.

In the following some fundamental research work and its consequences are reported which deal with the "soil-plant-system" concerning soil organic matter.

17. Uptake, transport and transformation of humic fractions or phenolic compounds in the plant.

17.1 Experimental prerequisites for the studies of uptake of labelled phenol carboxylic acids.

Experimental prerequisites must be provided for the use of labelled compounds in order that actually the effect of added compounds and not that of transformation products is observed.

The investigations of labelled fractions of humic substances are connected with some difficulties because their constituents are not yet chemically identified in detail. For this reason one does not know which transformation of these fractions occurs when they are sterilised.

The added substances can be degraded by activity of microorganisms and may penetrate into the plant faster than the original substances.

Therefore it seems absolutely necessary to us to work in sterile medium for investigations about uptake of defined compounds in order that no microbially caused transformation products with labelled carbon atom simulate an uptake of the added compounds by means of measured activity of roots and sprouts. The determination of the released carbon dioxide as in the case of addition carboxyl labelled phenol carboxylic acids allows to draw conclusions about the occuring reactions which transform the added compounds. Therefore in this connection a setup is briefly described which was used for our investigations (HARMS, 1967).

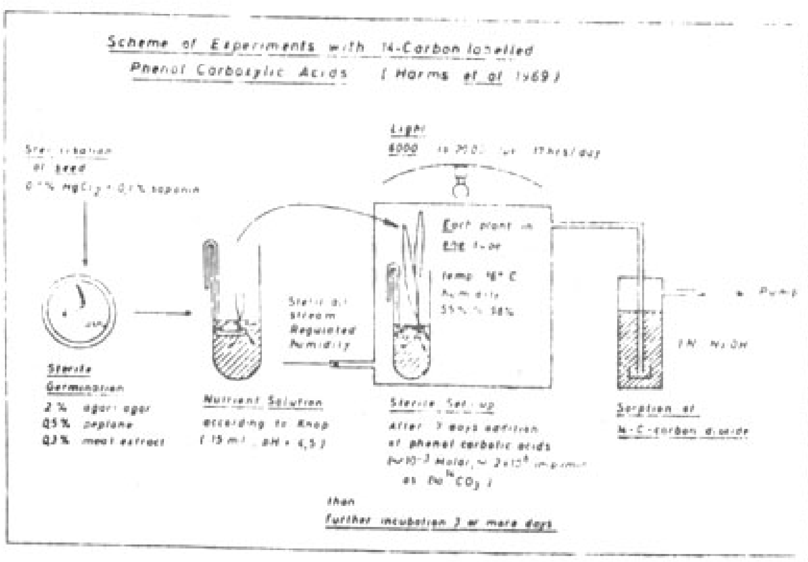


Fig. 18: Scheme of experiments with ^{14}C-labelled phenol carboxylic acids (HARMS et al. 1969)

Seeds have been sterilized in a 0.1 solution of $HgCl_2$ with 0.1 % saponin. The sterile germination was made at agar with 0.2 % peptone and 0.1 % malt extract. When the root has been 1 cm, the seed was transferred into nutrient solution, then fixed with small glass fork in a small vessel. Each plant in one tube has been brought in a close system through which a regulated stream of air was passed. The normal temperature was about 16°C, humidity about 55 %, and light intensity 18 000. These climatic factors could be regulated.

After 7 days the phenol carboxylic acids were added in a concentration of about 10^{-4} to 2×10^{-6} M.

Volatile reaction products mainly labelled CO_2 were transported by the air stream and sorbed in sodium hydroxide. The rate of stream is about 60 l/h. Plants have grown under these conditions between 3 and 42 days.

17.2 Phenol carboxylic acids (lignin degradation products)

The use of chemically defined and labelled compounds has the advantage that their uptake and distribution in the plants can be investigated very exactly. After extraction of plants with corresponding solvents, after separation of the extracted compounds by thinlayer chromatography and by determination of specific activity of the single compounds the uptake cannot only be determined in their order of magnitude, but also the transformations of the added compounds can be followed as long as the group with the labelled atom is not split off.

To study the uptake of phenolic lignin degradation products such as phenol carboxylic acids or others, they have been labelled in different carbon atoms. Thereby the transformation of added compounds could not only be determined more exactly but also their participation in reactions of metabolism could be followed in a better way (HARMS 1967; HARMS, SOCHTIG and HAIDER, 1969 a, b; HARMS, SOCHTIG and HAIDER, 1971; HARMS and PRIESS, 1973).

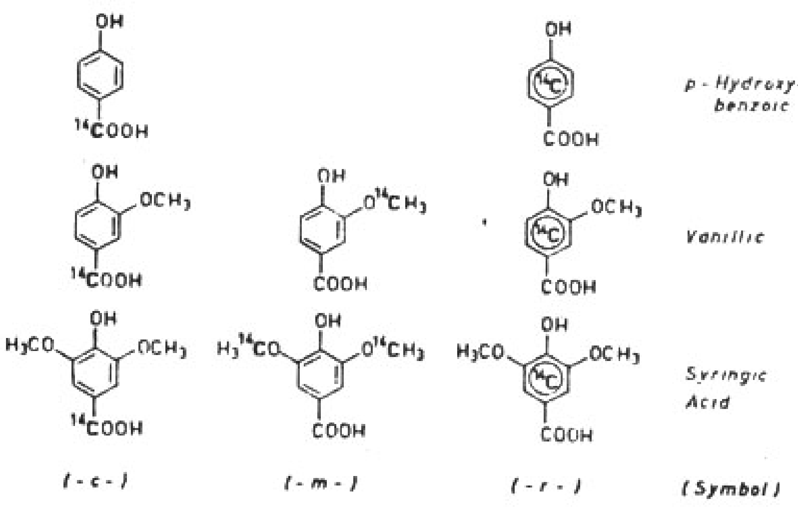


Fig. 19: Differently labelled phenol carboxylic acids

The phenol carboxylic acids are labelled in the carboxylic group (symbol c) in the methoxyl group (symbol - m) and uniformly in the ring (symbol - r). By the different labelling it was possible to elucidate some more reactions.

In the following at first some principal results of experiments with three different substituted phenol carboxylic acids will be mentioned.

<u>Table 5</u>: Relative distribution of the activity in the plant and in the released carbondioxide (the total sum of the assimilated activity = 100 %) after incubation with carboxyl labelled p-hydroxy-benzoic, vanillic and syringic acid for 3 to 6 days (HARMS et al. 1969)

		incubated with		
		p-hydroxybenzoic acid	vanillic acid	syringic acid
		percent of the assimilated activity		
incubated for 3 days	roots	69.5	56.4	40.1
	shoots	23.0	9.6	13.3
	released CO_2	7.5	34.0	46.6
incubated for 6 days	roots	67.0	51.5	45.9
	shoots	25.0	10.1	10.6
	released CO_2	8.0	38.4	43.5

The distribution of the activity was determined in roots, in sprouts and in liberated carbon dioxide. The numbers of the activity in percent of the quantity of phenol carboxylic acids added to nutrient solution after an incubation time of 3 and 6 days are depicted in table 5.

It can be concluded that:

1. The largest quantity of activity is in every case in the roots.

2. The quantity of activities increases in the roots, in the shoots and in the liberated carbon dioxide with incubation time.

3. The activity measured in the shoots is about 1 to 3 % of the activity which has been added in the form of phenol carboxylic acids or between 10 and 25 % of the assimilated activity. The quantity depends on the substitution of the benzoic acid with hydroxyl or methoxyl groups. The differences of uptaken activity in shoots are not large during the different incubation times.

4. The amount of liberated carbon dioxide differs remarkably; in the case of p-hydroxy-benzoic acid it was the smallest (about 0.5 % respectively 0.95 % of the added or 8 % of the assimilated quantity), in the case of vanillic acid it increases largely (about 35 % of the assimilated quantity) and in the case of syringic acid it was the highest (about 45 % of the assimilated quantity).

   Therefore the extent of decarboxylation increases with increasing number of methoxyl groups in o-position to the OH-group in 4-position.

At the end of the experiment it was established by analysis that besides the added phenol carboxylic acids no other labelled phenolic compounds remained in the nutrient solution. The sum of the activity in the nutrient solution, the uptaken and the respirated activity corresponds nearly to the added.

Above all the large part of the activity in the roots was noticeable. This could not be decreased by rinsing the roots with diluted sodium hydroxide solution. The investigations made hitherto cannot explain the type of binding. First of all we suppose that the accumulation is a sorption effect.

With the results of differently labelled vanillic acids the further principles of the reactions will be shown. They were also found in the case of other differently labelled phenol carboxylic acids.

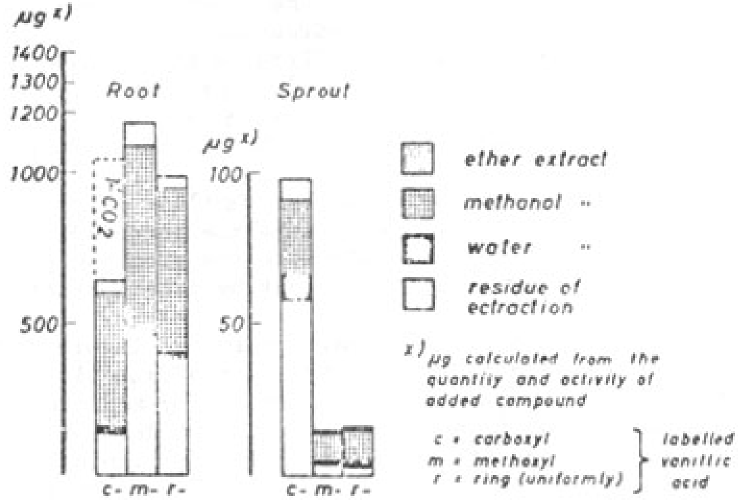


Fig. 20: Content of activity in sprouts and roots and in the different extracts after incubation with differently labelled vanillic acid (6 days) (HARMS et al. 1971)

The immediately deep-freezed, lyophylized and then pulverized plant organs were subsequently extracted with ether, then with methanol and finally with water for separation of activities which were in roots and sprouts.

In the case of carboxylic labelled vanillic, the sum of the activity in the roots is smaller than in the case of methoxyl and ring labelled vanillic acid. But when one adds the activity of released labelled carbondioxide the values correspond.

In the following only the principal differences are mentioned.

1. A small amount of free acid is found by thin layer chromatography only in the ether extract of the shoots of plants.

2. The sorptively bound and the transformed phenol carboxylic acids are extracted with methanol. These extracts contain by far the largest part of activity.

   The sorptively bound acids which were extractable with methanol were found by means of thin layer chromatography in all cases of added phenol carboxylic acids. Furthermore it could be demonstrated by hydrolysis with diluted sulfuric acid or by a β-glucosidase, by following thin layer chromatography as well as by means of UV-spectra and measuring of activity of the single compounds that the phenol carboxylic acids are present in the plant partly as glucose esters, glucosides or as glucose esters of glucosides.

   At the moment only assumptions can be made about the metabolic importance of the reactions between glucose and phenol carboxylic acids to the corresponding glucose derivatives as well as about the cleavage into the initial compounds again. It seems not sufficient to us to explain the formation of glucosides and/or esters only as a reaction to detoxicate the phenolic compounds.

3. The activity found in the water extracts and in the residues of extraction is explained with the endogenous fixation of carbon dioxide which is split off from the phenol carboxylic acids.

4. The activity of the residues of extraction of sprouts in the case of carboxyl labelled vanillic acid was mainly fixed in the holocellulose or α-cellulose respectively. After hydrolysis with 6N hydrochloric acid of the residues of extraction of sprouts the remaining activity is fixed in amino acids, soluble proteins and sugars (HARMS, SÜCHTIG and HAIDER 1969 b). The main part of activity was in the amino acids, aspartic and glutamic acid, which are formed by amination of oxalacetic acid and α-ketoglutaric acid from the citric acid cycle.

5. The activity in the roots of carboxyl-labelled vanillic acid treated plants is smaller than in the case of methoxyl- and ring-labelled acid. The reason is that a part of the vanillic acid and its decarboxylation products polymerizes. In the case of carboxyl-labelled acid activity is lost by decarboxylation.

In one of the first slides about the transformation of lignin degradation products it was mentioned that by oxidative decarboxylation of substituted phenol carboxylic acids, the corresponding hydroquinones are formed. By addition of differently labelled vanillic acids or syringic acids it could be demonstrated that methoxy- and 2,6-dimethoxy hydroquinone are also formed in the plants by decarboxylation. These compounds could be identified in a quantity which corresponds to about 1 % of the added activity (HARMS, SÜCHTIG and HAIDER, 1971). The hydroquinones are 10 to 100 times more physiologically active in plant metabolism than the corresponding phenol carboxylic acids.

17.3 <u>Transformation of phenolcarboxylic acids in cell suspension cultures of plants</u>

After collecting experience about uptake, transport and transformation of phenol-carboxylic acids with substitution pattern of lignin building blocks or its precursors in plants (HARMS *et al.*, 1969 a, b, 1971), experiments were made to study specific transformations of these compounds. For this purpose phenolcarboxylic acids differently substituted and labelled at different carbon atoms have been added to cell suspension cultures of soybean (*Glycine max.*), mung bean (*Phaseolus aureus Roxb*), and wheat (BERLIN *et al.* 1971, HARMS *et al.* 1972).

The results can be compiled as follows:

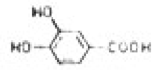
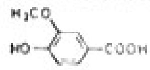
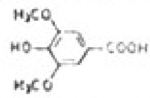
1. A decarboxylation of phenolcarboxylic acids is only affected if the carboxyl group is in p-position to the hydroxyl group. Salicylic acid is hardly decarboxylated. The mechanism of oxidative decarboxylation and the formation of corresponding hydroquinones has been reported above.

2. A demethylation occurs to a small extent in contrast to the microbial degradation when the methoxyl groups are in 3-position.

3. Nearly a complete demethylation takes place only in the case of the substitution of the ring with a methoxyl group in 4-position as it can be seen from the values of the corresponding labelled anisic and veratric acid.

4. The cleavage of the ring occurs only in the case when the hydroxylgroups are in o-position and leads to aliphatic keto acids.

5. The combination of the single results permits the statement that the ring system remains intact after decarboxylation and after demethylation.

	$^{14}COOH$	$-^{14}CH_3$	
	0	.	0
	21,1		1,0
	1,4		-
	65,9	.	12,5
	8,3	1,5	0,4
	8,6	1,5	-
 *)	1%	64%	0,1%
 *)		3-O-Methyl 0,8% 4-O-Methyl 52%	

<u>Fig. 21:</u> Released 14-carbondioxide from phenol-carboxylic acids in cell suspension cultures of soybean after 72 h (according to BERLIN <u>et al.</u> 1971; HARMS <u>et al.</u> 1972)

6. The demethylation of anisic acid to p-hydroxybenzoic acid occurs almost quantitatively in the cell. In contrast to the direct application of p-hydroxybenzoic acid to the cell cultures p-hydroxybenzoic acid is not decarboxylated when it is formed from anisic acid in the cell. This result could be explained therewith that p-hydroxy-benzoic acid formed in the cell is present as glycoside or that decarboxylation and demethylation occurs in different compartments of the cell.

7. According to these results it is possible that degradation products of the rings participate in the synthesis of plant substance. A part of the carbondioxide, originated from the carboxyl group of the phenolcarboxylic acids is evidently endogenous fixed and is found in the fractions of carbohydrates, lignin and protein (HARMS and coworkers 1969, b).

   This position specific O-demethylation of benzoic acids occurs also in wheat seedlings. These investigations were made with methoxy-phenol carboxylic acids contemporarily labelled with C^{14} and H^3 so that quantity of the different reaction products could be determined (HARMS and PRIESS 1973).

17.4 <u>Influence of environmental conditions on the uptake</u>

Some experiments have shown that environmental conditions have an influence on the uptake of phenol carboxylic acids by the plants.

Table 6: Influence of pH of the nutrient solution on the uptake of vanillic acid at 55 % rel. air humidity (HARMS et al. 1969)

	pH of nutrient solution		
	3.5	4.5	5.5
	percent of the added activity		
roots	2.43	4.35	3.96
sprouts	0.29	0.40	0.26
released CO_2	1.11	2.60	2.37
total	3.83	7.35	6.59

The uptake of vanillic acid in the sprouts depends upon the pH-value of the nutrient solution and is therefore differently large. The migration of vanillic acid into the shoots is the most when the pH-value of nutrient solution corresponds to the pH-value of vanillic acid which is 4.4. Similar observations were made in other cases of physiologically active substances.

Experiments with different relative humidity demonstrated that the dependence of uptake of vanillic acid from pH-value is larger in the case of a humidity of 50 % than in that of 98 % (HARMS 1967).

Furthermore light intensity as an environmental factor has also an influence on the uptake and transformation of phenol carboxylic acids.

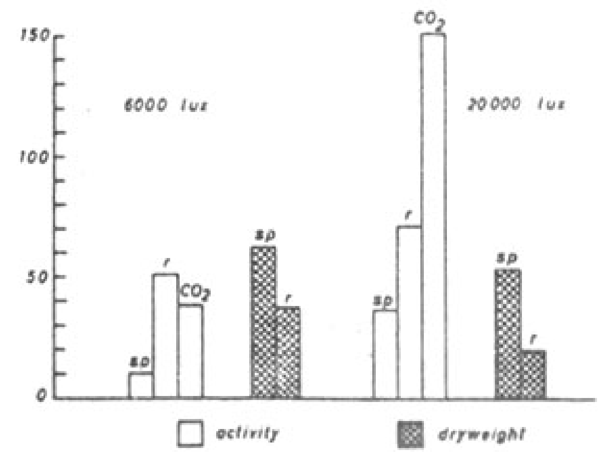


Fig. 22: Uptake of vanillic acid and formation of 14-carbondioxide in percent of added acid and dryweight of sprouts and roots; incubation time 6 days - relative numbers) (HARMS et al. 1969 a)

A higher light intensity increases activity in the roots to lower extent than the activity in sprouts. The uptake in the sproutswas nearly doubled and the released carbondioxide triple (HARMS et al. 1969 a).

The dryweight of the sproutsis not so much changed as the dry weight of the roots which decreased to a half in the case of higher light intensity.

18. Changes of plant metabolism by phenolic humus constituents

18.1 Model investigations about the influence of phenolic lignin degradation products on plant growth

Table 7: Influence of p-hydroxycinnamic and vanillic acid on the relative dryweight of rye seedling (sand culture)

Concentration in Mol	p-hydroxy cinnamic acid		Vanillic acid	
	Sprout	Root	Sprout	Root
0	100	100	100	100
10^{-4}	<u>116</u>	103	<u>123</u>	<u>130</u>
10^{-5}	118	103	<u>117</u>	<u>126</u>
10^{-6}	95	100	107	118

Influence of protocatechuic acid and vanillin on the relative yield of summer wheat (Mitscherlich Pots)

Concentration in Mol	Protocatechuic acid		Vanillin	
	Grain	Straw	Grain	Straw
0	100	100	100	100
6×10^{-5}	<u>111</u>	104	<u>113</u>	<u>108</u>
12×10^{-5}	<u>110</u>	<u>113</u>	<u>111</u>	<u>111</u>

Underlined values statistically significant

The dry weight of seedlings increased in dependence of the concentration of the added lignin degradation products in sand cultures using nutrient solution (SAALBACH 1958).

Furthermore, also in pot experiments it could be shown that these substances have influence on the production of grains and straw. The underlined values are statistically significant. In the case of these experiments as well as in field experiments the observation was made that larger differences occur mostly during the beginning of the growth.

The favourable effect of these lignin degradation products on the yield of grains and straw have been mainly observed when experiments were conducted under abnormal conditions.

18.2 Dependence of "direct" effect of humus constituents on environmental conditions

Several times it has been mentioned that the effect of phenolic humus constituents on plant growth depends on environmental conditions (SOCHTIG 1964). Phenolics may not be the only physiologically active substances in humus. There are observations that some others occur also in soil organic matter, but as it could be demonstrated many sources for phenolic compounds are present in soil.

Sometimes the described effects of these substances on yield have also been observed in field experiments (FLAIG and SAALBACH 1956, 1958).

Some results of special experiments which are interesting in connection with the use of organic materials as fertilizers are mentioned below.

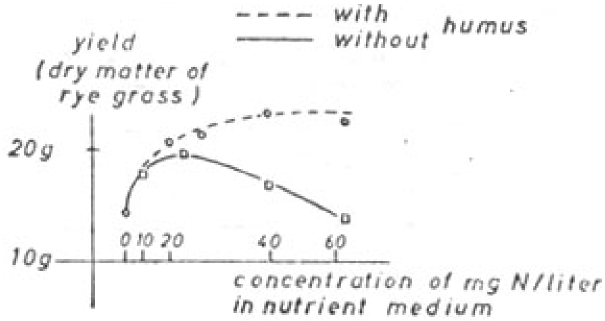


Fig. 23: Influence of humic substances on yield formation in the case of overdoses of inorganic nitrogenous salts (according to CHAMINADE 1966)

CHAMINADE (1966, 1968), for instance, found that overdoses of inorganic nitrogenous salts remain effective for yield production in the presence of humus, whilst without humus a decrease of yield occurred. The investigations were made in pots with sand cultures and rye grass.

Furthermore, he reports on a favourable effect on crop yield by addition of different types of organic materials on ferrallitic soils, whereby a better utilization of nitrogen occurred during several years.

Otherwise BOGUSLAWSKI and Von SAALBACH (1960) observed a dependence of the effect of a model substance of oxidized lignin degradation products such as thymohydroquinone on the different climatic conditions during four years of a field experiment and an intensive interaction with the nitrogen supply of the plants. The effect of thymohydroquinone on the growth of seedlings depends on humidity.

Table 8: Influence of humidity on the effect of thymohydroquinone (THQ) on the initial growth of summer rye (SAALBACH 1957)

sprouts				roots	
mg/l THQ	dry weight rel.	content of reducing sugars	content of water	dry weight rel.	content of reducing sugars
		mg %	%		mg %
100 % humidity					
0	100 (0.89 g)	200	93.0	100 (0.32g)	25
1.7	97	180	93.0	109	40
16.6	100	165	93.3	159	55
55 - 60 % humidity					
0	100 (0.75g)	200	91.5	100 (0.38g)	25
1.7	125	305	90.6	132	40
16.6	116	360	91.0	155	25

Underlined values statistically significant.

The dryweight of the seedlings was only increased by thymohydroquinone at lower humidity, whilst there was no effect at 100 % humidity. The content of reducing sugars in the treated plants was higher than in the untreated. Therefore the osmotic value was higher in these plants. They did not wilt at low humidity as compared to control. The treated plants had a larger resistance against drought. The same observation was made in the case of frost resistance (SÜCHTIG 1964). The mentioned and other experiments demonstrate that the effect of these metabolic active substances on plants depends on the environmental conditions (see also: SÜCHTIG 1967).

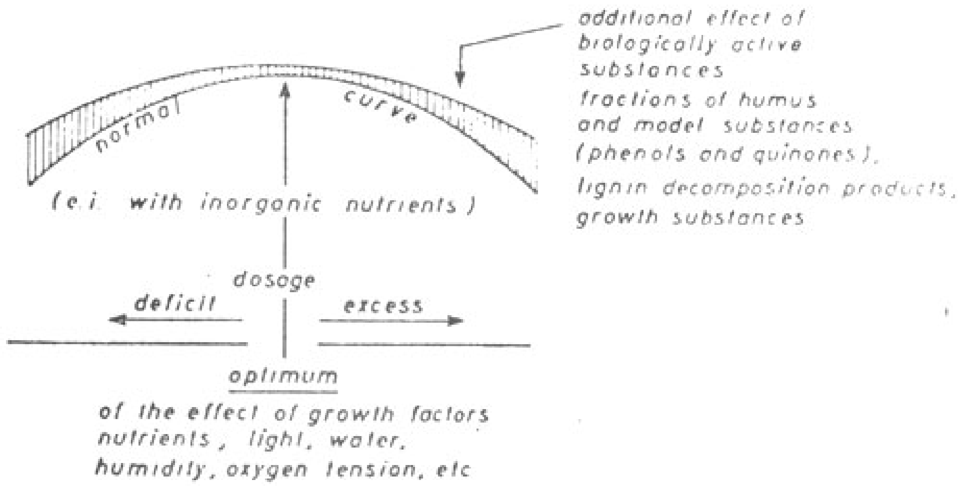


Fig. 24: Influence of physiologically active substances on yield formation in dependence on environmental factors

We explain the favourable effect of humus on plant growth and yield in the following way:

When growth factors such as temperature, humidity, light, oxygen tension of the culture medium, water saturation of the soil, as well as the supply or balance of nutrients are in the "optimum", the yield of the plant mass is the highest.

The effect of physiologically active substances improves the formation of yield if one or several growth factors are in deficit or in excess. With this explanation of the effect of substances from humus, lignin degradation products or other physiologically active substances, all the contradictory results from literature about the influence of humus constituents on plant growth can be explained. Economically, the results mentioned mean a partial diminution of the risk of yield depression by components of soil organic matter, a risk which is caused by climate factors, heavy rainfalls, dry seasons, and other abnormal conditions. Therefore soil organic matter can contribute to stabilization of soil productivity (FLAIG and SÜCHTIG 1973).

19. Conclusions

At the end of the report some remarks will be made about the efficiency of organic materials in soil and their transformation products on soil productivity and stabilization of yield potential by increased utilization of fertilizers, especially nitrogen, and by direct effects of constituents of soil organic matter on plant metabolism in the case of unfavourable environmental conditions.

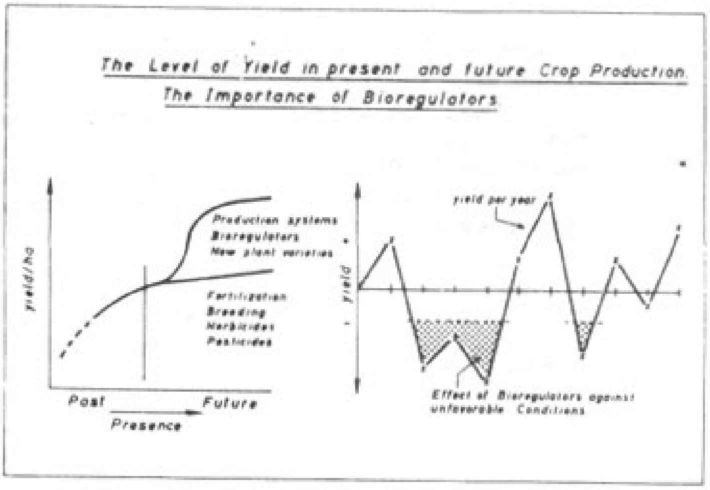


Fig. 25: Yield influencing factors

The enormous increase of yield from the past to the present was possible by the use of mineral fertilizer, plant breeding, plant protection and soil cultivation. The means are known, how to be used in principle. Spectacular effects in this field can no more be expected in developed countries. For an increase of yield per hectare one is trying to go new ways, for instance to use new plant varieties for production of food and feedstuff. One investigates other production systems. Many are too expensive, e.g. it is not possible to produce wheat for bread by hydroponics.

The use of bioregulators is another way to improve productivity potential in the system "soil-plant". A bioregulator which is used since several years is CCC (trichlorocholin-chloride, CYCOCEL). This decreases the length of the stem of wheat plants, so that under unfavourable conditions during vegetation - such as too large precipitation - lodging does not occur. As mentioned before, phenolic lignin degradation products influence also plant metabolism with favourable effects such as increase of resistance against drought, etc. Work is in progress about a higher resistance against plant disease in the case of varieties of cereals with a higher content of phenol carboxylic or phenol acrylic acids. If one could realize this effect by corresponding management of soil organic matter, less pesticides had to be applied.

These additional effects of rotted organic materials such as crop residues and cattle manure - which contain about 30 % lignin per dry weight - must also be studied more intensively and not only the effects of organic materials as resources of mineral nutrients or as soil conditioners.

From the economic point of view it is worth investigating bioregulating effects against unfavourable conditions during vegetation. By these effects the possibility exists to reduce the depression of the yield during the single years, when the yields are below a long-term average.

Studies about biochemistry of soil organic matter are the basis to find the causal connections between its properties caused by the conditions of its formation and transformations in different soil types on the one hand and on the other its effects on plant production, also its contribution as fertilizer.

Only when we learn to know these causal connections, we are really able to manage soil organic matter as a useful tool for production potential of soils as well as for the stabilization of yield.

20. Summary of discussion

During the discussion, several questions were raised concerning the influence of phenol carboxylic acids as humus constituents which could cause alterations of plant metabolism. It was pointed out that these substances do have an influence on glycolysis, on the citric acid cycle, phosphorylation, amino acids metabolism and other factors. This view is based on experiments made in sand cultures with nutrient solution, on nutrient solutions themselves, in Mitscherlich pots and in the field. Experiments supporting this view have also been made with slices of roots and leaves, with plant cell suspension cultures and with mitochondria.

REFERENCES

Allison, F.E.: Soil organic matter and its role in crop production, Elsevier Scientific Publishing Company, Amsterdam, London, New York (1973)

Bartlett, J.B.: The effect of decomposition of the lignin of plant materials. Iowa State Coll. J. Sci. 14, 11-13 (1939)

Bartlett, J.B., F.P. Smith and P.E. Brown: Lignin decomposition in soils. Proc. Iowa Acad. Sci. 44, 97-101 (1937)

Bartlett, J.B. and A.G. Norman: Changes in the lignin of some plant material as a result of decomposition. Soil Sci. Soc. Amer., Proc. 3, 210-216 (1938)

Belav, L.: Chemische Untersuchungen heimischer Torfbildner - ein Beitrag zur Kenntnis der Umwandlung von Pflanzenstoffen unter natürlichen und künstlichen Bedingungen. Dissertation, Rostock (1967)

Berlin, J., K. Barz, H. Harms and K. Haider: Degradation of phenolic compounds in plant cell cultures. FEBS LETTERS, 16(2), 141-146 (1971)

Boguslawski, E. v. and E. Saalbach: Die Wirkung von Thymochinon auf das Wachstum von Sommergerste in Abhängigkeit von der Höhe der Stickstoffdüngung. Z. Acker- u. Pflanzenbau 110, 2,153-162 (1960)

Bondietti, E., J.P. Martin and K. Haider: Influence of nitrogen source and clay on growth and phenolic polymer production by Stachy-Botrys species, Hendersonula toruloidea and Aspergillus sydowi. Proc. Soil Sci. Soc. Am. 35(6), 917-922 (1971)

Bondietti, E., J.P. Martin and K. Haider: Stabilization of amino sugar units in humid type polymers. Proc. Soil Sci. Soc. Am. 36, 597-602 (1972)

Bremner, J.M.: Organic forms of nitrogen. Ch. 85 Methods of Soil Analysis. (Agron. Monographs 9) ASA Madison (1965)

Broadbent, F.E.: Modification in chemical properties of straw during decomposition. Soil Sci. Soc. Amer., Proc. 18, 165-169 (1954)

Bruckert, S.F., F. Jacquin and M. Metche: Contribution à l'étude des acides phenols présents dans les sols. Bull. de l'Ecole Nationale Supérieure Agronomique de Nancy, IX, 73-92 (1967)

Burges, N.A., H.M. Hurst and B. Walkden: The phenolic constituents of humic acid and their relation to the lignin of the plant cover. Geochim. Cosmochim. Acta 28, 1547-1554 (1964)

Chaminade, R.: Effet physiologique des constituants de la matière organique des sols, sur le métabolisme des plantes, la croissance et le rendement. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press Ltd. Oxford 1966, 35-47.

Chaminade, R.: Rôle spécifique de la matière organique sur la nutrition et le rendement des végétaux. Pontificae academiae Scientiarum Scripta Varia 32, 777-800 (1968)

Dubach, P. and N.C. Mehta: The chemistry of soil humic substances. Soils Fertilizers XXVI, 293-300 (1963)

Farmer, V.C. and R.I. Morrison: Lignin in Sphagnum and phragmites and in peats derived from these plants. Geochim. Cosmochim. Acta 28, 1537-1546 (1964)

Filip, Z., K. Haider, W. Flaig, H. Beutelspacher, E. Kuster and J.P. Martin: Einfluss der Tonminerale auf die Huminstoffbildung einiger Bodenpilze. Landbauforschung Völkenrode, 21, 97-102 (1971)

Filip, Z., K. Haider and J.P. Martin: Influence of clay minerals on growth and metabolic activity of Epicoccum Nigrum and Stachybotrys Chartarum. Soil Bio. Biochem. 4, 135-145 (1972 a)

Filip, Z., K. Haider and J.P. Martin: Influence of clay minerals on the formation of humic substances by Epicoccum Nigrum and Stachybotrys chartarum. Soil Biol. Biochem. 4, 147-154 (1972 b)

Filip, Z., K. Haider, H. Beutelspacher and J.P. Martin: Comparisons of IR-Spectra from melanins of microscopic soil fungi, humic acids and model phenol polymers. Geoderma 11, 37-52 (1974)

Flaig, W.: Chemie der Humusstoffe. Suomen Kemistilehti A 33, 229-251 (1960 a)

Flaig, W.: Comparative chemical investigations on natural humic compounds and their model substances. Sci. Proc. Roy. Dublin Soc. Ser. A 1 , 4. 149 (1960 b)

Flaig, W.: Zur Umwandlung von Lignin in Humusstoffe. Freiberger Forschungshefte A 254, 39-56 (1962)

Flaig, W.: Chemische Untersuchungen an Humusstoffen. Z. Chem. 4, 253-265 (1964)

Flaig, W.: (c) Humusstoffe. Handbuch der Pflanzenernährung und Düngung. Bd. II: Boden und Düngemittel 1966, S. 282-458, Springer-Verlag Wien

Flaig, W.: Uptake of organic substances from soil organic matter by plant and their influence on metabolism. Pontificiae Academiae Scientiarum Scripta Varia 32, 723-770 (1968)

Flaig, W.: Contribution à la connaissance de la constitution et de la synthèse des acides humiques. Extrait de "Sciences du Sol", Supplement au Bulletin de l'Association Française pour l'Etude du Sol, No. 2, 39-72 (1970)

Flaig, W.: Organic compounds in soil. Soil Sci. 111, 19-33 (1971)

Flaig, W. and H. Beutelspacher: Investigations of humic acids with the analytical ultracentrifuge. In: Isotopes and radiation in soil organic matter studies. International Atomic Energy Agency, Vienna 1968, 23-30.

Flaig, W. and Th. Breyhan: Über das Vorkommen von Indolverbindungen in Schwarzerde-Huminsäuren. Z. Pflanzenernährung, Düngung, Bodenkunde 75, 132-135 (1956)

Flaig, W. and K. Haider: Reaktionen mit oxydierenden Enzymen aus Mikroorganismen. Planta Medica, Z. f. Arzneipflanzenforschung 2, 123-139 (1961 a)

Flaig, W. and K. Haider: Die Verwertung phenolischer Verbindungen durch Weissfäulepilze. Arch. Mikrobiol. 40, 212-223 (1961 b)

Flaig, W. and K. Haider: Über die Beteiligung von Phenolen am Aufbau von Huminsäuren. 9th International Congress of Soil Science Transactions III. 175-182 (1968)

Flaig, W. and E. Saalbach: Zur Kenntnis der Huminsäure. XIII. Untersuchungen über die Beeinflussung der Anfangsentwicklung von Getreide in Neubauerschalen durch Thymohydrochinon als Modellsubstanz von Vorstufen bezw. Abbauprodukten von Huminsäuren. Z. Pflanzenernährung, Düngung, Bodenk. 73, 7-15 (1956)

Flaig, W. and E. Saalbach: Beziehungen zwischen Kalium, Wasser und Boden. Kalium-Symposium, Bern 109-126 (1958)

Flaig, W., U. Schobinger and H. Deuel: Umwandlung von Lignin in Huminsäuren bei der Verrottung von Weizenstroh. Chem. Ber. 92, 1973-1982 (1959)

Flaig, W. and H. Söchtig: Organische Verbindungen als Stickstoffquelle für die Ernährung der Pflanzen. Anales de Edafología y Agrobiología XXVI, 801-828 (1967)

Flaig, W. and H. Söchtig: Wirkung organischer Bodensubstanzen und Ertragssicherung. Landbauforschung Völkenrode 23, 19-28 (1973)

Freudenberg, K.: Forschung am Lignin, Fortschr. Chem. org. Naturstoffe 20, 41 (1962)

Freudenberg, K.: Entwurf eines Konstitutionsschemas für das Lignin der Fichte, Holzforschg. 18, 3-9 (1964 a)

Freudenberg, K.: Ergänzung des Konstitutionsschemas für das Lignin der Fichte, Holzforschg. 18, 166 (1964 b)

Freudenberg, K. and J.M. Harkin: Ergänzung des Konstitutionsschemas für das Lignin der Fichte. Holzforschg. 18, 166-168 (1964)

Freudenberg, K. and A.C. Neish: Constitution and biosynthesis of lignin. Springer-Verlag Berlin-Heidelberg-New York (1968)

Führ, F. and D. Sauerbeck: Über die Aufnahme und Translokation ^{14}C-markierter organischer Rotteprodukte bei Raphanus sativus. Z. Pflanzenernährung, Düngung, Bodenkunde 105, 136 (1964)

Führ, F. and D. Sauerbeck: Die räumliche und chemische Verteilung durch die Wurzel aufgenommener organischer Rotteprodukte bei Daucus carota. Z. Landw. Forsch. 19, Sonderheft 153-162 (1965)

Führ, F. and D. Sauerbeck: The uptake of straw decomposition products by plant roots. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Oxford Pergamon Press Ltd., 73-83 (1966)

Führ, F. and D. Sauerbeck: The uptake of colloidal organic substances by plant roots as shown by experiments with ^{14}C-labelled humus compounds. Isotopes in plant nutrition and physiology. International Atomic Energy Agency, Vienna 1967, 317-328.

Führ, F. and D. Sauerbeck: Decomposition of wheat straw in the field as influenced by cropping and rotation. In: Isotopes and Radiation in Soil Organic Matter Studies. 241-250, IAEA, Vienna (1968)

Fusteo-Mathon, E., K. Haider and J.P. Matrin: Participation à la formation des composés humiques du sol de phénols microbiens synthetisés à partir d'hydrates de carbone. C.R. Acad. Sc. Paris, 276 Serie D, 929-932 (1973)

Glasser, G. and H.R. Glasser: Simulation of Reactions with Lignin by Computer (Simrel), II. A Model for Softwood Lignin. Holzforschg. 28, 5-11 (1974)

Grabbe, K. and K. Haider: Die Huminstoffbildung und die Stickstoffverteilung bei der Strohrotte in Beziehung zur mikrobiellen Phenolbildung. Z. Pflanzenern., Bodenkunde 129, 202-216 (1971)

Guckert, A., B. Cure and F. Jacquin: Comparative evolution of the polysaccharides of the humin after incubation of ^{14}C-glucose and ^{14}C-straw. Transactions International Symposium Humus et Planta V. 155-160, Prague, Sept. 1971(1971)

Haider, K.: Untersuchungen über den mikrobiellen Abbau von Lignin. Zbl. Bakterial. Parasitenkunde Infektionskrankh. und Hygiene, 198, 308-316 (1965)

Haider, K. and J.P. Martin: Synthesis and transformation of phenolic compounds by Epicoccum Nigrum in relation to humic acid formation. Proc. Soil Sci. Soc. Am. 31(6), 766-772 (1967)

Haider, K. and J.P. Martin: The role of microorganisms in the formation of humic acids. In: Isotopes and radiation in soil organic matter studies. Proceedings of the Symposium on the use of isotopes and radiation in soil organic matter studies. Intern. Atomic Energy Agency, Vienna 1968, 188-195.

Haider, K. and J.P. Martin: Humic acid-type phenolic polymers from Aspergillus sydowi culture medium. Stachybotrys spp. cells and autoxydized phenol mixtures. Soil Biol. Biochem. 2, 145-156 (1970)

Haider, K., S. Lim and W. Flaig: Untersuchungen über die Einwirkung von Mikroorganismen auf ^{14}C-markierte phenolische Verbindungen, Landw. Forschung 15, 3/4, 1-9 (1962)

Haider, K., S. Lim and W. Flaig: Experimente und Theorien über den Ligninabbau bei der Weissfäule des Holzes und bei der Verrottung pflanzlicher Substanz im Boden. Holzforschg. 18, 81-88 (1964)

Haider, K., L.R. Frederick and W. Flaig: Reactions between amino acid compounds and phenols during oxidation. Pland and Soil XXII, 49-64 (1965)

Harms, H.: Untersuchungen zur Aufnahme von phenolischen Ligninspaltstücken durch die Wurzeln von Weizenkeimpflanzen. Dissert. Justus-Liebig-Universität Giessen (1967)

Harms, H. and I. Priess: Positionsspezifische O-Demethylierung von Benzoesäuren in Weizenkeimpflanzen. Planta 109, 307-315 (1973)

Harms, H., H. Söchtig and K. Haider: Untersuchungen zur Aufnahme und Umwandlung C^{14}-markierter Phenole durch die Pflanze. I. Aufnahme von C^{14}-carboxylmarkierter p-Hydroxy-benzoe-, Vanillin- und Syringasäure durch die Wurzeln von Weizenkeimpflanzen und Verteilung der Aktivität über die Pflanze. Plant and Soil XXXI, No. 1 129-142 (1969 a)

Harms, H., H. Söchtig and K. Haider: Untersuchungen zur Aufnahme und Umwandlung C^{14}-markierter Phenole durch die Pflanze. II. Die Umwandlung von p-Hydroxy-benzoesäure, Vanillinsäure, sowie Syringasäure nach der Aufnahme durch die Wurzeln von Weizenkeimpflanzen. Plant and Soil XXXI, No. 2, 257-272 (1969 b)

Harms, H., H. Söchtig and K. Haider: Aufnahme und Umwandlung von unterschiedlichen Stellungen C^{14}-markierter Phenolcarbonsäuren in Weizenkeimpflanzen. Z. Pflanzenphysiologie 64, Heft 5, S. 437-445 (1971)

Harms, H., K. Haider, J. Berlin, P. Kiss and W. Barz: Über O-demethylierung und Decarboxylierung von Benzoesäuren in pflanzlichen Zellsuspensionskulturen. Planta 105, 342-351 (1972)

Jansson, S.L. and J. Person: Co-ordination of humus chemistry and soil organic matter biology by isotope techniques. In: Isotopes and radiation in soil organic matter studies. International Atomic Energy Agency, Vienna 1968, 111-123.

Jenkinson, D.S.: The turnover of organic matter in soil. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press. Ltd. Oxford, 187-197 (1966 a)

Jenkinson, D.S.: The priming action. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press, Ltd. Oxford, 199-208 (1966 b)

Jenkinson, D.S.: Experimental techniques for using carbon-14 in studies of soil organic matter. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press, Ltd. Oxford, 365-369 (1966 c)

Jenkinson, D.S.: Studies on the decomposition of plant materials in soil I-III. J. Soil Sci. 16, 104-115 (1965); 17, 280-302 (1966 d); 19, 25-39 (1968)

Jenkinson, D.S.: Studies on the decomposition of C^{14}-labelled organic matter in soil. Soil Sci. 111, 64-70 (1971)

Kaila, A.: Humification of straw at various temperatures. Acta agral. fenn. Helsinki 78, 3-32 (1952)

Khan, S.U. and M. Schnitzer: The potassium permanganate oxidation of methylated and unmethylated humic acids extracted from solonetz, solod and chernozem A_H horizons. Isr. J. Chem. 9, 667-677 (1971)

Kononova, M.M.: Humus der Hauptbodentypen der UdSSR, seine Natur und Bildungsweisen. Rapports VI. Congr. Internat. de la Science du Sol, Chemie du Sol, S. 5, Moscow (1956) (russ.)

Kononova, M.M.: Soil organic matter, its nature, its role in soil formation and in soil fertility. Pergamon Press, Oxford, London, Edinburgh, New York, Toronto, Sydney, Paris, Braunschweig (1966)

Kononova, M.M. and I.V. Alexandrova: Formation of humic acids during the plant residue humification and their nature. Geoderma 9, 157-164 (1973)

Kratzl, K., G. Billek, E. Klein, K. Butscher: Über das Verhalten von markiertem Coniferin in der verholzenden Pflanze. Monatsh. f. Chemie 88, 721-734 (1957)

Lim, S.: Beiträge zur Aufklärung der Zusammenhänge zwischen dem mikrobiellen Abbau des Lignins und der Bildung von Humusstoffen. Dissertation der Rheinischen Friedrich-Wilhelm-Universität Bonn (1965)

Maeder, H.: Chemische und pflanzenphysiologische Untersuchungen mit Rottestroh. Diss. Justus-Liebig-Universität Giessen (1960)

Martin, J.P. and K. Haider: Phenolic polymers of Stachybotrys atra, Stachybotrys chartarum and Epicoccum nigrum in relation to humic acid formation. Soil Sci. 107, 260-270 (1969)

Martin, J.P. and K. Haider: Microbial activity in relation to soil humus formation. Soil Science 111, No. 1, 54-63 (1971)

Martin, J.P., S.J. Richards and K. Haider: Properties and decomposition and binding action in soil of humic acid synthesized by Epicoccum nigrum. Soil Sci. Soc. Amer. Proc. 31, 657-662 (1967)

Martin, J.P., K. Haider, W.J. Farmer and E. Fustec-Mathon: Decomposition and distribution of residual activity of some ^{14}C-microbial polysaccharides and cells, glucose, cellulose and wheat straw in soil. Soil Biol. Biochem., 6, 221-230 (1974)

Mayaudon, J. and P. Simonart: Etude de la décomposition de la matière organique dans le sol au moyen de carbone radioactif. II. Décomposition du glucose radioactif dans le sol. A. Repartition de la radioactivité dans fractions humiques du sol. Plant and Soil IX, 376-380 (1958)

Mayaudon, J. and P. Simonart: Etude de la décomposition de la matière organique dans le sol au moyen de carbon radioactif. III. Décomposition des substances solubles dialysables des proteines et des hemicelluloses. Plant and Soil XI, 170 (1959 a)

Mayaudon, J. and P. Simonart: Etude de la décomposition de la matière organique dans le sol au moyen de carbone radioactif. V. Décomposition de cellulose et de lignine. Plant and Soil XI. 181-192 (1959 b)

Mayaudon, J. and P. Simonart: Stabilité de l'humus du sol étudiée à l'aide d'humus marqué au 14C. Arch. Internat. de Phys. et de Biochim. 68, 512 (1960)

Mayaudon, J. and P. Simonart: Decomposition of cellulose C^{14} and lignin C^{14} in the soil. Ecology of Soil Fungi (1961)

Mayaudon, J. and P. Simonart: Humification des microorganisms marqués par ^{14}C dans le sol. Anales de l'Inst. Pasteur 105, 257-266 (1963)

McCalla, T.M.: The adsorbed ions of colloidal clay as a factor in nitrogen fixation by Azotobacter. Soil Sci. 48, 281-286 (1939)

Mohtadi, S.: Beiträgezur Isolierung von pflanzenphysiologisch wirksamen Stoffen während der Rotte von Stroh. Dissertation Giessen (1962)

Morrison, R.I.: Products of the alkaline nitrobenzene oxidation of soil organic matter. J. Soil Sci. 14, 201-216 (1963)

Musso, H.: Uber Phenol-Oxydationen. Angew. Chem. 75, 965-977 (1963)

Musso, H., U.V. Gizycki, H. Kramer and H. Dopp: Uber Orceinfarbstoffe. XXIV. Uber den Autoxydationsmechanismus bei Resorcinderivaten. Chem. Ber. 98, 3952-3963 (1965)

Novak, B.: Contribution to the Theory of Microbial Formation of Humus. For. Social Agri. Sci. (Prague) 12, 401–418 (1963)

Novakova, J.: The effect of different amounts of bentonite and kaolinite on the decomposition of glucose. In: Studies about Humus. Trans. Intern. Symp. "Humus et planta IV , Prague: 185–188 (1967)

Novakova, J.: The influence of different quantities of bentonite and kaolinite on glucose mineralization, Rostlinna Vyroba (Prague) 15, 215–220 (1969)

Nehring, K. and R. Schiemann: Untersuchungen zum Humusproblem. I. Mitt. Beiträge zur Kenntnis der Vorgänge bei der Rotte von Stallmist und Komposten sowie zur Kenntnis der Huminsäuren. Z. Pflanzenernähr., Düng., Bodenkunde 57, 97–113 (1952 a)

Nehring, K. and R. Schiemann: Untersuchungen zum Humusproblem. I. Mitt. Beiträge zur Kenntnis der Vorgänge bei der Rotte von Stallmist und Komposten sowie zur Kenntnis der Huminsäuren. 2. Teil Beiträge zur Kenntnis der Huminsäuren. Z. Pflanzenernähr., Düng., Bodenkunde 57, 193–215 (1952 b)

Nimz, H.: Das Lignin der Buche. Entwurf eines Konstitutionsschemas. Angew. Chemie, 86, 336–344 (1974)

Oberländer, H.E. and K. Roth: Transformation of ^{14}C-labelled plant material in soils under field conditions. In: Isotopes and radiation in soil organic matter studies. International Atomic Energy Agency, Vienna 1968, 251–264

Philipps, M.: The chemistry of lignin. Chem. Rev. 14, 103–170 (1934)

Primavesi, A.: Organic matter and soil productivity in the tropics and subtropics. Pontificiae Academiae Scientiarium Scripta Varia 32, 655–696 (1968)

Reinhardt, G.: Untersuchungen über die Einwirkung von Lignin und dessen Abbauprodukten auf das Wachstum und den Stoffwechsel von Pflanzen. Dissertation Universität Giessen (1961)

Ritter, G.J., R.M. Seborg and R.L. Mitchell: Factors affecting quantitative determination of lignin by 72 percent sulfuric acid method. Ind. Eng. Chem. Analyt. Edit. 4, 202 (1932)

Saalbach, E.: Zur Kenntnis der Huminsäuren, XIV. Mitt. Einfluss von Modellsubstanzen von Humusstoffen auf den Stoffwechsel von Getreide, Landw. Forsch. 9. Sonderheft 95–100 (1957)

Saalbach, E.: Beitrag der Grundlagenforschung zum Problem der Strohdüngung. Landw. Forsch. 8, 83–84 (1958)

Sauerbeck, D.: Die Umsetzung markierter organischer Substanzen im Boden in Abhängigkeit von Art, Menge und Rottegrad. Landwirtsch. Forsch. 21, 91–102 (1968 a)

Sauerbeck, D.: Stability of recently formed humus compounds in soil. In: Isotopes and radiation in soil organic matter studies. International Atomic Energy Agency, Vienna 1968 b, 57–66.

Sauerbeck, D.: Comparison of plant material and animal manure in relation to their decomposition in soil. In: Isotopes and radiation in soil organic matter studies. International Atomic Energy Agency, Vienna 1968 c, 219–225.

Sauerbeck, D. and F. Führ: Alkali extraction and fractionation of labelled plant material before and after decomposition - a contribution to the technical problems in humification studies. In: Isotopes and radiation in soil organic matter studies. International Atomic Energy Agency, Vienna 1968, 3-11.

Sauerbeck, D. and F. Führ: Die Umsetzung von markiertem Pflanzenmaterial im Boden unter Feldbedingungen. Mitt. Deutsche Bodenkundl. Gesellschaft, 10, 174-177 (1970)

Scharpenseel, H.W.: Herstellung und Reinigung von tritiummarkierten Grau- und Braun-Huminsäurepräparaten sowie von Tritium-Purpurogallin. Z. Pflanzenernährung, Düng. und Bodenkunde, 91, 131-146 (1960 a)

Scharpenseel, H.W.: Untersuchungen mit radioaktiv markierten Huminsäuren und Vorstufen. 2. Teil. Z. Pflanzenernähr., Düng. und Bodenkunde, 91, 193-202 (1960 b)

Scharpenseel, H.W.: Labelling of soil organic matter. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press. Ltd. Oxford, 351-354 (1966)

Scharpenseel, H.W.: Aufbau und Bindungsform der Ton-Huminsäurekomplexe. Teil IV. Z. Pflanzenernähr., Düng. u. Bodenkunde, 55, 151-169 (1970)

Scharpenseel, H.W. and H. Beckmann: Untersuchung zur Kohlendioxydentbindung des Bodens. II. Teil. Spezielle Studien unter Verwendung radioaktiver Tracer. Z. Pflanzenernähr., Düng., Bodenkunde, 104, 110-119 (1964)

Scharpenseel, H.W. and R. Krausse: Aminosäureuntersuchungen an verschiedenen organischen Sedimenten, besonders Grau- und Braun-Huminsäurefraktionen verschiedener Bodentypen (einschliesslich C^{14}-markierter Huminsäuren). Z. Pflanzenernähr., Düng., Bodenkunde, 96, 11-34 (1962)

Schnitzer, M. and S.U. Khan: Humic substances in the Environment. Marcel Dekker Inc. New York (1972)

Schobinger, U.: Chemische Untersuchungen über die Umwandlung von Weizenstrohlignin im Laufe der Verrottung. Dissertation, ETH Zurich (1958)

Simonart, P. and J. Mayaudon: Etude de la décomposition de la matière organique dans le sol au moyen de carbone radioactif. I. Cinétique de l'oxydation en CO_2 de divers substrats radioactifs. Plant and Soil, 9, 367-375 (1958 a)

Simonart, P. and J. Mayaudon: Etude de la décomposition de la matière organique dans le sol au moyen de carbone radioactif. II. Décomposition du glucose radioactif dans le sol. B. Repartition de la radicactivité dans l'a-humus. Plant and Soil, 9, 381-384 (1958 b)

Simonart, P. and J. Mayaudon: Etude des transformations de la matière organique du sol au moyen du carbone-14. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press. Ltd. Oxford 1966, 245-258.

Simonart, P., J. Mayaudon and L. Batistic: Etude de la décomposition de la matière organique dans le sol au moyen de carbone radioactif. IV. Décomposition des pigments foliaires. Plant and Soil, 11, 176-180 (1959)

Simonart, P. and J. Mayaudon: Etude des transformations de la matière organique du sol au moyen du ^{14}C. In: The Use of Isotopes in Soil Organic Matter Studies, 245-257, FAO/IAEA 1966 (1968)

Söchtig, H.: Beeinflussung des Stoffwechsels der Pflanzen durch Humus und seine Bestandteile und die Auswirkung auf Wachstum und Ertrag. Landbauforschung Völkenrode, 14, 9-16 (1964)

Söchtig, H.: Ein Pflanzentest zur Feststellung der Wirkung stoffwechselaktiver Substanzen, Methodik und Erfahrungen. Deutsch-Polnisches Torf-Kolloquium DDR-Polen in Rostock (1967)

Söchtig, H. and H. Harms: Über den Einfluss von Torf auf Keimung und Anfangswachstum von Pflanzen. Landw. Forsch. 26/II., 148-174 (1971)

Söchtig, H. and F. Maciak: Bindung des Stickstoffs und Vorkommen phenolischer Verbindungen im Torf. Telma, 1, 49-61 (1971)

Sørensen, H.: Studies on the decomposition of ^{14}C-labelled barley straw in soil. Soil Sci. 95, 45-51 (1963)

Sørensen, H.: Formation of soil organic matter during decomposition of plant components. In: The use of isotopes in soil organic matter studies. Report of the FAO/IAEA Technical Meeting. Pergamon Press. Ltd. Oxford 1966, 271-274

Springer, U. and A. Lehner: Stoffabbau und Humusaufbau bei der aeroben und anaeroben Zersetzung landwirtschaftlich und forstwirtschaftlich wichtiger organischer Stoffe. I. Z. Pflanzenernähr., Düng., Bodenkunde, 58, 193-231 (1952 a)

Springer, U. and A. Lehner: Stoffabbau und Humusaufbau bei der aeroben und anaeroben Zersetzung landwirtschaftlich und forstwirtschaftlich wichtiger organischer Stoffe. II. Z. Pflanzenernähr., Düng., Bodenkunde, 59, 1-27 (1952 b)

Stöckli, A.: Über den Abbau von Lignin, Cellulose und Hemicellulose durch Pilze. Versuche mit Streumaterialien, Holz und Ligninsulfonsäure. Promotion ETH Zurich (1952)

Studies about Humus, I. Symposium Humus et Planta, Prague 1961, IV. Symposium 1967, V. Symposium 1971

Swaby, J.R.: Stability of soil organic matter and its significance in practical agriculture. Pontificiae Academiae Scientiarium Scripta Varia, 32, 583-604 (1968)

Waksman, S.A. and J.W. Smith: Transformation of methoxyl group in lignin in the process of decomposition of organic residues by microorganisms. J. Amer. Chem. Soc., 56, 1225 (1934)

Waksman, S.A., F.C. Tenney and R.A. Diehm: The chemical and microbiological principles underlaying the transformation of organic matter in the preparation of artificial manures. J.A.S.A. 21, 533-545 (1929)

2. PROPOSALS FOR THE CHARACTERIZATION OF SOIL ORGANIC MATTER AS AN APPROACH TO UNDERSTAND ITS DYNAMICS

by

J.-Chr. Salfeld and H. Söchtig *

An essential problem for the nutrition of the world population is the provision of agricultural and forest soils with sufficient nitrogen. For economic reasons and in order to maintain soil productivity an optimum harmonizing of mineral fertilizers and soil organic matter must be achieved.

There are many useful observations and results available in literature on the microbial decomposition of plant material and on the effect of humus components and of substances which may be humus components, on the plant growth and plant metabolism. These investigations are usually made in simplified systems and not in soil itself.

An effective humus management provides knowledge about correlations between humus dynamic and plant production. Therefore the question is of interest: What happens directly in soil? We know many things about transformation of organic substances under soil conditions, but only few about the metabolism of the soil organic matter system in a defined soil, its function depending on ecological and climatic conditions.

Considering the dynamic of soil organic matter systems it is useful to distinguish between two types of dynamic (Fig. 1):

<u>One path dynamic</u> (long time)	<u>Cyclic dynamic</u> (short time)
Under nearly constant conditions of vegetation and climate the dynamic goes in one direction to an equilibrium. Changes in the conditions lead to a new equilibrium.	Superimposed over the one path dynamic during the vegetation time chiefly dependent on the climatic conditions of the year.

<u>Fig. 1:</u> Types of the dynamic of organic substances in soil

1. <u>One path dynamic</u> (long time dynamic)

   Under constant conditions, as in nature or in a defined system of plant production, a development in one direction occurs which normally leads to an equilibrium corresponding to the conditions. If the conditions are changed, for instance by cultivation of a soil, a development for the establishment of a new equilibrium occurs.

2. <u>Cyclic dynamic</u> (short time dynamic)

   The long time "one path dynamic" is superimposed by a yearly cycle of humus dynamic which depends on the yearly climatic cycle. While the long time dynamic depends on the long time mean climatic parameters, the yearly cycle seems to be very sensitive to the climatic conditions of the particular year.

* Institut für Biochemie des Bodens, Forschungsanstalt für Landwirtschaft, 33 Braunschweig, Bundesallee 50, Fed. Rep. of Germany

The phase of soil organic matter metabolism most interesting for plant production is the composition of organic matter coupled with mineralization of nitrogen. The amount of mineralized nitrogen depends on the decomposition rate of soil organic matter. In the course of the yearly cycle this phase sets in at the moment when the conditions for plant growth are optimal, that means just at the moment when plants need nitrogen. Another phase which is important for an economical supply of nitrogen is the immobilization of nitrogen by synthesis of organic substances.

The optimum conditions of the soil organic matter system necessary for plant production should be:

1. Soil organic matter should decompose and mineralize only when plants need nitrogen.
2. The mineral nitrogen applied to soil should combine with the organic matter if the plant does not require it.
3. The nitrogen should only be combined with the organic matter in easily mineralizable form.

The stated conditions depend upon biological equilibriums which can be influenced by addition of organic materials or mineral nitrogen in desirable stage if sufficient knowledge about soil organic matter systems is available. To study the dependence of these equilibriums on pedological, climatic and cultural conditions, the changes in the chemical composition of soil organic matter system must be used as an indicator. These ideas can only be realized as far as convenient analytical data on the composition of the soil organic matter system are available. In the literature on humus studies a great number of data on chemical determinations about soil organic matter have been published. It is necessary to collect these data and evaluate them statistically. Due mainly to two reasons this evaluation of data from literature is a matter of question, firstly because of the variability of the methods used for chemical characterization, and secondly because of insufficient information on materials, methods and accuracy of results. By the heterogeneity of available data a general statistical evaluation seems to be impossible.

During the last decades in many east-European countries analyses of soil organic matter systems (SOMS) of different soils had been made to a great extent according to a single scheme described by TYURIN. KONONOVA and BEL'CHIKOVA (1961) later simplified this, but in principle the same parameters are determined. By this the carbon content in different alkaline extracts and their humic acid fractions are determined. After a critical discussion of suitability of the results obtained by this method, KONONOVA (1967) concluded that it is possible to find differences in SOMS of different soil types, but it is not possible to create an analytical basis for studying problems of humus dynamics, for instance under different cultivation practices, soil genesis problems or yearly changes.

Since that time we have been engaged in studies to find a concept for a chemical characterization of SOMS for the mentioned problems, and we have developed a scheme of methods which essentially enlarges the method of KONONOVA-BEL'CHIKOVA.

This scheme can be divided into three groups (Fig. 2):

1. Determinations on total soil samples
2. Determinations on hydrolysates of soil samples
3. Determinations on extracts of the soil and their fractions

Fig. 2: The combinations of methods have been divided into three groups

The following determinations are made on total soil samples (Fig. 3):

1. <u>Determinations on total soil samples</u>

1.1 N-determination according to Kjeldahl-procedure

1.2 N-determination by combustion at 1050°C according to Dumas

1.3 C-determination by wet oxidation

1.4 C-determination by dry combustion

Fig. 3

The determination of nitrogen by combustion can at the moment only be made with the available Micro-Rapid-N-analyzer Heraeus when the samples are rich in nitrogen and very finely ground because of the fact that samples must contain 0.5 mg of nitrogen in maximum 100 mg of sample material.

The determination of carbon by wet oxidation does not give the carbon content but an oxidation equivalent. This method is nevertheless used as it is used in most soil analyses published. The determination of dry combustion gives a real value of carbon.

The second group of analysis is as follows (Fig. 4):

2. <u>Determinations on hydrolysates of soil samples</u>

2.1 Hydrolysate with 6 N HCl
- N-functions (BREMNER 1965)

2.2 Hydrolysate with 2 % HCl
- easily decomposable carbohydrate fraction

2.3 Hydrolysate with 72 % H_2SO_4
- strongly decomposable carbohydrate fraction

Fig. 4

In the hydrolysate of soil with 6 N hydrochloric acids are determined according to BREMNER (1965):

the total nitrogen,
the ammonium and amide-nitrogen,
the hexosamine nitrogen and
the α-amino-nitrogen.

These determinations provide information on the distribution of nitrogen bound in different forms.

In order to have values about the different decomposable carbohydrate fractions two types of hydrolysis are used.

The third group concerns determinations on extracts and their fractions (Fig. 5):

3. <u>Determinations on the extracts and their fractions</u>

3.1 in 2 N KCl-extract - Ammonium and nitrate nitrogen

3.2 in $Na_4P_2O_7$ - NaOH-extracts [+]

3.3 in the acid precipitable fraction of 3.2 [+]

3.4 in NaOH-extracts [+]

3.5 in the acid precipitable fraction of 3.4 [+]

[+] carbon, nitrogen and spectral characteristics

Fig. 5

The determination of ammonium and nitrate gives the amount of available mineral nitrogen. The analyses mentioned in 3.2 to 3.5 are made according to KONONOVA and BEL'CHIKOVA (1961).

Free organic substances or combined with mobile forms of iron and aluminium can be extracted by sodium hydroxide. By the use of the mixture of sodium pyrophosphate-sodium hydroxide calcium, iron and aluminium ions are replaced by sodium and soluble sodium salts of organic substances as well as insoluble pyrophosphates of the formerly mentioned ions are formed.

It is assumed by the Russian colleagues that in this case substances can be isolated which were strongly combined with these ions and cannot be extracted with sodium hydroxide alone.

In the extracts of organic substances and the humic acid fractions the carbon and nitrogen content are determined according to the above-mentioned methods.

In addition spectral characteristics are taken into consideration. In general the optical characterization of dark coloured solutions of soil organic matter were made by measuring extinctions of two wavelengths and thus calculating a single extinction quotient, normally abbreviated as E_4/E_6.

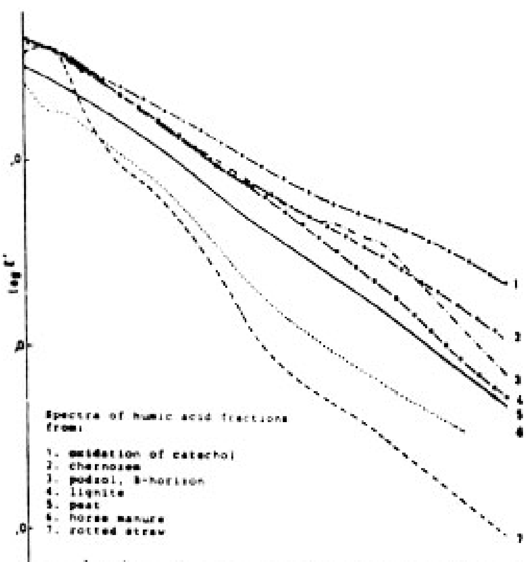


Fig. 6

It can be seen in the spectra that they do not show monotonously decreasing extinctions with increasing wavelengths and therefore contain more information than can be expressed by a single quotient.

For this reason extinctions at four wavelengths (400 nm, 500 nm, 600 nm and 700 nm) are measured and from these three extinction quotients are calculated (SALFELD, 1971).

The efficiency of the combination of methods has been demonstrated on a series of soil samples from Roumania with three variables: soil type, layer and cultivation.

The optical characteristics of soil organic matter extracted with a mixture of sodium pyrophosphate—sodium hydroxide correspond mainly to the soil type (Fig. 7). In the diagramme the extinction quotients EQ 45 and EQ 56 are plotted. The points form groups according to the soil type. In a particular group lie all four variants, two layers of cultivated and forest soils.

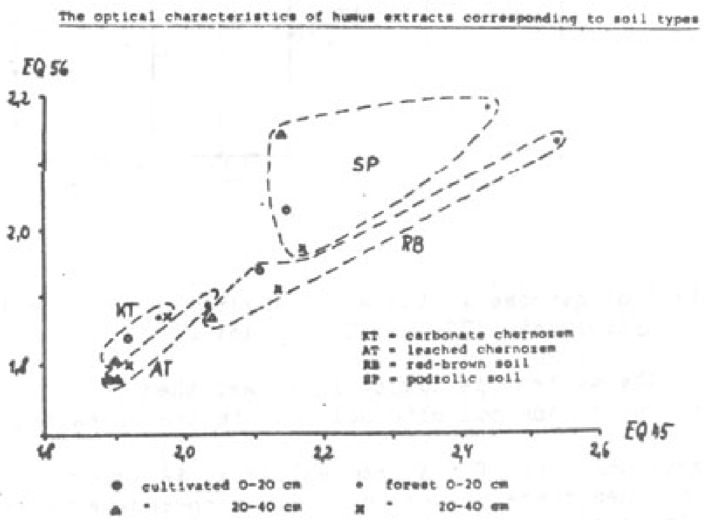


Fig. 7

In contrast to this, the correlation of nitrogen fractions corresponds to the cultivation system and to layer and not to the soil type (Fig. 8).

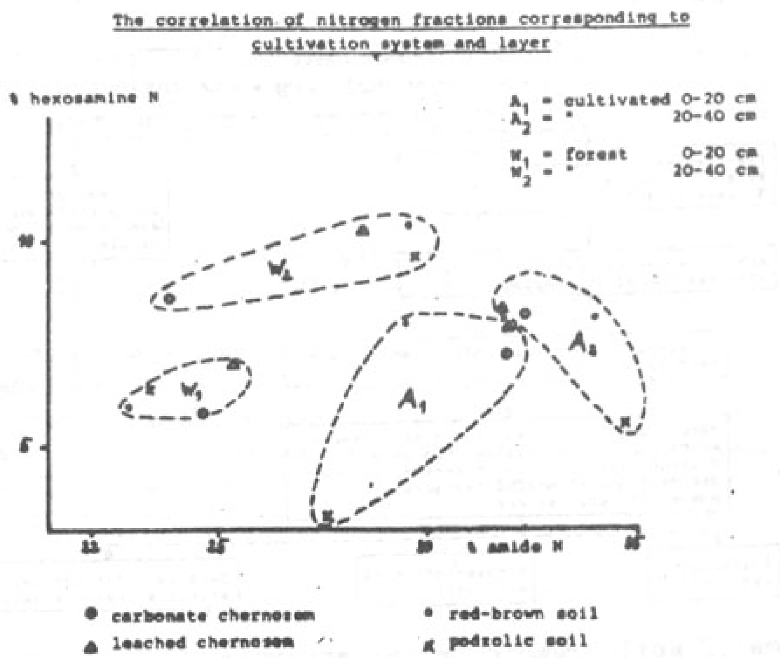


Fig. 8

In the figure hexosamine-N is plotted against amide-N in percent of total hydrolysable nitrogen. Four groups can be distinguished for each layer of each cultivation system.

The content of glucose in mg/g soil in the easily hydrolysable fraction and in total hydrolysate of the same series of soils are shown in Fig. 9.

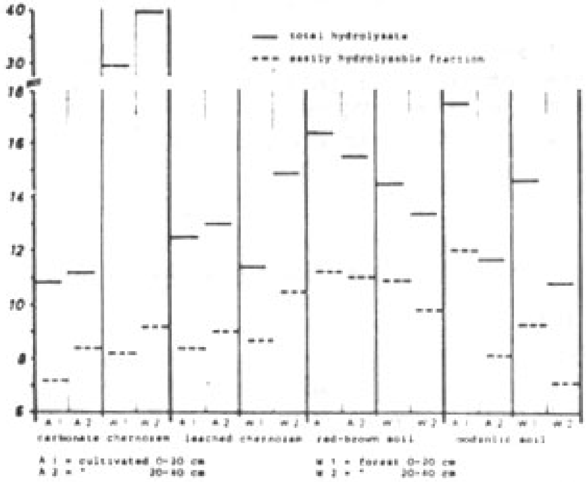


Fig. 9: Content of glucose in the easily hydrolysable fraction (2 % HCl) and in total hydrolysate (72 % H_2SO_4) in soils

In chernozemic soil the content is higher in forest than in cultivated land in both layers, while in the red-brown and the podzolic soils it is the opposite.

For a better and easy handling of measured values it is important to make use of a documentation system which punches these values on cards or on another data acquisition system, such as paper tape. This concerns the original measured values and all needed information for evaluation, and also data on soils and methods. Such a documentation system is more definite in nature, simplifies the exchange of information without loss and allows constant access to the original measured values. These are essential aspects for a multiregional or mondial cooperation and evaluation. A short review of our scheme of soil organic matter analysis is given in Fig. 10.

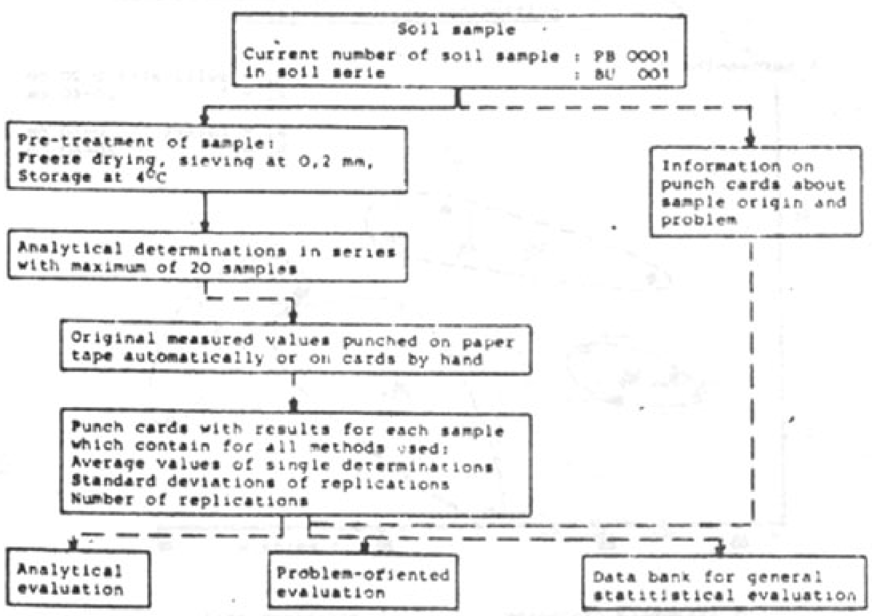


Fig. 10: Scheme of soil organic matter analysis

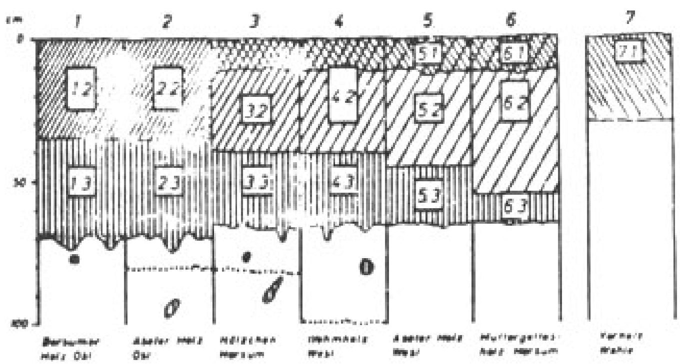
Each soil sample gets an identification in a series with a symbol and number. The analytical series contain a maximum of twenty samples. The original measured values for all aforementioned methods are punched on paper tape automatically as an output-value of automatically measuring instruments or on cards by hand. From all independent determinations with all methods, mean values, standard deviations and the number of replications are documented on a card for each soil sample. These cards are the starting point for analytical evaluation and the problem oriented evaluation. Later on there is a possibility to use this data bank for general statistical evaluation.

To discuss some problem oriented evaluations two examples are given. One concerns the long time dynamics of SOMS by degradation of a black earth (Hildesheim); the other is about cyclic dynamics in cultivated soil fertilized with organic material.

<u>Dynamics of the soil organic matter system in a black earth - griserde - morphosequence in the area of Hildesheim.</u>

During the transformation of black earth to griserde (grey brown podzolic soil derived from black earth with black clay migration) the decalcification, clay-formation and clay-migration increase. Simultaneously the black earth-mull-A-horizon becomes more and more pale.

This phenomenon of "bleaching" is not yet clear. An explanation of this problem will not only be important for this morphosequence but also for all steppe-forest-transitional regions.



<u>Fig. 11</u>

To see what sort of changes take place in SOMS during degradation, samples are taken from visually different subhorizons of the A-horizon under forest. The upper subhorizon differentiates in the course of development. The lower subhorizon remains unchanged as the old mull-A-horizon. For this reason we take two samples from the lesser degraded profile and three from the stronger degraded profile. The last profile is a grey-brown podzolic soil.

In the following two figures the data for the not subdivided upper horizon are represented as circles with point (⊙), after partition the upper subhorizon as points (•), the middle subhorizon as circles (O) and the lower subhorizon as crosses (x).

In this discussion it is not possible to describe the results in detail. Some changes occuring in SOMS during degradation are shortly demonstrated (Fig. 12). With an almost similar carbon content in the same subhorizons of different profiles, the extractability with sodium hydroxide increases with increasing degradation which indicates decalcification and has been proved by determining the calcium content. The solubility in the lower subhorizons is less than in the upper ones.

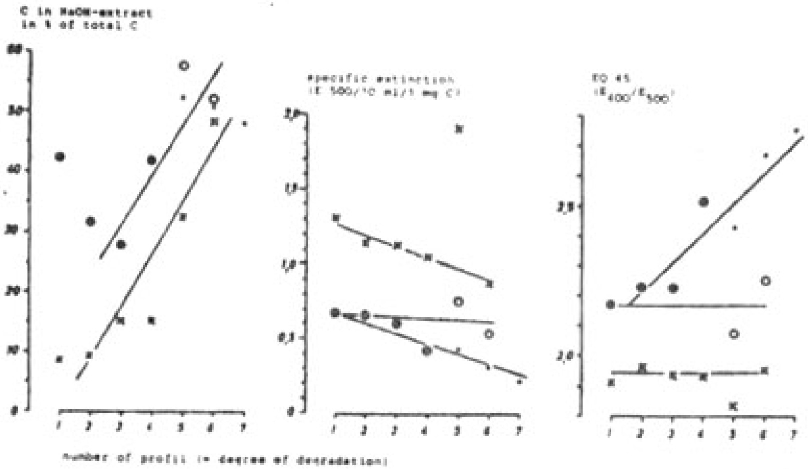


Fig. 12: Change of C-parameter and optical characteristics with degradation of black earth (Hildesheim)

The specific extinction of the sodium-pyrophosphate-sodium-hydroxide-extract indicates qualitative changes in SOMS. In the profiles it increases with depth. With degradation the specific extinction decreases in the lower and upper subhorizon but remains almost constant in the middle bleached subhorizon. Usually in humic solutions the extinction quotients change reciprocally to the specific extinction.

It can be that the SOMS of the upper subhorizon agrees to this. Contrary to this, in the lower subhorizon the extinction quotient remains constant although the specific extinction decreases to the same degree as in the upper subhorizon. The relation between specific extinction and extinction quotient for the lower subhorizon of sample 5 is normal. The middle subhorizon does not show any changes.

Contrary to the carbon content nitrogen decreases with degradation in all subhorizons. Whereas the percentage of hydrolysable nitrogen does not change in the upper subhorizon, it decreases in the other two subhorizons. Corresponding to the hydrolysability of nitrogen the α-amino-nitrogen changes (Fig. 13).

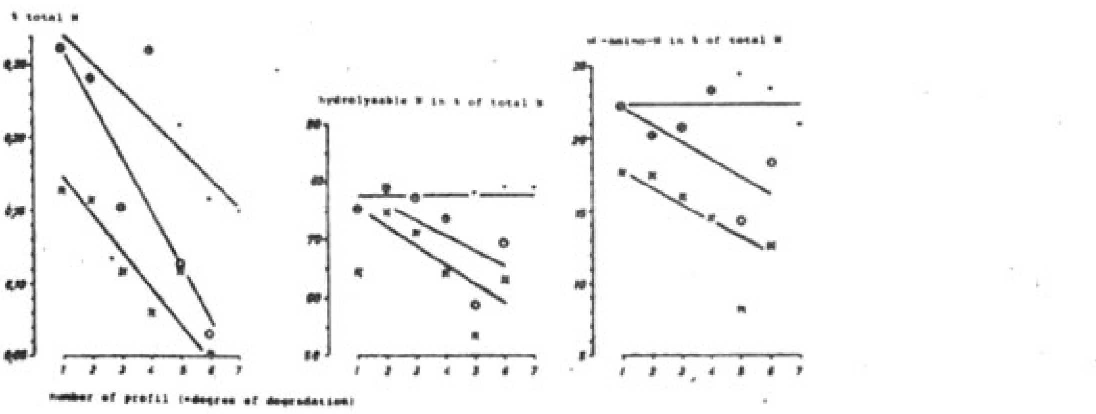


Fig. 13: Change of N-parameters with degradation of black earth (Hildesheim)

The changes with depth in all profiles are similar: decreasing extractability, extinction quotient, nitrogen content, content of hydrolysable and α-amino-nitrogen, and increasing specific extinction. This is probably due to a higher content of lesser humified organic material in the upper horizons.

Following this idea the degradation process with the included changes in composition of soil, as decalcification and decrease of pH, clay migration and decreased plant nutrient content, lead to a decreased velocity of decomposition of fresh plant material indicated by decreasing specific extinction and increasing extinction quotient in the upper subhorizon. In the other subhorizon an unhindered decomposition of easier decomposable parts of SOMS without a supplement of fresh material, due to less roots and mixing by soil animals, leads to a decreasing amount of hydrolysable and α-amino-nitrogen.

The cyclic dynamics had been studied on twenty variants of a field experiment which were continually fertilized with organic materials (SADAT, 1974).

In order to follow the changes of SOMS during the vegetation period soil samples were collected every 4 weeks. These were analysed with the methods mentioned before. Some of the results obtained are discussed below.

The changes of the total carbon content, extinction quotient E 400/E 500 (EQ 45) of the sodiumpyrophosphate-sodiumhydroxide-extract and the carbon content of the fulvic acid fraction are shown in Fig. 14 for three variants, which are from left to right: control, 5 t straw and 10 t straw/ha.

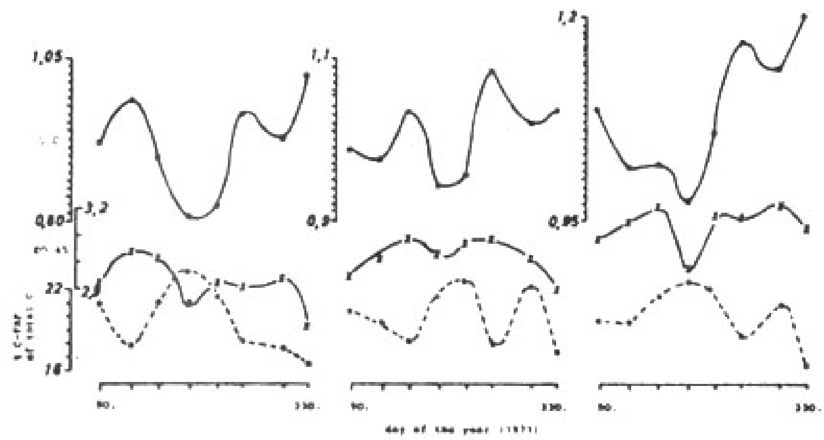


Fig. 14: Changes during the course of the vegetation time (1971) of the parameters: total C in %, extinction quotient E_{400}/E_{500} and C in the fulvic acids fraction in % of total C

For a better comparison the scales of the carbon content have been shifted according to convenience. The mean carbon content increases with the amount of added organic substances.

It can be seen that in the summer, around the beginning of July, a marked minimum in carbon content occurs. There are remarkable differences between the maximum and the minimum of the carbon content which indicate a large turnover of organic matter in the cultivated layers (0 – 23 cm).

The extinction quotient (EQ 45) shown in the figure by a curve with crosses follows more or less the same trend as the carbon content and a minimum at the same time during summer.

The carbon content of the fulvic acid fraction in percent of total carbon on the other hand has maxima where carbon content has minima.

During the time of stronger decomposition of organic materials in May and June the easily decomposable components are preferentially disintegrated. Due to this fact the extinction quotient decreases because the extinction quotient of strongly decomposable and humified materials is lower. At the same time the carbon content of the fulvic acid fraction increases. This means that here a product of decomposition is enriched which does not affect the extinction quotient of the extract and which can probably be transformed to acid precipitable material during the time of lower decomposition, e.g. amino acids and proteins.

The variations in nitrogen functions during vegetation time are demonstrated in Fig. 15. In curves 3 and 2 the ammonium-amide-nitrogen content and the α-amino-nitrogen content are given respectively and in curve 1 the total carbon content as in the previous figure is shown. At the left side are the curves of the variant 10 + straw per ha for the vegetation period 1971 and at the right of the same variant for 1972.

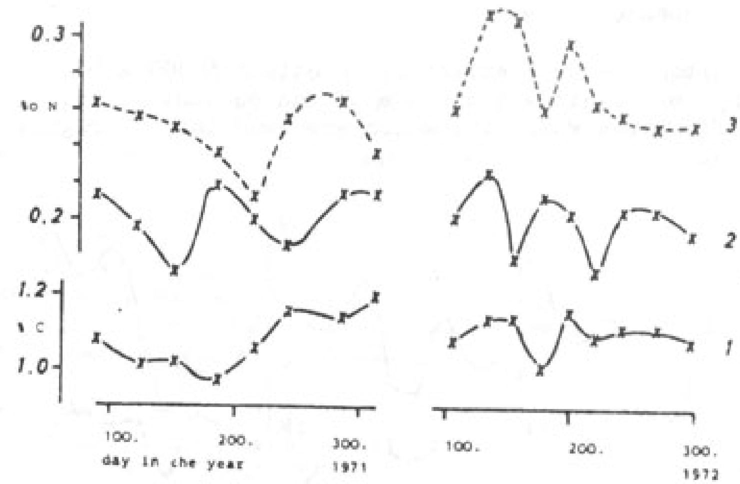


Fig. 15: Comparison of the humus dynamics during the vegetation times 1971 and 1972 (1. total C in % of soil, 2. α-amino-N in ‰ of soil, 3. ammonium and amide-N in ‰ of soil)

The curve for the α-amino-nitrogen (1971) has two minima and one maximum almost opposing the shape of the carbon curve. The amino-nitrogen-curve also shows a minimum during the summer time in the same range where α-amino-nitrogen has a maximum.

In spite of some differences in climatic and field experimental conditions in the following year (1972) the shape of the carbon curve remains in principle the same. But the summer minimum is shifted a little to an earlier stage. The difference between the two curves is that a maximum occurs in the second year immediately after the minimum in nearly all the investigated variants.

Also the curves for α-amino-nitrogen and amide-nitrogen in 1972 show in principle the same shape as in 1971, with a minimum in the amide-nitrogen curve and a maximum in the α-amino-nitrogen curve around the end of June and the beginning of July. A difference among the two years can be observed during springtime, especially in the case of the amide-nitrogen content there is a high maximum.

The differences in SOMS dynamics between the two years can be explained by the climatic conditions mainly in springtime. In the first year in the springtime the mean temperature was 2° C higher and the soil respiration therefore enhanced. To develop principal models of humus dynamics under different conditions, two studies in SOMS dynamics have been briefly reported.

Further knowledge is required, however, on

1. the chemical composition of humus in different climatic and pedogenetic regions of the world;
2. the dynamics of soil organic matter systems (SOMS) dependent on different cropping systems.

The basis for all these studies are convenient and comparable analytical data. For that reason the reported concept has been developed.

Summary of discussion

The questions raised on this paper concerned mainly the conditions for cyclic and short term dynamics. A case in 1972 was cited, when the average temperature was lower in the spring, and in addition the amount of precipitation was different. However, as mentioned in the lecture isolated singularities are of less importance than the causal connections in short term dynamics.

REFERENCES

Kononova, M.M. and N.P. Bel'Chikova (1961): Schnellmethode zur Bestimmung der Humuszusammensetzung in Mineralböden, Sov. Soil Sci., Washington, 1, 1112-1121

Kononova, M.M. (1967): Methoden der Humusbestimmung und ihre Rationalisierung. Sov. Soil Sci., Washington, 7, 894-902

Bremner, J.M. (1965): In C.A. Black: Modern Methods of Soil Analysis. Amer. Soc. Agron. Inc. Publ. Madison, Wisconsin, USA, 1238-1255

Salfeld, J.Chr. (1971): Optical measurements on humic systems. Studies about Humus. Transaction of the International Symposium "Humus et Planta V", Prague, 13 - 17 Sept. 1971, 257-266

Söchtig, H. and J.Chr. Salfeld (1971): Characterization of humic systems in a black earth-griserde-morphosequence in the area of Hildesheim. Studies about Humus. Transaction of the International Symposium "Humus et Planta V", Prague, 13 - 17 Sept. 1971, 247-256

Sadat-Dastegheibi, B. (1974): Dissert. Universität Giessen "Untersuchungen zur Stoffwechseldynamik in Ackerböden in Abhängigkeit von verschiedener organischer Düngung und Stickstoffdüngung"

C. CHARACTERISTICS, PROCESSING AND USE OF ORGANIC MATERIALS

1. USE OF ANIMAL WASTES AS A SOIL AMENDMENT

Rising fertilizer costs make animal wastes an attractive alternative source of nutrients for agricultural land

by

T.M. McCalla*

Manure from beef and swine is a resource and not a waste. Because manure contains water and valuable organic and inorganic materials, its management should be thought of as resource management and not waste management.

A thousand-pound steer produces 17 pounds of urine and 43 pounds of semisolids each day. Five pounds of this 60 pounds is dry organic and inorganic material. In a year's time this represents nearly 1 ton of dry manure. A ton of beef manure (80% moisture) contains about 14 pounds of nitrogen, 4 pounds of phosphorus, 9 pounds of potassium, about 373 pounds of organic material, and various amounts of numerous trace elements (4).

Almost 2 billion tons of animal waste are produced in the United States each year (20). Obviously, this quantity of waste can present a disposal problem. It also represents a tremendous resource.

At this time, the most practical method of utilization is land application. Animal wastes usually have been considered a low-value fertilizer and regarded as liabilities rather than assets. But increasing fertilizer costs and the value of organic matter to the structure of some soils may modify this view.

Elements in manure

Wastes contain the major fertilizer elements -- nitrogen, phosphorus, potassium and sulfur -- as well as many trace elements (Tables 1, 2, and 3). When wastes are applied to land, the fertilizer benefit and pollution potential of these elements are determined by management.

One of the most important nutrients in waste is nitrogen. Ammonium and nitrogen bound in the organic matter generally are the predominant forms of nitrogen in wastes. Normally, nitrate content is low. Crops can use ammonium or nitrate as nitrogen sources, but micro-organisms rapidly convert ammonium to nitrate when conditions are favourable for crop growth. Nitrogen bound in organic matter must be converted to ammonium before it can be used.

Because nitrate is the mobile form of nitrogen, it is the form usually associated with pollution (10). Ammonium and organic nitrogen compounds normally will not pollute unless carried in surface runoff. Nitrate can be carried in runoff. Also, excessive nitrate in the soil can be leached below the crop rooting zone and eventually to groundwater.

When manure is applied to cropland, nitrogen should not be applied at rates exceeding crop requirements. About one-half the nitrogen in manure is available for crop growth the first year of application because nitrogen bound in the organic matter acts as a slow-release fertilizer. It must be converted microbially to ammonium before it is available for crop growth.

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* Research leader and microbiologist with the Agricultural Reserach Service, U.S. Department of Agriculture, Lincoln, Nebraska 68503. This article is a contribution from the Animal Waste Management Research Unit, North Central Region, ARS, in co-operation with the Nebraska Agricultural Experiment Station and was funded partially by the U.S. Environmental Protection Agency.

The amount of manure applied to the soil can be geared to the amount of nitrogen the crop needs. If 150 pounds of available nitrogen would be adequate for maximum crop production, then manure containing 300 pounds of total nitrogen should be applied the first year. This would require between 10 and 20 tons of manure. In subsequent years, the soil should be tested to determine the amount of nitrogen and other nutrients that might be available from the previous application of manure, and then more nitrogen or other nutrients should be added to the soil to bring the amount up to crop needs (21).

Excessive nitrogen from any source may effect crop production by disrupting the nutritional balance and causing lower yields and late maturity, by increasing the tendency for the crop to lodge, by making the crop susceptible to diseases, or by causing undesirable plant composition. Perhaps most importantly, consumption of plants high in nitrate may be harmful to animals, which is another reason why excessive amounts of manure should not be applied to the land (1). Powell and Webb (16) described other possible reasons for yield reductions with heavy nitrogen applications. They indicated that in one year of their experiment the corn yield reduction with excessive application of nitrogen may have been due to high soluble salt concentrations, low soil pH levels, or some possible induced nutrient deficiency that did not exhibit any usual symptoms (16).

Wilkinson and Stuedemann found that mature cattle grazing tall fescue pastures heavily fertilized with broiler litter developed bovine fat necrosis (22). "The incidence of fat necrosis in cows is related to high nitrogen fertilization of fescue pastures rather than to any residual feed additive in the litter or any other factor associated with litter except its plant nutrient content" (22).

Surface-applied solids carried by runoff may contribute appreciable phosphorus, nitrogen, and organic matter to surface waters. This phosphorus and nitrogen can cause excessive plant and algal growth, making the water unsuitable for recreational uses, and organic matter can lower the oxygen level of the water to the point that acquatic animals suffocate. These problems can be prevented by incorporating wastes into the soil and by not applying wastes where they can be transported into surface waters. Erosion control practices are essential also.

Micronutrients in wastes are important to crop growth. For example, studies have shown that the application of animal wastes to cropland can correct soil zinc deficiences.

Phosphorus may be one of the more important elements limiting long-term manure application. Soil constituents immobilize phosphorus and their capacity to do so is very high. However, when phosphorus saturates the soil-fixing capacity, it can be moved out with return flows into surface waters.

Excessive phosphorus in soils can cause crop production problems before the level of saturation is reached. The most usual difficulty arises from interference of phosphorus with zinc nutrition of crops. Corn is particularly susceptible to zinc deficiency (14).

If high quantities of potassium are present, grasses absorb more potassium than magnesium or calcium. This does not harm the plants, but ruminant animals eating these plants can suffer from grass tetany (22).

Influence on crop yields

Value of farm manure

In 1911, King (5) vividly described the benefits of using manure and wastes for growing crops in China, Korea, and Japan over 40 centuries.

Many soil management studies begun by the agricultural experiment stations after passage of the Hatch Act in 1888 included value of manure for increasing crop yields. Where soils were

Table 1. Characteristics of animal manures (*4*).

Animal	*Moisture*	*N*	*P*	*K*	*S*	*Ca*	*Fe*	*Mg*	*Volatile Solids*	*Fat*
	%	*lb/ton manure*								
Dairy cattle	79	11.2	2.0	10.0	1.0	5.6	0.08	2.2	322	7
Finishing cattle	80	14.0	4.0	9.0	1.7	2.4	0.08	2.0	395	7
Hogs	75	10.0	2.8	7.6	2.7	11.4	0.56	1.6	399	9
Horses	60	13.8	2.0	12.0	1.4	15.7	0.27	2.8	386	6
Sheep	65	28.0	4.2	20.6	1.8	11.7	0.32	3.7	567	14

Table 2. Chemical analysis of slurry manure (a mixture of feces and urine) from confined beef cattle in Nebraska (*13*).

Constituent	*Wet-weight Basis*	*Each Ton Contains*	*20 T/a Supplies*
		lb	
N	0.29%	5.8	116
P_2O_5	0.18%	3.6	72
K_2O	0.31%	6.2	124
Moisture	85.0%		
Volatile solids	11.6%		
Total solids	15.33%		
Ash	3.73%		
NH_4N	0.05%		
NO_3N	0%		
COD	121,000 mg O_2/liter		
pH	7.3		
Conductivity	4.5 mmhos/cm²		

Note: I thank J. R. Ellis, ARS-USDA, for helping make these determinations.

Table 3. Trace element concentration of fresh manures[a] (*2*).

Element	*Minimum*	*Maximum*	*Average*
	ppm, dry-matter basis		
Boron	4.5	52.0	20.2
Manganese	75.0	549.0	201.1
Cobalt	0.25	4.70	1.04
Copper	7.6	40.8	15.6
Zinc	43.0	247.0	96.2
Molybdenum	0.84	15.83	2.37
Molybdenum[b]	0.84	4.18	2.06

[a]Data from 44 samples of farmyard manure representing fresh cow, horse, swine, sheep, poultry, and mixed manures and composted cow and mixed manures.
[b]With one exceptionally high value omitted.

shallow or leached, the response of crops to manure was striking in the humid sections of the United States. On soils high in natural organic matter, increases in crop yields from manure applications were small initially. In subhumid regions, heavy applications of farm manure reduced crop yields because of the increased transpiration of a limited supply of soil water. However, in the corn-producing and humid wheat-producing states, many investigators concluded that a sound system of fertility maintenance could not be developed without the return to the land of animal wastes from feeding the crops produced. Of these old experiments, the Rothamstead plots started over 150 years ago, the Sanborn Field Plots at Columbia, Missouri, started in 1888, and the Morrow plots at Urbana, Illinois, initiated in 1904, still provide data on the value of farm manure (15).

Data from over 39 years of manure application to land at Scottsbluff, Nebraska, show that 10 to 30 tons of manure per acre can be applied year after year with beneficial effects on soil properties and crop yields (8).

Heavy application of farm manure

In recent years, heavy applications of manure (up to 900 tons per acre) have been made on land for disposal purposes with adverse effects on soils and crops. Rates exceeding 50 to 60 tons per acre frequently have led to salt problems, poor seed germination, and reduced yields (3, 6, 7, 17, 18).

Effects on soil properties

Continuous application of large amounts of manure to the land does increase the amount of organic matter in the soil and generally improves soil physical properties (8). In some instances, however, excessive manure application may damage the physical properties of soil by increasing the salt content. Increased ammonification and nitrification of the soil nitrogen, as well as increased nitrite content, also may result with manure application (10).

While application of wastes to soil may improve fertility and soil structure, problems do exist: transportation costs, salt accumulations, nitrate pollution, unpleasant odors, metal toxicities and pathogen hazards. But with proper management, many of these problems can be reduced or eliminated (11).

Salt problems

Animal wastes contain appreciable quantities of salts. Excessive applications of solid or liquid wastes can produce salt accumulations in the soil that damage crop and soil structure. Damage to salt-sensitive crops can be expected when soil electrical conductivity reaches 2 mmhos/cm. If the conductivity reaches 16 mmhos/cm, few crops will grow.

Soil structure is damaged when too much sodium accumulates. This damage is manifested by increased soil compaction and reduced infiltration. When wastes are applied to soil, salt contents should be monitored carefully to avoid salt accumulations.

Toxic metals

Use of wastes for fertilizers does incur the possibility of toxic-metal problems. Industrial wastes, which may be included with municipal wastes may contain such metals as copper, lead, chromium, and cadmium. These metals, in excess, are toxic. If they accumulate in crops and soils, serious problems may result.

Use of animal wastes as fertilizers poses less of a problem than with municipal waste, but there may be problems nevertheless if animal wastes are applied at excessive rates. The diets of chickens and swine often contain arsenic and copper, respectively. Arsenic does not move in the soil, and if high loading rates are applied, it can make the soil unsuitable for plant growth. This is exemplified by some of the old fruit-growing areas in central Washington, where insecticides containing arsenic were used for many years. Now to establish a new tree in the area, one must remove a plug of the arsenic-tainted soil and replace it with uncontaminated soil.

Conversely, the application of waste may result in metal deficiencies. For instance, chicken manure applied to pastureland can result in magnesium deficiencies in some grasses, causing grass tetany in cows grazing the area (22). However, these problems usually are a function of application rate, and controlled application should prevent these difficulties.

Odor

Odors can be a troublesome problem in animal-waste handling. Wastes from confinement areas present the greatest problem because these wastes usually are stored anaerobically, resulting in a very odorous product. Present economics preclude treatment before application. Soil injection or immediate plowdown, however, will alleviate the odor problem.

Pathogens

Manure usually is relatively free of pathogens, but a potential hazard does exist.

Manure disposal methods

Solids application to soil

Manure solids can be applied to soil with a conventional manure spreader (15). However, the manure should be incorporated into the soil immediately. Otherwise, odor and fly problems may occur. Manure can be disked or ploughed into the soil. Redell (17, 18) used a system of deep ploughing (36 inches) for applications of up to 900 tons of manure per acre in Texas. Salter and Schollenberger (19) showed that if manure is not incorporated immediately, its relative value in increasing crop yields is reduced about 50 percent after 4 days' exposure under field conditions in Ohio.

Liquid application to soil

Runoff from feedlots or liquids, in lagoons or oxidation ditches may be applied to the land with sprinklers, by gravity irrigation, or by direct injection into the soil. Application of liquid manure with sprinklers or gravity irrigation may create odor and fly nuisances. Direct injection into the soil avoids some of these problems.

Transportation

In most cases, transportation of wastes from large feedlots is not a major problem because cropland is nearby.

Economics

As fertilizer costs increase, the economics of waste application for crop growth become more favourable. At this time, soil application is the most practical means of disposing of these wastes. The wastes must be applied on the basis of crop nutrient requirements, avoiding over-application of toxic elements. When wastes are applied to the soil, subsequent management must confine the wastes to the application area. Most important, research has shown that wastes can supply plant fertilizer needs. With proper application and management of wastes, excellent crop growth can be achieved.

Higher feed-grain prices dictate that a feeding installation, particularly for cattle, has a readily available source of feed. If this source is local, the manure can be redistributed on the land from which the feed was supplied.

Summary of discussion

After reviewing the wide range of animal wastes available for use of manure and the dangers of over-application of nitrogen, the question was raised as to what commercial nitrification inhibitors were available. For a 2-chloro-6 (tricloromethyle) Pyridine several formulations are available - for example N-SERVE 24-E is an emulsion: it can be used as a coating on the granule or mixed with the N-source and then granulated, or, formulated directly with liquid fertilizer systems, and there are several others.

There was no doubt that the whole spectrum of organic and inorganic materials for use in agriculture must be closely investigated with a view to using them to the best advantage but at the same time avoiding dangers of overmanuring, pollution and development of toxic substances.

REFERENCES CITED

1. Anonymous. 1973. *Impact of indiscriminate manure applications.* CALF News 11: 87.
2. Atkinson, H. J., G. R. Giles, and J. G. Desjardins. 1954. *Trace element content of farmyard manure.* Can. J. Agr. Sci. 34: 76-80.
3. Cross, O. E., A. P. Mazurak, and Leon Chesnin. 1973. *Animal waste utilization for pollution abatement.* Trans., ASAE 16: 160-163.
4. Loehr, Raymond C. 1968. *Pollution implications of animal wastes—a forward-oriented review.* Robert S. Kerr Water Res. Center, U. S. Dept. Int., Ada, Okla.
5. King, F. H. 1911. *Farmers of forty centuries of permanent agriculture in China, Korea and Japan.* Harcourt Brace and Co., New York, N. Y.
6. Mathers, A. C., and B. A. Stewart. 1971. *Crop production and soil analyses as affected by applications of cattle feedlot waste.* In *Livestock Waste Management and Pollution Abatement.* Am. Soc. Agr. Eng., St. Joseph, Mich. pp. 229-231.
7. Mathers, A. C., B. A. Stewart, J. D. Thomas, and B. J. Blair. 1973. *Effects of cattle feedlot manure on crop yields and soil conditions.* Proc., Symp. on Animal Waste Manage., Bushland, Tex. pp. 1-13.
8. Mazurak, A. P., H. R. Cosper, and H. F. Rhoades. 1955. *Rate of water entry into an irrigated Chestnut soil as affected by 39 years of cropping and manurial practices.* Agron. J. 47: 490-493.
9. McCalla, T. M. 1972. *Think of manure as a resource, not a waste.* Feedlot Manage. 14(5).
10. McCalla, T. M., and L. F. Elliott. 1971. *The role of microorganisms in the management of animal wastes on beef cattle feedlots.* In *Livestock Waste Management and Pollution Abatement.* Am. Soc. Agr. Eng., St. Joseph, Mich. pp. 132-134.
11. McCalla, T. M., and L. F. Elliott. 1974. *Municipal and animal wastes as fertilizers.* In *1974 McGraw-Hill Yearbook on Science and Technology.* McGraw-Hill Book Co., New York, N. Y. pp. 179-180.
12. McCalla, T. M., J. R. Ellis, C. B. Gilbertson, and W. R. Woods. 1972. *Chemical studies of solids, runoff, soil profile and groundwater from beef cattle feedlots at Mead, Nebraska.* Proc., 1972 Cornell Waste Manage. Conf., Syracuse, N. Y. pp. 211-223.
13. McCalla, T. M., L. R. Frederick, and G. L. Palmer. 1970. *Manure decomposition and fate of breakdown products in soil.* In *Agricultural Pesticides and Water Quality.* Iowa State Univ. Press, Ames. pp. 241-255.
14. Olson, R. A. 1971. *Fertilizer technology and use.* Soil Sci. Soc. Am., Madison, Wisc. p. 439.
15. Peterson, J. R., T. M. McCalla, and George E. Smith. 1971. *Human and animal wastes as fertilizers.* In *Fertilizer Technology and Use* (2nd ed.). Soil Sci. Soc. Am., Madison, Wisc. pp. 557-596.
16. Powell, R. D., and J. R. Webb. 1972. *Effect of high rates of N, P, K fertilizer on corn (Zea mays L.) grain yields.* Agron. J. 64: 653-656.
17. Reddell, D. L. 1973. *Crop yields from land receiving large manure applications.* Proc., Symp. on Animal Waste Manage., Bushland, Tex. pp. 14-25.
18. Reddell, Donald L., W. H. Johnson, P. J. Lyerly, and Price Hobgood. 1971. *Disposal of beef manure by deep plowing.* In *Livestock Waste Management and Pollution Abatement.* Am. Soc. Agr. Eng., St. Joseph, Mich. pp. 235-238.
19. Salter, Robert M., and C. J. Schollenberger. 1939. *Farm manure.* Bul. 605. Ohio Agr. Exp. Sta., Wooster.
20. Wadleigh, C. H. 1968. *Wastes in relation to agriculture and forestry.* Misc. Pub. 1065. U. S. Dept. Agr., Washington, D. C.
21. Wiese, R. A., and E. J. Schwartz. 1969. *How much do you know about the new soil-nitrogen test?* Nebraska Farmer (March 15): 10, 12, 46.
22. Wilkinson, S. R., and J. A. Stuedemann. 1974. *Fertilizer: animal health problems and pasture fertilization with poultry litter.* In *1974 McGraw-Hill Yearbook on Science and Technology.* McGraw-Hill Book Co., New York, N. Y. pp. 180-182.

2. A METHOD FOR CONSERVATION OF CATTLE MANURE

by

M.M. Musa *

Introduction

The soils of the Sudan are known to be low in organic matter and nitrogen (Greene 1937). In spite of this fact there is a remarkable lag in the use of organic manures due possibly to a variety of causes. These include factors such as the unilateral development of crop and animal systems of production, lack of appreciation of the value of organic manures in the maintenance of soil fertility, scarcity of the manures and paucity of information on methods of their preservation and storage. Organic manuring is so far restricted to the very limited traditional use in horticultural sites, and apart from minor efforts in the Northern Province it may truly be said that organic manures are not used for arable crops (Tothill 1948). Mineral fertilizers however are coming into common use in nearly all the irrigated areas of crop production.

In an effort to demonstrate the feasibility of conservation of cattle manure and for the purpose of attaining a good standard of sanitation in animal production centres, storage of cattle manure in pits was attempted.

Experimental

The experiments were carried out at Nisheisheiba Animal Production Centre near Wad Medani. Cattle manure composed mainly of droppings was collected in heaps and left for a few days before filling the pits. Five depths of pits of one, two, three, four and five feet, two lengths of five and ten feet (north-south) being the wind direction, and one breadth (east-west) were used. In all, twenty pits were dug, thus giving duplicate pits for each combination of depth and length. The quantity of manure filling each pit was recorded and the manure sprayed with water at each foot step to raise the moisture level to thirty per cent, as the material was moderately dry at the start. A layer of about six inches of soil finally covered the pit. After one, two and finally four months samples from the centre of the pit were collected by an auger for the determination of moisture, Kjeldahl nitrogen, using a microkjeldahl nitrogen method, and 0.1 N acid soluble nitrogen according to Tinsley and Nowakowski (1959). Organic carbon determination was carried out on selected samples by ashing. Replenishment of moisture was carried out at each sampling by spraying water on the surface of the pit, after removing the soil cover, to give the initial level of thirty per cent. This was found to give a satisfactory distribution of moisture down the pit. Microbiological determinations included the determination of viable counts of aerobic mesophilic micro-organisms using Topping's medium (Topping, 1937), incubated at 30°C. Respiration of incubated organic manures was carried out according to Cornfield (1961). Azotobacter numbers were determined on modified Ashby's medium (Abd el Malek and Ishag, 1968) and nitrifiers according to Stephenson (Stephenson, 1949). Pot and field experiments were carried out in quadruplicate using Abu Sabeen (Sorghum sp.) as a test crop to measure the suitability of the stored product for plant utilization of nitrogen and dry matter production. Organic manure was added to the pots and in the field to give a field rate of application of two tons/acre and two cuts of Sudan grass were taken.

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* Agricultural Research Corporation, Wad Medani, Sudan

Results and discussions

The capacity of pits of various sizes is presented in Table 1. Table 2 gives the composition of the manures at the start and after one and four months. The results showed that there was marked reduction in moisture content after one month of storage during the hot summer of 1967 (the storage extended from February to June 1967). This reduction was more marked in the shallow layers. The longer pits generally lost more moisture than the shorter ones. This probably attributed to easy circulation of air and a much larger exposed surface area of pit.

The Kjeldahl nitrogen, which was initially low, did not show marked fluctuations during the period of storage. This was possibly due to the fact that the cattle droppings lost an appreciable amount of labile nitrogen during collection and drying. It was also evident from analysis of droppings one day old and those exposed for more than one week that vast losses occurred in the form of ammonia. Furthermore, the dung represents an advanced stage of decomposition evidenced by its low biological activity.

Table 1: Quantity of cattle manure in pits of various sizes

Treatment Number	Dimensions of pit (ft)	Weight of manure (kg)
1	3.3 x 5 x 1	266
2	3.3 x 5 x 2	450
3	3.3 x 5 x 3	770
4	3.3 x 5 x 4	1 029
5	3.3 x 5 x 5	1 367
6	3.3 x 10 x 1	540
7	3.3 x 10 x 2	1 015
8	3.3 x 10 x 3	1 243
9	3.3 x 10 x 4	2 459
10	3.3 x 10 x 5	2 725

The carbon/nitrogen ratios presented for selected samples also showed that the material had an initially high ratio, but which decreased to about forty after four months with no distinct differences in pits of various sizes. The decrease in carbon/nitrogen ratio appears to be due more to a slight loss in carbon than to an increase in Kjeldahl N fraction. The pH of the organic manure, initially about 8.4, remained at this level at the one month sampling, but decreased generally to about 8.0 and slightly less after four months of storage, possibly associated with the formation of nitrates and other products of decomposition of the manure.

The variations in dilute 0.1 sulphuric acid, ammoniacal and nitrate nitrogen are given in Table 3. It shows that the manure initially contained about 0.06 per cent ammoniacal nitrogen. After one month of storage there was a general increase in both soluble and ammoniacal nitrogen fractions in all pits with the exception of the shallowest ones. This is possibly an indication of ammonia losses in pits of one and two feet depth due to their drying. Nitrate formation was not detectable at the start but its formation was noticeable after one month with no clear pattern related to the pit depth. However, after four months of storage there was a marked build-up of nitrate nitrogen, most pronounced in the longer shallow pits. The results presented evidently pointed out that the soluble nitrogen is predominantly ammoniacal and that nitrification in the pits does not reach high levels, possibly as a result of partial inhibition of the nitrifiers by ammonia (Stojanovic and Alexander, 1958). The accumulation of both soluble and ammonia nitrogen in deep pits indicated that the conditions were favourable for the hydrolysis of the organic nitrogen of the manure.

Table 2: Moisture, Kjeldahl nitrogen, carbon/nitrogen ratio and pH of manures

Treatment	At the start				One month			Four months			
No.	Moisture %	% N	C/N	pH 1:2	Moisture %	% N	pH 1:2	Moisture %	% N	C/N	pH 1:2
1	33.3	1.32	60	8.4	11.1	1.34	8.3	17.0	1.26	38.0	8.1
2	37.2	1.30	-	-	15.7	1.30	8.6	15.0	1.32	-	8.1
3	37.4	1.26	-	-	14.3	1.18	8.6	25.4	1.60	-	8.0
4	35.4	1.36	-	-	18.7	1.26	8.5	28.5	1.44	-	8.1
5	33.1	1.36	62	8.4	20.9	1.54	8.3	36.5	1.48	42.0	7.7
6	36.3	1.24	62	8.5	7.6	1.02	8.3	13.5	1.18	40.0	7.8
7	33.1	1.16	-	-	6.9	1.08	8.5	14.0	1.24	-	7.9
8	35.9	1.30	-		9.3	1.06	8.6	20.5	1.12	-	8.0
9	33.9	1.26	-	-	11.8	1.18	8.5	23.5	1.14	-	8.2
10	31.4	1.38	59	8.5	14.3	1.34	8.5	35.0	1.36	43.1	7.7

Table 3: 0.1N acid soluble, ammoniacal, and nitrate nitrogen in cattle manure (ppm N)

Treatment	At the start			one month			four months		
No.	SOL.N	NH_3-N	No_3-N	SOL.N	NH_3-N	No_3-N	SOL.N	NH_3-N	No_3-N
1	760	590	0.0	630	457	6	292	260	47
2	-	-	-	1316	1029	13	833	556	43
3	-	-	-	1295	1126	8	1380	1244	129
4	-	-	-	869	857	4	1496	1209	44
5	-	-	-	1260	724	1	1931	1771	64
6	-	-	-	609	461	5	473	256	183
7	-	-	-	833	767	13	522	267	212
8	-	-	-	779	700	17	1336	1044	64
9	-	-	-	742	581	17	1301	1260	55
10	-	-	-	1245	945	37	1302	1203	87

The manurial value of the stored cattle dung, measured by nitrogen uptake in pot experiments carried out on the one and four months old manures, is presented in Table 4. It was evident that after one month of storage manure from all pits slightly depressed nitrogen uptake compared with the fresh droppings, with no clear trend related to the depth of pit. However, when related to unamended soil, marked increase in nitrogen uptake was noted with all manures. The second pot experiment generally gave a much higher uptake of nitrogen than the first. Possibly climatic conditions in June were more favourable for the growth of Abu Sabeen sorghum. Furthermore, manures from pits of five feet in length (nos. 1-5) were slightly superior to manures from pits ten feet in length, with the exception of the deepest (no. 10). Differences in the quality of the manure would have been much clearer if more than two cuts of the test crop were feasible.

Table 4: Nitrogen uptake by Abu Sabeen Sorghum (mg. N/Pot)

Treatment No.	First Pot Experiment	Second Pot Experiment
1	3.50	7.00
2	3.32	8.15
3	3.48	7.92
4	3.59	7.71
5	3.61	7.10
6	3.42	6.52
7	4.31	6.87
8	4.29	6.90
9	3.91	6.67
10	3.87	8.61
Fresh dung	4.40	4.81
Unamended control soil	2.53	5.40
L.S.D. 5%	N.S.	2.10

The result of fresh matter production in the field experiment is presented in Table 5. It was evident that the addition of manures markedly enhanced fresh matter production, indicating its suitability to supply nitrogen to a crop grown under irrigation. It was also observed that under field conditions the differences between the fresh and the stored manures were small. Furthermore, the manurial value was generally higher for manures from the deepest pits. Contrary to the findings on composts reviewed by Harmsen and Van Schreven (1955) negligible nitrogen immobilization was observed in manures in spite of their high carbon/nitrogen ratio. This substantiates the fact that the carbon of manure is present mostly in a very slowly decomposable form.

Table 5: Yield of fresh matter of Abu Sabeen Sorghum (tons/acre)

Treatment number		Yield of Fresh Matter (tons/acre)
1		7.77
2		8.42
3		9.73
4		9.53
5		10.00
6		7.84
7		8.93
8		9.33
9		9.43
10		9.97
Fresh dung		9.45
Control soil		5.57
L.S.D.	5%	1.10
	1%	1.48

Results of microbiological investigations, presented in Table 6, showed that the mesophilic microbial population was high in the fresh dung material and this decreased abruptly with storage. This was more noticeable in deeper pits, due probably to restricted aeration and high temperature being maintained for longer periods. Unfortunately no record of the changes in the thermophilic microflora was taken, which should obviously show some stimulation. The dung was originally low in both Azotobacter and nitrifying micro-organisms. It thus seems to be a good practice to add a slight amount of soil as inoculum to the various layers of the pit. This should help nitrogen fixation and ensure more nitrification of the manure.

Table 6: Viable counts of mesophilic bacteria, azotobacter nitrifiers and microbiological activity of cattle manures

Stage of sampling	Bacterial counts / g manure			CO_2 Evolution $mg\ CO_2$ / 50 g manure	
	Mesophilic bacteria x 10^6	Azotobacter	Nitrifiers	fresh	dried
Initial	120	< 100	< 1 000	52	104
One month	68	< 200	< 100	80	68
Four months	49	< 200	< 100	98	57

Incubation of manures from the final sampling evidently showed that evolution of carbon dioxide was higher from the deeper pits, most likely due to excess soluble organic material exposed quickly to aerated conditions of incubation. It was found that the use of carbon dioxide as a measure of the stage of decomposability of the manure gave more consistent results if the material was uniformly dried overnight at room temperature prior to incubation.

The general results of the analyses of manures pointed to the conservation of ammonia in deeper pits. However, in shallower pits nitrate generally accumulated to a higher level, but possibly ammonia losses were greater. Both the ammonia and the soluble nitrogen contents proved not harmful to plants in pots and under field conditions. It was also clear that even though the fresh dung material was nearly similar in manurial value to the stored product, it is expected that the accumulation of fresh dung to await the cropping season would result in vast losses of nitrogen and increased sanitation hazards. Pits of the largest size investigated (3.3 x 10 x 5 ft) have a capacity of nearly three tons of manure stored in a satisfactory and hygienic manner. This method would be useful for cattle owners in villages and small farms. For obtaining a bulky organic manure a straw bedding helps both to increase the amount composted and conserve most of the ammonia lost by volatilization, run-off and seepage.

Conclusions

1. Cattle manure thus stored is exposed to minimum conditions of drying during the very hot summer months and to leaching by rains during the rainy season. It is recognized that storage is essential as applications of manure are conveniently made at the time of land preparation.

2. The soluble nitrogen fraction is not only maintained but more nitrogen is solubilized after storage for four months, this being especially pronounced in deeper pits.

3. Both pot and field experiments with sorghum fodder species using the stored cattle manure showed that, after storage for four months, the product was free from undesirable products inhibitory to plant growth and invariably superior to the fresh material and gave a significant increase in growth in relation to unamended soil.

4. This method would be very practical for cattle owners in villages and small farms where labour and space are not limited.

Summary of discussion

The discussions centered on the differences in making cattle manure in Sudan compared to other countries with higher rainfall or lower temperatures, and different farming systems. There are difficulties of collection because of the predominantly nomadic system of cattle raising. The addition of phosphate was suggested to speed up decomposition, but it was pointed out that the response to phosphate, at least in the central part of Sudan is slow. Making heaps instead of filling pits was not satisfactory because of rapid moisture loss during high summer temperatures.

REFERENCES

Abd el Malek, Y. and Ishag, Y.Z. (1968). Evaluation of methods used in counting azotobacter. J. appl. bact. 31, 367-370

Cornfield, A.H. (1961). A simple technique for determining mineralization of carbon during incubation of soil treated with organic materials. Plant and Soil 14, 90 - 93

Greene, H. (1937). Soil problems of the Anglo-Egyptian Sudan. Emp. J. Expt. Agric. 5, 1-10

Harmsen, G.W. and Van Schreven, D.A. (1955). Mineralization of organic nitrogen in soil. Advances in Agronomy 7, 299-398

Musa, M.M. (1963). Chemical and Microbiological Studies in Straw Composts. Ph.D. Thesis, Aberdeen University

Stephenson, J. (1949). Bacterial metabolism. 3rd. edn. p. 317

Stojanovic, B.J. and Alexander, M. (1958). Effect of inorganic nitrogen on nitrification. Soil Sci. 86, 208-215

Tinsley, J. and Nowakowski, T.Z. (1959). The composition and manurial value of poultry excreta, straw-droppings composts and deep litter. Introduction, experimental materials, methods of sampling and analysis. J. Sc. Agric. 3, 145-149

Topping, L.E. (1937). The predominant micro-organisms in soil. Zbl. Bakt. (Abt. 2), 97, 289

Tothill, J.D. (1948). Agriculture in the Sudan. Oxford University Press

3. MULTCHING FOR IMPROVED SOIL FERTILITY AND CROP PRODUCTION

by

A. Ayanaba and B.N. Okigbo*

Summary

Mulching is an agricultural practice in which organic or inorganic materials are placed on the surface of or incorporated with soil to maintain or improve soil fertility. Soil thus treated is affected physically, biologically and chemically.

Physical effects of mulching include conservation of soil moisture, improvement of infiltration rate, control of run-off and erosional losses, reduction in weeding and weed competition, lowering of soil temperature and the improvement of soil structure.

Biological changes include increased activity of soil microorganisms and animals, effects on phytopathogenic nematodes and fungi, and phytotoxic effects.

Chemical changes elicited by mulching are increases in humus and cation exchange capacity as well as mobilization or immobilization of plant nutrients, depending on the conditions prevailing. Nutrient deficiencies or toxicities may result.

These changes in soil properties improve soil fertility and yields of cereals, grain legumes and tuberous crops are improved significantly. In instances where added organic materials do not supply nutrients in sufficient quantities to yield a good crop adding chemical fertilizers significantly increases yields.

It is concluded that mulches are efficient fertilizers if properly utilized, and the research needed to maximize the potential of mulches is discussed.

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* International Institute of Tropical Agriculture, Ibadan, Nigeria

Introduction

The addition of organic materials to soil elicits physical, chemical and biological changes in that soil. Thus, although the use of organic materials as fertilizers would suggest a consideration only of the chemical changes any adequate discussion is impossible without simultaneously considering the physical and biological changes.

Organic materials added to soil include manure, mulch, compost, night soil, green manures and domestic and industrial wastes. This paper considers mulching.

Mulching as used here denotes the addition to soil of mature or immature crop residues to improve soil productivity. The organic material may be produced and used *in situ* or grown in one locality and used in another. Mulches have been obtained from any and every source and used for various reasons, but usually, for physical improvement of soil. It is necessary to broaden the concept of mulching to include the placement on soil of materials such as plastics, fiber glass, paper, etc. (IITA, 1973; Jacks, Brind and Smith, 1955). Inorganic mulches have an indirect effect only, as they, for example, are not biodegradable nor can they release nutrients.

These changes will be reviewed, following which the research needs and prospects will be discussed.

The effects of mulching

A. Physical effects of mulching

Mulching conserves soil moisture and improves infiltration rate of water, lowers soil temperatures, controls run-off losses and soil erosion, reduces weeding and weed competition, and improves soil structure (Jacks, et al., 1955).

1. Moisture.

Plant response is greatly influenced by moisture in arid and semi-arid environments. In humid tropical areas where there may be plentiful but intermittent rainfall, moisture availability to plants is not uniform during the growth period. It is in these areas that moisture conservation may assume immense significance as moisture stress at critical stages would adversely affect crop performance. It is in such areas that significant moisture conservation is often recorded. Thus, Rajput and Singh (1970) showed that in India irrigation water conserved by straw, polythene and petroleum mulches were 40, 55 and 15%, respectively.

Agboola and Udom (1967) reported that 8.8 - 11 tons of straw mulch per hectare in Nigeria increased the average per cent soil moisture in November from 4.3% in unmulched plots to 7.8% in mulched plots.

Significant findings have been made at the International Institute of Tropical Agriculture in Ibadan, Nigeria. Moisture retention was improved by mulching, the difference between moisture retained in mulched versus unmulched plots increasing from the soil surface to a depth of 15 cm. The infiltration rate of water was also greater in mulched than in unmulched plots (IITA, 1972). Surface run-off was reduced by mulching (IITA, 1972). A surface mulch (at 4 t/ha) was found to be more effective in increasing soil moisture than the same organic material (5 t/ha) buried at 10 cm below the surface (IITA, 1973).

Table 1. Effect of rate of mulch on soil loss. Total rainfall = 64.01 mm.

Mulch rate,	Slope, %				
t/ha	1	5	10	15	Mean
	Soil loss, t/ha				
0	0.48	12.19	27.06	12.25	13.00
2	0.01	3.49	0.82	0.64	1.24
4	0.00	0.67	0.11	0.31	0.27
6	0.00	0.16	0.03	0.08	0.07

2. Temperature.

Soil temperature in tropical and subtropical areas is normally lower when soil is mulched. Thus at Ibadan the differences, (38^{o}C for mulched vs 30^{o}C for unmulched) were sufficient to improve germination of maize and soybean significantly (IITA, 1972-73). Mulching within rows of soybean, cassava, maize or cowpea produced differences of 0.1 - 3.4^{o}C below the temperatures of inter-row mulched plots (IITA, 1973). In Uganda, mulching produced soil temperatures as low as those in an adjacent bush shade (Griffith, 1951). Jacks et al. (1955) review the effect of mulching under high air temperatures.

3. Erosion.

Mulching reduces soil losses due to wind and the losses are generally less when the much is left on the surface than when it is incorporated into soil to increase aggregation (Chepil, 1955).

Soil losses due to water erosion on continuous maize plots were found in Ibadan to be lower on mulched plots (Table 1). Significant losses of soil can be avoided by mulch rates of 3-4 t/ha even at 15% slope.

4. Weeding and weed control.

A good mulch cover prevents rapid proliferation of weeds during early stages of plant growth. The importance of weeds and weeding in shifting cultivation is well known (Nye and Greenland, 1960). A reduction in weed population not only conserves labour but it also minimizes competition.

A study in Nigeria showed that mulching reduced the competitive effects of weeds to such an extent that yields of maize grain were doubled (Agboola and Udom, 1967). Okigbo (1965) demonstrated that the number and frequency of weedings were more important in unmulched than in mulched plots.

5. Soil structure.

Athough the general effect of mulches is the improvement of soil structure (due to earthworm activity, stimulation of microbial activity, etc.) widely differing results are given by different workers because "soil structure is a highly complex phenomenon, the resultant of most of the physical, chemical and biological influences operating on the soil" (Jacks et al, 1955).

B. Biological effects of mulching.

Biological activity is increased by the addition of mulch to soil. Populations and activities of microorganisms and the soil fauna involved in the decomposition increase and the added organic materials may also stimulate decomposition of soil organic matter. Bacteria, fungi, actinomycetes, termites, earthworms and millipedes are involved in the decomposition. (Alexander, 1961; Burges and Raw, 1967; Jacks et al., 1955).

Microorganisms are present on organic materials before they even touch the soil (Burges and Raw, 1967) so that decomposition commences before then. As microorganisms mineralize the added organic matter the products are proteins and amino acids, cellulose, lignin, vitamins, minerals and pentosans (Alexander, 1961), but the release of nutrients occurs only after the microbes have satisfied their own biochemical demands. Thus, the released nutrients are mostly excretory products. Because microbiologically immobilized nutrients are only mineralized upon death of the microbes such immobilization can mean the temporary absence of nutrients for a growing crop. Correspondingly care must be exercised in the use of organic mulches (Russell, 1973).

Decomposition of organic materials is dependent on the carbon: nitrogen ratio and type of added material as well as several environmental variables. The major environmental factor (relevant to this paper) which determines the kinds and concentrations of nutrients released is oxygen in the mulched environment. Anaerobic decomposition results in the production chiefly of humus, organic acids, gases, and minerals whereas aerobic decomposition, which is more complete, produces carbon dioxide, water, minerals and less humus (Alexander, 1961; Russell, 1973; Tusneem and Patrick, 1971).

Decomposition products of mulch will affect saprobic and phytopathogenic microorganisms as well as plants.

1. Effect on saprobic microorganisms.

In general the bacterial population increases in the early stages of decomposition; fungi and actinomycetes predominate in the later stages or during decomposition of resistant or mature organic materials (Ghildyal and Gupta, 1951). Gupta and Idnani (1970) noted that nitrate release was reduced, suggesting immobilization. The reverse has been described in Ugandan soils

(Griffith, 1951) emphasizing the dependence of microbial activity on the composition, especially nitrogen content, of added organic matter. Because nitrification and immobilization proceed simultaneously the observed effect depends on the greater process.

Mulching increased nodulation (IITA, 1971) and symbiotic nitrogen fixation in soybean (Ayanaba, unpublished).

Rice straw mulch increased non-symbiotic fixation of $^{15}N_2$ in the Philippines (MacRae and Castro, 1967), possibly because of added carbohydrates. Moore and Abaelu (1959) could not increase non-symbiotic fixation of N in a Nigerian soil by mulching with wood shavings.

2. Effect on phytopathogenic nematodes.

Organic amendments have been associated with decreases in populations of phytopathogenic nematodes in a number of instances. A review by Sayre (1971) discussed decreases in root-knot incidence with residue amendment. When eight organic amendments were made to tomato, timothy hay was successful in controlling the root lesion nematode, cellulose decreased populations of Heterodera and soybean meal reduced the populations of Pratylenchus penetrans (Sayre, 1971). Webster (1972) discussed the control of Heterodera schactii in beets, and root-knot in cowpea when organic amendments were made to soil.

Sayre (1971) discussed theories on the probable mechanism of action of decomposing organic materials in decreasing nematode populations, and suggested that these could be due to:

a) direct effect of the decomposition products such as alkaloids or volatile fatty acids.

Thus, Daulton and Curtis (1963) found alpha-terthienyl, an alkaloid, on the roots of tagetes and suggested it as the likely active chemical.

b) indirect effects. Nematodes feeding on microbes decomposing organic matter increase in number; so do their enemies. It is suggested that these enemies, notably, nematode-trapping fungi parasitize and feed on the pathogenic nematodes.

c) alteration in host physiology. Decomposition products affect hosts (see below) rendering them more or less susceptible to attack.

3. Effect on phytopathogenic fungi

According to Huber and Watson (1970) and Patrick and Toussoun (1970) crop residues may affect plant pathogens by:

a) increasing the "biological buffering capacity" of the soil, thereby regulating the proportions of each population.

b) directly reducing the numbers of the pathogen, especially during anaerobic decomposition.

c) denying the pathogen a host during the interim of an unsuitable crop,

d) serving as food for the pathogen.

Evidence exists that supports some of these hypotheses.

Papavizas (1970) mentioned that a cropping practice designed to keep organic matter out of the upper level of soil gave excellent control of peanut root and pod rot caused by Sclerotium rolfsii Sacc. and Rhizoctonia sp. Volatile compounds from decomposing alfalfa hay were found to stimulate the germination of sclerotia of S. rolfsii and the germinated sclerotia quickly died (Linderman and Gilbert, 1968). Similar stimulatory effects have been described by Linderman (1970) for spores of Fusarium oxysporium. Diseases also reduced in the presence of decomposing organic materials are the "take all" disease of wheat, Phymatotrichum root rot of cotton, potato scab, root rot of strawberry, and Phytophthora rot of avocado (Oswald and Lorenz, 1966; Patrick and Toussoun, 1970).

Organic materials do not always decrease disease incidence or numbers of pathogens. Black root rot of tobacco and bean, caused by Thielaviopsis basicola was increased by residue extracts (Linderman, 1970) and a Rhizoctonia sp. was found to infect peanut in the presence of extracts of organic materials (Papavizas, 1970).

Thus, organic residues generally stimulate activity of pathogens. Whether a diseased condition is initiated, increased or decreased then depends on the presence of a suitable host at the time, the status of antagonists, and the prevalent environmental conditions. Futher, since pathogens are often usually still in a viable state on organic materials used as mulch, very careful consideration must be given to the likely transfer of diseases in these amendments or to the possibility of supplying a pathogen with a chance to survive in the absence of its host.

4. Phytotoxic effects.

Decomposing plant materials not only contain substances injurious to microorganisms but also to plants. Linderman (1970) showed that barley, cowpea, soybean, and cotton produced acids phytotoxic to tobacco. The chemicals were identified as benzoic, phenylacetic, 3-phenylpropionic, and 4-phenylbutyric acids. Phenolic compounds - vanillin, ferulic acid, and protocatechuic acid - have also been extracted from plant residues. Langdale (1970) found extracts of stem residues of lespedeza to effectively depress maize growth in the field, green house and growth chamber. Tillage, liming or micronutrients could not reverse the phytotoxic effect. No information is available on the effects of extracts from tropical mulch materials such as banana leaves, groundnut shells, palm leaves, etc.

C. Chemical effects of mulching.

Now, to a consideration of the plant nutritional aspect of mulching. This section is divided, for ease of presentation, into three sections, namely increase in humus and cation exchange capacity (CEC), supply of fertilizer elements and effects on yield of crops.

1. Increase in humus and cation exchange capacity.

It has been stated above that adding mulch to soil stimulates decomposition of both added residues and soil humus. However, a certain amount of the added organic matter is resistant to degradation, or is degraded slowly, so that the net result is usually at least a temporary increase in humus. For example, during decomposition of *Crotolaria juncea* at different stages of growth, considerable quantities of water-soluble organic matter, pentosans, and cellulose were lost whereas lignin, fats and waxes were slowly decomposed (Ghildyal and Gupta, 1959). Thus, a benefit of adding fresh organic matter is to increase the soil humus (Alexander, 1961; Russell, 1973), but the increase represents the net effect of the dynamics of the rate of input and the increased rate of decomposition.

In Nigeria, a groundnut shell mulch applied to soil for nine years significantly increased organic carbon (Jones, 1971).

Work in Ibadan indicated that residue return could maintain soil humus (Table 2, IITA, 1972-3).

Addition of organic materials are important in improving or at least maintaining CEC as can be seen from Table 2 (IITA, 1973).

2. Supply of fertilizer elements.

Mulched soils frequently show increases in plant nutrients (Jacks *et al.*, 1955).

Table 2. Residue management and effect on carbon and CEC.

Residue Treatment	Amount Returned, t/ha	Organic C, %	CEC meq/100 g
Retained	16.4	1.63	6.82
Removed	-	1.04	4.64

Several experiments have been conducted on the release of N. In general, the return of crop residues as mulches has significantly increased mineralizable N. Nitrogen mineralized after air drying of soils of the treatments shown in Table 2 (Jenkinson, unpublished) were respectively found to be 12.2 and 8.3 ppm N in plots where maize residues were retained or removed. The soil was treated with NPK fertilizer. The release of K, Ca and Mg increased with time and in the presence of rice straw under anaerobic conditions (Table 3). Griffith (1951) found that in Uganda soil under the grass, *Pennisetum purpureum*, gave 150 ppm nitrate in the second year but only 10-20 ppm nitrate in the first year of mulch. Griffith (1959) suggested that such levels of nitrate could replace nitrogenous fertilizer if properly utilized.

A mulch of *Imperata cylindrica* in Uganda decreased nitrate content (Griffith, 1951) and in S.E. Asia a mulch of *I. arundinacea*, "about one fist thick" was not considered a mulch by Vries (1949), although he considered it "hard, rich in silicates, poor in humus and readily decomposable organic matter ..."

Table 3. The influence of rice straw on release of inorganic ions in a submerged silty clay loam. (Clark and Resnicky, quoted in Alexander, 1961)

Period of Submergence days	No rice straw			0.8% Rice Straw		
	K	Ca	Mg	K	Ca	Mg
1	6	9	2.0	12	10	3.5
11	8	26	4.5	20	45	11
21	10	18	7.5	23	64	23
35	10	32	11	24	108	43
49	10	48	16	25	138	50

When N, P and K are adequate, S content of organic amendments can lead to S deficiency (Stewart, Porter and Viets, 1966). Stewart et al. (1966) showed that unless the S content of wheat straw contains at least 0.15% S, deficiency in S will be observed.

Other nutrients, including soluble salts, vitamins and micronutrients are released by organic materials undergoing decomposition (Alexander, 1961; U.S. Plant Nutrition Staff, 1965). Decomposition produces chelates which may mobilize some nutrients but immobilize others. Thus decomposing organic matter mobilizes Fe, but immobilizes Mn and Cu (U.S. Plant Nutrition Staff, 1965), and Mn becomes toxic under certain mulched conditions (Jacks et al., 1955).

3. Effect on yield.

It is important to consider how applications of organic materials to soil affect crop yield. To be considered efficient sources of plant nutrients, organic materials must give yields as good as or better than chemical fertilizers. This appears to be suggested by the results of the majority of experiments reviewed here.

In Ibadan, Nigeria, return of organic residues maintained good crop yields over a three year period in continuous maize plots (Table 4). When maize straw was applied to a soil at 0, 1, 2, 4, 6 and 8 t/ha on the surface or at 10 cm, surface mulch gave greater yields of maize grain than buried mulch. Average grain yields for two seasons were maximum at 6 t/ha, in plots mulched on the surface (IITA, 1973).

Table 4. Residue management and maize yield at IITA, Ibadan (IITA, 1963).

Treatment	1971	1972	1973
	Maize grain yield, kg/ha*		
Maize, without residue return	5480	6680	5710
Maize, with residue returned	6170	7320	8350

*Each value represents the average of two seasons' yields. Plots were fertilized with 150 kg N, 26 kg p, 2.5 kg K and 1 kg Zn, all per ha.

At Nsukka in Nigeria, Okigbo (1965) found maize plant populations, number of ears, and grain yield to be significantly higher in mulched plots. A later study (Okigbo, unpublished) also indicated significant increases in maize stover and seed yield and also of cassava tubers in mulched plots (Table 5).

In another study Okigbo (1972) examined the effect of 12 mulches on maize performance. The mulches included translucent and transparent polythene, groundnut, Stylosanthes, Centrosema, Panicum maximum Pennisetum, maize and rice. Most of the mulches increased stover and grain yield. The same mulch treatments which gave the greatest yields of maize also gave the greatest yields of cassava when cassava was grown immediately after maize.

Yields of cotton and Eleusine were significantly improved by mulching (Griffith, 1951). The data in Table 6 indicate that mulching was superior to fertilization with either ammonium sulfate (applied on a nitrate equivalent basis) or sodium nitrate.

Table 5. Mulching on maize and cassava yields at Nsukka, Nigeria (Okigbo, unpublished)

Crop	Component	Year	Unmulched	Mulched
			Yield, kg/ha	
Maize	Stover	1971	4893	5877
		1972	2659	3300
	Grain, dry	1971	1387	1850
		1972	1542	2621
Cassava	Tubers, fresh	1971-72	2733	3931
		1972-73	2016	2489

Table 6. Yield of Eleusine and cotton in Uganda as influenced by fertilizer, manure or mulch (Griffith, 1951).

Crop	Ammonium Sulfate, 493 kg nitrate /ha	Sodium Nitrate, 493 kg nitrate /ha	Kraal manure, 20T/ha	Control	Mulch
Eleusine, total yield, T/ha	19	18	42	18	24
Cotton, seed, kg/ha	370	347	448	258	1053

Data converted to metric units from original.

Research needs on mulching

for improved soil fertility in the humid tropics

Nye and Greenland (1960) remarked that "in the humid tropics the intense rainfall renders permanent cropping with a succession of well fertilized annual crops extremely hazardous on many soils, even when erosion defences have been installed". It is suggested in this apt statement that fertilization in the areas of high rainfall and high temperature must be practised with extreme caution. Alternatives to fertilization must be sought. The recent energy crisis and its attendant problems of shortages in fertilizer production and distribution necessitated a re-examination of alternatives to chemical fertilizers. It is evident from the preceding review on mulching that the addition of organic materials to soil can give good yields of crops when the materials are used in place of or in conjunction with chemical fertilizers. Crops grown on organic manures are, quality-wise, as good as those grown on chemical fertilizers (U.S. Plant Nutrition Staff, 1965). Mulches may therefore be used in place of or in addition to chemical fertilizers where feasible.

In the less developed countries availability and distribution of fertilizers pose such problems that organic residues should be examined systematically as sources of plant nutrients. The farmer in these countries who now practises mulching must be encouraged to continue the practice and the one who is not yet doing so must be convinced that it is economic to adopt the practice of residue amendments.

The point here is not to underestimate the impact of chemical fertilizers. It is fully recognized that much higher yields may be obtainable with the use of these chemicals. However, it is nevertheless a fact that if the farmer can, by adopting the new practices, maintain a slightly higher but steady yield than he now gets the impact will be greater on world food production.

If it is accepted that organic materials can, if used judiciously, maintain soil fertility levels thereby increasing the productivity of a humid tropical soil what then, would be the research needs in the future? And what are the prospects of realizing these needs?

The following eight research needs are appropriate:

1. Kind of organic material

Research in this area should examine grasses, cereal crops and legumes separately or together. Aquatic plants with nitrogen-fixing algae, like *Azolla* (Moore, 1969), as well as algae themselves, should be examined. Grasses should be examined for their ability to produce large quantities of organic matter and to stimulate nitrogen fixation by rhizosphere bacteria. Legumes should be examined chiefly as sources of nitrogen. Plants which can symbiose with mycorrhyzal fungi to absorb and mobilize soil phosphorus should be selected.

Motta (1953) reported that *Panicum maximum* could produce 13-48 tons green matter/ha/yr with 0.73% P_2O_5 and 0.88% CaO. Nitrogen fixation is significant in grasses such as *Digitaria decumbens* (Dobereiner and Day, 1974), *Pennisetum purpureum* and *Panicum maximum* (IITA, 1973) and in tropical legumes such as *Mucuna* sp., *Vigna unguiculata*, *Glycine max*, *Psophocarpus tetragonolobus*, *Cajanus cajan* and *Phaseolus lunatus* (IITA, 1973). In general, tropical legumes fix 73-577 kg N/ha/yr (Henzell and Norris, 1962), which represents the minimum of a potential that remains to be fully exploited. Ephasis must be placed on inoculation of legumes with the proper strains of *Rhizobium*, for the amount of N fixed in the tropics can be improved significantly if legumes are inoculated with the appropriate strains of *Rhizobium*. Increased levels of fixation should be examined in conjunction with high photosynthetic capabilities so that dry matter yields can be increased. With increases in nitrogen fixation the legumes mentioned used for human and animal consumption, can be successfully grown for amendment to soil.

In attempting to use organic materials as nutrient sources it must be borne in mind that net mineralization leading to release of nitrogen (and other nutrients) is governed by the amount of nitrogen in the added organic material (about 1.5-2.5% being optimum for release), its C/N ratio, and its age (Tusneem and Patrick, 1971; Russell, 1973). Drying decreases the rate of decomposition and N mineralization due to water loss and increased C:N ratio (Schreven, 1964).

2. How much organic material must be added to obtain economic gains?

Conditions in the humid tropics promote rapid decomposition so that sufficient quantities over time must be added to elicit desired physical and biological properties, to maintain soil humus levels, and to supply needed nutrients. Thus, research is needed to ascertain and to systematize the quantities of organic materials that must be added to soil to obtain increased yield responses. Too much residue must not be added as this will lead to the problems already discussed. It may be necessary to issue recommendations. It may be found to be economic to combine chemical fertilizers with organic materials in order to obtain the best yields.

3. When must organic amendments be made to soil?

It remains to be stated the best time to make amendments. At times it is better to mulch after harvest. At other times it is better to mulch immediately before cropping. More precise information than that is needed. The effect of plant pathogens and microbial immobilization of nutrients must be kept well in mind when testing for the optimum time of residue amendment.

4. Placement of residues.

Must the added residue be spread over the soil surface, placed in bands between rows or must it be worked into the soil?

Under humid tropical acid soil conditions a problem arises. Burial in anaerobic soil layers leads to production of acids and volatiles, making the soil more acid, some nutrients more available and others less so. Placement on the surface or in well-ventilated soil may lead to complete decomposition and humus is not formed (Primavesi, 1968). Suffice is to say that for each soil type and for each mulch, adequate experimentation must precede large scale application.

5. Isolating the mulch effect.

Since the addition of mulch affects soil moisture, temperature, erosion, aggregation, microorganisms, soil fauna, and nutrient levels, it is necessary to isolate and characterize which effects are most important under which conditions. This will permit maximum improvement in crop production. The use of inert materials such as plastics (Okigbo, 1972; IITA, 1973) could be of aid in this regard, as interpretation of data would be simplified considerably.

6. Soil management.

Research is needed on the type of soil management that will give the desired rate and extent of decomposition. Nutrients can be obtained in the required amounts at the times crops need them, in a manner akin to splitting or timing the application of chemical fertilizers to coincide with peak demand periods. Tillage and weeding are examples of practices that need to be examined.

7. Live mulches, intercropping and relay cropping.

All these areas need to be carefully examined as they are related to mulching. Plants with "leaky" systems should be looked for; they can excrete nutrients while growing next to economic crops. Also requiring some examination are plants that will grow rapidly and can be killed by herbicides, just before planting to supply needed plant nutrients.

8. Economic considerations.

In the final analysis, if mulching is uneconomical farmers will not accept it. Research into maximizing the cost to benefit ratio must be conducted. An economist must work hand-in-hand with scientists engaged in research on mulching and use of chemical fertilizers so that an acceptable economic offer can be made to the farmer.

Summary of discussion

The discussion ranged on the beneficial and adverse effects of mulching in general; for example in some cases increased yields were obtained, and in some other cases yields could be depressed. There was no doubt however of the beneficial effects of mulching in soil and water conservation. More research was needed on the effects of mulching and the effects of temperature and rainfall.

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REFERENCE

1. Agboola, A. and G.E. Udom. 1967. Effects of weeding and mulching on the response of late maize to fertilizer treatments. Niger. Agric. J 4:69-72.

2. Alexander, M. 1961. Introduction to Soil Microbiology. John Wiley and Sons, Inc. N.Y. 472p.

3. Burges, A. and E. Raw, ed. 1967. Soil Biology. Academic Press. London. 532p.

4. Chepil, W.S. 1955. Factors that influence clod structure and erodibility of soil by wind : V. Organic matter at various stages of decomposition. Soil Sci. 80:413-421.

5. Daulton, R.A.C. and R.F. Curtis. 1963. The effect of Tagetes spp. on Meloidogyne javanica in South Rhodesia. Nematologica 9:357-362.

6. Dobereiner, J. and J.M. Day. 1974. Associative symbioses in tropical grasses: characterization of microorganisms and dinitrogen fixing sites. Paper Presented at International Symposium on Nitrogen Fixation, June 3-7, 1974. Washington State University, Pullman, Washington. U.S.A.

7. Ghildyal, B.P. and U.C. Gupta. 1959. A study of the biochemical and microbiological changes during the decomposition of Crotolaria juncea (Sann hemp) at different stages of growth in soil. Plant and Soil 11:312-330.

8. Griffith, G. 1949. Fertility problems in Uganda. P. 160-165. Proc. First Commonwealth Confr. on Tropical and Sub-tropical soils, 1948. Commonwealth Bureau of Soil Sci. Technical Communication No. 46.

9. Griffith, G. Ap. 1951. Factors influencing nitrate accumulation in Uganda soil. Expt. Agric. 19:1-12.

10. Gupta, R.C. and M.A. Idnani. 1970. Utilization of organic materials by enrichment with nitrogen. Indian J. Agric. Sci. 40:211-215.

11. Henzell, E.F. and D.O. Norris. 1962. Processes by which nitrogen is added to the soil, p. 1-18. In A review of nitrogen in the tropics with particular reference to pastures. Bulletin 46, Comm. Bur. Past. Field Crops Farnham Royal, Bucks, England.

12. Huber, D.M. and R.D. Watson. 1970. Effect of inorganic enrichment on soil-borne plant pathogens. Phytopathology 60:22-26.

13. International Institute of Tropical Agriculture (IITA). Farming systems Program Annual Reports, 1971, 1972, 1973.

14. Jacks, G.V., W.D. Brind and R. Smith. 1955. Mulching. Technical communication No. 49. Comm. Agric. Bureaux. Farnham Royal, Bucks, England.

15. Jones, M.J. 1971. The maintenance of soil organic matter under continuous cultivation at Samaru, Nigeria. J. Agric. Sci. 77:473-482.

16. Langdale, G.W. 1970. Phytotoxic phenolic compounds in Sericea lespedeza residues. Diss. Abstr. Int. B. 30:3454-B.

17. Linderman, R.G. 1970. Plant residue decomposition products and their effects on host roots and fungi pathogenic to roots. Phytopathology 60:19-22.

18. Linderman, R.G. and R.G. Gilbert. 1968. Stimulation of *Sclerotium rolfsii* and its antagonists by volatile components of alfalfa hay. Phytopathology 58:1057. (Abstr.)

19. MacRae, I.C. and T.F. Castro. 1967. Nitrogen fixation in some tropical rice soils. Soil Sci. 103:277-280.

20. Moore, A.W. 1969. *Azolla*; Biology and agronomic significance. Bot. Rev. 35:17-34.

21. Moore, A.W. and J.N. Abaelu. 1959. Non-symbiotic nitrogen fixation in a soil of the Nigerian rain forest zone Nature 184:75.

22. Motta, M.S. 1953. Panicum maximum. Expt. Agric. 21:33-41.

23. Nye, P.H. and D.J. Greenland. 1960. The soil under shifting cultivation. Tech. Commun. No. 51. Commonwealth Bur. Soils, Harpenden, England.

24. Okigbo, B.N. 1965. Effects of mulching and frequency of weeding on the performance and yield of maize. Niger. Agric. J. 2:7-9.

25. Okigbo, B.N. 1972. Essais sur le mais dans la plaine de Nsukka (Nigeria). III. Les effèts de differentes sortes de mulch sur le rendement du maise en climat tropical humide. Agron. Trop. 10:1037-1047. (English Summary).

26. Oswald, J.W. and O. A. Lorenz. 1956. Soybeans as a green manure crop for the prevention of potato scab. Phytopathology 46:22 (Abstr).

27. Papavizas, G.C. 1970. Colonization and growth of Rhizoctonia solani in soil, p 108-122. In Rhizoctonia solani; Biology and pathology. Univ. of California Press, Berkeley.

28. Patrick, Z.A. and T.A. Toussoun. 1970. Plant residues and organic amendments in relation to biological control, p 440-459. In Ecology of soil-borne plant pathogens. Prelude to biological control. Univ. of California Press, Berkeley.

29. Primavesi, A. 1968. Organic matter and soil productivity in the tropics and sub-tropics, p. 653-699. In Organic matter and soil fertility. North-Holland Publ. Co., Amsterdam and Wiley Intersciences, New York.

30. Rajput, R.K. and M. Singh. 1970. Efficacy of different mulches in conserving soil moisture in cotton. Indian J. Agron. 15:41-45.

31. Russell, E.W. 1973. Soil Conditions and plant growth. 10th. ed. Longmans, Green and Co. Ltd, London. 849p.

32. Sayre, R.M. 1971. Biotic influences in soil environment, p. 235-236. In Plant parasitic nematodes. Academic Press, New York.

33. Schreven Van, D.A. 1964. A comparison between the fresh and dried organic materials added to soil and carbon and nitrogen mineralisation. Plant Soil. 20:149-165.

34. Staff of the U.S. Plant, Soil and Nutrition Laboratory. 1965. The effects of soils and fertilizers on the nutritional quality of plants. Agric. Res. Service, U.S. Dept. of Agric. and Cornell Univ. Agric. Expt. Station. Information Bulletin No. 299. 24p.

35. Stewart, B.A., L.K. Porter and F.G. Viets, Jr. 1966. Effect of sulfur content of straws on rates of decomposition and plant growth. Soil Sci. Soc. Amer., Proc. 30:355-358.

36. Tiwari, Y.D., T.A. Singh, J.P. Mahajan and A.N. Sharma. 1970. Effect of surface mulch on yield of wheat (Triticum aestivum L.). Indian J. Agric. Sci. 40:203-206.

37. Tusneem, M.E. and W.H. Patrick, Jr. 1971. Nitrogen transformations in waterlogged soil. Louisiana State Univ., Louisiana, U.S.A. Bulletin No. 657. 75p.

38. Vries, de O. 1949. Remarks on some aspects of the soil-fertility problem in the tropics, p. 157-160. Proc. First Commonwealth Confr. on Tropical and Sub-tropical soils, 1948. Commonwealth Bureau of Soil Sci. Technical Communication No. 46.

39. Webster, J.M. 1972. Nematodes and biological control, p. 469-496. In Economic nematology. Academic Press, New York.

4. USE OF COMPOST IN KOREA

by

J.F. Parr

The annual application of rice straw compost to paddy soils in Korea has been a long established agricultural practice. Composting is a time-consuming and laborious process in which rice straw is first chopped into 50-60cm segments, by hand, and then mixed with varying proportions of chicken litter, urea, lime, and night soil. Recently, treble superphosphate has been added to provide some acidification for reducing the volatilization losses of ammonia (NH_3) during incubation. Under Korean conditions about a 30 percent reduction in the weight of rice straw can be obtained in 90-100 days. Yet, the use of compost for Korean paddy soils is currently being reassessed since significant yield increases are apparent only where soils are inherently low in organic matter. There seems to be little effect of compost on rice yields when soils contain more than about 2 percent organic matter. Moreover, paddy soils low in organic matter often produce higher yields following application of uncomposted rice straw, and sufficient urea N to support decomposition, than from compost. A possible explanation here is that most Korean paddy soils are low in silica which may be more available from rice straw than from compost. On the other hand, compost applied to upland soils in Korea - soils from granitic parent material, coarse textured, extremely low in organic matter, low cation exchange capacity (CEC), and subject to extensive erosion - often results in higher crop yields than uncomposted rice straw with supplemental N. Possible explanations include increased moisture retention, increased CEC, less runoff of plant nutrients, and less erosion where composed has been applied.

Summary of discussion

Discussion of the paper revealed that there is in conclusive evidence on the efficacy of compost made from out rice straw on yields of paddy. Whereas Government recommendations in Korea called for the use of compost on paddy, evidence suggested that rice straw, uncomposted, produced better results - possibly due to increased availability of silica. Experience in Japan suggested that compost on paddy was beneficial, but this had to be weighed against high labour costs.

5. Chemical and Biochemical Considerations for Maximizing the Efficiency of Fertilizer Nitrogen[1]

J. F. Parr[2]

ABSTRACT

Fertilizer nitrogen is subject to loss from the soil-root zone, and immobilization by the soil and rhizosphere microfloras, which can result in low recovery and use efficiency of the applied nitrogen. With increasing rates of application, fertilizer nitrogen efficiency decreases progressively, while leaving an increasing amount of unused nitrogen as a potential pollution hazard. Since the point of greatest economic return from this nutrient is usually somewhere below the point of maximum yield, it should be possible to adjust fertilizer nitrogen rates for maximum return and minimum loss to the environment. This can be achieved through improved soil and crop management practices, including proper timing of application of conventional nitrogen fertilizers and use of deep-rooted crops for recovery of leached nitrate. A rational approach to more meaningful nitrogen recommendations is needed, one which would account for residual fertilizer nitrogen and mineralizable soil nitrogen, and allow an accurate prediction of the amount of supplemental fertilizer nitrogen necessary to produce the desired yield. Efficiency of fertilizer nitrogen might also be increased with controlled release fertilizers, including the use of coated granules, and compounds of limited water solubility blended with conventional nitrogen fertilizers, to achieve a specific release rate coincident with the nitrogen requirements of a crop. Formulation of ammoniacal fertilizers with nitrification inhibitors offers considerable opportunity for increasing fertilizer nitrogen efficiency.

Additional Index Words: controlled release fertilizer, nitrification inhibitors, ground water pollution.

Fertilizer nitrogen (N) use efficiency may be defined as the *percentage recovery of fertilizer N by a crop. It may be estimated as the difference in N uptake by the aboveground portions of fertilized and unfertilized plants, and expressed as a percent of the N applied.* Efficiency will vary depending on the N source, the rate applied, method and time of application, type of crop grown and its N requirement, extent of microbiological and chemical immobilization of the applied N, and a host of soil, climatic, and management factors. Under favorable conditions, 80% or more of the fertilizer N may be recovered by the crop to which it was applied. However, under many soil and cropping conditions, efficiencies of 50% or less are not uncommon (2, 4). While there is general agreement that the low efficiency of fertilizer N is due largely to a net loss of N from the soil-root zone by leaching and denitrification, a soil N balance sheet approach to the problem has merely shown that much of the N is unaccounted for, providing little reliable information concerning the exact fate of the applied N (2).

There are several ways in which fertilizer N use efficiency could be increased, (i) by minimizing losses of N from the soil-root zone, and (ii) by manipulating environmental and management factors to allow the plant to fulfill its genetic capability for maximum yield and high product quality, which in itself would enhance the recovery of applied N.

[1]Contribution from the Agricultural Research Service, U. S. Department of Agriculture, cooperating with the Louisiana Agr. Exp. Sta., Baton Rouge, La. 70803. Received March 16, 1972.

[2]Microbiologist.

In view of (i) the increased use of fertilizer, particularly N, to sustain maximum yields for economic production; and (ii) agriculture's potential contribution to the eutrophication of surface water resources, as well as nitrate enrichment of ground water from deep percolation and the possible health hazards which could result therefrom, the objective of this review is to consider chemical and biochemical approaches for maximizing the efficiency of fertilizer N. A discussion of the fate of fertilizer N in soil, consumption patterns and trends, recent evidence of enrichment of natural waters by fertilizer N, and the relationship between N use efficiency and maximum yields is pertinent to this objective.

FATE OF FERTILIZER N IN SOIL

Most N fertilizers are subject to certain chemical, physical, and biochemical events which can result in significant losses of N from the soil-root zone after application. A schematic representation of the fate of both soluble and slow-release fertilizer N is shown in Fig. 1. Losses occur principally through (i) leaching of nitrite (NO_2^-) and nitrate (NO_3^-); (ii) biological denitrification of both NO_2^- and NO_3^-; (iii) volatilization of ammonia (NH_3) from improper application of anhydrous or aqua NH_3, and surface application of urea and other ammoniacal N sources to alkaline soils; and (iv) chemical denitrification according to mechanisms proposed by Allison (3). Fertilizer N can also be lost through (v) surface runoff and erosion, (vi) inter-lattice fixation of ammonium (NH_4^+) by clay minerals, (vii) microbiological immobilization, and (viii) chemical immobilization involving reactions of fertilizer N with soil organic components.

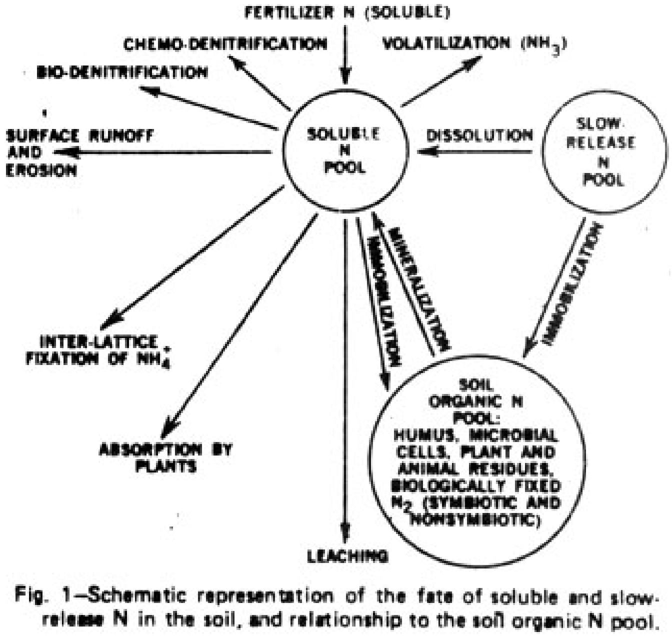

Fig. 1—Schematic representation of the fate of soluble and slow-release N in the soil, and relationship to the soil organic N pool.

Slow-release or controlled-release N fertilizer sources would either enter the soluble N pool directly, depending on specific dissolution properties and release characteristics, or possibly undergo immobilization into the soil organic N pool. The microbiological or chemical immobilization of either slow-release N or more soluble N sources into organic compounds that are more or less resistant to mineralization by the soil microflora could markedly affect the efficiency of fertilizer N (16, 28).

Ammoniacal N in most soils is lost only after nitrification to NO_2^- and NO_3^- by autotrophic bacteria—NH_4^+ is electrostatically adsorbed by the cation exchange complex and thus relatively immobile, while these anionic forms are subject to both leaching and denitrification. It appears that most crop plants can absorb and assimilate either NH_4^+ or NO_3^-, often with equal effectiveness, provided certain conditions are met (12, 20).

FERTILIZER N CONSUMPTION: PATTERNS AND TRENDS

The increased consumption of fertilizer N in the USA during the past two decades has indeed been dramatic (Fig. 2). Where little more than 0.5 million metric tons were applied in 1945, 6.6 million tons were applied in 1970. According to Ibach (19), consumption of fertilizer N in the USA should reach about 11 million tons by 1980, or approximately 10% of the total world consumption which is now projected at 115 million tons (30).

The N consumption pattern for United States agriculture is directly related to increased N fertilizer rates for basic crops such as corn, which have increased in several Corn Belt States from 10 kg N/ha in 1950 to about 120 kg/ha in 1967 (Fig. 3). When one considers that during this time the population in the USA increased by 50 million people, while the area of cropland decreased by about 10 million hectares, the intensity of N fertilizer use relative to increased crop production is particularly apparent.

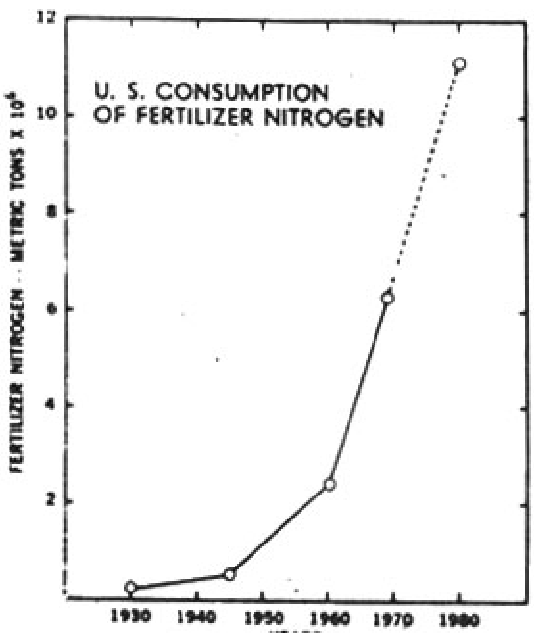

Fig. 2—Consumption of fertilizer N in the USA since 1930 with a projected estimate to 1980.

Table 1—Balance sheet of N in the USA: estimated changes from 1930 to 1969 on harvested cropland

Item	Nitrogen—millions of tons 1930*	1947†	1969‡
Inputs of Nitrogen from:			
1. Fertilizer N	0.3	0.7	6.8
2. N fixed by legumes	1.7	1.7	2.0
3. N fixed (nonsymbiotic)	1.0	1.0	1.0
4. Barnyard manure	1.9	1.3	1.0
5. Roots of unharvested portions of crops	1.1	1.5	2.5
6. Rainfall	0.8	1.0	1.5
Total	6.8	7.2	14.8
Removals of Nitrogen by:			
7. Harvested crops	4.6	6.5	9.5
8. Erosion	5.0	4.0	3.0
9. Leaching of soil N	4.0	3.0	2.0
10. Leaching of fertilizer N	0	0	?
11. Denitrification	?	?	?
Total	13.6	13.5	14.5

* Lipman and Conybeare (25). † Mehring and Parks (27). ‡ Stanford et al. (45).

Table 1 shows the estimated changes in inputs and removals of fertilizer and soil N from 1930 through 1969. While estimates for certain categories are somewhat speculative, these data indicate that through 1969, considerably more N was removed in harvested crops than was applied by N fertilizers. This has prompted some agricultural spokesmen to conclude that agriculture cannot be contributing to nutrient pollution of natural waters. The fallacy of this assumption, however, is apparent when considering the regional differences between cropping systems and fertilizer N use patterns. Indeed, the more progressive farmers tend to add more nutrients than their crops recover, while the opposite is true for those who are still "mining" the native soil fertility (11). According to White (56), the total nutrients applied as fertilizers to corn, cotton, and sugarcane in the USA now exceed the total nutrients removed in harvested material.

The zeros and question marks in lieu of actual values for leaching and denitrification indicate that little is known conclusively of the magnitude of these losses. Nevertheless, for 1930 and 1947, estimates of total N removed far exceeded the total input. However, by 1969 this pattern had been reversed, and it is likely that total N input will exceed N removal by even greater margins

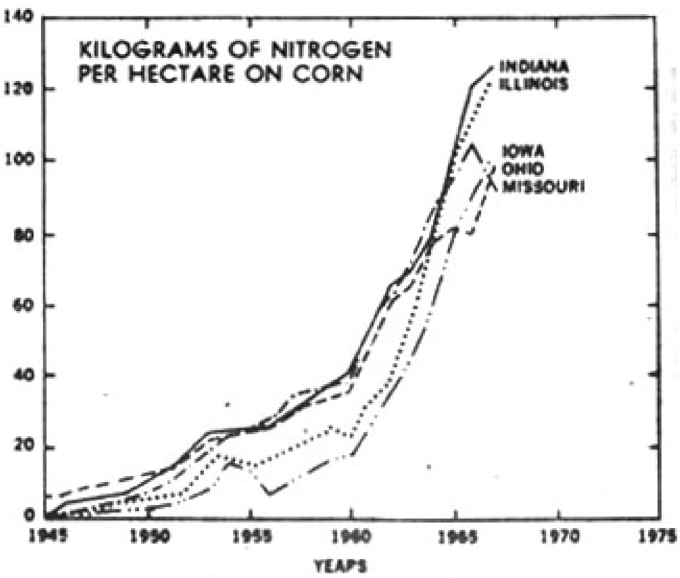

Fig. 3—Trend in use of fertilizer N in several midwestern states. From Thompson (50).

in the future. These data allow some speculation as to what extent fertilizer N might be contributing to enrichment of natural waters by 1980.

According to Nelson (30):

> Future increases in fertilizer consumption in the USA must come largely from increased application on presently low fertilizer-using crops and low fertilizer-using areas because many of the present high fertilizer-using crops, including corn, already are approaching the maximum profitable rates of application.

Recent trends concerning fertilizer N rates for corn (Fig. 3) suggest that several states may be approaching such levels. A pertinent question then is whether increased application of fertilizer N to low N-requiring crops, such as soybeans (*Glycine max* L.), and the expanded use of fertilizer N in areas where, presently, crop production is limited by certain soil and climatic factors, will pose an even greater potential for loss of applied N. A real challenge for agricultural scientists in the future will be to seek ways and means of maximizing the efficient use of fertilizer N on low N-using crops and in presently low N-using areas.

NITROGEN FERTILIZER USE AND ENVIRONMENTAL QUALITY

That some loss of fertilizer N does occur from the soil-root zone is an undeniable fact of a progressive agriculture. However, the magnitude and possible consequences of these losses are currently the basis of considerable controversy. More and more, ecologists are associating the increased use of fertilizers, particularly N and P sources, with environmental pollution. They contend that excessive rates of fertilizer N are contributing significantly, through runoff and leaching, to accumulation of NO_3^- in surface and ground water (10). This, in turn, is related to increased eutrophication of streams, lakes, and reservoirs, and to potential health hazards[3] to humans (particularly infants, from methemoglobinemia) and livestock (particularly ruminants) which might consume surface and ground waters of excessive NO_3^- content. They also charge that the high NO_3^- content of certain vegetables (e.g., beets, cabbage, and spinach) is related to excessive use of fertilizer N, and thus constitutes a health hazard, especially in baby foods.

Agriculturists, on the other hand, have responded to these accusations in a most defensive way, insisting that fertilizers are not currently a serious source of enrichment of surface and ground waters, and that increased NO_3^- levels monitored in streams and ground water in close proximity to agricultural areas (21) are not sufficient proof that fertilizers are involved. They point out that sources of NO_3^- other than fertilizers could be contributing in a much more significant way to this phenomenon. These sources of NO_3^- include treated and untreated sewage effluent, animal wastes, food processing wastes, industrial effluent, biological N_2 fixation in aquatic environments, mineralization of soil organic N, and movement of water through geologic formations of high NO_3^- content. Support for this thesis can be found in some recent reviews by Aldrich (1), Viets (53), and Viets and Hageman (54), who conclude that nutrient enrichment of water resources from fertilizers is probably minimal under most conditions.

A number of agricultural spokesmen, however, readily admit that at the present time there is not sufficient reliable experimental data to adequately evaluate the real and/or potential contribution of fertilizers to the pollution of natural waters. For example, Nelson (29) concluded:

> Field research is needed as soon as possible to determine whether fertilizers contribute to contamination of natural waters; if so, how much, where and under what conditions; and whether, in relation to other sources of N and P, the fertilizer contribution is enough to justify strong control measures. Such information does not exist.

He also urged that, "field research should be initiated on amount, time, method of application, and kinds of fertilizer needed to improve crop recovery and reduce nutrient losses," and suggested several approaches for determining the contribution of fertilizer nutrients to surface and ground waters. One involves the use of small confined watersheds or tile-drain plots where the fate of different fertilizers could be accurately evaluated by continuous or frequent monitoring of the nutrient content of the runoff, leachate, and ground water. Another approach concerns the application of fertilizers to conventional erosion plots, and subsequent monitoring of the nutrient content of runoff, sediment, soil (by depth increments), and ground water.

In his appraisal of the countless field experiments conducted over the last 30 years to assess crop response to fertilizers, Viets (53) commented:

> Almost universally the experiments have failed to determine how much of the fertilizer runs off, is carried off on eroding particles of soil, or percolates below the root zone.

He further emphasized:

> ---we do not have a balance sheet of inputs and outputs of nutrients applied to a cropping system over a long period of time in any section of the country.

Comments by Viets and Hageman (54) regarding NO_3^- enrichment of ground water in the midwestern USA are also appropriate:

> The rate of water recharge from deep percolation is so slow that the possible nitrate pollution of aquifers from our modern technology will take decades. However, once nitrate gets into the aquifer, decades will be required to replace the water with low nitrate water. Fifty to 100 years might be required to establish a time trend, considering the heterogeneity of the aquifers. By the time the trend was established, a dangerous situation could be in the making that could not be corrected in a time shorter than it took to create.

[3] The U. S. Public Health Service Drinking Water Standards recommend that the nitrate content of domestic water not exceed 45 mg/liter (ppm) as NO_3^- (equivalent to 10 mg/liter as NO_3^--N). Health effects of nitrates in water are discussed elsewhere (9).

One wonders just how far we might be into this time trend already for certain aquifers.

Since so little information is available on this subject, the validity of certain assumptions, opinions, and conclusions expressed on the plant nutrient-water quality issue is open to serious question.

EVIDENCE OF THE ENRICHMENT OF NATURAL WATERS BY FERTILIZER N

Based on a number of recent reports, it would appear that in some situations fertilizer N may be contributing to NO_3^- enrichment of surface and ground waters.

Bingham et al. (6) evaluated the NO_3^- leaching losses from an irrigated 384-hectare citrus watershed in California which received 144 kg N/ha per year. The mean concentration of NO_3^- in the effluent drainage water over a 3-year period was 50 to 60 mg/liter and represents a loss of 45% of the applied N.

Stewart et al. (47, 48) analyzed soil core samples from the South Platte Valley of Colorado and found that the mean NO_3^--N concentration to a depth of 6.7 m as related to land use was: alfalfa 70, native grassland 81, cultivated dryland 233, irrigated fields (excluding alfalfa) 452, and feedlots 1,282 kg/ha. They estimated that 28 to 33 kg N/ha per year were lost to the water table from irrigated fields.

Ward (55) reported on five problem areas in California where from 1953 to 1968 the NO_3^- content of water pumped for domestic use exceeded the USPHS standard of 45 mg/liter. The major contributor of NO_3^- to ground water in one area was domestic sewage discharge. However, the principal source of NO_3^- enrichment in at least two areas was related to the increased use of fertilizer N under irrigation.

Harmeson and Larson (14) and Harmeson et al. (15) reported that the NO_3^- content of surface waters in Illinois sampled prior to 1956 did not exceed the USPHS standard of 45 mg/liter. Since then, this standard has been equalled or exceeded in at least nine major streams. High NO_3^- concentrations were associated with areas of intensive agricultural production where soils are well-drained, fertile, rich in organic N, and where high levels of fertilizer N are applied. Increased NO_3^- concentrations were correlated with increased stream flow, both reaching maximums during late winter and early spring, with minimums attained in late summer and early fall. This pattern would suggest an agricultural source of NO_3^- as the principal contributor, in view of the constancy of seasonal N outputs from sewage treatment plants. Where sewage discharge was a significant source of NO_3^-, the pattern would likely be reversed because of dilution during periods of increased stream flow. Maximum NO_3^- concentrations in late winter were attributed to drainage from cropland after excessive precipitation. Mineralization of soil organic N and nitrification of both soil and fertilizer N would contribute seasonally to this phenomenon.

Harmeson and Larson (14) estimated that of the total nitrate contribution to the Kaskaskia River above Shelbyville, Illinois, more than 60% originated from soils, about 25% from N fertilizers, 8% from animal wastes, 4% from atmospheric sources, and less than 1% from sewage treatment plants. Kohl et al. (21) calculated that from 55% to 60% of the nitrate entering Lake Decatur (Illinois) in the spring of 1970 originated from fertilizer N. These values have been the subject of considerable controversy. Nevertheless, hearings were held by the Illinois Pollution Control Board (IPCB) in late 1971 on a proposal to regulate the application of fertilizers and animal manure on Illinois farms. While the IPCB subsequently voted not to adopt the proposal, it is likely that similar situations involving other states may arise in the future.

The time has come for agriculturists to assume a less defensive, and indeed, more positive attitude in their approach to the plant nutrient-water quality issue. We may have no alternative but to accept the fact that in some cases agriculture is contributing to environmental pollution. Where these situations exist we must seek corrective and preventive measures. However, responding to emotional accusations by issuing equally emotional denials of any and all evidence which might implicate the contribution of fertilizers to impaired water quality—and to do so with little evidence to the contrary—will gain neither the support nor respect of the general public which is so essential to agriculture.

Our mission as agricultural scientists is to assist farmers in producing the necessary food and fiber with the least possible damage to our environment, and to provide them with as many options as possible. There are a number of options for minimizing the loss of fertilizer N from the soil-root zone and increasing its utilization efficiency, which will subsequently be discussed.

EFFICIENCY OF FERTILIZER N AND MAXIMUM YIELDS

For the past three decades farmers in the USA have been using N fertilizers in ever increasing quantities. This has been brought about principally by State and Federal research and extension agencies, as well as the fertilizer industry, who have emphasized that the highest permissi-

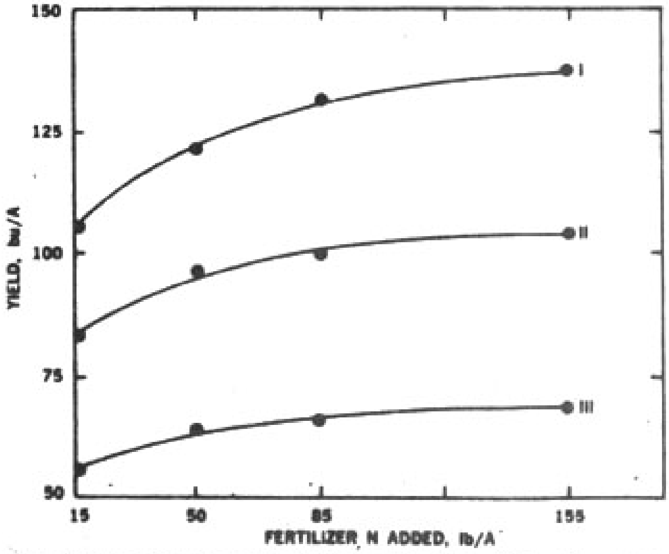

Fig. 4—Response of corn (grain) to applied N for 21 location-years of data in New York, The curve labeled I is the mean of the 7 highest yielding experiments, curve II the mean of 7 intermediate experiments, and curve III the mean of the 7 lowest yielding experiments. From Lathwell et al. (22).

ble or recommended rate of fertilizer usage was necessary to achieve maximum crop yields. From 1960 to 1967 N consumption increased by about 10 kg N/ha per year (Fig. 3), while corn yields increased at a rate of 180 kg/ha per year. Assuming that only the grain was removed from the field, some two-thirds of the applied N cannot be accounted for in the crop (22).

Yield response of corn to applied N for high, intermediate, and low-yielding experiments by Lathwell et al. (22) (Fig. 4) illustrate that response to N increases with increasing yield; that is, response to N was greater at Group I sites compared with Group III sites. Moreover, these results show the characteristic diminishing response with each additional increment of N. Corresponding data by these authors (Fig. 5) illustrate the fact that the N content of the above-ground portion of the plants parallels the yield curves. The percentage values indicate the efficiency of recovery of applied N by the crop. Two points here are significant. First, as the rate of applied N increased, the percentage recovery (i.e., efficiency) decreased progressively for each yield level. Second, for each increment of N applied, the percentage recovery increased as the yield level increased. These data are quite typical of most experiments conducted to evaluate crop response (yield or uptake) as a function of N rate, and illustrate the diminishing response to successive fertilizer N increments, and the rapid decrease in efficiency of utilization with increased application rates.

If one could increase the yield potential of a crop, fertilizer N use efficiency would also increase from utilization of excess N. However, until such time that research scientists can find ways and means of moving off the yield plateau that presently exists for most crops, we are confronted with a situation similar to that shown in Fig. 6, wherein farmers must apply progressively less efficient increments of fertilizer N to attain maximum yields. In this hypothetical example, corresponding values for corn grain yields, profit gains, and recoveries of N in the grain from successive increments of fertilizer N are shown in Table 2. The first increment of N was the most efficient,

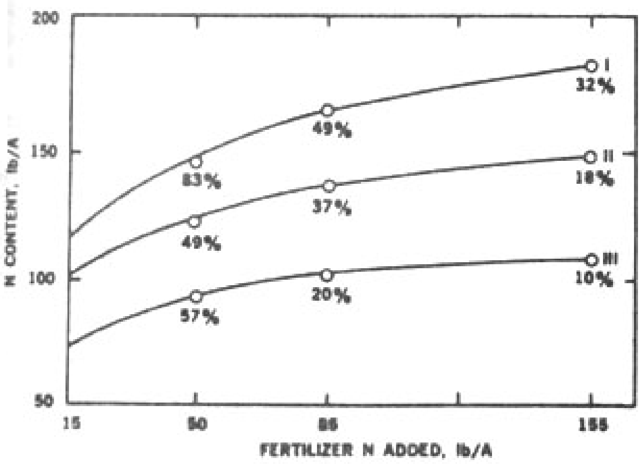

Fig. 5—Nitrogen content of the above-ground dry matter of corn relative to applied N for 21 location-years of data in New York. Curves I, II, and III correspond to the definitions given in Fig. 4. Numbers adjacent to the curves are the increases in N content resulting from each increment of N expressed as percent of the fertilizer N applied. From Lathwell et al. (22).

Table 2—Yield of corn grain, profit gain from N fertilization, and recovery of N in grain from successive increments of fertilizer N

Fertilizer N applied		Yield of corn grain		Cost* of N applied	Profit gain†	Recovery of N in grain from each increment
increment	kg/ha	bu/acre	kg/ha	$	$	%
0	0	55	3,300	0	0	0
1	56	105	6,300	4	45	80
2	56	130	7,800	4	21	40
3	56	138	8,280	4	4	15
4	56	142	8,520	4	0	7

* Based on an estimate of $0.07 per kg N per ha.
† Based on a corn price of $1.00 per bushel.

with a recovery of 80%, an increase in grain yield of 3,000 kg/ha, and a profit gain of $46. Similarly, the second and third increments were also profitable, yielding gains of $21 and $4, while the efficiency of N utilization decreased to 40% and 15%, respectively.

The result of the fourth increment of fertilizer N is of particular interest since it produced only 240 kg/ha of corn grain, and based on the selling price and the cost of N applied, the profit gain was zero. It didn't pay this farmer to apply the last increment of fertilizer even though he did reach the point of maximum yield by doing so. Some would argue that this last increment of N is necessary to ensure economic production and low food costs. However, in most cases the point of greatest economic return to applied N is somewhere below the point of maximum yield, and it is doubtful whether the last increment of N could be justified. Either of these points is somewhat difficult to predict accurately over a wide range of field conditions. Thus, the prevailing philosophy is that the farmer has little to lose even when he exceeds the optimum N rate by 50 or 100 kg N/ha. In considering fertilizer N as a production input, most farmers in the USA think in terms of maximum yields rather than the point of greatest economic return.

Little more than 7% of the applied N was recovered

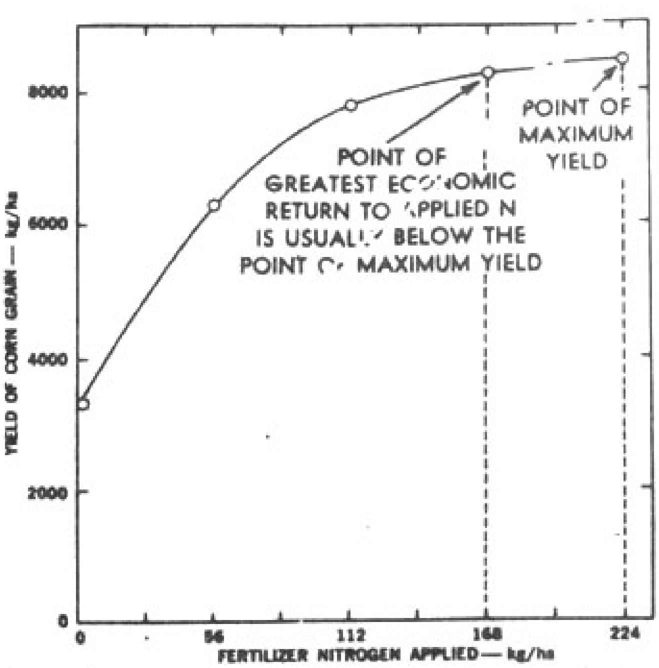

Fig. 6—Hypothetical representation of crop response as a function of N rate, illustrating the point of greatest economic return to applied N and the point of maximum yield.

from the fourth increment, leaving 90% as a potential pollution hazard. While the cost of fertilizer N is cheap enough to tolerate these low recoveries from a strictly economic standpoint, it is doubtful that the general public will tolerate such an obvious pollution hazard. Lathwell et al. (22) also concluded that, "a careful economic analysis of application rates [N] must be made since at high rates little yield response to the final increments is obtained and the efficiency of use is very low. Thus, rate of application must be adjusted to maximize return and minimize loss to the environment." Olsen et al. (32) suggested that fertilizer N rates be limited to approximately that required by the crop, as did Linville and Smith (24) who concluded that to avoid unnecessary contributions of NO_3^- to ground water, fertilizer N greatly in excess of that required by the crop should not be applied.

It would therefore seem that increasing the efficiency of fertilizer N is among agriculture's highest research priorities. A breakthrough in this area might allow a significant reduction in fertilizer rates without lowering the yield potential.

A RATIONAL APPROACH TO FERTILIZER N RECOMMENDATIONS

A more rational approach to fertilizer N recommendations is needed. Fertilizer use practices are influenced primarily by such considerations as (i) field experiments relating crop response to N rate, (ii) expected crop yields, (iii) cost of fertilizer N, (iv) availability of applicating equipment, and (v) experience and preference of the farmer. The amount of mineralizable soil N and residual fertilizer N, both of which can contribute significantly toward the N requirement of crops, are largely ignored in formulating N fertilizer recommendations. In view of the high rates of fertilizer N currently applied, decreased utilization efficiency at maximum yields, and the potential for N loss to natural waters, it is important that we eliminate, as much as possible, the "guesswork" presently involved in making fertilizer N recommendations. Comments by Stanford (43) are appropriate:

> In formulating recommendations for nitrogen fertilizer use, agronomists and soil scientists have relied mainly on experience and interpretations of the numerous field and associated laboratory studies conducted over the years. These efforts have served the farmer and the agricultural chemical industry well. Future progress, however, demands that less empirical means be developed for predicting and meeting the nitrogen needs of crops.

A rational approach to more meaningful N fertilizer recommendations requires a knowledge of three criteria, i.e., the N requirements of crops for expected attainable yields, the mineralization potential of soil organic N, and the amount of residual fertilizer N available from previous applications. An estimate of the efficiency of N use for a specific set of crop, soil, climatic, and management conditions is also essential.

The usual objective in applying fertilizer N is to ensure that crop yields will not be limited by inadequacy of N. However, according to Stanford (43), relatively few field experiments have provided an understanding of the minimum amounts of N that must be absorbed by a crop for various attainable yields. The N requirement of a crop is defined as *the minimum amount of N in the above-ground portion associated with maximum production* (43). Although this value is variable for forage grasses, it is reasonably well-defined for such crops as sugarcane, small grains, and corn. For example, Stanford (43) reported that maximum corn yields for a wide range of soil and climatic conditions were correlated with a N content (grain and stover) of 1.2% to 1.3%. As the N content dropped below 1.2, corn yields (grain) declined rapidly.

More than 95% of the total N in surface mineral soils is in an organic form (7), and subject to mineralization by microbial processes at rates ranging from 1% to 3% during a cropping season. For example, a soil with 2% organic matter would contain about 44,000 kg of organic matter/ha (based on 2.2×10^6 kg soil/ha to a 15-cm depth), equivalent to approximately 2,200 kg N/ha (based on organic matter containing 5% N). At a mineralization rate of 2%, the soil would supply the crop with about 44 kg N/ha which in most cases would have to be supplemented by the application of fertilizer N.

Admittedly, this type of calculation is often unreliable since the specific mineralization rate and amount of potentially mineralizable N for a particular soil is essentially unknown. Soil and crop scientists have long recognized the need for a method that would provide a reliable index of soil N availability—one that would allow an accurate prediction of the amount of fertilizer N necessary to produce the desired yield. Although a number of biological and chemical methods have been developed during the past three decades, few, if any, have gained widespread acceptance (8). This is attributed to (i) poor correlations of various laboratory indexes with soil N availability, (ii) a recognition of the extreme complexity of the system and the generally pessimistic attitude regarding prospects for developing reliable quantitative methods for assessing soil N availability (G. Stanford, personal communication), and (iii) the low cost of fertilizer N relative to other crop production costs.

Presently, there is greater need than ever before for a reliable quantitative index of soil N availability. Recent work by Smith and Stanford (42) appears to be promising. They reported that the alkali-distillable N fraction obtained by autoclaving soil in 0.01*M* $CaCl_2$ for 16 hours was a satisfactory chemical index of soil N availability, and was highly correlated with soil N mineralized after 4 weeks of either aerobic or anaerobic incubation. Subsequently, they (44) calculated the mineralization rate constants and amounts of potentially mineralizable N for 39 different soils throughout the USA. Additional research is in progress to determine the reliability of this index.

The amount of residual fertilizer N in soil, both NO_3^- and NH_4^+, should be a primary consideration in formulating N fertilizer recommendations. Careful assessment of residual mineral N, especially that leached to lower depths in the soil profile, but still positionally available to plant roots, might allow substantial reduction of current high fertilizer N rates. The amount of NO_3^--N in the soil profile is being determined by some soil testing laboratories for dryland areas of the USA and Canada.

Lathwell et al. (22) concluded that the amount of residual fertilizer N in soils of New York state was negligible. However, in soils of the Southeastern USA, where annual precipitation often exceeds 125 cm, Pearson et al. (37) observed considerable residual effects of spring-applied N over a period of 16 months based on both yield and N uptake by crops. Mean uptakes of 28 and 38 kg N/ha were attained by the second and third crops of corn from an initial application of 224 kg N/ha. Residual N in these studies produced a mean corn grain yield of 1,140 kg/ha.

Residual N also tends to accumulate in soils of the less humid midwestern USA, particularly where fertilizer N is applied at high rates. Herron et al. (17) concluded that utilization of residual NO_3^--N by crops was essential for preventing accumulation of nitrates in soil. Moreover, they suggested that N fertilizer rates could probably be reduced at 3- to 4-year intervals without appreciably lowering the yield potential. Herron et al. (17, 18), Olsen et al. (32), and Pearson et al. (37) all emphasized the importance of sampling and testing both surface and subsurface soils for residual fertilizer N to ensure more meaningful and accurate N fertilizer recommendations.

With reliable information on mineralizable soil N and residual mineral N, the following equation would provide a rational basis for predicting the amount of fertilizer N to be applied to corn.

$$N_f = \frac{CR - (N_{om} + N_r)}{E}$$

where:

N_f = amount of fertilizer N to apply
CR = N requirement of crop [total dry matter (grain + stover) × 1.2%]
N_{om} = N mineralized from soil organic matter
N_r = residual mineral N (NO_3^- and NH_4^+)
E = efficiency factor.

An assumption here is that mineralizable and residual N are utilized at the same efficiency as fertilizer N.

A corn crop (grain) of 6,000 kg/ha contains about 5,500 kg of dry matter and about the same amount of stover for a total dry matter production of 11,000 kg/ha. Since the N content of this plant material near maximum yields is about 1.2%, the crop requirement for N would be 130 kg/ha (11,000 kg dry matter × .012). If we assume that mineralizable N will be 40 kg/ha, residual N 30 kg/ha, and a 60% efficiency factor, the amount of fertilizer N to apply is approximately 100 kg/ha.

Thus, the ultimate objective in applying fertilizer N is really twofold: (i) to supplement the amount of potentially available soil N and residual mineral N so that crop yields are not limited by inadequacy of N, and (ii) to ensure that the level of N applied does not greatly exceed that necessary for attainable crop yields.

INCREASING FERTILIZER N EFFICIENCY THROUGH SOIL AND CROP MANAGEMENT

There are a number of ways in which the efficiency of fertilizer N can be increased through soil and crop management practices. Lathwell et al. (22) concluded that proper timing of application is the most important consideration for increasing the efficiency of fertilizer N. When fertilizer N is applied far in advance of the time of maximum demand by the crop, there is greater probability of loss by the mechanisms described earlier. If applied just prior to the grand stage of growth, such as in a sidedress application, less N will be required to produce the same yield. The relative effectiveness of fall-applied N compared with sidedress applied N on corn yields in New York state was only 40%; whereas, the effectiveness of spring-applied N compared with sidedress N was about 80% (22). Similar data were reported by Pearson et al. (37) which indicated that fall applied N in the southeastern USA was only 50% as effective as spring applied N for corn. In terms of N recovered, the relative effectiveness was about 60%.

Another option that could increase the efficiency of applied N, and minimize its movement to ground water, is the use of deep-rooted crops, such as alfalfa, in rotation with high N-requiring crops. Stewart et al. (47) reported little accumulation of NO_3^- in soil under alfalfa, suggesting its capability as a "scavenger" for NO_3^- leached below the normal rooting depth of shallow-rooted crops.

In addition to limiting rates of fertilizer N to approximately that required by the crop, Olsen et al. (32) proposed that the amount of NO_3^--N passing through the soil profile to ground water could be limited by reducing the acreage and frequency of corn or other crops receiving N in the rotation, and maintaining cover crops on the land where feasible.

THE CONTROLLED RELEASE CONCEPT

Recognition of the low use efficiency of fertilizer N has stimulated the fertilizer industry toward the development of products that would minimize leaching and immobilization losses while releasing N at a rate coincident with the apparent N requirement patterns of growing crops. This concept of a controlled release of plant nutrients has been discussed by Nelson and Hauck (31), Parr (34), and most recently by Lunt (26).

The Coated Granule Approach

One approach to controlled release N has commonly involved the coating of conventional N fertilizer granules, such as urea and ammonium nitrate, with various plastics, resins, waxes, paraffins, and elemental sulfur. Coatings have been characterized as semipermeable, perforated, or solid membranes through which N is released by membrane rupture, direct channels, or abrasive action.

One of the more successful efforts has been the development of sulfur-coated urea (SCU) by the Tennessee Valley Authority. Unfortunately, coating adds to the cost of a fertilizer and SCU is no exception. According to Prasad (38), the N contained in SCU will probably cost 25% to 50% more than uncoated urea N. Moreover, to achieve satisfactory N release patterns the material must contain 15% to 25% sulfur which would provide little benefit in other than sulfur-deficient soils.

It is unlikely that coated granular N will ever seriously compete with conventional N fertilizers particularly for crops such as corn that demand most of their N over a short period during early growth. In this case, proper timing of application may be the best choice for increasing N use efficiency. Nevertheless, compounds such as SCU have been applied with some success to crops having a more sustained N uptake pattern, such as turf and forages, and offer some promise in certain areas subject to excessive N losses by leaching (30).

The Balanced Dissolution Approach

Another approach to the controlled release concept has involved N fertilizers of limited water solubility. Compounds such as oxamide undergo dissolution in soil at rates which vary inversely with the granule size; that is, the smaller the granule, the more rapid the dissolution rate. Thus, a specific N release rate could be achieved through balanced dissolution by selection and blending of different sized granules of oxamide, or similar compounds.

Highly soluble fertilizers such as urea or ammonium sulfate might be selectively blended with compounds of limited water solubility such as isobutylidenediurea (IBDU), oxamide or ureaform, to achieve the desired N release rate. IBDU, a condensation product from the reaction of urea and isobutyraldehyde, can be mixed or blended with most granular fertilizers, except strongly acidic superphosphate (38). In addition to IBDU, Mitsubishi Chemical Industries, Ltd., Tokyo, manufactures five blended fertilizers in which some N is supplied as IBDU and the balance as ammonium sulfate, urea, or diammonium phosphate. According to Prasad et al. (38) mixtures of IBDU and conventional N sources are often associated with greater yields than either component alone. Additional research and development is needed in this area, particularly in view of the relative simplicity of bulk-blending granular materials and lower probable production costs, compared with the coated granule approach.

NITRIFICATION INHIBITORS

The formulation of ammoniacal fertilizers with certain chemicals to inhibit nitrification by soil bacteria, thus maintaining N as NH_4^+ for extended periods, offers considerable opportunity for increasing the efficiency of fertilizer N. Probably the most widely publicized compound to date has been Dow Chemical Company's N-Serve[2-chloro-6-(trichloromethyl)pyridine], a specific inhibitor of the genus *Nitrosomonas* which oxidizes NH_4^+ to NO_2^-. A number of other compounds, including thiourea, methionine, dicyandiamide, some pesticides, and AM (2-amino-4-chloro-6-methyl pyrimidine), manufactured by Toyo Koatsu Industries, Tokyo, have been reported to inhibit nitrification (38).

Initially, the inhibitors were simply mixed with granular ammoniacal fertilizers or applied as coatings to the surface of fertilizer granules (49, 51). Few experiments have been reported where chemical inhibitors were formulated in liquid NH_3 and applied directly to soil in an attempt to suppress the rate and extent of nitrification of NH_3-N (35, 51). The relative ease of formulating and applying liquid fertilizer-inhibitor solutions in the field offers distinct advantages compared with granular preparations (41). Papendick et al. (33) reported that potassium azide (KN_3) formulated with anhydrous NH_3 was an effective nitrification inhibitor which increased N use efficiency in the winter wheat area of eastern Washington State. Parr et al. (36) reported increased efficiency of anhydrous NH_3 when formulated with N-Serve and applied to sugarcane in Louisiana.

Inhibition of nitrification would cause plants to utilize NH_4^+-N to a greater extent than in the absence of such inhibition. The effects of NH_4^+ and NO_3^- ions in plant nutrition have been the subject of investigation for the past 50 years. Plants supplied with NH_4^+-N often contain lower concentrations of certain inorganic cations such as Ca, Mg, and K, and higher concentrations of elements absorbed as anions, i.e., S, P, and Cl, compared with tissues of plants receiving NO_3^--N. Moreover, plants subject to NH_4^+ nutrition usually contain higher concentrations of amino acids but lower concentrations of organic acids. A number of researchers have reported that plants supplied wholly with an NH_4^+ form of N grow less vigorously than with NO_3^-.

Possible reasons for such differences including (i) effect on electron transfer systems, (ii) interrelationships with carbohydrate metabolism, (iii) NH_3 toxicity, (iv) ion uptake and competitive interactions, and (v) effects of pH were discussed by Kirkby and Hughes (20). For example, NH_4^+ absorption for most plants reaches a maximum above pH 7, whereas that for NO_3^- is near pH 4. Nevertheless, where adequate pH control of the rooting medium (soil or solution) is maintained, it appears that NH_4^+ is probably as effective a source of N as NO_3^-, providing there is proper balance of other nutrients. Goring (12) speculated that the optimal nutrient balance for NH_4^+ nutrition would be somewhat different than the optimal balance for NO_3^- nutrition. He also points out that current fertilization practices are based on NO_3^- nutrition. Thus, with the increased potential for use of nitrification inhibitors, and consequent shift toward NH_4^+ nutrition, such practices may be subject to considerable revision. Future agronomic research in this area should receive high priority.

RHIZOSPHERE INTERACTIONS

Soil microorganisms are more abundant in the region of contact between the root and soil, i.e., the rhizosphere, than in soil beyond the influence of plant roots, because of substrates arising from sloughed-off root hairs or epidermal cells, or exuded from normal healthy plant roots. Bartholomew and Clark (5) and Legg and Allison (23) concluded that significant amounts of fertilizer N are rapidly assimilated and immobilized by the rhizosphere microflora, resulting in decreased fertilizer N efficiency.

There is evidence that the chemical nature of plant root exudates can be changed through foliar application of different chemical compounds, including fertilizers such as urea. Such treatments have reportedly caused significant quantitative and qualitative changes in root surface-rhizosphere populations (39, 52). These observations provide a basis for future research which could contribute substantially toward increasing the efficiency of fertilizer N. For example, compounds might be applied to soil or foliage, to deliberately change the chemical nature of plant root exudates, resulting in a shift from a rhizosphere population causing extensive immobilization of N to one involving less immobilization. The principal objective here according to Rovira (40) and Starkey (46) would be that of controlling the rhizosphere microflora to the advantage of the crop.

CONCLUSIONS

It is likely that the plant nutrient-water quality controversy will continue for some time—certainly until agriculturists obtain convincing and undisputable evidence to answer charges that the increased use of fertilizer is contributing significantly to environmental pollution. The fact that such information does not now exist is indeed a dilemma. Responding to accusations with denials of any and all evidence which might implicate fertilizers as environmental pollutants, and to do so with little evidence to the contrary, will gain neither the support nor respect of the general public that is so important to agriculture. Research may reveal that in some cases fertilizers, particularly N, are contributing to the detrimental enrichment of natural waters. Where these situations exist we must seek corrective and preventive measures, and if necessary employ the most competent scientific and engineering talent available in solving the problem.

Our mission in agricultural research is to assist farmers in producing the quantity and quality of food and fiber to sustain our needs, with the least possible damage to the environment. This paper has discussed some options for minimizing the loss of fertilizer N and its immobilization in soil. While in some cases their practical significance is yet to be determined, the important consideration is that there are alternatives, and future research will undoubtedly provide others. Maximizing the efficiency of fertilizer N is one of agriculture's highest research priorities.

LITERATURE CITED

1. Aldrich, S. R. 1970. Influence of cropping patterns, soil management, and fertilizers on nitrates. p. 153-176. *In* Nitrate and water supply: Source and control, 12th Sanitary Eng. Conf. Proc. College of Eng., Univ. of Illinois at Urbana-Champaign.
2. Allison, F. E. 1955. The enigma of soil nitrogen balance sheets. Advan. Agron. 7:213-250.
3. Allison, F. E. 1963. Losses of gaseous nitrogen from soils by chemical mechanisms involving nitrous acid and nitrites. Soil Sci. 96:404-409.
4. Allison, F. E. 1966. The fate of nitrogen applied to soils. Advan. Agron. 18:219-258.
5. Bartholomew, W. V., and F. E. Clark. 1950. Nitrogen transformations in soil in relation to the rhizosphere microflora. Int. Congr. Soil Sci., Trans. 4th (Amsterdam) 2:112-113.
6. Bingham, F. T., S. Davis, and E. Shade. 1971. Water relations, salt balance, and nitrate leaching losses of a 960-acre citrus watershed. Soil Sci. 112:410-418.
7. Bremner, J. M. 1965. Organic forms of nitrogen. p. 1238-1255. *In* C. A. Black et al. (ed.) Methods of soil analysis, part 2. Amer. Soc. Agron., Madison, Wis. Agronomy Vol. 9.
8. Bremner, J. M. 1965. Nitrogen availability indexes. p. 1324-1345. *In* C. A. Black et al. (ed.) Methods of soil analysis, part 2. Amer. Soc. Agron., Madison, Wis. Agronomy Vol. 9.
9. Case, A. A., A. Gelpenn, P. C. Ward, and E. F. Winton. 1970. The health effects of nitrates in water. p. 40-65. *In* Nitrate and water supply: Source and control, 12th Sanitary Eng Conf. Proc. College of Eng., Univ. of Illinois at Urbana Champaign.
10. Commoner, B. 1971. The closing circle. Alfred A. Knopf, New York. p. 81-93.
11. Frink, C. R. 1971. Plant nutrients and water quality. Agr. Sci. Rev. 9(2):11-25.
12. Goring, C. A. I. 1962. Control of nitrification by 2-chloro-6-(trichloromethyl)pyridine. Soil Sci. 93:211-218.
13. Goring, C. A. I. 1962. Control of nitrification by ammonium fertilizers and urea by 2-chloro-6-(trichloromethyl)pyridine. Soil Sci. 93:431-439.
14. Harmeson, R. H., and T. E. Larson. 1970. Existing levels of nitrates in waters—the Illinois situation. p. 27-39. *In* Nitrate and water supply: Source and control, 12th Sanitary Eng Conf. Proc. College of Eng., Univ. of Illinois at Urbana-Champaign.
15. Harmeson, R. H., F. W. Sollo, and T. E. Larson. 1971. The nitrate situation in Illinois. J. Amer. Water Works Assoc. 63:303-310.
16. Hauck, R. D. 1968. Nitrogen requirements in different soil-plant systems. p. 47-57. *In* Forest fertilization—theory and practice. Tennessee Valley Authority, Muscle Shoals, Ala.
17. Herron, G. M., G. L. Terman, A. F. Dreier, and R. A. Olson. 1968. Residual nitrate nitrogen in fertilized deep loess-derived soils. Agron. J. 60:477-482.
18. Herron, G. M., A. F. Dreier, A. D. Flowerday, W. L. Colville, and R. A. Olson. 1971. Residual mineral N accumulation in soil and its utilization by irrigated corn (*Zea mays* L.) Agron. J. 63:322-327.
19. Ibach, D. B. 1966. Fertilizer use in the United States—economic position and outlook. USDA Econ. Rep. No. 92. 26 p.
20. Kirkby, E. A., and A. D. Hughes. 1970. Some aspects of ammonium and nitrate nutrition in plant metabolism. p. 69-77. *In* E. A. Kirkby (ed.) Nitrogen nutrition of the plant. The Univ. of Leeds, England.
21. Kohl, D. H., G. B. Shearer, and B. Commoner. 1971. Fertilizer nitrogen: Contribution to nitrate in surface water in a Corn Belt watershed. Science 174:1331-1334.
22. Lathwell, D. J., D. R. Bouldin, and W. S. Reid. 1970. Effects of nitrogen fertilizer applications in agriculture. p. 192-206. *In* Relationship of agriculture to soil and water pollution. Cornell Univ. Conf. on Agr. Waste Mgmt. Proc. Rochester, New York.
23. Legg, J. O., and F. E. Allison. 1960. Role of rhizosphere microorganisms in the uptake of nitrogen by plants. Int. Congr. Soil Sci., Trans. 7th (Madison, Wis.) 3:545-550.
24. Linville, K. W., and G. E. Smith. 1971. Nitrate content of soil cores from corn plots after repeated nitrogen fertilization. Soil Sci. 112:249-255.
25. Lipman, J. G., and A. B. Conybeare. 1936. Preliminary note on the inventory and balance sheet of plant nutrients in the United States. New Jersey Agr. Exp. Sta. Bull. 607.
26. Lunt, O. R. 1971. Controlled-release fertilizers: Achievements and potential. J. Agr. Food Chem. 19:797-800.
27. Mehring, A. L., and R. Q. Parks. 1949. How nutrients removed from soil by harvested crops are replaced by fertilizers. Part I and II. Agr. Chem. 4(10):36-40 and 4(11):33-39.
28. Mortland, M. M. 1958. Reactions of ammonia in soils. Advan. Agron. 10:325-348.
29. Nelson, L. B. 1969. Research needed to resolve the plant nutrient-water quality issue. Agron. Abstr. p. 127. See also p. 75-81. *In* O. P. Engelstad (ed.) Nutrient mobility in soils: Accumulation and losses. 1970. Soil Sci. Soc. Amer. Spec. Publ. No. 4, Madison, Wis.
30. Nelson, L. B. 1971. Agricultural chemicals in relation to environmental quality: Chemical fertilizers present and future. J. Environ. Quality 1:2-6.
31. Nelson, L. B., and R. D. Hauck. 1965. Nitrogen fertilizers: Progress and problems. Agr. Sci. Rev. 3:38-47.
32. Olsen, R. J., R. F. Hensler, O. J. Attoe, S. A. Witzel, and L. A. Peterson. 1970. Fertilizer nitrogen and crop rotation in relation to movement of nitrate nitrogen through soil profiles. Soil Sci. Soc. Amer. Proc. 34:448-452.
33. Papendick, R. I., J. F. Parr, S. Smith, and R. W. Smiley. 1971. Nitrification inhibition in soil: II. Evaluation of anhydrous ammonia-potassium azide solutions in eastern Washington. Soil Sci. Soc. Amer. Proc. 35:579-583.

34. Parr, J. F. 1967. Biochemical considerations for increasing the efficiency of nitrogen fertilizers. Soils Fert. 30:207-213.

35. Parr, J. F., B. R. Carroll, and S. Smith. 1971. Nitrification inhibition in soil: I. A comparison of 2-chloro-6-(trichloromethyl)pyridine and potassium azide formulated with anhydrous ammonia. Soil Sci. Soc. Amer. Proc. 35:469-473.

36. Parr, J. F., B. R. Carroll, and S. Smith. 1972. Effectiveness of nitrification inhibitors formulated with anhydrous ammonia when applied to sugarcane in Louisiana. Proc. Int. Soc. Sugar Cane Technol. 14:754-761.

37. Pearson, R. W., H. V. Jordan, O. L. Bennett, C. E. Scarsbrook, W. E. Adams, and A. W. White. 1961. Residual effects of fall- and spring-applied nitrogen fertilizers on crop yields in the Southeastern United States. U. S. Dept. Agr., Agr. Res. Serv., Tech. Bull. 1254. 19 p.

38. Prasad, R., G. B. Rajale, and B. A. Lakhdive. 1971. Nitrification retarders and slow-release nitrogen fertilizers. Advan. Agron. 23:337-383.

39. Ramachandra-Reddy, T. K. 1959. Foliar spray of urea and rhizosphere microflora of rice (*Oryza sativa* L.). Phytopath. Z. 36:286-289.

40. Rovira, A. D. 1962. Plant-root exudates in relation to the rhizosphere microflora. Soils Fert. 25:167-172.

41. Smiley, R. W., and R. I. Papendick. 1970. Design and use of an anhydrous NH_3 applicator for field research. Agron. J. 62:833-835.

42. Smith, S. J., and G. Stanford. 1971. Evaluation of a chemical index of soil nitrogen availability. Soil Sci. 111:228-232.

43. Stanford, G. 1966. Nitrogen requirements of crops for maximum yield. p. 237-257. *In* M. H. McVickar et al. (ed.) Agricultural anhydrous ammonia—technology and use. Amer. Soc. Agron., Madison, Wis.

44. Stanford, G., and S. J. Smith. 1972. Nitrogen mineralization potentials of soils. Soil Sci. Soc. Amer. Proc. 36:465-472.

45. Stanford, G., C. B. England, and A. W. Taylor. 1970. Fertilizer use and water quality. U. S. Dept. Agr., Agr. Res. Serv., ARS 41-168. 19 p.

46. Starkey, R. L. 1958. Interrelations between microorganisms and plant roots in the rhizosphere. Bact. Rev. 22:154-172.

47. Stewart, B. A., F. G. Viets, and G. L. Hutchinson. 1968. Agriculture's effect on nitrate pollution of groundwater. J. Soil Water Conserv. 23:13-15.

48. Stewart, B. A., F. G. Viets, G. L. Hutchinson, and W. D. Kemper. 1967. Nitrate and other water pollutants under fields and feedlots. Environ. Sci. Tech. 1:736-739.

49. Swezey, A. W., and G. O. Turner. 1962. Crop experiments on the effect of 2-chloro-6-(trichloromethyl)pyridine for control of nitrification of ammonium and urea fertilizers. Agron. J. 54:532-535.

50. Thompson, L. M. 1969. Weather and technology in the production of corn in the U. S. Corn Belt. Agron. J. 61:453-456.

51. Turner, G. O., and C. A. I. Goring. 1966. N-Serve—a status report. Down to Earth 22:19-25.

52. Venkata Ram, C. S. 1960. Foliar applications of nutrients and rhizosphere microflora of *Camellia sinensis*. Nature 187: 621-622.

53. Viets, F. G. 1970. Soil use and water quality—a loo . into the future. J. Agr. Food Chem. 18:789-792.

54. Viets, F. G., and R. H. Hageman. 1971. Factors affecting the accumulation of nitrate in soil, water, and plants. U. S. Dept. Agr., Agr. Res. Serv., Agriculture Handbook No. 413. 63 p.

55. Ward, P. C. 1970. Existing levels of nitrates in waters—the California situation. p. 14-26. *In* Nitrate and water supply: source and control. 12th Sanitary Eng. Conf. Proc., College of Eng., Univ. of Illinois at Urbana-Champaign.

56. White, W. C. 1965. Plant nutrient toll: 1965 harvest, U.S.A. Plant Food Rev. 11(4):16-17 (Winter, 1965).

Summary of discussion

The discussion revolved on how to meet the vast increased need for nitrogen fertilizer now that it is no longer cheap. It was noted that in most cases little more than 50% of the fertilizer nitrogen applied to soil is recovered by the crop. Among the possible approaches discussed to maximize the efficiency of fertilizer nitrogen were the use of coated fertilizer granules, nitrification inhibitors, and the bulk blending of soluble N-fertilizers with N-sources of limited solubility. In conjunction with this, deficiencies of N-fertilizer would have to be made up from organic sources, including agricultural and domestic wastes.

6. PEAT IN HORTICULTURE

by

Viljo Puustjärvi *

1. The world's food supply

Supplying food to the people of the world is a monumental task. Every day nearly 4 000 million people must be fed. The size of the task is rapidly increasing as the world experiences its greatest population explosion.

Although man has learned to use many kinds of plants for food, he still depends primarily upon few crops for his main supply. Within this narrow range of primary food crops, large groups of people depend upon even fewer crops, and many on only one, for their main food supplies.

Many factors affect the diet of the people. The density of the human population has an important bearing upon the way in which land must be utilized. As the amount of land per person diminishes, more of it must be used for the intensive cultivation of basic food crops and less can be committed to crops that yield relatively low amounts of food per unit area.

In many countries the economic level is so low that people cannot afford to eat large quantities of food, and most of that which they do consume must be of the relatively inexpensive carbon hydrate and starch types, such as cereals and potatoes and other starchy roots. This results in deficiency diseases. When the standard of living rises the consumption of the products of the intensive horticulture - in addition to the fat and protein - increases. This results in a healthy nutrition.

2. Land available for plant production

The land occupies approximately 29 per cent of the earth's surface. About one fifth of it are the permafrost regions, more than another fifth is too rugged or too lofty and one fifth is too arid for cultivation. Thus the habitable lands that have climatic and physical conditions permitting the growth of crops constitute no more than two fifths - about 60 million km^2 - of the earth's land surface. Much of this portion is not inhabited or is only sparsely populated, and some such areas could be brought under cultivation only at great expense.

Supposing that the population of the world amounts to 4 billions and the arable land area are those 60 million km^2 mentioned above, it would mean 1.5 hectares of arable land per capita. The present arable land area per capita, abt. 0.5 hectare, can yet be considered sufficient.

The total of the arable land, however, will not remain constant. Buildings, roads, etc. will occupy an increasing amount of it. Land will be lost due to various reasons, e.g. erosion. The extent to which man will be forced to bring new areas under cultivation will depend on man's success in increasing yields on lands already under cultivation.

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* Peat Research Institute, Finland

3. Possibilities of increasing yields

Looking ahead, it seems inevitable that the amount of arable land per person will gradually decrease. The need for increasing supplies of food will necessarily be met primarily by increasing production per unit area.

Wide differences exist between production levels. The development in agriculture that has led to a very substantial increase in production per unit area of land in the more developed countries has depended upon many factors, such as improved seeds, better tillage methods, insecticides, pesticides and better utilization of water and fertilizers.

The highly developed countries have not yet reached the maximum in yields, and the developing countries are generally far from such a goal. Many obstacles must be overcome, particularly in the developing areas, before large increases in levels of production can be achieved. One of the most important obstacles is the low productivity of the soil. The other obstacle is the lack of modern culture techniques. Although it is impossible to predict the rate of future development, it is obvious that the level of yield must increase in the near future, particularly in developing areas.

4. Actual and potential yields

Life on earth is maintained by the continuous inflow of sunlight captured by plants and stored in plant material. At low light intensities the relation between photosynthesis and light intensity is linear. In that region the efficiency of light utilization is constant and maximal. At higher light intensities the efficiency is lower. The more favourable the growth conditions are, up to the higher light intensity the relation between growth and light intensity is linear. In greenhouse culture the ratio seems to be linear - according to experiments of the Peat Research Institute - up to about 400 cal/cm^2/day (outside the house).

The energy conversion, the ratio of the chemical energy stored to total radiant energy per unit of surface, in plant growth under optimal conditions can be expected to range between 7 to 20 % for closed-crop surfaces. The figure of 7 % represents a minimum value for the optimal efficiency. An additional correction (at least in the order of 5-10 %) is needed to account for respiration losses during nights.

In the field, however, some factors (CO_2 concentration, not complete coverage, water and nutrient deficiencies, poor soil aeration, etc.) depress the yields. Therefore they are only of the order of 1 to 3 % over the entire growing season for the common crops. So, actual yields are at the moment lower than the potential yields. It can therefore be supposed that by improving growth factors, particularly those involved with soil, the yields can be increased. This concerns especially southern developing countries, in which the solar radiation is usually high (Table 1).

Table 1: Yearly average of daily total global radiation at some meteorological stations in cal/cm^2/day

Station	Country	Latitude	Altitude	Radiation
Bergen	Norway	66°	400 m	185
Helsinki	Finland	60°	45 m	221
Taastrup	Denmark	56°	28 m	230
Uccle	Belgium	51°	100 m	325
Bolzano	Italy	46°	241 m	273
Coimbra	Portugal	40°	141 m	418
Beirut	Lebanon	34°	18 m	375
Jerusalem	Israel	32°	809 m	492
Poona	India	19°	500 m	551
Nairobi	Kenya	1°	1 807 m	437

5. What a highly fertile soil is like

This question should be examined from the point of view of the plant. Plants take up water, oxygen and nutrients from the soil. It can be assumed that the easier it is for the plant to absorb all of these substances, the faster they grow. Water and nutrients are absorbed against a concentration gradient. The rate of absorption of water must therefore be in ratio to the free energy of the water and the rate of nutrient absorption in ratio to the activity of the nutrients.

These facts tell us something about the ideal soil:

1. It should contain plenty of water with as low free energy as possible. At the same time it should be sufficiently aerated.

2. It should be able to store an abundance of all nutrients required. The activity of the nutrients should be sufficiently high.

From the point of view of the plant, it is immaterial whether the medium is sand, clay, peat, a soil mix etc., provided it meets the above requirements.

From the foregoing it can be concluded that the ideal material for a growing medium must satisfy the following demands:

1. The pore space should be as large as possible.
2. Some of the pores should be small enough to be full of water at the prevailing suction and some of them large enough to be full of air (non-capillary porosity).
3. The cation exchange capacity of soil ingredients - or of some of them - should be as high as possible.

6. Increasing the fertility of mineral soils

The pore space of the pure mineral soils is fairly low, usually of the order of 50 volume-%. In fine-textured soils the air space is too low and in coarse soils, on the other hand, the capillary porosity is too low. In both cases the growth conditions can be improved by increasing the organic fraction content of the soils. The organic fraction affects plant growth indirectly through its properties of binding soil particles (in fine-textured soils) together into structural units and holding cations in exchangeable form. In coarse soils the organic fraction increases the water-holding capacity of the soil. In both cases the organic fraction increases the pore space of the soils.

The enduring effect of organic matter on soil structure is probably the result of an intergrowth of stable residues of organic matter decomposition that are combined chemically with the surfaces of the mineral particles. The conversion of fresh organic matter into the state of a cement is irreversible. After the mechanical dispersion of soil, therefore, the already decomposed organic matter is no longer able to form new aggregates. So for maintaining the soil in good structure, the provision of new undecomposed organic matter is essential.

It has been shown that waterstable aggregates can be formed through the action of mould fungi, which appear in abundance on fresh plant residues. This results probably from production of mucilaginous material and fungal hyphae.

From the foregoing it can be concluded that the organic matter which is used as soil improving material should be undecomposed organic matter, in which the micro-organism activity is as high as possible (high C/N-ratio, easily decomposable organic substances).

Peat as a soil improvement material

Peat is a complex polydispersed system. It comprises true solutions, hydrophilic semi-colloids, hydrophobic soils etc., all of them in a dynamic state. In addition to the decomposed component it contains also coarse-dispersed fraction which is composed of undecomposed plant residues. The properties of peat are determined by the quality of peat-forming plants and by the degree of decomposition. The most typical peat types are undecomposed *Sphagnum* peat and decomposed amorphous peat.

1. Undecomposed Sphagnum peat

Undecomposed Sphagnum peat is usually called moss peat. It is considered the best peat type for horticultural purposes. *Sphagnum* plants consist of a central stem covered with leaves and many branches. The leaves are the thickness of a single cell. Some of the cells are large, swollen, dead cells, capable of storing water. Each of these large cells has a pore through which water enters easily, with ringlike thickenings of the wall to strengthen it. Thanks to these numerous porous cells, *Sphagnum* is capable of retaining large quantities of water.

Peat moss consists of weak colloidal acids. Due to these, peat moss is capable of storing high quantities of nutrients in available form (the cation exchange capacity is about 140 ml/100 g).

In slightly humified *Sphagnum* peat, the moss structure is still intact. Phenolic compounds may be liberated from the lignin-like substance called sphagnol. Sphagnol is more easily converted into a water soluble form than lignines and is therefore more likely to be attacked by microbial enzymes than the latter. In decomposing, sphagnol is oxidized for the most part into carbon dioxide and water. Hydrophobic components, therefore, are not formed.

Besides sphagnol *Sphagnum* peat contains cellulose and hemicellulose. The C/N-ratio is high, about 80. Because of these facts the activity of the micro-organisms in Sphagnum peat is fairly high. An abundance of active bacterial slime, therefore, is continuously formed. (Many micro-organisms synthesize polysaccharides so that they do not disappear entirely. They are highly effective in forming soil aggregates).

2. Decomposed peats

The colloidal fraction of decomposed peat consists mainly of humates of polyvalent metals which form micelles or compact coagulated aggregates. The coagulated condition is the result of a low degree of dispersion and a smaller content of hydrophilic material. The behaviour of the colloids is determined mainly by the composition and quantity of adsorbed cations. The humic acids are irreversible colloids. From the foregoing it can be concluded that the decomposed peats are less effective in forming and maintaining the mineral soil in good structure.

3. Greenhouse culture

Greenhouse culture is the most intensive form of plant production. Climate in greenhouse (temperature, relatively humidity, carbon dioxide concentration) is controlled. Therefore, high yields are obtainable if only the growing medium is a good one. If it is, the conversion of solar energy might be unusually high.

At the moment moss peat is commonly considered the best available growing medium for the intensive greenhouse culture.

4. Horticulture in developing countries

In developing countries the humus content of the soil is usually fairly low. Due to this, the fertility of the soil is low, too. Fairly good water, aeration and nutrient regimes in agriculture are produced in soil with a finecrumb macro-structure, in which the aggregate size is 1-3 mm. This type of structure is formed little by little for example under a cover of perennial grass-legume vegetation. It takes, however, plenty of time.

In horticulture - for example in orchards - the value of crop is usually much higher than in agriculture. So, in some cases it might be economical to increase the humus content of horticultural soil by organic matter of a good quality. As earlier stated, an undecomposed moss peat is one possibility - particularly in fine-textured soils in which continuously decomposing plant material is needed in order to produce highly effective bacterial slimes. Small amounts of peat might be sufficient enough. According to the experiments of the Peat Research Institute the dry matter losses under favourable conditions for micro-organisms - temperature: 40°C, moisture content: field capacity - have been about 5-10% per year. So, the effect of moss peat might be long lasting.

In some areas of developing countries the climatic conditions for intensive greenhouse culture (glass or plastic houses) are excellent - for example in high plateaus (high solar radiation, bright days, cool nights). In those areas the developing countries could produce horticultural products for export to industrialized countries (Kenya and Colombia for example are already at the moment exporting flowers to the European market). To increase the productivity, know-how and maybe growing medium (moss peat) also are needed. The programmed basin peat culture, developed in the Peat Research Institute in Finland, might be one possibility. For transport, moss peat is dried up and compressed to small volume. When wetted, it returns almost to its original volume. The same moss peat can be used for several years. In spite of high cost of transport, it may well become economical to utilize moss peat in intensive culture. The most important factor of profitability will anyway be the high yield level. Moss peat and programmed culture with special attention to the local circumstances secure good possibilities for high yields.

Peat moss - an ideal growing medium

There are thousands of plant species in the world and each has its own characteristics. This is because they normally grow under dissimilar conditions. Most of them take their nutrients from the soil, some live as parasites on host plants, while a few are carnivorous. There are even plants that grow under such poor conditions that they are obliged to take all their water and nutrients from the air. Could this be taking modesty to extremes? The *Sphagnum* species are of this kind.

Sphagnum mosses

Peat mosses comprise a single genus, *Sphagnum*, with 335 or so species. Their distribution is worldwide, but they are most abundant in the cold temperate zone. They grow in rich, damp forests, wet meadows and acid ponds and lakes. Some grow as a floating mat over open water, others thrive in areas where they receive only rain water. They form a distinct subclass of mosses, important because they alter the landscape by turning mineral soils and shallow lakes into bogs. They are one of natures most powerful tools.

High moors

Perhaps the most extraordinary of all the bog types is the raised bog. When a bog rises about 30 cm above the groundwater table it gradually changes from a ground-water-conditioned to a rain-water-conditioned (ombrogenous) formation. From this point on it receives all its materials, nutrients as well as water, from the air alone. Such a bog supports only a few species of *Sphagnum*, mostly *Sphagnum fuscum*. It gradually builds up until its centre is higher than its edges. This is why it is called a raised bog.

The formation of a raised bog calls for a certain kind of climate, a certain amount of rainfall and a given temperature range. The more suitable the climate, the better the raised bog grows, which is why thick raised bogs develop in very few parts of the world. In Finland, for instance, they form only in the southwest. Though they do grow in other parts of the country their development is much weaker. The raised bog mattress is thin and impure, and there are other plants among the Sphagnums.

The structure of Sphagnum moss

A *Sphagnum* plant consists of a central stem covered by leaves and branches (Fig. 1). Some of the branches grow downwards and sheaths the stem. The leaves are only one cell thick (Fig. 2B). In mature leaves these cells are of two types, small narrow cells containing chlorophyll and large, swollen and dead cells, capable of storing water.

Each of these large cells has pores through which water penetrates, and ring-like thickenings of the wall, which strengthen it (Fig. 2A). It is owing to the large number of these porous cells that sphagna are capable of holding great quantities of water.

On surfaces of the cells there are carboxyl groups. These groups dissociate hydrogen ions. So *Sphagnum* mosses behave like colloidal acids, have a high cation exchange capacity. It is this property that enables sphagna to store large amounts of nutrients in available form.

What is an ideal growing medium like?

Plants extract water and nutrients from their medium. The faster they grow, the higher is the oxygen requirement of their roots. These facts tell us something about the ideal medium.

1. It should be porous. The pore space should be as large as possible.
2. Some of the pores should be large so as to fill with air. Others should be small so as to fill with water.
3. The ratio of large pores (for air) to small pores(for water) should correspond to the needs of the plant.
4. The material should be capable of storing nutrients in available form.
5. The weight per volume should be as low as possible.

Sphagnum moss as an ideal growing medium

There is one material that meets all the demands mentioned above - peat moss.

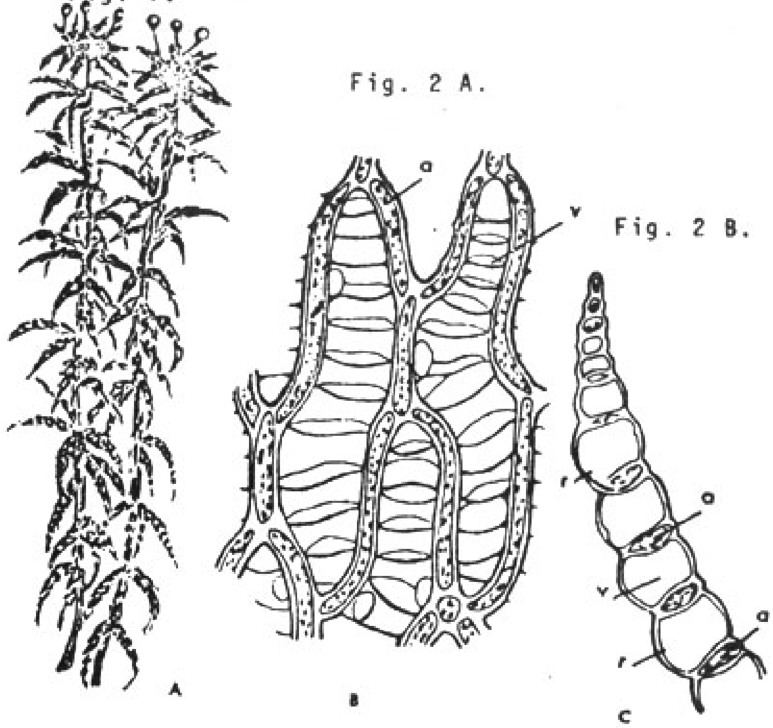
1. Peat moss is porous. Its pore volume is about 96 percent of the total volume.
2. In peat moss the pore volume can be distributed between air and water in almost any ratio desired, simply by altering its structure to make it coarse, medium or fine.
3. Peat moss is capable of storing large quantities of nutrients in available form.
4. The dry weight-to-volume ratio of unfertilized peat is not more than about 60 kg per m^3. From this it can be concluded that peat moss is very near the ideal as a growing medium.

FIGURES 1, 2 A and 2 B

Fig. 1.

Fig. 2 A.

Fig. 2 B.



<u>Figure 1.</u>

A. <u>Sphagnum</u>, natural size

<u>Figure 2 A.</u>

B. Leaf cell tissue from above (300/1)

<u>Figure 2 B.</u>

C. Crosscut of leat (300/1)

a) Narrow chlorophyllic cells

Water or <u>Sphagnum</u> cells with ringshaped thicknenings

b) Holes

PROGRAMMED CULTURE

1. Need of programming

Horticulture is increasingly turning into industrial plant production. The grower cannot regulate all details in the process of production any more. Rationalisation is needed, as well as simplified working methods. Plain simplicity is however not sufficient. The method must also be sure and give high yields.

Basin peat culture is as such already one step forward in rationalized growing. Besides, it makes it possible to develop further growing techniques - programming of watering and fertilizing.

Theoretical background of programming

Plant production is really converting radiant energy into chemical energy and storing it in this form in the plant matter. So a plant can be considered as an integrator of solar energy. Attention should be paid to the following points in the process.

1. Only part of the radiant energy absorbed into the plants causes photosynthesis. The better the other growth factors are, the more of the radiant energy can be used.

2. Part of the matter formed in photosynthesis is used in respiration.

Photosynthesis

Photosynthesis takes place when the temperature is above 0°C and when even little light is available. The photosynthesis is governed by the following equation:

$$\frac{dy}{dx} = c\,(A-y) \qquad (1)$$

where y represents the amount of photosynthesis' products, which the energy amount x produces. A represents the amount of photosynthesis products which are formed by other growth factors - not including radiation - being in optimum. C is constant.

Growth

To change further the material formed by photo synthesis requires usage of energy. Plants obtain energy as a result of respiration. In respiration part of the matter formed by photo synthesis is used.

Photosynthesis or growth is as follows:

(2) Growth = photosynthesis - respiration

The amount of matter used in respiration is mainly determined by the duration of the dark period and night temperature. According to the experimental results obtained by the Peat Research Institute it seems as if in glasshouse culture, photosynthesis and respiration in spring and autumn are equal, the daily radiant energy amount being as outside light approx. 70 cal/cm² (inside light approx, 40-50 cal per cm²). Actual growth takes place only when the daily radiant energy exceeds 70 cal/cm².

The daily radiant energy having exceeded 70 cl/cm², growth being according to equation (1). In practice growth can be considered to take place up to quite high radiation values as an almost linear function of the amount of radiation, when other growth factors - especially the carbon dioxide of air - are favourable. The amount of such radiant energy can be considered to be 300-400 cal/cm²/day. After this the growth curve, equation (2) begins to slow down, approaching asympthotically the value of A. This as far as approx. to 450 cal/cm².

When the radiant energy exceeds even this value, the plants easily begin to suffer from severe water deficiency. Due to this at least the vegetative growth easily starts decreasing reproduction growth, for example, stiffening of flowers, can however speed up.

When the amount of radiant energy exceeds the mentioned 400–500 cal/cm^2 per day, the water uptake of plants should be eased by spraying. If this is not possible, shading has to be used. The best result is achieved by using both methods together.

Nutrient requirements as a function of solar radiation

In forming as a result of photosynthesis a certain amount of plant matter, the plant has to use also a certain amount of nutrients. As growth is determined as a function of radiant energy, the nutrient requirement of plants is also determined as a function of radiant energy.

At the Peat Research Institute, the fertilization requirement of different plants has been tried to be determined as a function of radiant energy. Attention has then firstly been paid to nitrogen and potassium.

Besides the plants, also micro organisms take up nutrients, especially nitrogen. The fertilization requirement is therefore determined both by the requirements of plants and micro organisms.

Since as growing medium in the experiments at the Peat Research Institute light Sphagnum fuscum peat has been used the following figures are mainly only suitable for this medium.

Table 2 Corresponding nitrogen and potassium fertilization requirements (mg/m^2/day) with 100 cal/cm^2/day in light Sphagnum fuscum peat for some of the most important plants grown under glass

PLANT	Nitrogen	Potassium
	mg/m^2/day/100 cal/cm^2	
Cucumber	198	257
Tomato	170	281
Carnation	133	156
Rose	100	60

In Table 2 the fertilization need of some of the most important crops grown under glass for nitrogen and potassium calculated for 100 radiant calories is given.

Fertilization mixtures and nutrient solutions

A fertilization corresponding to table 2 can easily be made by mixing different fertilizers as for example urea and potassium carbonate to correspond to the different nutrient relations. In Table 3 the different mixing instructions for these mixes and instructions for making the stock solution and how to dilute the stock solutions are given.

Table 3 Required fertilization mixes for liquid feeding of some of the most important crops grown under glass

PLANT	PARTS PER WEIGHT		%		STOCK SOLUTION
	UREA	POTASSIUM CARBONATE	N	K	g/l
Cucumber	100	66	27.7	21.5	286
Tomato	100	140	19.1	31.8	356
Carnation	100	100	23.0	27.0	231
Rose	100	51	30.5	17.9	131

Table 4 Fertilization/watering need (litres/sq.metre/day) in different countries.

	J	F	M	A	M	J	J	A	S	O	N	D
Finland (Helsinki)	(0.26)	(0.69)	1.68	3.02	4.24	5.23	4.64	3.35	1.99	0.95	(0.29)	(0.12)
Sweden (Stockholm)	(0.13)	(0.62)	1.62	3.15	4.36	(4.95)	4.55	2.94	1.66	(0.62)	(0.18)	(0.02)
Denmark (Copenhagen)	(0.45)	1.02	1.92	3.10	4.18	(4.92)	(4.92)	3.51	2.32	1.19	(0.49)	(0.29)
U.K. (Rothamsted)	0.59	0.95	2.19	2.92	4.11	(4.54)	4.17	3.71	2.77	1.52	0.76	(0.47)
Skotland (Eskdale-muir)	0.48	0.95	1.89	2.89	3.93	4.05	4.04	3.09	2.27	1.29	0.74	0.37
Holland (De Bilt)	0.52	1.06	1.79	2.88	4.01	4.11	3.84	3.39	2.35	1.35	(0.65)	0.39
W-Germany (Braun-schweig)	(0.49)	1.01	1.87	2.83	3.89	4.30	3.83	3.47	2.28	1.32	(0.54)	(0.33)
Belgium (Uccle)	(0.53)	1.02	1.82	2.93	4.05	4.18	3.89	3.45	2.56	1.46	0.72	(0.38)
France (Paris)	(0.67)	1.20	2.11	3.22	3.91	(4.66)	4.30	3.59	2.71	1.59	0.77	(0.50)
Austria (Wien)	0.76	1.31	2.17	3.34	4.10	(4.64)	(4.59)	3.65	2.71	1.69	0.72	(0.59)
Portugal (Lisboa)	1.94	2.35	3.59	(4.80)	(5.87)	(6.19)	(6.40)	5.71	4.36	2.88	2.03	1.73
N-Italy (Bolzano)	0.95	1.37	2.27	3.00	3.57	4.03	3.81	3.29	2.72	1.72	0.94	0.72
M-Italy (Rome)	1.51	2.01	3.10	4.02	(4.89)	(5.08)	(5.45)	(4.66)	3.70	2.53	1.53	1.19
Sicily (Messina)	1.19	1.73	2.49	3.35	3.84	4.14	4.13	3.53	2.82	2.06	1.34	1.04
Malta (Qrendi)	2.45	3.57	(4.88)	(6.05)	(7.41)	(7.80)	(7.78)	(6.77)	(5.56)	4.01	2.96	2.36
Greece (Athens)	1.63	2.28	3.24	4.46	(5.23)	(5.58)	(5.88)	(5.13)	4.07	2.86	1.79	1.42
Israel (Jerusalem)	2.62	3.16	4.41	(5.45)	(6.50)	(7.30)	(7.29)	(6.50)	(5.71)	4.35	3.76	2.51
N-Japan (Sapporo)	1.32	2.05	2.88	3.71	4.16	4.37	3.87	3.59	3.00	2.20	1.38	1.05
M-Japan (Osaka)	1.62	2.00	2.74	3.17	3.18	2.90	3.45	3.74	2.88	1.77	1.71	1.36
S-Japan (Tateno)	2.18	2.84	3.44	3.65	4.42	3.92	3.41	3.96	2.90	2.51	2.06	1.84
Kenia (Nairobi)	(5.64)	(5.46)	(5.05)	4.22	3.89	3.52	2.91	3.25	4.42	4.43	4.29	(5.32)

HISTORY

Finland is the most northern country in the world which practices agriculture. One-third of all the fields north of the 60° latitude are situated in Finland. It is therefore understandable that in viewing the agriculture of Finland in general, it has to be practised under exceptionally difficult circumstances. This is especially true in speaking of one special form of agriculture, that is horticulture. The area under glass north of 60° latitude is negligible, excepting Finland. In spite of the severe circumstances, the horticulture of Finland is at the moment very strong. Its gross income is approx. 10% of the agricultural gross income, even though the country produces products 10-15% over its own needs.

The glasshouse industry of Finland has developed to be vigorous only after the second world war. One, if not the most important, reason for the rapid development has been the quick development of peat culture. The development of peat culture started after the second world war mainly with the object of raising the ability to compete with horticulture. The use of products grown under glass was low and the products were mostly imported. Today the use of cut flowers in Finland is almost the largest in the world and the products, except for some import in the winter, are completely grown in Finland. Considering the northern situation of the country, this can be considered a remarkable achievement. As mentioned, this has to a great extent become possible because of peat culture and restrictions on imports.

Goal setting for peat culture

When starting peat culture, the following goals were set:

1. Maximum yields, allowed by the climate
2. Securing of yield levels
3. Simplifying of culture techniques
4. The rationalization of culture techniques.

1. Normal peat culture

It was the aim of peat culture to substitute the earlier so frequently used soil mixture with peat.

2. Basin peat culture

The essential factors with basin peat culture were:

(a) Preventing of water and nutrients from leaving the root layer and
(b) Preventing of spreading of diseases to the root layer.

3. Programmed basin peat culture

The latest stage in the development is programmed basin peat culture. This stage has only last year passed some trials outside the institute under practical circumstances. The trials have been so successful that the marketing of the method can be started. The development of this method is naturally continued. The fundamental idea of the method and the results achieved with it are as follows:

THEORY OF PROGRAMMED CULTURE

Plant production is storing of radient energy in the form of chemical energy in the plant matter. Therefore, all growing depends on radiant energy. It means that also all growing methods are determined by this same energy. Growing methods, which depend on radiation are namely watering, fertilization and temperature.

1. <u>Watering</u>

The main part of radiation coming into the glasshouse is absorbed into the leaf cover when it is fully dense. Only a few percent of the radiation is used for assimilation. The main part is turned into heat so that the temperature of the plant should not rise too high, the plant binds the excessive heat energy for evaporation of water. The plant takes up water with the roots from the medium and transfers it through the leaves. For this approximately 1 l/m^2 is needed for every 100 cal/cm^2 as radiant energy coming from outside of the glasshouse. The plants water requirement can therefore be estimated according to the radiant energy.

In normal culture the main part of the water is leached into the ground soil. This increases the need for watering. In basin culture this does not happen. The need for watering is therefore equal to the plants water requirement (1 l/m^2/day per 100 cal/cm^2/day). The above is valid for full leaf cover. The lesser the need for water, the lower is the percentage of cover.

2. <u>Fertilization</u>

The basic fertilization of peat is the same as has been given before. All these elements, which can be given in excessive amounts without harmful effects, are in excess: all except for nitrogen and potassium. An exception is boron of trace elements, which has to be added once or twice during the growing season, each time 1 g/m^2 as boric acid or borax. Another exception is roses, to which iron has to be added, for example in the form of chelate according to the instructions of the producers. Of the main elements phosphorus can be bound in non-usable form, especially if the water contains iron and aluminium. Phosphorus can be added once or twice during the growing season either as triple superphosphate or in watersoluble form.

Excluding the above mentioned nutrients usually nothing else except nitrogen and potassium has to be added during the growing season. The speed of the growth as well as the net growth of plants depend on the radiant energy. The need for minerals depends on the net growth. Therefore the nutrient requirement of plants is determined by the radiant energy. A known net growth binds a known amount of minerals given as fertilizers. The plants fertilization requirement can be estimated by the radiant energy.

Besides the plants, also micro-organisms in peat take up nutrients, especially nitrogen added as fertilizers. Besides the plants needs, micro-organisms have to be counted to the fertilization requirement in the beginning of the culture, which partly release later on. The fixed and released amounts of nutrients depend mainly on the type of peat. If the peat is always the same - the organic composition being the same - the amounts of nutrients which are fixed and released by the micro-organisms are always almost the same. The trial and research work give facts of the amounts of nutrients fixed and released.

<u>NEED OF FERTILIZATION IN CORRELATION TO RADIANT ENERGY</u>

The fertilization requirement is composed of:

(a) The plants need for nutrients
(b) The need for micro-organisms and
(c) nutrients fixed to the peat.

The plants need for nutrients is determined by the yield level. The nutrients fixed by micro-organisms and peat are determined by the organic composition of the peat. The fertilization requirement figures given below are for light <u>Sphagnum</u> moss peat.

The figures for amounts of water, nitrogen and potassium are the amounts which correspond to a radiation of 100 cal/m^2/day.

	Water $l/m^2/day$	Nitrogen $mg/m^2/day$	Potassium $mg/m^2/day$
Carnation	1	133	150
Tomato	1	170	280
Cucumber	1	200	150
Rose	1	100	60

The values are mainly for the culture of the first year. During the second year the need for nitrogen slightly decreases.

Comparatively small changes in the organic composition of the peat have an effect on its fertilization requirement.

AMOUNTS OF NUTRIENTS FIXED BY THE YIELD COUNTED PER UNIT

To achieve a certain crop unit, a certain amount of fertilizer has to be added and this amount depends on several factors. In basin culture these factors can be mastered with comparative accuracy. As factors which cause changes there remains only the changes in the organic composition of the peat, washing out done during the growing season and nutrients leaching out due to overwatering.

In spite of these changes to produce one crop unit, the average nutrient amounts are as follows:-

		Nitrogen	Potassium
Carnation	1 flower	0.15 g	0.20 g
Tomato	1 kg	4.3	7.9
Cucumber	1 kg	2.8	2.2

Summary of discussion

Questions were raised on the distribution of the world's peat lands. Apart from the U.S.S.R. having 60% of peat lands, it was pointed out that even one country, like Indonesia for example, has more than 11 to 12 million hectares; Malaysia also has 2 to 3 million hectares. However, it was appreciated that exact information on the world's peat resources, particularly in tropical countries, is not yet available. There is also the difficulty of defining peat soils among other organic soils which do not have the properties of peat.

7. PROBLEMS OF IMPROVING SOIL FERTILITY BY THE USE OF GREEN MANURING IN THE TROPICAL FARMING SYSTEM

by

Akinola A. Agboola

For centuries people in the tropics have utilized the seemingly inexhaustible areas of forest and moist savannah for crop production under a system of shifting cultivation. Basically this system has involved the use of digging sticks, cutlass, hoe, and axe for preparing the seed bed after burning the plant residues. Under this system, the farmer crops the land for two or three years consecutively and when yields decline the land is allowed to regenerate for 10 to 20 years. This process is repeated in the new area.

Under the shifting cultivation system the yield level of crop depends mainly on the cropping interval (fallow period). Nye and Greenland (1960) brought to light the reasons why shifting cultivation has been adapted in the tropics. He suggested that "the clearing of forests and ploughing under of grasslands completely disrupt the ecological processes". Repeated cropping in such cleared areas leads to

- i. reduction of nutrient status of soil.
- ii. deterioration of soil physical condition
- iii. decline in soil organic matter
- iv. erosion of top soil
- v. increase in weeds infestation
- vi. multiplication of pests and diseases
- viii. changes in the number and composition of soil flora and fauna

These modifications give rise to a progressive decline in crop yields and necessitate abandonment of the land to a fallow of five or more years during which the natural regeneration of vegetation improves the physical and chemical properties of the soil.

The fallow period has been decreasing steadily to meet the rising demands for food. This has resulted in insufficient build up of soil nutrients status, causing successive declines in crop yields after each cycle of fallow except for fertilized crops. Forests are being transformed into woodland savannas and in some areas such as the middle belt of West Africa the fallow has completely disappeared.

What the fallow does is to recycle the plant nutrients back into a vegetation cover and into organic matter to arrest and prevent erosion during the fallow period, to permit an improvement in soil structure and to increase the soil organic matter particularly the so called active fraction that can mineralise and furnish available nutrients to a subsequent crop. Moreover, the fallow plant cover, the cutting and generally burning of the residue creates a sequence of biological environment which suppresses plant pests and weeds. Since organic matter appears to be an essential factor in promoting many of these desirable results, the question arises, should organic matter be maintained in the tropics? If the answer is yes, at what level or levels should it be maintained, and how best can it be done economically by management practices that are compatible with conventional farming systems.

An increase in food production in the tropics is essential to feed an expanding population. This will require an increase in the average productivity per unit of arable land. Increase in production requires increase in plant nutrient elements. At present it is only by fallow alone that a higher level of fertility in tropical soils can be achieved.

Department of Agronomy, University of Ibadan, Ibadan, Nigeria

It appears imperative that increased food production will require the use of fertilizer. However, farming experience and experimental data strongly support the conclusion that organic fertilizers and agricultural chemicals alone are not the best answer to increase crop production in the tropics. Let us now examine some data on cropping systems and fertilisation in order to better understand the relationship of organic matter and certain cultural practices on soil productivity.

Experiments have shown a progressive decline of yield under continuous cultivation with or without fertilisation (Table 1). At present the price of fertilizer is becoming so high that farmers in this region cannot afford to buy, still they have to produce food. If production must continue in the tropics organic matter must be made to exert its maximum impact on soil productivity. The big problem is that soil organic matter declines very rapidly under clean and continuous cultivation of crops and reduction in soil organic matter affects yield (Table 2). Before I continue, as a matter of orientation I need to demonstrate that organic matter plays a significant role in the productivity of tropical soils.

Table 3 indicates that soil organic matter plays a vital role in a tropical soil environment because almost all the soil nutrients are associated with it. Cation exchange capacity is highly correlated with soil organic matter. This goes on to confirm the propositions of Agboola and Corey (1973) that soil organic matter functions as a source of some nutrients and principal source of cation exchange capacity in most of these soils. Since organic matter provides most of the exchange sites most of the soil available cations are therefore associated with it. Apparently there is a positive and non-significant correlation between soil P, percent clay and soil cation exchange capacity, showing that most of the soil P is not associated with soil clay but with the soil organic matter. Actually most of these soils contain kaolinitic clays which are very low in cation exchange capacity.

There is a negative but significant correlation between soil clay and soil organic matter. This is the reverse of that which has frequently been reported in temperate zones. Correlation between soil organic matter and available P is related to the level of soil organic matter. On soils with organic matter below 2% the correlation is not significant. This is clearly shown in Fig. 1 where the r value was 0.111. On soils having more than 3% organic matter there is a positive and significant correlation between extractable P and soil organic matter. The positive correlation between percent organic matter and soil pH is probably due to the gradual acidification which occurs as the organic matter decomposes as well as to the leaching and removal of plant nutrients by crops which occur during the period of cultivation. Considering the importance of organic matter to soil fertility in the tropics, the question now arises how can organic matter be maintained in tropical environment. It appears to the author that the conventional and to date the most successful way to do this is by the fallowing technique (Table 4), but we are all aware of the problems of land fallow as mentioned before. Moreover, in the face of the population explosion with its attendant necessity to produce more food, in order to increase caloric intake per capita and to produce adequate live-stock feeds, a new system of cultivation apart from the fallow system has to be developed.

One method of continuous use of land has been centered around the use of organic manure. The organic manure apart from accumulating the nutrients at the soil surface, improves soil tilth. In addition, it shades and protects the soil from the impact of rain drops. Apart from the direct role as a nutrient supplier, organic manure is considered to have an indirect effect on the availability of nutrients. For example:

i. It increases the humus content and the effectiveness of the N and Mg in the soil.

ii. It prevents phosphate fixation in the soil or at least makes the phosphate more available.

iii. It produces complexing agents which are capable of chelating micrometals in the soil.

iv. It improves soils structure, infiltration, as well as the water holding capacity. Furthermore it gives sand cohesion and water retaining power, while by loosely binding together the finest particles of clay soil, it renders them more porous and friable.

v. Finally it has a neutralizing action on soil acids.

There are different forms of organic manure, but I am going to limit myself to green manuring. There are several ways of using green manure to improve soil fertility.

(i) Inclusion of legumes in the rotation.

To include legume as a green manure crop in rotation, farmers will have to allow the legume to grow for at least one growing season. Most of the research done in this area has been on planting a legume as a sole crop. Table 5 presents the changes obtained by growing one of such legume sunhemp, in one growing season. Within a growing season, soil organic matter increased from 1.06% to 1.19% an increase of 0.13% while available P increased by 4.3 kg/ha and exchangeable K by 45.3 kg/ha. The increase during one growing season compares favourably with a fallow of more than 4 years. This, not withstanding, it has not solved the problem of the farmer who does not get any benefit in terms of cash or food from the land for a growing season.

This type of approach has been rejected by the Nigerian farmers. A good example was the case of mucuna. The use of mucuna in rotation did not gain any wide acceptance despite the wide publicity given to it by the Ministry of Agriculture because:

i. There is no immediate returns in terms of cash or food

ii. Digging in of heavy green manure annually is difficult with hand tools especially as it appears to the peasant farmer to be unnecessary labour.

iii. Planting green manure as a sole crop does not fit into the farmers system of agriculture which is largely mixed cropping.

Work at Moor Plantation in Ibadan, Nigeria, by Faulkner and his colleagues (1934) has suggested that yield could be maintained indefinitely by growing mucuna annually in rotation on the same field. Furthermore, it showed that it made no difference to the yield of maize following <u>Stilozobium</u> spp whether the latter was burnt or dug in. A possible explanation is that of a transfer of nutrients from the dying aerial portions back into the root system. It was also possible that loss of nitrogen was in fact incurred by burning, but that the subterranean portions of the crop were sufficient to support the maize yields. Also, burning or heating a soil tends to stimulate subsequent mineralisation of N. This point needs further checking, since if burning off the legume at the end of the dry season results in the same yield of maize as when the legume was ploughed in it could possibly be more acceptable than digging it in. Presently, we must not lose sight of the fact that the conditions of 1930s do not exist any more in most parts of the tropics.

Moreover, Vine (1953) pointed out that the increase in crop yield originally attributed to the incorporation of crops of mucuna were greatly exaggerated and that the apparent maintenance of fertility over the first ten years was principally due to the fact that the experimental sites had been newly cleared from secondary forest and that the accumulated humus provided a supply of nitrate adequate for more than ten years cropping and that the humus built up had not been seriously depleted during light cropping and bush fallow prior to 1922. It has been frequently shown that green manure acts like a readily available fertilizer but has no residual effect beyond one succeeding cropping season.

When legumes are ploughed under, the decaying green manure produces carbon dioxide which aids in the liberation of nutrients from the soil particles, and the minerals contained in these materials are made readily available. Further benefits also result from green manures which occupy the soil during periods when regular crops are absent. Under such conditions a reduction in erosion and in loss of nutrients through leaching may be accomplished. If the problem of erosion can be solved in the tropics, either by minimum exposure or minimum tillage, one of the problems of continuous use of the land will be solved.

During exposure, in clean cultivation some soil nutrients may be leached below the rooting zones of the plant and therefore a deep rooted crop is thereby required to recycle the nutrients and bring them back to the soil surface.

To solve the problem of immediate returns Bromfield (1967) suggested that a grain legume such as cowpea could be grown as the sole crop. This would serve as a food crop while performing the same function of providing a nitrogen supply to the succeeding crop. Preferably it could be left to grow on through the dry season and subsequently ploughed in or burnt off before planting the early season crop. Unfortunately when vines of legumes are ploughed under, the amount of nitrogen ploughed under is relatively small. For example Miller (1958) found that when soyabean was harvested and the stover burned the soil lost about 4 kg/ha of N. Results from various parts of the tropics have actually showed the same trend; which seems to be in contrast to the earlier reports at Moor Plantation.

One of the major objections of sole cropping of green manures is that it occupies the land for a cropping season without returning anything for cash or for food. This could be overcome by intercropping shade tolerant legumes with cereals especially maize. The results of experiments conducted at Ibadan, Nigeria, have clearly demonstrated the suitability of certain legumes in intercropping with cereals. Apart from the fact that inerplanting is a cropping practice of the peasant farmers, it has the same attribute of sole cropping of legume when interplanted with early crop of maize.

The results in Table 6 show that fertilizer (55-10-55 kg/ha of NPK) as well as interplanted legumes without fertilizer namely greengram (Phaseolus aureous), cowpea (Vigna sisensis) and calopo (Calopogonium mucounoides), either interplanted or rotated, increased the average yield of maize over the control in four growing seasons. Legume, green manure with fertilizer did not seem to increase the yield over that of the fertilized check.

Calopo, cowpea and greengram fixed N when planted alone and when interplanted with maize. Unfertilized cowpea and calopo when interplanted with maize did not benefit the early maize crop but as green manure they were an important source of N for the maize in the late cropping season (Table 7 and 8) and thereby performed the same purpose as sole cropping of legume that serves as a green manure.

During the early cropping season, maize yields from most of the plots with interplanted cowpea receiving N application were significantly higher than those where no N was applied except the plot where greengram was interplanted with maize during the early cropping season. The maize yield from this plot was not significantly different from two of the plots treated with N alone but was significantly higher than the control and the other two legumes with no N plots. However, unfertilized cowpea and calopo supplied the late crop with an equivalent of about 45 kg of fertilizer N/ha (Table 8). Thus the interplanted legumes serve much the same purpose as legumes grown as a sole crop, namely:

it suppresses weeds during the early crop season and
it acts like fertilizer N to the late crop of maize.

These results suggest that more work of screening local legumes to identify those that will tolerate shading and at the same time fix nitrogen is still needed.

It is a well established fact that legumes grown over the same period could usually provide very little benefit to non-legume companion crops but greengram in their study appears to be an exception. It supplied N through excretion and decomposition of its underground parts. This is probably because it flowered after 4 to 5 weeks and by the sixth week N was being released from its decomposing sloughed off modules and decaying roots and rootlets.

Results of earlier experiments as reported in Table 7 indicate that 3 080 kg/ha yield of maize was obtained from plots interplanted with greengram without fertilizer. This was among the highest yields in the experiment.

In another experiment unfertilized greengram interplanted with maize in the early season increased the yield of the early maize but contributed very little to the yield of late maize crop (Table 7 and 8). It is obvious that the extent of such benefit however will depend upon the age of the land before cropping and the length of cropping. Under intensive cultivation, interplanted legumes with the early season crop of maize may have to be supplemented with inorganic fertilizers in order to obtain high yields of maize from the second crop. The amount of residue produced will also be important. In this experiment the amount of legume residue produced by the legumes was reflected by the maize yield. The calopo plots produced higher maize yields than the other legume plots. Calopo competed less with maize than the other legumes because its time of rapid growth usually began after the maize has tasseled. Greengram produced a low crop residue because it flowered six weeks after planting and very little residue was left at the time of turning it under for the late maize crop.

Efforts should therefore be directed to finding legumes that grow in association with cereals to keep the ground covered during the dry season. Calopo can probably serve such a purpose.

The results of later greenhouse studies showed the causes for some of the field results with green manures. After seven weeks of growth greengram roots, nodules and rootlets supplied about 31.3 kg/ha N (6.7 kg/ha from excretion and 24.6 kg/ha from the substrate) that could be utilized by maize intercropped with it (Table 9). All over the tropics there are legumes that nodulate well during short growing season which can be interplanted with cereals.

On interplanting of legumes, we are now looking into the possibility of using herbicides with no residual effect so that the next crop following interplanted legumes with maize could be planted with little or no disturbance to the soil two weeks after the application of herbicides. We are also looking into the possibility of interplanting melon and pigeon pea with yam; which are the traditional intercrop with yam in the Southern parts of Nigeria.

There is evidence that sole green manure crops have a marked lowering effect on soil organic matter content. Fig. 2 shows the extent of total N variation under different soil management practices for four growing seasons. Although the initial total N was not significantly different from each other; the loss of N in plots carrying different legumes was greater. It is a wrong assumption that planting of legumes in a rotation could increase the amount of total N. In fact, they may actually increase the rate of organic matter decomposition and the resulting nitrate nitrogen increase the yield of the following crop, if the NO_3-N was not leached away from the rooting zone before the succeeding crops were grown.

This effect is due to the fact that immature green tissue decomposes more rapidly leaving little residue and that the addition of easily decomposable material to a soil may stimulate the decomposition of the more resistant organic matter in the soil. This again means that when soil organic matter is low, the impact of the stimulation by planting of legumes either as a sole crop or as an intercrop may be unimportant.

Another alternative that could be adapted in much of the tropical forest zone and in the moist savanna is the use of grass-legume mixtures, in the development of mixed farming systems. After several years of research on the genus Cynodon, genotypes have been identified with high adaptability to the varying soil and climatic conditions of Southern Nigeria. A Cynodon IB 8 pasture grown on soils subjected to several years of continuous cropping produced around 10-12 tons per hectare of above ground dry matter (Chheda, 1971, 1973). The herbage contains an average of 1.22% N. 0.25% P, 1.74% K, 0.37% Ca and 0.34% Mg thus mobilising over 109 kg N, 22 kg P, 156 kg K, 33 kg Ca and 266 kg Mg per hectare annually. To this must be added an unknown but substantial quantity of these elements stored in the roots and stolons. Soil cleared on the University Farm in 1959 with an initial pH of 6.2 declined to 4.2 in 1972 because of continued annual application of 100 to 200 kilograms of ammonium sulphate per hectare. When Cynodon IB 8 was established on this soil there was a steady rise in pH of the top soil reaching a value of 5.3 at the end of one growing season. Cynodon was able to mobilise and translocate nutrients from the deeper soil horizons, because it was observed that 14% of Cynodon IB 8 roots were found in soil layers went below 30 centimetres while some reached depths of more than 1.5 meters. Thus a conservative estimate of 20% nutrient uptake by Cynodon IB 8 from soil layers below 30 cm gives an annual pumping up of over 10 kg N, 2kg P, 1.5 kg K, 3 kg Ca and 2.5 kg Mg per hectare. These figures compare favourably with those reported for the early years of forest fallow by Nye and Greenland (1960). This upward translocation of nutrients can be a very important factor in counter-balancing the nutrient losses from top soil due to leaching.

The top 10 cm of fertile soil under tropical forest contains about 2 to 5% organic matter while the next 20 centimetres contain about 0.5 to 2%. Under continuous cropping the soil organic matter generally declines but is built up again as a result of leaf and litter deposits and root residues of bush fallow of several years duration. Babalola and Chheda (1972) studied the effects of crops and management systems on soil organic matter using plots of the University Farm which were under uncut forest, oil palm plantation and continuous cultivation for varying periods of time under temporary and permanent pastures. The results as summarized in Table 10 show that continuous cultivation resulted in about 63% loss of organic matter from the top soil. Growing Cynodon pastures for four years substantially increased the soil organic matter and improved the physical properties of the soil.

This again seems to indicate another area of needed research, namely that of building up the nutrient status of tropical soils under continuous use without using inorganic fertilizer.

In conclusion, three ways have been examined for regenerating fertility and productivity other than sole cropping with green manure. They are:

(i) By soil cropping legumes that can be harvested as food crop, e.g. cowpea and pigeon pea. If this system is properly managed it can improve the land utility index to 50% or more. The forest fallow may eventually be replaced by the leguminous fallow. The soil will regain its fertility within shorter periods by recycling the nutrients. Harvesting of grain will continue annually for about two to three years.

Pigeon pea which absorbs nitrogen from the air provides good ground cover and the roots deeply penetrate the soil. Depending on the soil climate of the area, two to three years of pigeon pea fallow with about two to three years of cropping will increase the land utilization percentage.

(ii) By intercropping shade tolerant legumes with different food crops.

(iii) By interplanting legume with grasses (grass-legume mixture).

Each of these methods has its advantages and disadvantages. At present interplanting of shade tolerant legumes could easily be adopted by the peasant farmers because it fits into their own farming system. Furthermore, it has many of the same merits as sole cropping of non-edible green manures. It can also supply nitrogen to crops especially cereals during the first two years after clearing a bush fallow. This system has the disadvantage of not eliminating the use of fertilizer under intensive cultivation. For the more advanced farmers, especially those in the savannah zone, grass legumes will be ideal. In other words, mixed farming where a system of crop rotation is alternated with grazed planted grass-legume mixture. Furthermore, the systems examined have three important features in common. They are:

i. A supply of active organic matter to the soil although the total supply of stable organic matter may not be increased.

ii. The mobilizing of plant nutrient elements in the vegetation cover along with a general recycling of plant food from the lower parts of the solum.

iii. The establishment of ground cover during and after the actual growth period with its attendant beneficial influence on soil water, soil temperature and soil structure.

The intercropping practice, green manuring and grass legume fallow would all contribute to soil productivity in the same way whether or not fertilizers were used in the cropping systems. However, where substantial amounts of inorganic fertilizers are used the above mentioned benefits will need to be reevaluated as to their importance.

Summary of discussion

The paper reviewed the role of organic matter and long fallows for maintaining soil fertility in the soils of the humid tropics under traditional systems of farming and the changes taking place due to population pressure and the need for increased food production. The fallow was the best way to maintain fertility and structure, but it was inevitable now that the fallow period would have to be progressively shortened and fertilization increased through organic manuring. One of the possibilities considered in the paper was green manuring. Comments and suggestions related to trying legumes such as alfalfa and soya beans and studying the possibility of nitrogen fixation by grasses and cereals. It was considered that if research work on this aspect could be initiated and if it were successful, it would mean a major breakthrough in capturing atmospheric nitrogen. There was general agreement that it was not economic to grow a crop simply to plough it under as a fertilizer, but most farmers in the tropics, knowing the value of mulching, incorporation of residues and the need to keep the soil covered, would continue to practise mixed cropping. The best line of approach would be to introduce legumes into a mixed cropping system.

A question raised on the role of fallow initiated considerable discussion. A view expressed was that under dryland conditions fallow improved only the physical properties of the soil, but failed to increase nutrient content of the soil. The author explained that conditions were different in Southern Nigeria. There, conditions are favourable for rapid growth, which results in rapid and extensive plant cover when the land is left to fallow. This fallow growth absorbs nutrients from the lower horizon and these are brought to the soil surface through leaf fall, where they decompose. The temperature is lower and so also is the rate of decomposition. This decomposing material tends to bind the soil particles together, thus improving the soil structure; this in turn leads to improved aeration, water holding capacity and rate of water infiltration. Thus both the physical and chemical properties of the soil are improved.

Table 1: Effect of continuous land use on maize yield under three different soil series

Soil Series	Crop yield in Kilograms per hectare					
	1st Crop		2nd Crop		3rd Crop	
Fertilizer treatment	-	Fertilizer*	-	Fertilizer	-	Fertilizer
Iwo	3,960	4,780	3,120	3,880	3,100	3,600
Ibadan	3.430	4,470	3,030	3,690	2,800	3,700
Gambari	3,530	3,960	2,200	2,920	2,670	3,100

* Fertilizer applied: 60 kg N, 10 kg P, 60 kg K per hectare

Table 2: Effect of variation of organic matter in % maize yield at different location in Western Nigeria

Location	% max yield	% soil organic matter
Ife	77	3.3
	33	2.9
Ilesha	48	5.0
	77	4.6
	51	2.5
	28	3.8
	36	2.6
Esa Oke	79	3.6
	58	2.2
Ile Oluji	49	2.1
	94	5.1
Akure	18	1.0
	75	4.2

Table 3: Simple, Correlation Co-efficient for the relationships between the soil variables - organic matter, available phosphorus; available potassium, exchangeable calcium, exchangeable magnesium, cation exchange capacity and percent clay

Correlation Co-efficient							
Soil Variable	P	K	Mg	Ca	O.M.	C.E.C.	% Clay
K	.632	-					
Mg	.943**	.524	-				
Ca	.977**	.563	.965**	-			
OM	.982**	.824*	.982**	.987**	-	-	
CEC	.642	.624	.976**	.982**	.988**	-	
% Clay	.604	.600	.662	.632	.922**	.574	-

Table 4: Variation in % organic matter with length of fallow as compared with sunhemp fallow of one growing season

	% organic carbon	% total N	% organic matter	Available P kg/ha	Exch. K kg/ha	Soil pH
Under forest 10 years	2.42	0.21	4.20	30.44	300	6.5
Cleared forest and left for about 3 years under natural fallow	1.70	0.15	2.90	21.12	200	6.0
Forest soil under cultivation	1.44	0.13	2.5	18.11	170	5.7
Derived Savannah under grass fallow for 4 years	1.00	0.08	1.7	10.58	140	5.8
Cultivated derived Savannah under sun-hemp for one growing season	0.69	0.06	1.2	12.1	152.5	5.4

Table 5: Chemical Analysis of soil before planting sunhemp and Cotolaria juncea and at planting of early maize that followed in Fashola (A derived Savannah Zone.)

	Organic carbon	Total N	Organic matter	Available P	Exchange-able K	Soil pH
	%	%	%	kg/ha	kg/ha	-
Pre-planting sunhemp	0.62	0.041	1.06	7.8	107.2	5
Pre-planting maize	0.69	0.061	1.19	12.1	152.5	5.4
Change	0.07	0.020	0.13	4.3	45.3	0.4

Table 6 : Effect of different soil management systems on yield of maize (kg/ha)

Cropping Season	No legume		Cowpea Interplanted		Calopo Interplanted		Greengrain Interplanted		Rotated Maize							
									Weed maize maize weed		Cowpea maize maize cowpea		Calopo maize maize calopo		Greengrain maize, maize greengrain	
	-	Fert*	-	Fert	-	Fert	-	Fert	-	Fert	-	Fert	-	Fert	-	Fert
Early Maize	2,520a	2,900a	2,670a	2,810a	2,690a	2,800a	2,800a	2,900a	-	-	-	-	-	-	-	-
Late Maize	1,190b	2,170a	1,150b	1,960a	2,000a	1,990a	1,150b	1,830a	1,270b	1,810a	1,720a	1,430ab	1,950a	1,680a	1,830a	1,830a
Early Maize	1,610b	2,910a	2,390a	2,480a	2,560a	2,550a	2,550a	2,490a	1,960b	2,670a	2,390a	2,420ab	2,690a	2,700a	2,800a	2,620a
Late Maize	710b	1,790a	1,270a	1,270a	1,270a	1,230ab	1,570a	-	-	-	-	-	-	-	-	-
Average for 4 Seasons	1,510b	2,460a	1,870ab	2,090a	2,240a	2,265a	1,930ab	2,200a	810c	995bc	1,025bc	960c	1,160bc	1,095	1,155bc	1,080bc

Plot size .003 hectare.

* Fertilizer application 56 - 10 - 56 kg/ha N.P.K.
Comparison is between dry grain of each cropping season
Vacant plots are planted to legumes.

Table 7: Yield of early maize as affected by interplanted legumes and four levels of N (Agboola and Fayemi 1972)

Fertilizer N kg/ha	Yield of shelled corn kg/ha			
	Interplanted legume			
	None	Cowpea	Greengram	Calopo
None	1,790 c*	1,850 bc	3,060 a	1,850 bc
45	3,000 a	2,780 ab	3,070 a	3,080 a
90	3,420 a	2,750 ab	2,780 ab	3,070 a
135	2,880 b	2,920 ab	1,960 bc	2,920 ab

* Numbers followed by the same letter are not different. (P = 05)

Table 8 : Yield of late maize as affected by legumes interplanted with early maize and by four levels of N.

	Yield of shelled maize kg/ha			
	Legume interplanted with early maize			
	None	Cowpea	Greengram	Calopo
None	1,210 c*	1,970 bc	1,810 a	2,120 bc
45	2,720 ab	2,880 ab	2,570 ab	2,720 ab
90	2,880 ab	2,990 ab	2,880 ab	2,400 a
135	2,870 ab	2,420 bc	2,720 ab	2,900 ab

* Numbers followed by the same letter are not different (P = 0.5)

Table 9: Nitrogen balance sheet as estimated from different inoculated legumes grown in N free sand culture and harvested at anthesis[1]

N mg/pot							
Legume	N in plant	N in leachate	N in sand subtrate	Total N	Estimated N[2]	Excreted N[3]	
	-	mg/pot	-	kg/ha		%	kg/ha
Cowpea	459a*	2.1 c	12 b*	473.1b	364 b	0.46c	1.6 c
Calopo	581 a	8.1 b	19 b	606.1a	480 a	0.86b	2.8 b
Greengrain	262 b	9.2 a	33 a	303.2c	234 c	3.00a	6.7 a

1. 7 weeks of growth for greengain, 11 weeks for cowpea and 18 for calopo.

2. Based on converting mg N fixed in 5 kg soil to N fixed in furrow slice.

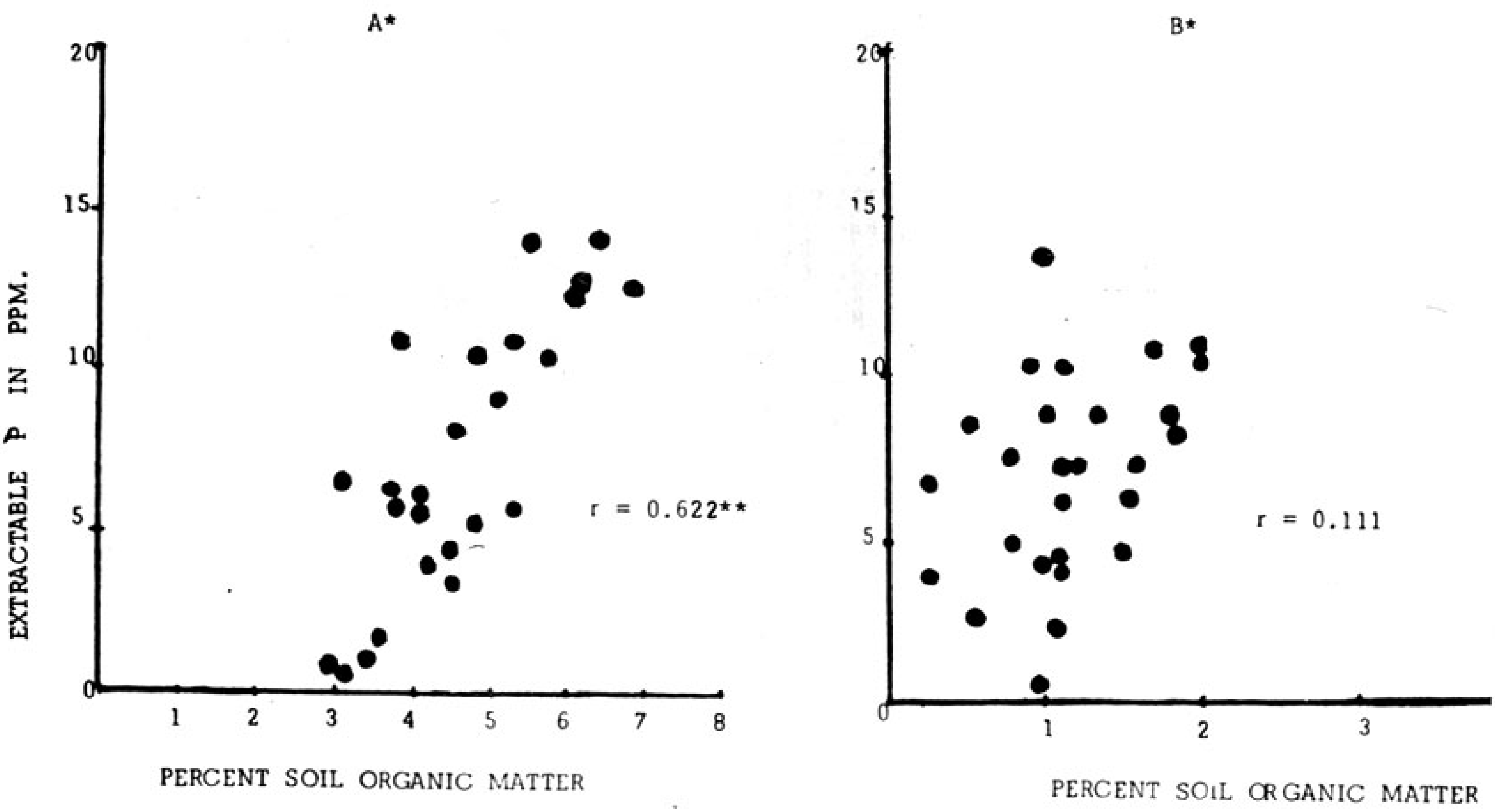
3. % N excreted = N in leachate/Total N fixed x 100.

* Numbers followed by the same letter are not different (P = 0.5)

Table 10: Effects of crops and management systems on soil organic matter and mean weight diameter (MWD) of aggregates. University of Ibadan Research Farm. (Babalola and Chheda 1972)

Treatment	% OM		MWD (mm)	
	0–15cm	0–30cm	0–15cm	15–30cm
1. Uncut forest	2.30	0.74	0.930	1.076
2. Permanent pasture	1.38	0.84	0.876	1.111
3. Oil palm plantation Continuous Cultivation	1.35	0.16	0.907	1.022
4. For i 20 years	0.86	0.69	0.766	0.906
5. ii 10 years	0.85	0.79	0.935	0.961
6. iii 2 years	1.20	1.11	0.846	0.918
Continuous cultivation for 15 years followed				
7. by i 3 years of elephant grass	0.94	0.60	0.846	0.822
8. ii 4 years of *Cynodon* IB 8	1.46	1.22	1.066	1.183

FIG. I THE RELATIONSHIP BETWEEN EXTRACTABLE P BY BRAY'S P_1 EXTRACTANT AND SOIL ORGANIC MATTE



A* ORGANIC MATTER HIGHER THAN 3%

B* ORGANIC MATTER LESS THAN 2%

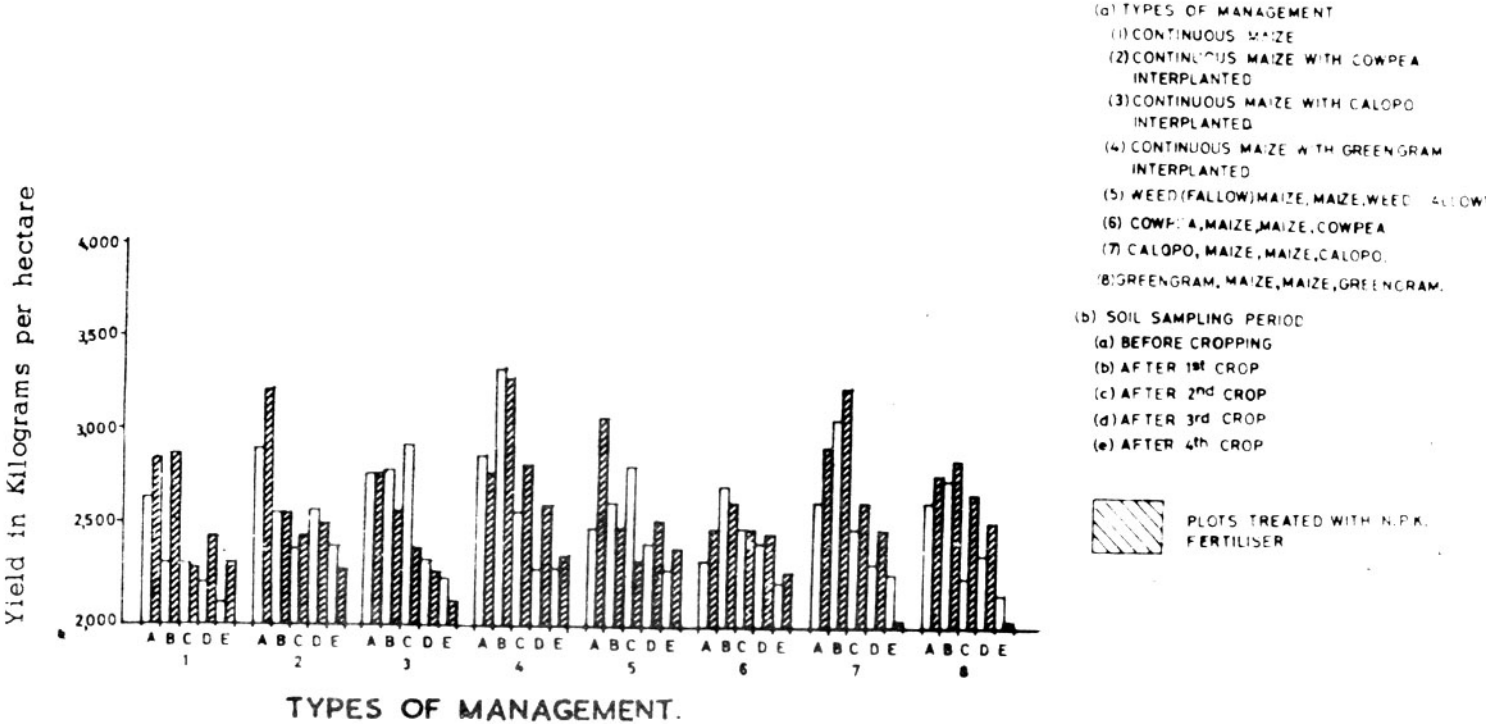


FIG. 2 LOSS OF TOTAL SOIL NITROGEN UNDER DIFFERENT TYPES OF MANAGEMENT.

Literature cited

1. Agboola A.A. (1970). Preliminary investigation on the effect of continuous cropping of maize on grain yield and on total nitrogen, available phosphorus and exchangeable potassium on three Nigeria soils. Nigerian J.Sc. 89-99.

2. Agboola, A.A. and R.B. Corey (1973). The relationship between soil pH, organic matter, available phosphorus, exchangeable potassiu, calcium, magnesium and nine elements in the maize tissue. Soil Science 115 367-375.

3. Agboola, A.A. and A.A.A. Fayemi (1971). Preliminary trials on the intercropping of maize with different tropical legumes. In Western Nigeria. J.Agric. 77 219-225.

4. Agboola, and A.A.A. Fayemi (1972). Fixation and excretion of nitrogen by tropical legumes. Agron. J. 64 409-412.

5. Agboola, A.A. and A.A.A. Fayemi (1972). Effect of soil management on corn yield and soil nutrients in the rain forest zone of Western Nigeria. Agron. J. 64 641-644.

6. Babalola, O. and H.R. Chheda (1972). Effects of crops and management systems on soil structure in a Western Nigerian soil. Nigerian soil. Nigerian J.Sc. 8.

7. Bromfield, A.R. (1967). End of tour report soil and Chemistry Section Research Division Western State Ministry of Agric. and Natural Resources Ibadan.

8. Chheda, H.R. (1971). Cynodon improvement in Nigeria - Paper presented to Seminar on Forage crop research in West Africa. Ford Foundation/IRAT/IITA. University of Ibadan, Nigeria.

9. Chheda, H.R. (1973). Forage crops research at Ibadan I. Cynodon spp paper presented at Int. '1. sump. Animal Production in Tropics University of Ibadan Nigeria.

10. Faulkner, O.T. (1934). Some experiments with leguminous crops at Ibadan Southern Nigeria., 1925-33. Emp. Journ. Exptl. Agric. 3 39-102.

11. Millar, C.E. (1955). Soil Fertility John Wiley and Sons Ltd. New York. pp. 299-301, 301, 308-309.

12. Nye, P.H. and D.J. Greenland (1960). 'Soil Fertility' Agriculture and Land use in Ghana. Oxford University Press.

13. Vine, H. (1953). Experiments on the maintenance of soil fertility at Ibadan, Nigeria Emp. Journ. Exptl. Agric. 21 65-85.

8. Biological Source of Nitrogen in Natural Ecosystems and Crop Production

by

Tomio Yoshida*

Introduction

Nitrogen is the element that often becomes a limiting factor for food production in many parts of the world. Most Asian countries have insufficient supply of fertilizer and depend on imports from other countries. They use very much less fertilizer than do some developed countries. These countries depend largely on natural fertility of the soil as the source of nitrogen for crop production. For successful crop production in these countries, fertilizer must be used efficiently. The recent energy crisis and the subsequent fertilizer shortage problem have emphasized the need for economical use of fertilizer. The environmental pollution problem has caused concern also to reduce use of fertilizers in some developing countries.

Both developed and developing countries are minimizing the use of fertilizer and investigating other sources of nitrogen for crop production. Now is the best time for all nations to cooperate in promoting research directed toward solving the world's pressing food and fertilizer problems.

There is a huge potential in promoting the fertilizer industry to meet the country's need for fertilizer in crop production. However, research on the use of nitrogen sources other than chemical fertilizer should be carried out at the same time. The biological fixation of atmospheric nitrogen has great potential as a source of nitrogen for crop production. Various kinds of biological nitrogen fixation systems, symbiotic and asymbiotic, in the tropics may be applicable to crop production. Organic materials, animal and human wastes not only provide crop nutrients for crop production, but also maintain the quality of our ecosystem. Chemical fertilizers, which are available in limited amounts must be used efficiently.

This paper discusses current research at IRRI on nitrogen fixation, organic sources, and efficient use of fertilizer. This paper also discusses the potential of such research and the opportunities for its development.

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* The International Rice Research Institute, Los Baños, Laguna, Philippines

Research underway at IRRI

Role of nitrogen-fixing blue-green algae in natural soil environment. Free-living nitrogen-fixing microorganisms that occur in rice paddies are the major agents in the nitrogen enrichment of the soil. Yet, there is no clear information regarding which microorganisms fix nitrogen, how they fix nitrogen and how much nitrogen fixation takes places biologically in paddy soils.

While a number of reports suggest that nitrogen-fixing blue-green algae play an important role in maintaining the nitrogen fertility of rice paddies, the exact role of these algae in natural soil environments in situ conditions is not known. Ecological studies on the nitrogen-fixing blue-green algae under natural conditions in paddy soils are few. The algal growth often observed in paddy soils fluctuates, depending on the environmental conditions of fields. Algal growth generally is poor in flooded rice soil with low pH or low phosphorus content.

The role of algae in fixing nitrogen in rice paddies under natural conditions is being investigated at IRRI, where a device that measures the nitrogen-fixing activities in situ conditions has shown that nitrogen fixation by algae takes place during the early stages of plant growth both in planted and unplanted rice fields. A field experiment conducted in the southern part of Luzon in the Philippines showed that the nitrogen fixation by blue-green algae increased after flooding and reached the maximum level at about a month after transplanting. The total estimated amount of nitrogen fixation during a crop season ranged from 2.3 to 5.7 kg N/ha in one field and from 17.5 to 33.3 in another. The feasibility of increasing rice yields through algal inoculation has not been established in the IRRI experimental farm.

Microbial fixation of nitrogen in rice rhizosphere. Experiments conducted at IRRI showed that certain bacteria living in the root zone (rhizosphere) of the rice plant are capable of fixing atmospheric nitrogen. The amount of nitrogen fixed is greater in planted and in flooded rice fields but is much less in unplanted and non-flooded paddies or under upland conditions. The nitrogen-fixing activity starts to increase rapidly at about the end of the vegetative stage of rice and reaches maximum at about the flowering stage of the plant. The total estimated amount of nitrogen fixed by the association between rice crops and nitrogen-fixing bacteria in the rhizosphere was about 35 kg N/ha in flooded rice paddies and 2 to 4 kg N/ha in upland rice soils per crop season.

The mechanism of nitrogen fixation in the rice rhizosphere has been investigated at IRRI. Through the leaves, organic materials and nitrogen gas in air reach the rhizosphere where nitrogen-fixing bacteria convert nitrogen gas to ammonium. The ammonium is converted to amino acid and protein in the microbial cells. The nitrogen fixed by bacteria will be available as source of nitrogen for rice crops. The nitrogen in the rhizosphere at the reproductive stages of rice, can be effectively utilized by the rice plant in increasing grain number, grain yield, and protein content. The anaerobic nature of lowland rhizosphere favors bacterial nitrogen fixation. The aerobic environment of upland or rainfed rice during certain periods of rice growth is not favorable for nitrogen fixation.

IRRI has extended its study to finding possible ways of using the nitrogen-fixing activity in the rice rhizosphere to maximize rice production. IRRI's current research on the nitrogen fixation by the rice crop has three objectives: (1) to find if rice varieties differ in nitrogen-fixing activity in the rhizosphere. If found, the difference in the gene-source for high nitrogen-fixing activity can be used for achieving economical use of fertilizer nitrogen in rice production. (2) to search in the rice rhizosphere for bacteria which have high nitrogen-fixing activity. The bacteria can be used as a seed inoculant, the same way a rhizobium inoculant is used for grain legumes. Various kinds of free-living nitrogen-fixing bacteria other than azotobacters and clostridia. were found in the rice rhizosphere. Most of these bacteria are facultative nitrogen fixers. (3) to find the environmental factors that increase nitrogen-fixing activity in the rice rhizosphere, such as the effect of temperature, sunlight, or soil type.

Atmospheric nitrogen fixation by legumes and other upland crops. Most studies on symbiotic nitrogen fixation in tropics have been conducted in Australia in relation with pasture problems. There are hardly any studies of rhizobium-legume relationship in Southeast Asian countries. IRRI's research is aimed at finding out to what extent mungbeans and cowpeas, the major food legumes in the Philippines, depend on atmospheric nitrogen fixation for their nitrogen nutrient. It was found that mungbeans and cowpeas in field conditions depend on the atmospheric nitrogen fixation for only less than one-fifth of the total crop nitrogen, suggesting that mungbeans and cowpeas have no proper rhizobia to make nodule effective in fixing atmospheric nitrogen.

IRRI is also seeking varieties of leguminous crops which under excessive drought and moist soil conditions can make nodules. These legumes, if available, should be able to contribute to nitrogen fertility in rice-growing areas. The amount of nitrogen fixed by other upland rice crops, such as sorghum and corn, was estimated to be less than a few kilograms.

Potential research and opportunity for its development

The fixation of atmospheric nitrogen in the rhizosphere of lowland rice has great potential for practical agriculture as well as for basic science. Several soil microbiologists in different countries recently reported that nitrogen fixation occurs in the rhizosphere of rice. The amount of nitrogen that was fixed in the rhizosphere of the rice plants probably did not exceed the amount needed to maintain the natural nitrogen fertility of rice paddies under local conditions. The possibilities of using microbial nitrogen fixation in the rice rhizosphere for increasing rice yields need to be investigated.

Identification of the factors that affect nitrogen fixation and of the method for amplifying the effects of such factors may lead to the successful use of microbial fixation of nitrogen in the rice rhizosphere. Research is focused on:

(1) The asymbiotic nitrogen fixation in the crop-soil system, including the mechanism of nitrogen fixation in the rice rhizosphere. Parallel field studies will be conducted at IRRI as well as in various other agro-climatic zones on the aspects of these findings.

(2) The screening of varieties which are capable of fixing greater amounts of atmospheric nitrogen in their rhizosphere. These varieties may have larger root system and, therefore greater rhizosphere areas, as well as higher nitrogenase activity in the rhizosphere.

(3) Environmental factors that stimulate nitrogen fixation; for example, increased carbon dioxide concentrations in rice fields or appropriate soil management practices.

(4) Continued search for more efficient nitrogen-fixing microorganisms in the rice rhizosphere and use of the bacteria as seed inoculant.

(5) Other possible sources of biological nitrogen fixation in rice fields, for example, an algal association such as azolla, lichen, leaf nodules, mycorrhiza, non-leguminous nodule or phyllosphere (leaf surface) microorganisms. Azolla fixes nitrogen symbiotically in association with blue-green algae and water fern which grow abundantly in rice paddies in Indonesia and the Philippines. The potential of this nitrogen fixation system for rice cultivation system needs to be investigated.

Nitrogen fixation by blue-green algae also needs further study, particularly since algal nitrogen fixation has great advantage over bacterial nitrogen fixation, algae being dependent on both atmospheric carbon and nitrogen, which are abundantly available in the atmosphere as carbon dioxide and nitrogen gas. However, it is difficult to establish new algal flora in the natural ecosystem in rice paddies and therefore the investigation of stimulating nitrogenase activity of nitrogen-fixing blue-green algae which naturally grow in rice paddies should receive greater emphasis.

The research on the rhizobium-legume relationship to make more effective nodules in various grain legumes in the tropics has great potential. Legume species for food grains in the tropical countries, particularly mung-beans, soybeans, peanuts, and cowpeas should be investigated for the nodulation problem. Growers should receive instruction on the proper inoculation procedure. The study of the possibility of finding crop which can grow and fix atmospheric nitrogen under severe drought or excessively moist conditions should be continued. To search for, classify, and maintain, various nitrogen-fixing microorganisms, particularly rhizobium strains, from various locations in the tropics should receive encouragement.

Organic Sources

Research underway at IRRI

In the South and Southeast Asian countries studies on the organic sources of nitrogen in rice crop production are few. The organic sources of plant nutrition have been classified into: (1) native soil organic nitrogen; (2) organic matters such as rural or town compost, rice straw, rice hull, green manure, sawdust, and farmyard manure, which supply plant nutrients in small quantities; (3) organic matter, such as poultry, cow dung, blood, meat and fish meal, which supplies plant nutrients in large quantities; and (4) city wastes and sewages.

The organic matter in the soil itself is a major source of nitrogen for the rice crop. The soil contains from 1,000 to 6,000 kg N/ha mostly in organic forms. The organic matter in soil originates from the organic sources which had once been incorporated into the soil by natural or artificial means. The availability of soil nitrogen to the rice crop in the Philippine soils was found to be very high. The availability index of soil nitrogen to rice crop (A-value) in submerged Philippine soils was high compared with indices reported for temperature zones or for upland soils. Philippine paddy soils and Indonesian paddy soil, which is continuously rejuvenated by volcanic ejector, have been reported to have the highest inherent potentiality among soils in the tropical Asian countries.

Rice plants grown in IRRI's experimental fields took up 86 kg N/ha from soil which did not receive chemical fertilizers. From soil which received 50 kg N/ha of broadcast fertilizer their uptake of soil nitrogen increased to 94 kg/ha. The nitrogen uptake increased to 113 kg/ha from soil into which fertilizer was incorporated. Fertilizer nitrogen that was applied as basal ceased to be taken up by the plants several weeks after transplanting, although their nitrogen uptake continually increased throughout growth. The pattern of mineralization of soil organic nitrogen also affects the availability of fertilizer nitrogen applied to the rice paddy. Using the tracer technique, IRRI studied the fate of fertilizer nitrogen that was applied with and without added rice straw. IRRI is now investigating on differences among rice cultivars in their utilization of soil nitrogen.

The immediate source of organic matter available in rice farming is, of course, rice straw or organic matter consisting of rice straw such as compost. In many tropical countries, however, the farmers either burn or incorporate the straw into the paddy soil or feed it to animals. They do not make compost or farmyard manure.

IRRI has done little research on the effect of rice straw and green manure in rice cultures of rotation practice. IRRI has done some laboratory and greenhouse work on green manure and rice straw application. Applying green manure to submerged rice soil causes the formation of organic acid which is toxic to rice at certain concentrations. However, the effect of applying green manure in the field is generally not a serious problem if rice is transplanted 2 to 4 weeks after green manure had been incorporated into the soil. In India rice is planted 6 weeks after incorporation of green manure. In Japan it is recommended that rice be transplanted 10 days to 1 month after green manure application.

The addition of rice straw in moderate amounts may have a beneficial effect on yields particularly if the application is timed so that the competition with the rice plant for nitrogen is minimized. Adding large amounts (12 tons or more) of rice straw or farmyard manure to the rice paddy retards the growth of rice crops. The rice growth retardation seems to be caused by both organic injury and nitrogen deficiency at the early growth stages. The addition of ammonium sulfate reduces the rice growth injury. But rice straw that is incorporated into the soil after harvest usually does not cause serious problem for rice production. Applying organic matter to submerged rice soil increases the formation of ethylene gas in amount toxic to plant. But rice roots were found capable of degrading ethylene in the rice rhizosphere in association with rhizosphere bacteria.

Organic matter is a source of the plant elements, nitrogen, phosphorus, potassium silica, magnesium, iron, and some minor elements. Organic matter applied to rice paddy is often considered advantageous for rice as a nutrient source. But it has several other possible advantages besides its being a source of plant nutrient. A report has indicated that ethylene formation favors the control of soil pathogens at certain concentrations. A study underway at IRRI has indicated that the application of organic matter increases the concentration of carbon dioxide in ground surface and promotes the photosynthetic activity of the rice crop resulting in greater grain yield production. In a study at the University of the Philippines organic matter added to flooded soil stimulates bacteria to fix nitrogen in the surface soil. Some organic compounds released from organic materials are reported to promote the growth of rice in Japan.

Other organic manures which contain high amounts of plant nutrients, such as soybean meal or fish meal, are not available in sufficiently large quantities in the tropics. Animal and human wastes in the form of compost or after being used as fuel have a great potential as sources of nitrogen. The latter has been extensively studied in some Asian countries during the past 2 decades but further study is needed for conclusive results.

The feasibility of using organic matter in rice production in tropical Asian countries should be evaluated from the economic and the agronomic standpoint. Rice straw contains a sizeable amount of plant nutrients. In fact, the estimated amount of nitrogen contained in all the straw produced in these countries is more than one-third of the fertilizer nitrogen which these countries use.

To ascertain the feasibility of using organic sources of plant nutrients in rice cultivation, the following subjects should soon be studied:

(1) Use of organic matter (principally rice straw) supplemented with fertilizer to reduce the use of applied chemical fertilizers.

(2) Use of farmyard manure and compost.

(3) Utilization of city and rural wastes for fuel production (methane gas) and subsequent use of the waste by-products in rice cultivation.

(4) Possible advantages of manipulating naturally occuring organic compounds in rice cultivation.

(5) Better use of organic nitrogen in soil as a source of plant nutrients.

Potential research and development opportunity

The use of organic manure or compost in the rice farms of South and Southeast Asian countries can help alleviate fertilizer shortages. In these countries, however, the organic materials have not been utilized as a source of crop nutrients in rice cultivation. Organic fertilizers have been frequently used on upland crops and their effectiveness has been markedly affected by soil characteristics. Rice farmers in Japan use organic sources in rice cultivation. But recent labor shortages and the subsequent mechanization of rice farming has promoted the direct application of straw without first being converted into making compost into the rice field.

Long-term experiments at several places have shown that no difference between the yields of lowland rices treated with farmyard manure and of lowland rices treated with chemical fertilizer was found at the same level of nitrogen. However, compost is very bulky. Ten tons of organic manure (total nitrogen equivalent to about 80 kg N/ha) had to be applied to Japanese rice paddies to improve rice yield over the yield without applied nitrogen. The advantage of farmyard manure or compost is that it contains (in addition to nitrogen) phosphorus, potassium silica, and minor elements. The addition of animal wastes to rice straw and compost improves the level of plant nutrients present in them.

The major focus of further research should be on the more efficient use of rice straw, a large part of which is now being burned or wasted. Studies on the utilization of rice straw in rice culture should focus on: (1) the amount of available plant residues now being burned in lowland rice areas and their nutrient content, the estimated loss of plant nutrients due to burning, and the potential benefits of recycling rice straw in the cultivation of rice; and (2) the mechanical problems involved in making compost and in incorporating plant residues into rice soils.

Efficient Use of Chemical Fertilizers

Research underway at IRRI

The use of fertilizer in rice culture in tropical countries has been extremely limited. Most of the rice production in these countries depends on the natural fertility of the rice soil. IRRI has been studying for several years how to use fertilizer nitrogen most efficiently in rice production. By using the tracer technique IRRI studied the mechanism involved in the loss of fertilizer nitrogen in rice soil and found that microbial activity in rice soil is the major factor involved in the loss of fertilizer nitrogen. The amounts of nitrogen losses through chemical volatilization, through run-off from surface water, and through leaching appear small compared with those resulting from microbial activity. The major causes of nitrogen loss in paddy soils are microbial nitrification and subsequent denitrification.

Another microbial factor causing the inefficiency of fertilizer nitrogen is immobilization - the microbial function that converts inorganic nitrogen to organic nitrogen. Immobilization of nitrogen decreases the amount of available nitrogen. Chemical fixation by clay were small in the Philippine rice soils used in this study.

Different water regimes - submerged, upland, or alternating submerged and upland conditions affected the fate of fertilizer nitrogen in the rice crop. More fertilizer nitrogen was lost and immobilized in upland than in submerged soils and the most was lost in the alternating soil conditions. There was no difference in amount of nitrogen uptake among the rice crops subjected to soil moisture tensions varying between 0 to 47 centibars. However, the amount of nitrogen in straw was higher while the amount of nitrogen in the grain was lower as soil moisture tension increased. Nitrogen taken up by rice roots seemed not to be transported to the grain during the reproductive stage of the rice plant at soil moisture tensions higher than that at field capacity.

These methods of increasing effectiveness of fertilizer nitrogen were examined: (1) deep layer placement of fertilizer, (2) slow release fertilizer, (3) granulated fertilizer, (4) organic fertilizer, (5) nitrification inhibitor incorporated fertilizer, (6) large-sized fertilizer such as "dango" or mudball fertilizer, (7) application of fertilizer at the proper time of rice-growth stage.

IRRI found some conventional fertilizer practices economical. Deep-layer application of fertilizer and the application of large-sized fertilizer resulted in better utilization of nitrogen and greater grain production than did the broadcasting method. Fertilizer nitrogen was more efficient when applied at later stages of rice growth until about the booting stage. Generally, the split application of fertilizer at about panicle initiation increased spikelet number and grain yield. Fertilizer applied in the form of mudballs at 35 days before heading gave the best results in nitrogen uptake, grain number, and grain yield.

Potential research and development opportunity

An agricultural practice that improves the efficiency of fertilizer nitrogen in Japanese rice culture was developed years ago, at the time of fertilizer shortage around World War II. In 1935 the Japanese government tested the method of applying fertilizer by incorporating into soil 9 cm deep as basal and compared it with broadcasting in soil surface at 2 cm. The grain yield of rice in the fertilizer incorporated treatment was 107 to 126% greater than the grain yield in broadcast treatment (100%).

In 1951, the "dango" or mudball fertilizer was tested in 116 places scattered over 27 provinces in Japan. An average 10% yield increase was obtained in this experiment. The split application of fertilizer at panicle initiation, at heading, at maturity stage of rice crop was extensively studied in all provinces in Japan.

Results obtained in IRRI and the data available in Japan, show that the conventional practices of applying fertilizer in Japanese rice culture may be applicable in tropical conditions. But these techniques will be affected by soil characteristics and other environmental factors. Extensive research work should be undertaken to determine the applicability of the conventional practices under the various climatic conditions in South and Southeastern countries. Soil surveys in tropical rice-growing aaeas should be undertaken along with this kind of research. Soils may have to be ameliorated to adapt them to the conventional practices of fertilizer application.

Conclusion

Research on nitrogen fixation promises a large-pay-off in the future, because of its importance in ecology and soil resource development and its large potential for crop production. However, since the amount of nitrogen that contributes to the nitrogen enrichment of crop soil is not likely to exceed the amount required for maintaining the soil's natural nitrogen fertility, a more intensive research program should be planned for the coming decade to utilize nitrogen from a biological source for intensified crop production.

Preliminary research should be planned to find economical ways of using organic sources of nitrogen for improving soil management and crop production in tropical countries. The pay-off may be large for environmental problems but moderate for crop production. The promotion of animal husbandry should significantly improve the use of organic sources for crop production.

Research on the efficient use of fertilizer by conventional methods of application has potential for improving crop production and enrivonmental quality. Some conventional fertilizer practices in temperate regions can be applied in crop production in tropical countries.

Summary of discussion

During the discussion, the importance of atmospheric nitrogen fixation to the farmer was stressed, because of the low cost and expenditure of energy involved, but further research was needed, particularly on inoculation. However, the author considered that positive results in this field could be available in a few years. There were several comments on the high yields of paddy obtained in the experiments described, but as explained by the author, Philippine soils are well adapted to paddy cultivation. Concerning the fixing of atmospheric nitrogen comments on experience in Sudan and Australia suggested that this had not been so successful as in the author's own country. Nevertheless, the author felt that there should be a potential for obtaining improved results in these countries. It was also noted that there are many areas in the world where legumes can be grown without inoculation and in others inoculation could be more effective; more research is needed to find out why. According to experiments in Japan, the application of a small amount of fertilizer can stimulate nodulation and it was suggested this might be tried in other areas where it is difficult to achieve nodulation.

9. EXPERIENCE IN BIOLOGICAL NITROGEN FIXATION IN SOUTH AMERICA

LEGUME INOCULATION IN LATIN AMERICA

C. Batthyany [1]

Biological nitrogen fixation is one of the most important factors to assure continuity of life. There is no need to go into details of the importance of nitrogen fixation at this meeting where it is evident that everyone is aware of the nature of the process.

Non symbiotic nitrogen fixation has gained in the last decade more and more importance, as research is progressing there is still the need for increasing knowledge. However, it is recognized the importance of different microorganism. In Latin America the centre for these investigations is in Brazil - IPEACS - where Dr. J. Dobereiner and her staff are actively working on this subject. Up to date the practical application of non symbiotic fixation is at an early stage. However, we expect that in the near future we will be able to use this process of gaining Nitrogen in agriculture, and in particular in those areas with difficult environments.

Symbiotic nitrogen fixation by legume Rhizobium is the best known and most widely used by man. Furthermore, we must stress the fact that the need of nitrogen is already one of the limiting factors to increased food supplies, and we expect that this problem will become more and more acute. For this reason, the use of legumes is in a vertiginous increase, both for the production of vegetable protein (grain legumes) and for conversion into animal protein which is the case with pasture and forage legumes.

In Latin America, the use of nitrogen fertilizer has become expensive and in most cases uneconomical, especially because of the high prices of nitrogen and relatively low value of the final agricultural product.

Nitrogen can be obtained at almost no cost from the symbiotic fixation, to produce high protein products and concurrently increase soil fertility and therefore improve soil productivity.

the incorporation of high quality Rhizobium to the seed may give us a great benefit when properly handled, which in some cases can be more effective than the use of nitrogenous fertilizer. On the other hand, the use of low quality inoculants will give us complete failure.

Today it is worldwide known the importance of the inoculation but unfortunately the practical application to field conditions is still bad in developing countries. There are two basic reasons for this: A: Lack of knowledge in the use of Rhizobia and B: the commercialisation of really bad inoculants.

Rhizobiology in Latin America

Considering the practical advances obtained in this field, the example of Uruguay could be the best to describe and show that in a relatively short time a successful programme can be established.

Uruguay is the first and only country in Latin America that has managed to totally succeed in the large scale utilization of legume inoculation in the field. This success has been partially due to the urgent economic need to produce more meat and wool, and also

[1] Chief, Laboratorio de Microbiología de Suelos y Control de Inoculantes
Montevideo, Uruguay

to the geographical, climatic (sub-tropical and temperate zones in South America) and the relatively small area of the country.

In 1951 work began with Rhizobium with a private pharmaceutical laboratory (DISPERT. S.A.) where the first order for inoculant was made by Dr. A. Boerger for use with clovers and luzerne at the Ministry of Agricultural Experimental Station.

The first results with liquid and agar cultures were variable, and clearly demonstrated the need to obtain technical assistance, in order to gain precious time and safety. In 1962, Dr. R.A. Date from CSIRO Australia began to work as an FAO specialist in inoculants. His work was initiated with the control of strains to be used under field conditions, at the same time the selection and control of peat to be used as a carrier for inoculant was made. Once the above problems were resolved, commercial production began, which was the first peat inoculant in Latin America. Already the following year 1963, 50% of the local needs were covered, and since 1964, 100%.

According to the needs we produced specific inoculants for Medicago spp, Trifolium spp, Lotus spp. Our experience shows that polyvolent inoculants are of much lower quality. The Medicago strain U.45 is a Uruguayan native strain used now all over the world. Since 1972 production includes inoculants for Soya - Vicia and Arachis. Two factories are now in production for inoculants and already exporting to other Latin American countries.

It is important to note that at the same time that commercial production began, the Government set up an official Laboratory to Control the Quality of the Production. In Uruguay, no inoculant can be used unless it has been subject to the official control of the Government.

The Standard Requirements for Quality of inoculants were gradually raised and are now: less than 100 million Rhizobium per gram is rejected - between 100 million and 500 million accepted for use between 3 and 6 months - over 500 million can be used up to 6 months.

Once the high standard of inoculants was obtained, the Government initiated a campaign of extension for the field use of inoculants which was very successful. At present, no legume seed is sown without inoculation, of which 80% of the seed is inoculated in the form of pellets.

With the assistance of the FAO expert, Dr. R.A. Date, initial contacts were made with legume bacteriologists from neighbouring countries (Brazil, Argentina and Chile), which gave the origin to the establishment of the first Latin American Rhizobium Conference, which was attended by 8 professionals, while in the Seventh Conference, the numbers increased already to over 100. These meetings are used to organize seminars and training courses which take place either before or after the conference; recently we had the participation of Drs.Norris, Nutman, Vincent, Bergersen, Graham, Hubball, etc.

Before finishing this small practical contribution, I will allow myself to again quote some examples from Uruguay, where by the correct use of high quality inoculants, it has been possible to increase the meat production from 40 kg to 400 kg liveweight/per annum per hectare, and wool from 18 kg to 180 kg. This has been possible by the high yields of grass/legume pastures where Trifolium subterraneum has the major contribution, which does not grow without its specific inoculant.

We are aware that in the tropics similar benefits could and should be urgently achieved by correct application of this known technology.

Summary of discussion

In answer to questions it was noted that Uruguay had two nitrogen factories, producing 60 tons per year, and Brazil imported last year 400 doses of nitrogen from Uruguay, each dose being of 200 grams.

10. NITROGEN FIXATION BY SOME LEGUMES IN THE SUDAN GEZIRA

by

M.M. Musa*

Introduction

The cultivation of leguminous plants is probably the most important method of adding nitrogen to the soil/plant system and it is accepted that the permanent agricultural systems of temperate regions are traditionally based on this legume/Rhizobium symbiosis. However, in the tropics and the subtropics information on the role of legumes in the enrichment of soil nitrogen and plant nitrogen production is scanty.

In the Sudan, forage legumes were very soon recognised as being useful in early rotations, designed at a time when artificial fertilizers were not known and practices such as the use of legumes and fallows were employed to maintain soil fertility. Rotations with unfertilized cotton have long shown the beneficial effect of legumes in the rotation (Burham and Mansi 1967). With the recent need for diversification of cropping and the integration of livestock into the farming system knowledge of the relative value of legumes both as fodder crops and fertility improvers is becoming more obvious.

In an effort to assess the production of nitrogen by different legumes grown under irrigation and the assessment of the nitrogen fixed by symbiotic association the results of a number of field experiments are herewith presented.

Experimental

Experiment 1 The amount of nitrogen fixed by the legumes, Lubia, Dolichos lablab, Philipesara, Phaseolus trilobus, Clitoria Clitoria ternata, Greengram, Phaseolus aureus and Groundnuts Arachis hypogaea was assessed under irrigated Gezira clay soil conditions for three seasons using two methods. These are:

(a) A method in which an indicator non-legume crop is used to measure the ability of soil to supply nitrogen to a non-legume, this being sesame. Evaluation takes into account both soil nitrogen changes and plant nitrogen produced as given below.

$$\text{Nitrogen Fixed} = K_{legume} - K_{non-legume}$$

where K indicates the balance of nitrogen changes under the legume and non-legume. This was carried out having in mind the number of assumptions involved.

(b) A calibration method commonly used in assessing some pasture legumes for their ability to fix atmospheric nitrogen. Here, values of nitrogen fixed can be obtained by comparison of the nitrogen harvested from a legume/grass association with the quantity of nitrogen recovered from a pure stand of the same grass receiving different rates of nitrogeneous fertilizer. However, the results were limited by the compatability of the grass with the variety of legumes investigated. Furthermore, the experiment would give a ready information on the feasibility of growing the above mentioned legumes with a popular fodder, Sudan grass.

Experiment 2 This was carried out in collaboration with Agronomy and Crop Physiology Section for four seasons with the view to the evaluation of the legumes most important in the Gezira rotation namely Lubia, Dolichos lablab, Philipesara, Phaseolus trilobus and groundnuts Arachis hypogaea for their ability to produce fodder (i.e. when cut and removed) and to measure their effect on a succeeding cotton crop. A complete record of the extent and pattern of nodulation, and the contribution of the various parts of the legume to plant nitrogen yield is sought. The changes in soil mineral nitrogen were also investigated.

* Agricultural Research Corporation, Wad Medani, Sudan

'll the legumes were planted in July and two cuts were made during six months except in groundnuts which were harvested once in mid December. Irrigation was given according to the standard practice of the Gezira Research Station (Anon 1967). Full experimental details are given by Musa and Burhan (1974).

Results and discussion

A summary of the results giving the amounts of nitrogen fixed by the different legumes for the two seasons 1972/1973 and 1973/1974 is presented in Table 1 for Experiment 1.

It was evident that the two seasons were very markedly different in the legume performance and nitrogen fixation. Season 1972/1973 evidently outyielded season 1973/74. Nitrogen production was clearly higher in the two cuts taken. Neither soil nitrate at the start of season nor number of nodules could account for the differences in growth. Possibly humidity and temperature patterns were responsible for the differences obtained.

The different legumes fixed appreciable amounts of atmospheric nitrogen being about highest for groundnuts (50 kg. N/acre), and lowest for Clitoria (43 kg. N/acre), when grown for about 200 days under irrigation. This is quite appreciable when one recognizes that the normal Gezira soil is low in nitrogen (0.035%) and unfertilized farm soil supplies to a cotton crop about 25 kg N/season and up to 30 kg N/season for winter wheat. Thus the realization of about 80 kg N/acre for the various legumes was achieved as a result of active symbiotic nitrogen fixation by these legumes.

The method (b) was noted to give consistently lower yield of the legume component and this tended to reduce the value of the atmospheric nitrogen fixed. This was more noticeable in small legumes like groundnuts which are easily smothered and shading seems to account for the weak and tall growth of Clitoria and Philipesara. A shorter much adapted grass would have given results in line with method (a).

Results of nodulation of the different legumes used in Experiment 2 are given in Table 2. Nodule formation started very early in Lubia and Groundnuts and slowest in Clitoria. The initiation of nitrogen fixation as judged by the appearance of pink pigment in nodules was manifest two weeks after germination in Lubia and about three weeks in Groundnuts. Groundnuts, however, had most nodules and the greatest weight of nodules per plant; Lubia and Philipesara had moderate counts of much larger nodules, and the nodules of Clitoria were small and scattered all over the root system.

The legumes investigated showed different habits of nodule formation and persistence. Thus Groundnut root-system was clustered with permanent nodules, of which the larger about 2 mm. diameter were located on the main root, whereas Lubia, and Philipesara invariably had nodules between 2-4 mm diameter on the main root with smaller nodules on laterals. However, nodules of Lubia and Philipesara were weakly attached to the root and their shedding and decay was a common feature following the first cut. Drought was also observed to increase their shedding. The active formation of new nodules was recorded on newly formed roots after the first cut.

Table 3 gives the nitrogen yield of the different legumes during the seasons 1970/1973. The nitrogen yield showed marked seasonal variability as did dry matter production but satisfactory conclusions can be drawn with respect to each crop. In forage legumes such as Philipesara and Lubia about 80% of plant nitrogen accumulated in leaves and stems, but in groundnuts about 60% of the nitrogen was in the kernels. The root systems including nodules contained between 2 and 10 kg N/acre in one season and between 5 and 8 kg N/acre in another. However, the proportion of root and nodule contribution to plant nitrogen varied in different legumes.

After these legumes have been finally cut, at about ground-level, their contribution to the enrichment of soil nitrogen can be assessed with regard both to the amount of plant residue left and their habit of nodulation. Thus the contribution of Lubia, Philipesara and (to a lesser extent) Clitoria whose nodules are easily detached during growth and on sampling would be greatly underestimated if consideration is given only to the final root and nodule nitrogen content. Besides their contribution through roots and nodules, legumes such as Lubia, Philipesara and, to a lesser extent, Clitoria contribute to end-of-season nitrogen returned to the soil through fallen senescent leaf litter.

The small non-significant increase in soil organic nitrogen associated with cut legumes grown for part of the year in a semi-arid environment under irrigation (Musa and Burhan 1974) reflects the small amount of residue incorporated and the high rate of decomposition compared with what happens under temperate conditions. Furthermore, ploughing and fallowing markedly speed up the mineralization of fallen residues under semi-arid conditions. The figures available, however, confirmed that the legume investigated fixed appreciable amounts of atmospheric nitrogen. The low level of soil nitrogen and the high rate of photosynthesis and transport of carbohydrates are known to enhance the atmospheric nitrogen fixation processes (Vincent 1965).

Experimental results of the effects of these legumes on a succeeding cotton crop grown immediately or after an intervening fallow indicated that the value of unfertilized cotton after legumes was higher than after fallows in adjacent plots or after wheat. However, marked responses to added urea fertilizer applied at the rate of 54 kg N/acre were found. This shows that the residual effect of cut legumes is not big enough to meet the requirements of a well grown cotton crop. Ideally, a calibration method with different rates of nitrogen fertilizer, at the lower levels of application, would have given a better indication of the differential contribution of these legumes to a succeeding crop under field conditions. This was not feasible under field conditions. To achieve this an experiment carried out under greenhouse conditions in trays containing soil from plots previously under the various legumes and using Sudan grass showed that grass yields were only noticeably enhanced by application rates of urea fertilizer above 10 kg N/acre. No clear differences between soils under the various legumes were observed. It must be stated that the soils in trays were homogenized to facilitate seeding. However, we must not lose sight of the fact that under field conditions the differential effects of these legumes on the succeeding crop may also be influenced by the effects of rooting habits of these legumes on soil physical conditions.

Summary of discussion

It was noted that the results from the experiments carried out in Sudan were similar to those obtained in French-speaking Africa. In answer to a question it was noted that the legumes grown were fed to animals; this meant the nitrogen would be removed from the soil. The alternative was to grow the legumes as a crop to fix nitrogen without feeding it to animals. It was noted that some legumes did not respond to inoculants, and there were difficulties in growing inoculants. So far there was no policy on inoculation in Sudan.

REFERENCES

Anon (1967): Standard Practices at the Gezira Res. Station. Agric. Res. Corp. Sudan, Tech. Bull. No. 1 (N.S.)

Burhan, H.O. and Mansi, M.G. (1967): Rotation Responses of cotton in the Sudan Gezira 1. The effect of crop rotation on cotton yields. J. agric. sci. Camb. 68, 255-261

Musa, M.M. and Burhan, H.O. (1974): The relative performance of forage legumes as rotational crops in the Gezira. Expl. Agric. 10, 131-140.

Vincent, J.M. (1965): In "Soil Nitrogen", edited by Bartholomew and Clark, American Soc. of Agronomy Inc.

Table 1 Amounts of nitrogen fixed by the various legumes (kg. N/acre)

Legume	Method (a)			Method (b)		
	1972/73	1973/74	Mean	1972/73	1973/74	Mean
Lubia	55	40	47.5	34	30	32.0
Philipesara	61	48	54.5	44	36	40.0
Clitoria	46	41	43.5	29	28	28.5
Groundnuts	48	52	50.0	21	22	21.5

Table 2. Nodulation of forage legumes at different stages of growth

Forage crop	Initiation of nodulation (days form germination)	Initation of N fixation (days from germination)	Nodule number at maximum plant weight	Fresh nodule weight per plant (gm)	Nodule weight as % plant weight	Habit of nodulation
Philipesara	10 - 14	17 - 23	52 ± 11	0.52	1.32	Medium size nodules, diffuse, lobed, easily shed
Clitoria	13 - 18	21 - 26	48 ± 6	0.20	0.83	Small, few in number, scattered, weak, easily shed
Lubia	7 - 12	14 - 19	57 ± 7	0.72	1.65	Nodules large, mainly on the main root, slightly lobed, easily shed
Groundnuts (Ashford)	8 - 13	22 - 25	306 ± 75	1.17	1.82	Generally small, less than 2 mm. diameter, distributed throughout the root system smooth surfaced, firmly attached to roots.

Table 5. Nitrogen yield of the various forage legumes (kg. N/acre)

Season	Forage crop	Leaves	Stems	Roots	Nodules	Fruits	Total N
1970/71	*Philipesara*	36.4	21.5	2.2	0.7	5.6	66.4
	Clitoria	23.5	25.0	7.2	0.4	4.2	69.3
	Lubia	31.4	16.2	2.3	1.3	10.1	63.3
	Groundnuts	19.9	7.8	3.8	1.8	39.2	72.5
1971/72	*Philipesara*	39.2	38.2	6.4	1.6	9.9	95.5
	Clitoria	33.5	35.0	9.1	0.8	4.0	82.4
	Lubia	37.9	32.7	5.0	2.3	12.0	89.9
	Groundnuts	18.0	11.0	4.2	2.9	38.8	74.9
1972/73	*Philipesara*	33.9	29.1	3.9	1.1	14.7	82.7
	Clitoria	36.6	22.0	6.9	1.0	19.3	85.9
	Lubia	32.3	22.8	4.2	2.7	9.3	71.3
	Groundnuts	15.7	8.8	4.2	2.4	64.3	95.4
	Mean	30.6	22.7	4.9	1.6	19.3	79.1

11. SURVEY OF CITY REFUSE COMPOSTING

by
D. Stickelberger *

1. The general situation

There is no doubt that recent years have brought a slowdown if not a reversal in the construction of composting plants in most industrialized countries. Even in the Netherlands, where city refuse composting originated, a preference for incineration has been noted. Other examples abound. In the United States as many as 14 of the 18 large-scale composting facilities constructed after 1951 had already been closed down by 1971 (2). On the other hand, 230 composting plants were still in operation in Western Europe in 1973 (3,4). While, to my knowledge, no statistics are available for Eastern Europe, the following facts speak for themselves. The composting plant in Moscow, with a capacity of 200'000 tons of refuse per year, is probably the largest in the world. The facilities in Leningrad, which process 140'000 t/year are also among the largest (5), surpassed only by those in Rome with 170'000 t/year. In addition, Rome also boasts 2 recycling plants with a total capacity of 430'000 t/year (1600 t/d). The refuse is divided into 5 channels and processed separately (6). A few plants were also built in Latin America, Africa and Asia (Bangkok, Japan, the Philippines) but did not function smoothly enough to inspire imitation. Nevertheless composting is still practiced in a number of places. The city of Calcutta, for example, is proceeding more systematically. An examination of municipal refuse revealed that 47% was suited for composting (7); a detailed case study was published (8).

In contrast to the extensive facilities in Rome and the two Soviet cities, 2500 small urban settlements in India produced 3 1/2 million tons of compost within the framework of the third national 5-year plan. This amounts to a yearly production of 700'000 tons (9). Thus considerable quantities of compost are produced, usually manually, in innumerable small treatment plants. In terms of India's urban population of 78.8 million, approximately 9 kg of compost per year and inhabitant are produced. What might at first glance seem like a high figure is exceeded by far in industrialized countries like France. Here, 97 composting plants, operated according to 13 different processing systems, will have produced 920'000 tons of compost by the end of 1974, yielding a per capita rate of 18.5 kg (10). In the Netherlands about 15 kg per inhabitant, in Switzerland 13, are produced on an average. Yet even France, with its high per capita production rate, composts only approximately 10% of the total refuse generated; 20% of the wastes are incinerated and the remaining 70% tipped (11).

* Deputy Manager, WHO International Reference Centre, Dübendorf, Switzerland

But enough of general figures; let us now get down to the crux. of the matter.

1.1. Model of wastes management in a big city

Before attempting an explanation for the reasons behind the stagnation in urban wastes composting and before describing some processing procedures I should like to show on the basis of a model how urban wastes are composted in a large city or by a joint association for refuse disposal. [Fig. 1].

The refuse is transported to the various composting plants on the outskirts of the district which is also the potential marketing area. As little use as possible is made of roads because of the decentralized site of the plants. The return trip of the collecting vehicle is used to transport the non-recyclable wastes from the composting plant back to a central processing plant (incineration or diversified recycling). This residue represents only a fraction of the original refuse weight and volume so that, again, there is a reduced strain on the transportation network. This model can also be applied to a joint association for refuse disposal. Owing to reasons of transportation horticulturists are usually found near urban settlements. Since they rarely raise livestock themselves and have difficulties finding organic material (barnyard manure) for their soil, they must look to other sources. Compost derived from urban refuse offers the perfect solution and thereby disproves the widespread opinion that composting urban refuse in big cities is useless.

2. Reasons for the stagnation of urban wastes composting

How can we explain the stagnation in urban wastes composting in most industrialized countries with the exception of France and Spain? The sharpest decline in composting can be found in the USA. Contrary to Europe, where the taxpayer pays up to $ 25.- per ton of refuse for incineration, sanitary landfilling in the USA costs only $ 1.- per ton. Sophisticated incineration facilities are practically unknown. If - as was the case in Phoenix, Arizona - the private owner of a composting plant receives $ 1.- per ton of compost in accordance with the normal costs for waste disposal, it will be difficult for him to finance operations in a country where there is no demand for compost and where it is also poor in quality. In Phoenix the private enterpreneur was soon forced to close facilities. Similar shutdowns have occurred in other cities as well, so that the authorities felt justified in dismissing composting as an inadequate disposal method.

In Europe the development was more diversified:

- In the 1950s a naive enthusiasm for the natural cycle of organic substances spread; unfortunately, however, these recycling proponents stressed engineering and overlooked the significance of the biological aspects.

  We shall return to this point when dealing with the question of processing techniques. The quality was unsatisfactory and no interest was ever shown.

  Quality standards have been elaborated only recently (12). They distinguish between three grades based on water content, percentage of foreign particles, loss on ignition and degree of maturity.

- A major obstacle has been the inclination of municipal authorities to see refuse merely as wastes that should be disposed of as quickly as possible. The potential buyers reacted accordingly: farmers refused to be charged with the cities' filth and - what is more - even be expected to pay for it.

- Another crucial flaw in the approach to composting is that no clear distinction is made between what the taxpayer must pay for waste disposal and how much an enterpreneur can afford to ask if he wants to keep his product marketable.

- By far the most important reason for the failure to make composting an accepted disposal method for urban wastes, however, is the fact that agricultural research institutes and authorities took no notice of its potential. Influenced by Liebig's discovery agriculture chose to focus its sights on the temptingly simple nutrient balance principle. The resulting increase in crop yield seemed to justify thinking almost exclusively in terms of nitrogen, potassium and phosphorus, the main nutrients that should be made available to plants in soluble form. From this perspective the use of compost appears uneconomical; all substances that do not come under the heading of nutrients or trace elements must per force be ballast not even worth transporting. On the other hand, the following example of the alternatives to enriching the soil with the trace element boron illustrates how one-sided the approach in fact is (13). It was considered senseless to spread 10 railroad car loads of compost on a sugar beet field if the boron deficiency for the same surface could be eliminated with just a small bag of plain boric acid. If offsetting the boron deficiency were the main concern, then this simple deduction would certainly be valid. However, if an attempt is made to do justice to the broader ecological correlations with their infinite synergistic and antagonistic interplay, this method is untenable.

  It is therefore inappropriate to use urban refuse exclusively for its nutrient content and trace elements. Aside from the nutrient input, compost also influences the physics and biology of the soil. As a result the constitution of plants and cattle can be improved, and their resistance against disease and vermin increased.

Until now few attempts have been made to objectify this hypothesis since industry has had no interest in this type of research. A few fundamental projects of this kind have nevertheless been carried out (14, 15, 16, 17, 18, 19, 20, 21, 22, 23).

One of the main reasons for the agronomists' marked reticence concerning the use of urban compost probably lies in the complexity of effects. This is contrary to the comfortable nutrient balance approach with its simple stoichiometric relations. Recently the question of toxic heavy metals in urban compost has come to complicate the discussion (24, 25, 26, 27). To deal with the problems arising out of this question would, however, exceed the framework of this report, especially since it has not been posed with such acuteness in developing countries.

3. The balance of resources

Everything that lives and grows from both the plant and animal kingdoms sooner or later winds up as wastes. In the soil these wastes undergo a metamorphosis, a cycle is closed and a new foundation for growth evolves out of wastes.

On the other hand, if the wastes are tipped or incinerated, the waste material is removed from the natural cycling mechanism and enters the environment in a form which restricts or eliminates its possible recovery. In this fashion, the rate of entropy production is accelerated, because additional energy must be expended to replace the lost material. In addition, the benefits of compost must be replaced by another source. [Fig. 2 and 3].

Making such potential available, especially through the production of artificial fertilizer, entails additional costs, energy consumption and squandering our dwindling resources (phosphates, peat).

4. Approach to composting technologies

There are about 25 different methods of mechanical compost production but two main processes are distinguished if details are exempt.

They are the: - static process

- dynamic process

According to the static process the material which is pressed or spread in layers and well ventilated remains in one place and is turned once or only a few times during the process of composting. Most characteristic of this process is the intense development of fungi (Actinomycetes, Ascomycetes, Basidiomycetes).

In the dynamic process the decaying material is constantly kept in motion so that the flora consists mainly of bacteria. Usually this phase is followed by a static one, windrowing. Dynamic processes by their very nature presuppose more machinery.

From the biological point of view the static process is more justifiable since fungi, especially the colored actinomycetes, represent the first stage of humus formation and since in nature, the rotting leaves are not turned during the process of humification either.

To demonstrate the treatment process I should like to show a few slides. They manifest that a compost produced with simple means is equal in quality to a compost produced with sophisticated machinery. Unfortunately authorities in industrialized countries have often been misled by expensive and impressive technology without realizing that composting was primarily a biological and not a technical problem.

Figure 4 shows an old installation from the 1950s in Dantumadeel, in the northern part of Holland. These very simple facilities sufficed to process the household refuse and feces of a community of 10'000 inhabitants and to produce hygienic compost (29).

Figure 5 shows a more recent development with a variety of conveyor belts and technical gadgets. The technical quality of the compost is superior to that of Dantumadeel but still not ideal. In addition it must be purchased with greater effort and a large amount of non-compostable material. A considerable number of just such facilities has unfortunately been built.

Figure 6 shows a plant of the most recent type where the choice of material application presents itself directly following fermentation. Very little rejects remain. Operations at this plant situated in the Constance district are based on the old principle of keeping plant and effort at a minimum.

A good-quality product attained with a minimum of technology: This simple formula has been disregarded all too often in industrialized countries. It could, however, be applied very advantageously in developing countries since labor is plentiful.

In this context I should like to show you a picture [Fig. 7] of two plants; one is cheap, the other expensive to operate. Both are still in operation, but the cheaper one produces a superior product. The next figure [8] shows the repertory of technical possibilities for processing urban refuse to produce compost.

4.1. Technical quality of compost

From the functional point of view the technology of composting can be reduced to three main processes: size reduction, turning, sieving.

4.1.1. Size reduction

Three types of machines are used in this process: drums, rasps and mills.

Size reduction machinery should be generously dimensioned to accommodate incoming refuse, should operate without danger of explosion and provide a satisfactory degree of homogenization.

The drum is not suited for size reduction; its already doubtful efficacy is dependent on the work load and retention time in the drum. A serious disadvantage in using the drum for size reduction is that lumps and long braids of soft fibrous materials tend to form. Tangles of this type can weigh up to half a ton and have to be removed with tractors or similar heavy machinery.

The rasp machine is a slow-moving grinder that works with relatively little attrition. It also provides preliminary screening although a considerable amount of compostable material is removed, a fact which is proven by the rise in temperature when the screening rejects are put out in windrows. Thus we see that the process of separating compostable and non-compostable material still needs improvement.

There are two types of mills: hammer and crushing mills. Rapid-moving machines are subject to wear and present greater danger of explosion.

A slow-grinding refuse comminutor has recently appeared on the market which can grind wastes with no prior screening and without rejects.

4.1.2. Mixing

Mixing is of importance only if liquids or thick suspensions such as sewage sludge, feces or hog manure are to be composted along with the household refuse.

Besides providing size reduction, the drum also mixes wastes. Its function is to homogenize the material as far as possible with refuse - even if viscous or liquid substances are added.

The drum fulfills this task inadequately as soon as liquids or thick suspensions (dehydrated sewage sludge) are added. Balls of various sizes depending on the water content devebp. The balls can be homogenized with the rest of the wastes only after passing through a second mill, which, however, involves a further processing step.

Forced mixing is therefore best suited to attain the homogenity needed.

4.1.3. Screening

Depending on the system, screening is either coupled with grating (rasp) or takes place directly after size reduction as in the Dano facilities. To produce a particularly fine quality it may also follow composting.

Basically it can safely be said that screening before composting does not guarantee thorough separation of compostable and non-compostable material, as no distinction can be made between organic and inorganic particles. After the biodegradable matter is fermented, however, the difference becomes apparent; the screening rejects are consequently practically free of organic particles even when a very fine screen is used. Even in screening the composted household refuse in industrialized countries screening rejects can be kept as low as 30% of the refuse (10).

5. Biological characteristcs of compost

The aim of the following description of the three phases of composting is to show that technical steps (besides magnetic separation) can be restricted to size reduction, mixing and screening. With these three operations good technical quality can be achieved. The biological quality of the compost, on the other hand, is more difficult to define. An established fact is that a strong fungi development during the first stage of decomposition (static composting) stimulates the process of humification considerably. Recent as yet unpublished EAWAG studies show clearly that pressed refuse bricks with a developed fungi population were more stimulating to plant growth than compost obtained by other means.

The composting process can most readily be compared to humification in a mixed forest.

[Fig. 9]

a) The uppermost layer or forest cover consists of leaves and other undecomposed residues. This organic cover, called litter, acts as a protective shield as well as a point of contact between the soil and external influences such as wind, rain and sun. It stores energy for later use.

b) Underneath the litter we find the layer in which decay takes place. Fungi and actinomycetes abound here, serving as agents in the rapid, exothermic decomposition of structured carbohydrates. Plants forced to grow in such an area will show signs of disease or lower resistance; in fact, they very often die. Budding is prevented or delayed. This second, "aggressive" phase of decay in which enzymes, vitamines and antibiotics are formed corresponds to what is known as fresh compost in the field of composting. The dyes that develop here represent a preliminary stage in the production of humic acid.

This layer of decomposition is unstable by nature.

c) The original forms and structures of leaves and larvae are no longer recognizable in the stable humus layer. Decomposition here has been completed. This final stage can be compared to mature compost, which stimulates plant growth. The edaphon, among which we count the earthworm, mixes the organic material with minerals in the soil and brings about the formation of clay-humus complexes and protein-humus complexes.

The humus layer is stable by its very nature (30).

5.1. Mulching

According to the principle of mulching in layers, hygienized fresh compost (after heating once) can be spread directly on fields. New layers of immature compost are added every year or at regular time intervals. The previous year's cover thus becomes the layer of decomposition and the decayed layer humifies. With such soil structures turning and plowing in depth are inexpedient since it would prevent layer formation. Given the nature of layer decay, such fields are best tilled with the traditional harrow plow or more modern rotary hoe.

5.2. Fermentation process

The typical temperature curve [Fig.10] in a windrow can be brought into relation with the previous figure illustrating the three phases of decomposition, although the first phase, which corresponds to the mechanical treatment of undecayed refuse, does not appear. The sharp rise in temperature to 50 to 70°C corresponds to the second rapid phase of decomposition. At this point oxygen is in such great supply that anaerobic pockets develop in the centre of the windrow. Anaerobic processes can, however, be prevented by making low windrows (1.20 meters in height) and stacking the pressed combined refuse and sewage sludge bricks.

A slow temperature development (compare with the autoclave) is a prerequisite for making the compost germfree; spore-forming pathogenic germs (ex. anthrax) are forced to germinate and can thus be killed off at a relatively low temperature (50-60) within a few days. Worm eggs and parasites are also destroyed (31, 37).

Mixing compost with soil and using it in plant cultivation when it is in a crude state or in this phase of temperature development will severely damage sensitive plants owing to impeded nitrogen fixation and antibiotic effects. Compost that has not matured sufficiently can be used only for mulching and should not be applied to plant roots. Moreover, the antibiotics that develop during the fungi phase also act as germ killers.

A compost is considered mature only after the temperature curve has definitely leveled off and does not react to turning.

5.3. Determination of the degree of maturity

Various methods are at our disposal to determine a compost's degree of maturity (C/N ratio, H_2S determination, seedling tests etc.), but are inadequate or too time consuming for satisfactory practical application.

The EAWAG has recently carried out more extensive work on paper chromatography. The slides show the main phases of humification: decomposition of the raw material, development of humic material, mineralization. With advancing compost maturity the dark stain concentrates around the center, while the edges get lighter. Crude material leaves a pattern characterized by a dark periphery (33). [Figures 11, 12, 13, 14].

6. The effects of compost on the soil

A detailed description of the effect compost has on the soil exceeds the aim of this paper. The most essential point I should like to convey is that compost cannot merely be used as a substitute for artificial fertilizers that have become too expensive.

Compost has a three-fold effect: it works chemically as a nutrient, physically and biologically.

6.1. Nutrients

Analysis publications have revealed that compost contains a relatively small percentage of nutrients. It has, however, been ascertained that fertile soil did not contain maximum but rather minimum quantities of nutrients. Thus the best humic soils for gardening contain no more than 2% potassium, 1.5% phosphorus and 1% nitrogen. Far more important than maximum nutrient values is the ecological balance between the particular elements (34).
A ten-year experiment in which compost without nutrient additives was spread on badlands confirms this fact (35).

6.2. Physics of soil

Physically, compost acts as a soil improver. It helps prevent soil erosion by wind and water (36, 37, 38), increases the water retention capacity and porosity of the soil (39) and improves its crumb structure (40, 41).

6.3. Biology of soil

From the biological point of view, the use of compost causes an increase in the number of microorganisms in the soil. Rather than stimulating the proliferation of a particular species, it is conductive to organism diversity, that is, the coexistence of various species.

According to Thinemann's Law a biotop is considered healthy as long as it has a large number of species and a low individual count. An unhealthy biotop is characterized by a high individual count and a small number of species (42).

In nature itself the one-sided use of fertilizers causes a proliferation of a particular species which soon develop into a pest that cannot be held in check by the other organisms. The intensive use of pesticides then disrupts the ecological balance.

7. Conclusion

In conclusion I should like to present you with the order of priorities set by one of our Federal Agricultural Experimental Stations. It should also be borne in mind that mass livestock breeding is to be avoided for a number of reasons that cannot be dealt with here [Fig. 15].

FIGURE 1

URBAN REFUSE MANAGEMENT MODEL

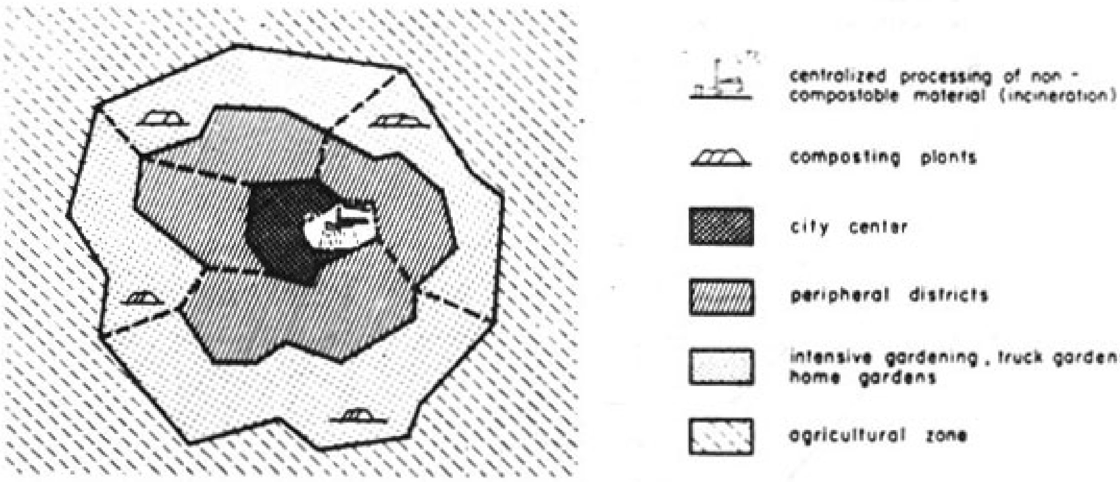


FIGURE 2

The way of the plant nutrients

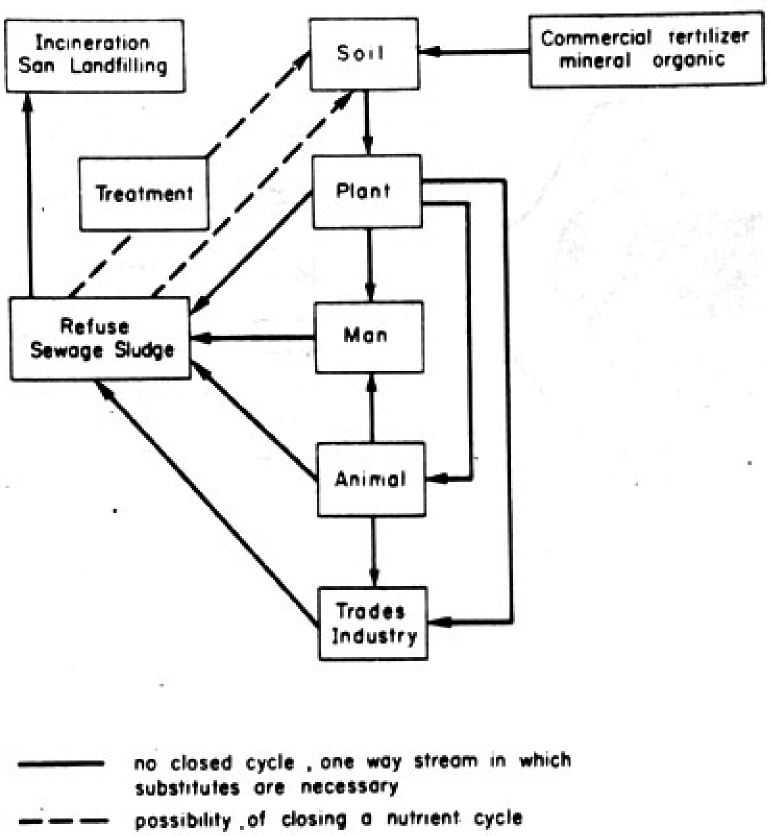


FIGURE 3

Scheme illustrating the additional effort needed when using substitutes made of new raw materials instead of recycled organic refuse.

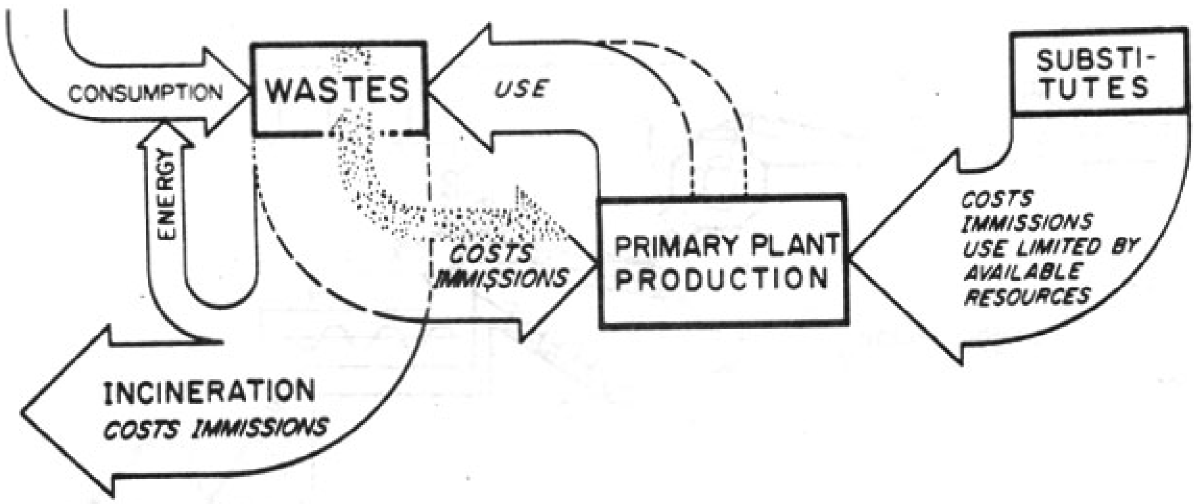


FIGURE 4

In the 1950s very little plant and equipment were necessary to produce compost from refuse and night soil (Dantumadeel, Holland).

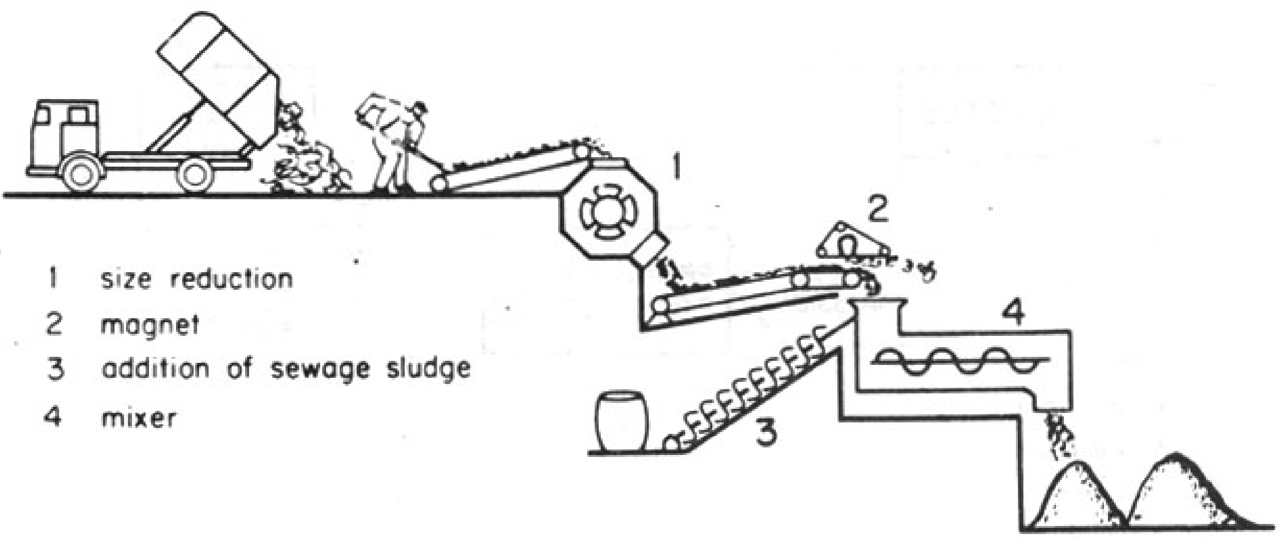


FIGURE 5

Sophisticated composting plant with an imposing display of technology

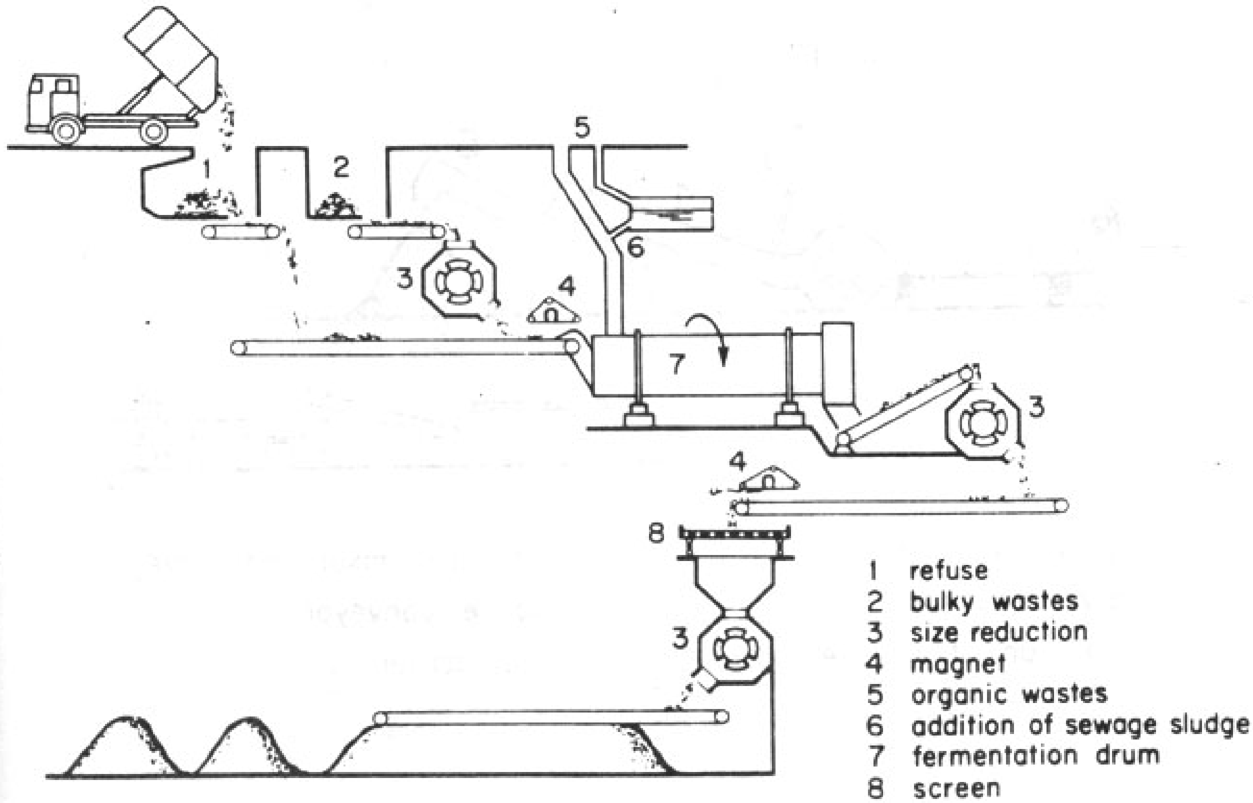
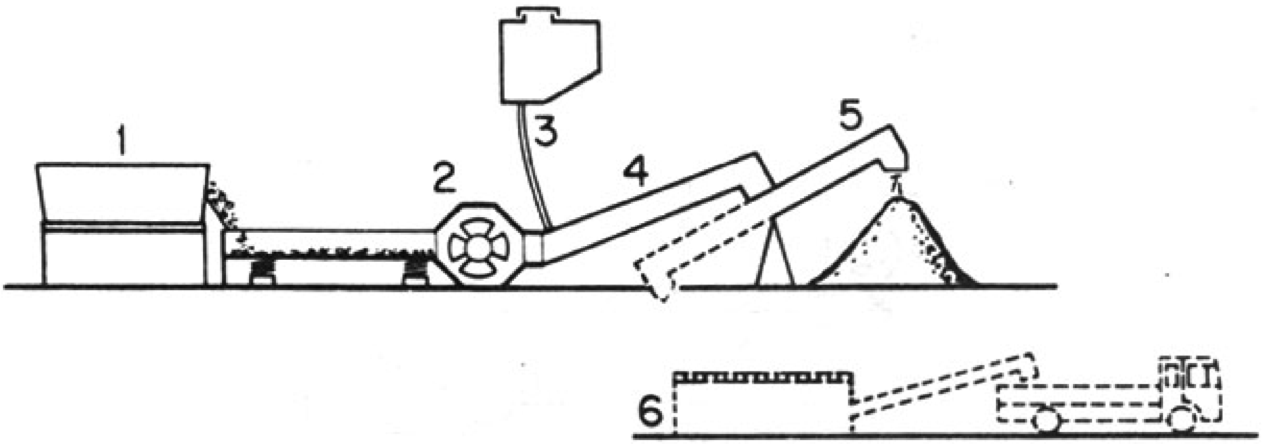


FIGURE 6

Modern plant with minimum technology



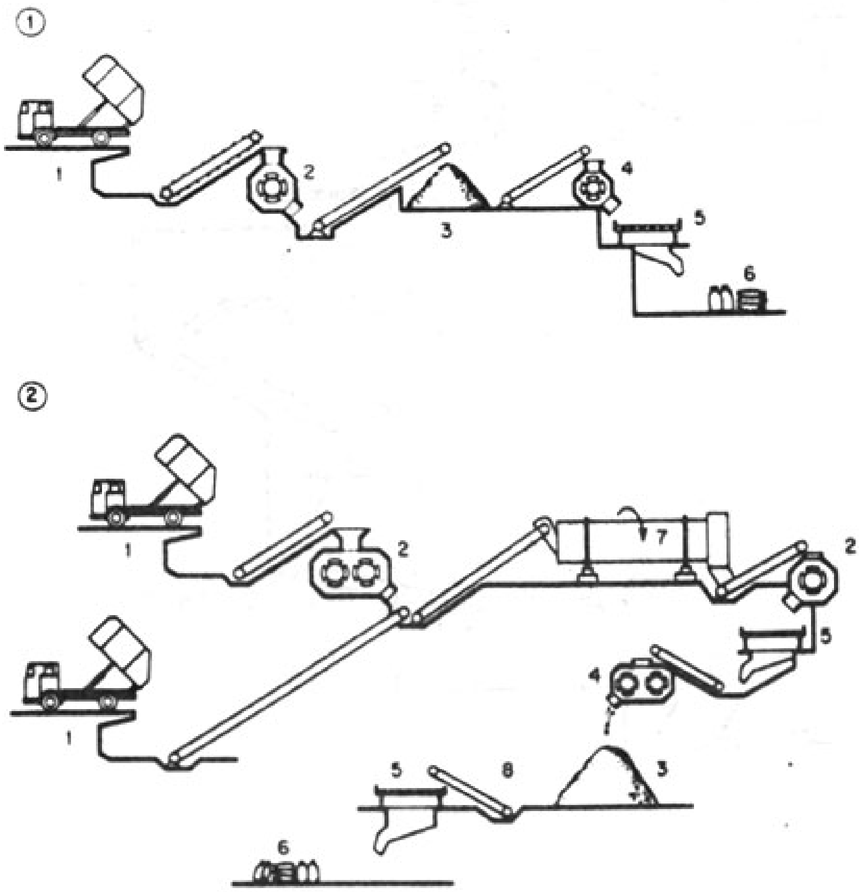
1 unloading hopper
2 size reduction
3 addition of sewage sludge
4 combined mixer and conveyor
5 mobile conveyor
6 final screening

FIGURE 7

Two plants producing fine quality compost:

above: with low expenditure of money and energy and a low emission rate a good product results

below: with much expenditure a not so good product results



1 hopper
2 size reduction
3 fermentation heap
4 final size reduction
5 screen
6 compost filled into bags
7 fermentation drum
8 drying

FIGURE 8

Repertory of technical possibilities for processing urban refuse to produce compost

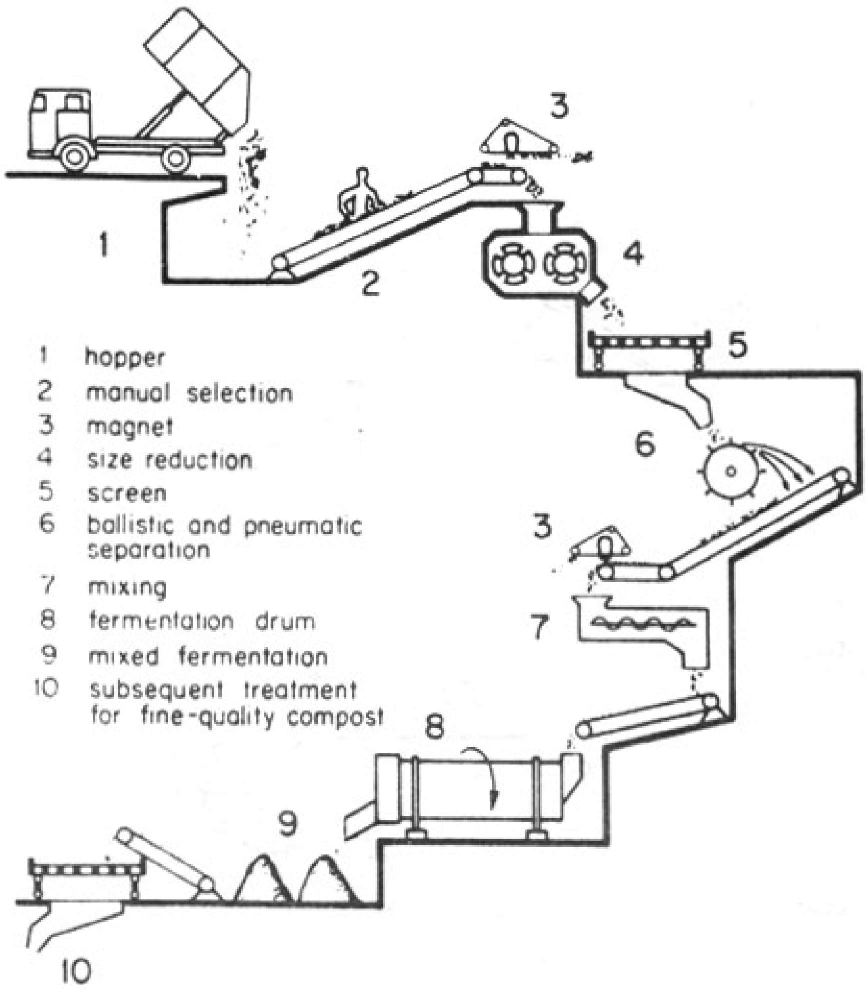
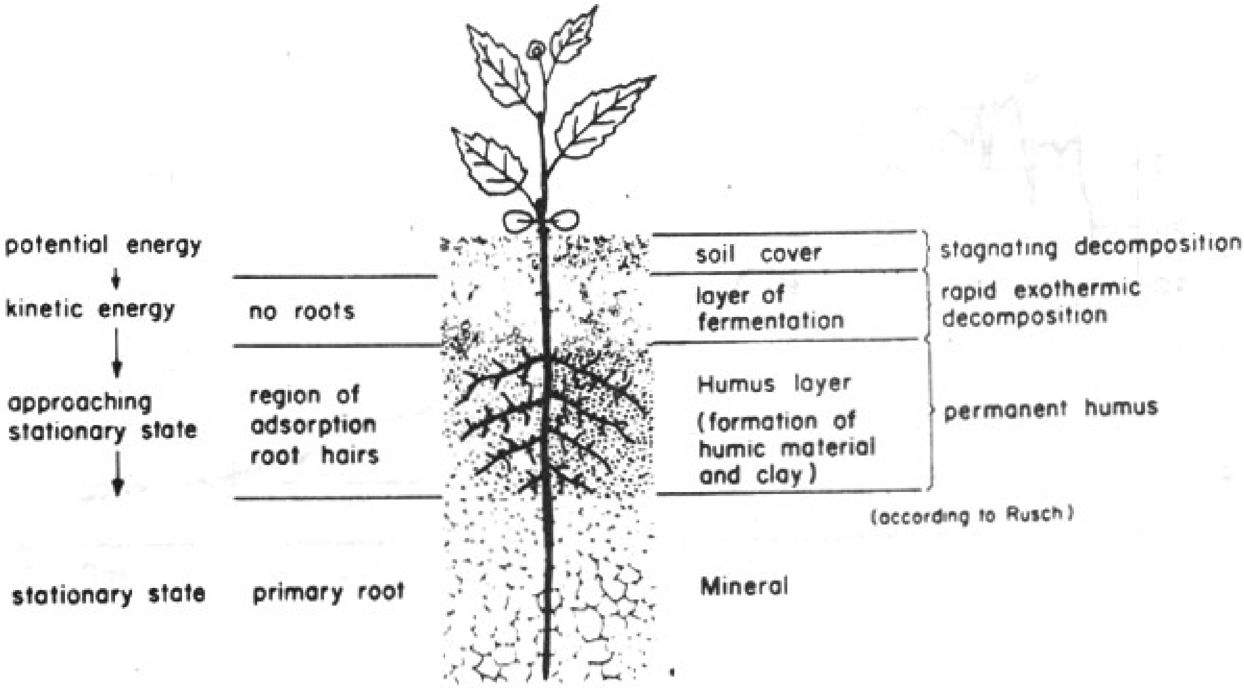


FIGURE 9

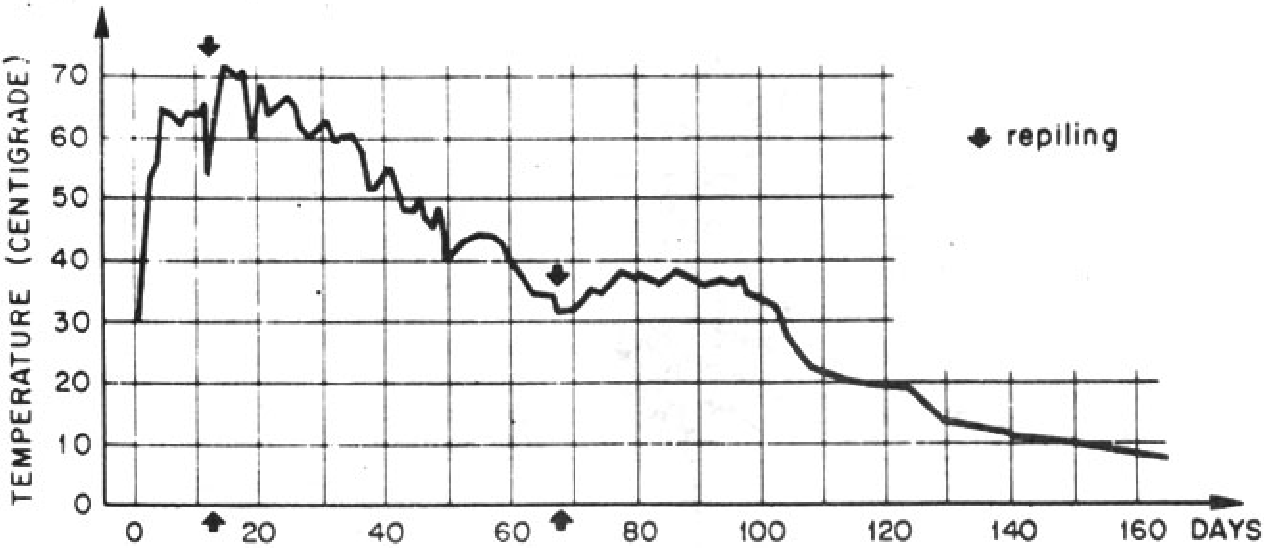
The three phases of humification in a forest



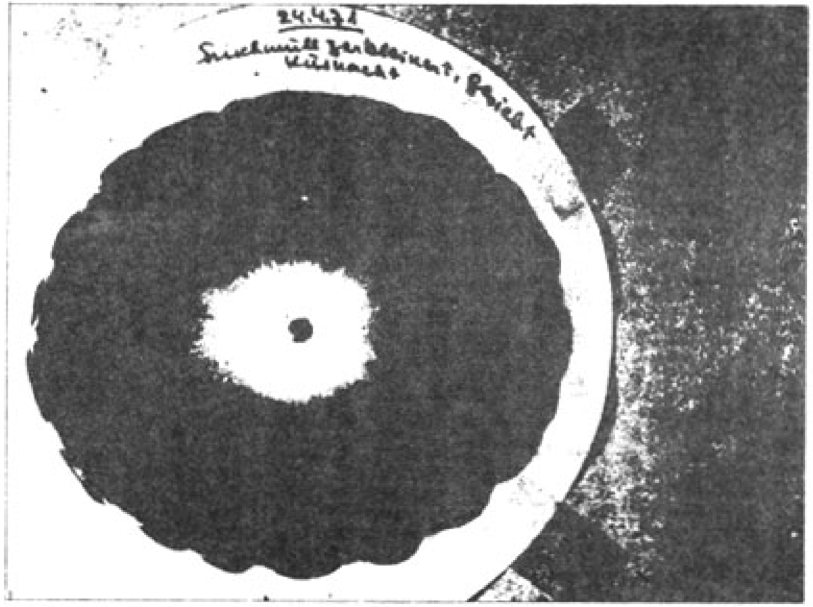
The three phases of humification in a forest

FIGURE 10

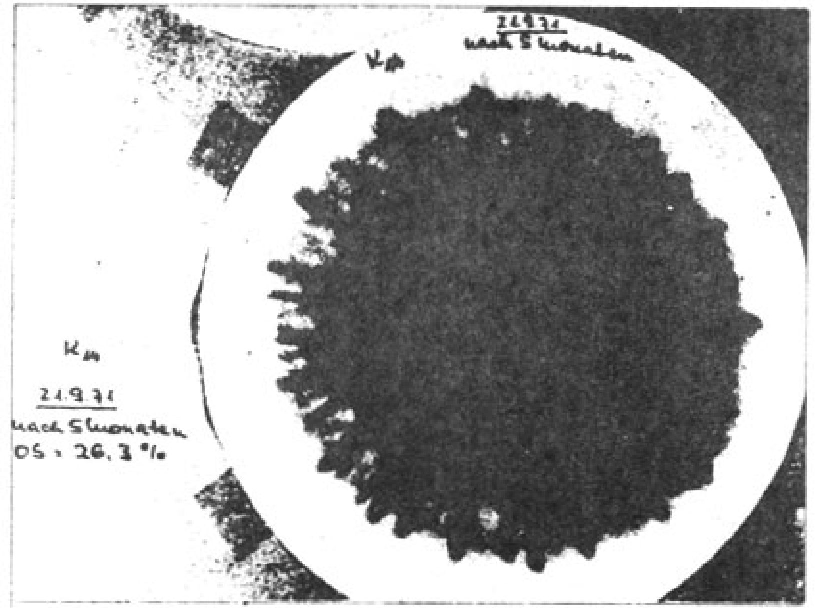
A typical temperature curve in a windrow



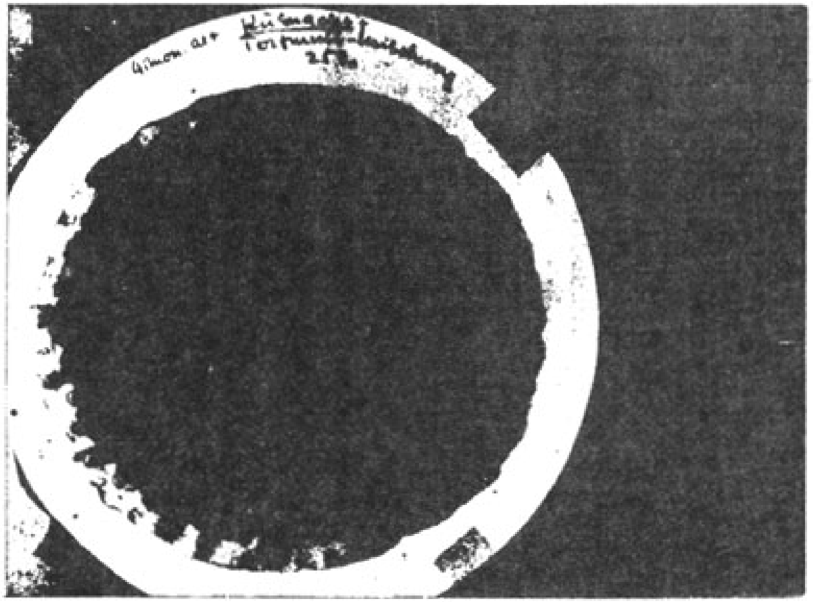
Determination of the degree of maturity by paper chromatography



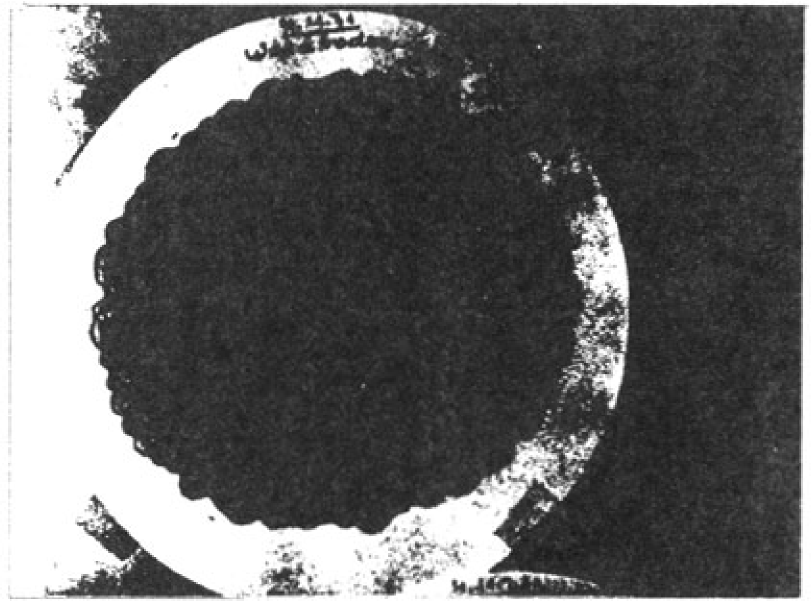
Pulverized refuse. sieved, no fermentation (11)



The same material after 5 months composting (12)



The same material after 4 months composting, mixed with 25% peat (13)



Forest soil (14)

FIGURE 15

Order of priorities for the use of fertilizers (according to Hasler)

PRIORITY	NUTRIENTS FROM	COMMENT
1	Livestock raising on farm Barnyard manure Liquid manure	Can be used without reservation
2	Mass livestock breeding Liquid manure Dried manure Manure combined with 3	Can be used without reservation
3	Urban refuse and other organic wastes	If suited, to be used as far as possible
4	Commercial fertilizer	As a substitute or complement for 1,2,3

LITERATURE

1. VAM-NACHRICHTEN, Sept. 1973.

2. Carel C. DeWinkel: Composting in the United States Reconsidered. Febr. 1974.

3. Kumpf-Maas-Straub: Müll- und Abfallbeseitigung. Erich-Schmidt Verlag, Ciffre 8501 ff, 1967-1974.

4. Centre d'Etudes et de Recherches des Charbonnages de France: Documentation Jan.1974.

5. Rasnoschik, W.W.: Beschleunigte Unschädlichmachung und Verarbeitung fester Siedlungsabfälle zu organischen Düngemitteln. Obzory po gorodskomu chozjajstru, Moskva, Gosinti 1970.

6. Stickelberger, D., G. Rollé, W. Moser: Report on a Study Trip to the Refuse Processing Plants of the City of Rome, Zürich Nov. 1973.

7. Bhide, A.D., et al: Quality and Quantity of Refuse from Calcutta City, Indian J. Environm. Health, Vol. 14, No. 1, 80-87, 1972.

8. Bhide, A.D., et al: Refuse Disposal of Calcutta City, A Case Study, Indian J. Environm. Health, 14, 121-30, 1972.

9. Amerik Singh Cheema: India Develops Urban Compost-Sewage Use Plan, Compost Science, Autumn 1967 - Winter 1968.

10. Hirschheydt, A.v.: Zur Abfallverwertung durch Kompostierung in Belgien und Frankreich. Bericht über eine Studienreise, interner EAWAG-Bericht, Sept. 1974.

11. Billig, M. et M. Tenaille, Association Générale des Hygiénistes et Techniciens Municipaux: "Le Marché de Compost en 1973 en France". Congrès de Rome 1973.

12. Hirschheydt, A.v.: "Quality Standards for Swine Refuse Composts", ISWA-Information Bulletin No. 13, June 1974.

13. Geering, J., Eidg. Landwirtschaftliche Versuchsanstalt - Reckenholz, "Diskussions-Ecke", I.A.M.-Informationsblatt No. 33, August 1968.

14. Matile, Ph.; Institut für allgemeine Botanik der Eidg. Techn. Hochschule Zürich: "Biologie und Landwirtschaft", ANS-Mitteilungen Nr. 37 und 39. 1973.

15. Schiller, H. et al: Fruchtbarkeitsstörungen bei Rindern im Zusammenhang mit Düngung, Flora und Mineralstoffgehalt des Wiesenfutters". Veröffentlichung der landwirtschaftlich-chemischen Bundesanstalt Linz/Donau, Bd 7, 1967.

16. Romanowski, W.: Wirtschaftsintensität gegen Fruchtbarkeit. Mitteilungen der DLG, Heft 11, 13.3.1966, 450-454.

17. Voisin, A.: Die Weidetetanie. BLV-Verlag 1963.

18. Hahn, J. et al: Uterus- und Ovarbefunde bei Kaninchen nach Fütterung mit Heu von ungedüngtem und intensiv gedüngtem Grünland. Dtsch. tierärztl. Wschr. 78, 73-148, 1971.

19. Aehnelt. E., und J. Hahn: Beobachtungen über die Fruchtbarkeit von Besamungsbullen bei unterschiedlicher Grünlandbewirtschaftung. Experimentelle Pflanzensoziologie, Den Haag 1969.

20. Farkasdi, G.: Die Bedeutung der Abfallkompostierung für den praktischen Lebensschutz. Ztsch. Vitalstoffe - Zivilisationskrankheiten Nr. 1/69.

21. Bundesanstalt für Qualitätsforschung pflanzlicher Erzeugnisse, Geisenheim: Düngung und wertbestimmende Inhaltsstoffe. Jahresbericht 1969.

22. Voisin, A.: Les nouvelles lois scientifiques d'application des engrais. Les Presses de l'Université Laval, Québec 1964.

23. A survey of literature on organic farming is given in: alternatieve Landbouw, Commissie Overzoek Biologische Landbouwmethoden, Centrum voor Landbouwpublikaties en Landbouwdocumentatie. Wageningen 1974.

24. Siegel, O., und H. Rasp: Ergebnisse eines 12-jährigen Düngungsversuches mit Siedlungsabfällen. Ztsch. Landw. Forschung 27, 1. Heft, 73, 85, 1973.

25. Wagner, K.H., und L. Siddiqi: Gefährliche Stoffe in Bodenverbesserungsmitteln. Naturwissenschaft 60, 160-61, 1973.

26. Wagner, K.H., und L. Siddiqi: Schwermetallkontamination durch industrielle Immission. Naturwissenschaft 60, 161, 1973.

27. Rohde, G.: Schwermetalle - ihre Bedeutung und mögliche Anreicherung im Boden durch Müll- und Müllklärschlammkomposte. Sonderdruck der ANS Mitteilungen, München 1973.

28. Hirschheydt, A.v.: Gedanken zur Verfahrenstechnik bei der Müllkompostierung. Vortrag am 17. Informationsgespräch des ANS, Okt. 1974, Wiesbaden.

29. IRGRD, Information Bulletin Numbers 1-12, Nov. 1956 to Sept. 1961. Edited by John S. Wiley, Division of Environmental Engineering and Food Protection, U.S. Public Health Service.

30. Stickelberger, D.: Model of Organic Wastes Recycling. WHO/IRC at the Seminar of the Austrian Association of Water Economy. IRCWD News March 1972.

31. Burger, G.: Möglichkeiten und Grenzen der Entseuchung infektiöser Siedlungsabfälle auf dem Wege der aeroben Kompostierung. 2. ges. Hyg. 11, 1965, H.6.

32. Knoll, K.H.: Allgemeine Verfahren der Kompostierung im Hinblick auf ihren hygienischen Effekt. Kumpf-Maas-Straub, Müll- und Abfallbeseitigung, Kennzahl 5152, 5155.

33. Hertelendy, K.: Qualitätsbeurteilung von Kompost aus Siedlungsabfällen. Jahresbericht EAWAG 1973.

34. Francé-Hanau, A.: Die letzte Chance. Bayerischer Landwirtschaftsverlag GmbH, München 1950.

35. Rohde, G.: Kompostierung der Stadtabfälle. Wissenschaftliche Zeitschrift der Humboldt-Universität Berlin, Jhrg. IV, 1954/55.

36. Stichting "Compost", Afdeling Landbouwzaken Verstag van de proefnemingen over het jaar 1964, Amsterdam 1965.

37. Deutscher Weinbauernverband, 53 Bonn, Heussallee 26: Richtlinien für die Anwendung von Müll- und Müllklärschlammkomposten im Weinbau. Stuttgart 1966.

38. Peyer, E.: Erosion Damage in Viniculture and Preventive Measures. International Research Group on Refuse Disposal (IRGRD). Information Bulletin Numbers 13-20, No. 15 August 1962. Bureau of Solid Waste Management. Rockville Maryland.

39. Banse, H.J.: Influencing Physical Fertility of Soil by Application of Compost, IRGRD, Information Bulletin Numbers 13-20, No. 13 Dec. 1961, Bureau of Solid Waste Management, Rockville, Maryland.

40. Peyer, K.: Der Einfluss organischer Substanz auf die Beständigkeit von Bodenkrümeln. Die Grüne, Jg. 91, Heft 22, 683-90, 1963.

41. Graff, O.: Untersuchungen über die Bodenfauna im Ackerboden. Habilitationsschrift zur Erlangung der venia legendi an der Landwirtschaftlichen Fakultät der Justus-Liebig-Universität Giessen, 1964.

42. Thienemann, A.F.: Leben und Umwelt. Rowolt Berlin 1956, 122.

43. Rohde, G.: Kompostierung der Stadtabfälle. Wissenschaftliche Zeitschrift der Humboldt-Universität Berlin, Jg. IV, 1954/55.

12. PRINCIPAL PROBLEMS OF THE USE OF CITY WASTES FOR CROP PRODUCTION AND SOIL CONSERVATION

by

C. Tietjen*

City Wastes: Solid Waste, Wastewater, and Sewage Sludge: Definitions, Properties

The term "solid waste" means garbage, refuse, and other discarded solid materials, including such materials resulting from industrial, commercial, and agricultural operations, and from community activities (13). In municipal wastes the portion of industrial and agricultural materials is smaller, domestic and commercial wastes predominate. "Hazardous wastes" that present a significant hazard to human health and the environment are to be excluded.

Used water from the individual sources in the community is collected and transported by municipal waste water systems and through sewers to some dumping point. Normally sanitary and industrial waters are included, also urban runoff of streets etc., and sometimes agricultural wastes. For the handling in a sewage treatment plant industrial wastes are to be excluded, if they present a health hazard to the sewage works operators, or if they are corrosive to parts of the facilities, or if the pollution load of the effluent is still too high for the discharge into a watercourse.

After primary, secondary, or tertiary treatment, wastewater is transformed into two new constituents, effluent and sludge. The liquid product of treatment is effluent. The final disposal of effluent is relatively easy; it is discharged into a watercourse and little attention is paid on the usual accompanying problems of water pollution or eutrophication, or it is handled by some way of land treatment to re-enter the water cycle with a minimum of disruption of nature.

Sludge is the solid residue of the wastewater purification process, a product of screening, sedimentation, filtering, pressing, bacterial digestion, chemical precipitation and oxidation. Sludge is not so easily disposed of as effluent. The more steps of treatment, the more efficient the process of purification, the bigger is the volume of solid produced. Handling this quantity of sludge solids is obviously expensive (12).

Criteria for Decisions in Waste Management

In the effort to develop and operate waste management programmes in a responsive manner, decisions are to be made which are essentially determined by four basic categories of criteria: costs, environmental factors, resource conservation, and institutional factors (4). Each category includes the following key points:

Costs
- Operating and maintenance
- Capital

Environmental factors
- Water pollution
- Air pollution
- Other health factors
- Aesthetic consideration

* Institut für Pflanzenbau und Saatgutforschung, Forschungsanstalt für Landwirtschaft, D 33 Braunschweig, Bundesallee 50, Fed. Rep. of Germany

Resource conservation
- Energy
- Materials
- Land

Institutional factors
- Political feasibility
- Legislative constraints
- Administrative simplicity

Normally we are used to see in the cost criteria the most important one; but often institutional factors are of major concern since they can prevent a decision from being made or eliminate an alternative.

As the members of communities are becoming increasingly conscious of some need for resource conservation, this criteria gains in importance. But to quantify it is difficult as long as there is no aim distinctly fixed. This is different in the very moment when wastes are considered 'resources out of place' with regard to the fact that a good portion of the constituents would exercize a beneficial effect on the soil and the crop growth, if applied to the land.

Land Disposal versus Reutilization for Crop Production and Soil Conservation

The decision to rank 'resource conservation' in the first place leads to the necessity to design properly some technique of land use which is different from the common land disposal. Although to return waste into the natural cycle of transformations by land treatment means final waste disposal at the same time, both, land disposal and land treatment, must be considered as alternatives. The design and operation of facilities classed as land treatment recognize and accommodate both the qualities of the natural conditions of the site and the qualities of the applied waste which are utilized to produce crops. This often requires some pretreatment and considerable capital investment.

Solid waste consists of organic and inorganic materials, of biodegradables and nonbiodegradables or noncompostables. Removal of some of the latter is often necessary in order to upgrade the quality of the compost. Furthermore, to ensure a sufficiently rapid, and hence economic processing time, particle size reduction is being done, and also separation by handpicking, screening, some kind of classifying, and magnetic separators, adjusted to the technology of composting in windrows or in a digester, in a bin, tank or drum.

Wastewater destined to provide fertilizer and irrigation for the production of food and the restoration of greenery require a pretreatment excluding constituents which are toxic to crops or present a health hazard to man or animal. It is important to distinguish between disposal and reutilization; designers of land treatment systems have different purposes in mind: the goal of maximum disposal may be mutually exclusive with the goal of maximum reutilization.

An example is given in (12): At Seabrook Farms, New Jersey, U.S.A., a food processing plant must handle 45 000 m^3 wastewater per day on 80 ha (20,5 m per year). Because of the fortuitous soil and climatic conditions this can be done by spraying the daily output directly onto 34 ha of land (132 mm per application). This procedure does not achieve the maximum irrigation potential, but it does accomplish the design goal of disposing of 45 000 m^3 without polluting the local watercourses.

On the other hand, the municipal facility at Muskegon, Michigan, U.S.A., is designed to handle 163 000 m^3 per day. To produce some economic benefit for the county it serves, 4 000 ha of relatively infertile land are selected for spray irrigation to stimulate crop production and agriculture (1,5 m per year in height).

Another example can be given with a still farther decreased load: The Sewage Utilization Association of Braunschweig, Germany (F.R.), handles about 33 000 m^3 per day by spray irrigation upon 4 000 ha of cropland, an area of the same size as at Muskegon, but the load of 300 mm per year is only one fifth. It corresponds with the average water deficit in the main growing period from spring to fall at this site.

Use of Composts from Solid Waste: Criteria of Quality.

Municipal refuse compost is used in all areas of crop growing and soil melioration, that is, in crop farming and in grassland farming, in horticulture, floriculture, and in vegetable growing, in fruitculture, viticulture, and in tree-nursery, as well as in forestry, in reforestation areas, land reclamation, and the various fields of landscaping.

An outstanding example for compost production and compost use is given by the Netherlands already over a long period of years (The Netherlands also rank first in the world in the rate of mineral fertilizer consumption). Table 1 gives a survey of the compost production in this country from 1959 to 1971; it shows also the main areas of compost use and the change of their shares (14).

Table 1. Change in Compost Use in Holland

(VAM, Amsterdam)

Area of Use	1959	1963	1967	1971
		per cent		
Crop and grassland	48	22	9	0
Chicken and pig husbandry	2	1	2	4
Fruit culture, vegetables, flower bulbs	25	47	40	16
Forests	3	0	0	0
Landscaping, Recreation areas	22	30	49	80
Total production, t	194.300	205.600	182.700	
VAM-production, t		154.600	162.800	138.550

Of course, what the different crops and trees, flowers and vegetable, etc. need for best growth, cannot be supplied with the same compost. While the variability of crop needs is great, the same is the case with the composition from one compost to another, due to differences in type or combinations of types of material being composted. Thus, if necessary the compost can be adjusted or fortified by additives or special fertilizing material according to special demands of crops (7).

The three most important requirements concerning compost quality are:

1. an absence of substances that are injurious to man, crop or soil;
2. a high content of organic matter and plant nutrients;
3. a low content of useless substances like stones, slags, fragments, plastics, etc.

Additional sorting and sieving are necessary to lower the content of useless substances, thus increasing costs in producing special grades of compost. Therefore it is commendable to make cost saving gradations according to the purpose of application. For instance, quality demands are less for waste land reclamation and reforestation areas than for woodland areas; they are higher for viticulture and fruitculture, still higher for agriculture, and the highest for vegetable growing in gardens and for pasture farming.

Several quality and price gradations could be considered, i.e., for inexpensively produced compost to be used on wasteland that is being reforested, and for better grades of compost, free of glass and metal splinters, that may be used on pastures and in gardens.

Furthermore, different gradations are produced according to the particular processes of composting used. The first product might be shredded or ground refuse, 'raw compost', with a high content of easily decomposable organic matter, beneficial for mulching purposes. After treatment in a digester for a few days, this product might be called 'fresh compost'. Usually, the hygiene test shows that this product is already free of pathogenic organisms. Storing fresh compost in windrows is for a long period accompanied by organic matter breakdown. Heat energy usually accumulates, the temperature of the mass is high until the readily decomposable material has been broken down. At that point bacterial activity begins to decline, and the temperature drops correspondingly (7). The product is called 'rotted compost'.

Raw compost, fresh compost and rotted compost are gradations according to the process of decomposition. More variation is caused by the type of material being composted. This shows already that a general standardization of compost according to the contents of physiologically efficient ingredients is impossible. Furthermore, living conditions and habits in a community are changing permanently, the composition of waste correspondingly. Figure 1 is an example for this, demonstrating the steady increase of organic matter in fresh compost after treatment in a Dano drum and in rotted compost after storing in windrows at Bad Kreuznach from 1959 to 1973.

Evaluation as a Fertilizer

A comparison of stable manure and municipal compost in table 2 shows a low content of plant available nutrients in the compost. In order to achieve high crop yields, compost applications must be completed by quick-acting fertilizers. The contents of trace elements in compost (i.e. Cu, Zn, Mn, Mo, B) is ten to a hundred times higher than in stable manure; thus the application of very great quantities of compost could be injurious to crop growth (8).

Table 2. Comparison of Stable Manure and Municipal Compost

(H. Kick, 1971)

	Manure (kg in 10 t)	Compost (kg in 10 t)
Yield effective in the first year:		
N	15 – 20	8 – 10
P_2O_5	15 – 20	10
K_2O	60 – 70	30 – 40
Alkalinity (CaO)	60	500 – 1 000
Organic Matter	1 800	900 – 1 500
Total:		
MgO	10 – 20	40 – 50
Na_2O	20	40 – 50
S	20 – 30	50 – 300
Cu	0.02	0.8 – 1.2
Zn	0.12	8 – 12
Mn	0.4	4 – 6
Mo	0.001	0.1
B	0.03 – 0.04	0.6 – 3.6

Table 3 demonstrates how the yield increase by compost depends on the general yield level that is given by the natural fertility level of the soil or by the use of fertilizer. A high yield increase of 23 to 26 % was brought by compost on the lowest yield level which was affected by lack of nitrogen and lack of phosphorus. With both these nutrients added as quick-acting fertilizers, the relative amount of yield increase by compost reduced to only 4 %.

Table 3. Yield Increase by Municipal Compost

average of 1959 to 1973 potatoes, rye, oats dry matter
five compost applications total 480 t/ha

No Compost dt/ha. year	Rotted Compost	Fresh Compost
	relative values	
No P fertilizer:		
No N fertilizer 37.9 = 100	123	126
With N fertilizer 59.7 = 100	106	109
With P fertilizer:		
No N fertilizer 42.5 = 100	114	118
With N fertilizer 61.7 = 100	104	104
Rotted compost 6 to 9 months	Fresh compost 1 week	

This example of a compost fertilizer investigation over a period of 15 years demonstrates that municipal refuse compost has a low fertilizer value in areas with a high yield level.

Evaluation as a Soil Conditioner

Use of compost in the sense of good humus husbandry effects crop growth and yield indirectly by soil conservation and soil improvement. Compost promotes soil aggregation and stabilizes soil structure. This improves the air-water relationship of soil, thus increasing the water retention capacity and encouraging more extensive development of root systems of plants (7). Figure 3 is an example of the long lasting effect of compost application on the water holding capacity. The differences shown in the figure were caused by a single compost application; they are of great importance in the experiment area that has an annual rainfall of less than twenty inches (1).

Improved soil structure counteracts soil erosion. Figure 2 shows the soil conservation effect of compost in a vineyard with plots arranged for measuring erosion and run-off during a short but heavy rain. The compost applied to one plot in a great quantity twelve months before the storm almost completely prevented any run-off (2, 10).

Land Application of Wastewater

Municipal wastewater contains suspended and dissolved solids, organic and inorganic substances. In purification processes by primary and secondary treatment, mechanical and biological, these substances can be removed only in part. After secondary treatment, a community's waste water may still contain levels of pollution which are damaging to the receiving stream. To meet this problem, methods of advanced waste water treatment are available. They are regarded as tertiary additions to the secondary treatment facilities.

Land treatment of wastewater is also classed as an advanced wastewater treatment method with an extremely high effectiveness in purification. If properly designed and operated according to present knowledge and technology, land treatment is regarded as one of the most innovative techniques available for wastewater treatment (12).

Wastewater applied to cropland is not only purified, its ingredients are utilized. Plant growth as a biological medium of treatment may be regarded as a significant element in controlled land treatment facilities of long lasting efficiency.

Some systems provide primary or secondary treatment prior to application to the land. This pretreatment is provided, not out of consideration for the limits of the soil and plant filter, but as a consequence of legally mandated wastewater treatment (12).

Municipal wastewater characteristics are listed in table 4, for untreated sewage and also for water as applied to land, according to a recent investigation (11). Evidently, the pretreatment removed some organic substances and reduced the values for BOD and COD.

Table 4. Municipal Wastewater Characteristics

(Ch.E. Pound; R.W. Crites; R.E. Thomas, 1973)

Constituent	mg/L Untreated Sewage	mg/L Actual quality applied to land
Total solids	700	760 - 1 200
BOD	200	10 - 42
COD	500	30 - 80
N	40	10 - 60
P	10	10 - 25
B		0 - 1.0
Na		190 - 250
K		10 - 40
Ca		20 - 120
Mg		10 - 50

Climate, Soil, Groundwater

When the decision is made to utilize wastewater by land application for crop production, a few dominating criteria determine the details of site selection, design and, later on, the operation.

Wastewater is above all a source of water supply. Where there is no need for water, no success in crop production will be achieved by wastewater land treatment. The growth promoting substances in the wastewater can reach their maximum efficiency only accordant with a beneficial effect of an additional water supply. The climatic water balance, the difference between precipitation and evaporation, gives a hold for the estimation of the average need of a water supply in addition to natural rainfall, Figure 6. Arrangements have to be made for humid and cold periods to store the wastewater, i.e. in lagoons.

Soil is another important factor in wastewater land treatment. Properties of infiltration and percolation must be thoroughly surveyed to prevent soil clogging by wrong wastewater application techniques.

Attention must be paid to the depth of the groundwater table. Wastewater land treatment with the primary goal of crop production is expected to utilize the applied water and its ingredients entirely by the crop. There is at least in the beginning no idea of groundwater recharging. Wells and drains can be employed to insure that the groundwater level remains constant below an underground drainage system which prevents that the applied wastewater percolates down to the water table. Monitoring of treated effluent is possible to insure quality standards.

Rates and Methods of Application

Each proposed land treatment facility is approached as a unique combination of natural systems, to be evaluated in connection with the goals of the wastewater processor. A thorough survey of soil, climate, hydrology, and the vegetative cover must be taken. Different land application approaches are possible, the three most important are irrigation, overland flow, and infiltration-percolation (11). Figure 4 illustrates the differences with regard to the goals of the wastewater treatment, Figure 5 shows which soil type is the best for the different land application approaches, and in table 5 characteristics of the three approaches are listed for comparison (11). 'Irrigation', spray or surface, is the only approach which is 'excellent' adjusted to crop production. In comparison with the other methods, 'irrigation' admits the smallest application rate, needs the largest area, claims a soil of good productivity, excludes not the probability of influencing the groundwater quality with an annual application rate of 2 to 8 ft and a depth to the groundwater table of about 5 ft.

Table 5. Comparative Characteristics of Wastewater Land Application Approaches

(R.E. Thomas; C.C. Harlin, 1972)

Factor	Irrigation	Overland Flow	Infiltration-Percolation
Annual application	2 to 8 ft	8 to 24 ft	18 to 500 ft
Land required for 1-mgd flow	140 to 560 acres plus buffer zones	46 to 140 acres plus buffer zones	2 to 62 acres plus buffer zones
Application techniques	Spray or surface	Usually spray	Usually surface
Soils	Moderately permeable with good productivity	Slowly permeable clay loams and clay	Rapidly permeable sands and sandy loams
Probability of influencing groundwater quality	Moderate	Slight	Certain
Needed depth to groundwater	About 5 ft	Undetermined	About 15 ft
Use to grow crops	Excellent	Fair	Poor
Use in cold climates	Fair	-	Excellent

Use of Sewage Sludge

The normal purpose of a sewage treatment plant is to accept the collected and in sewers transmissed wastewater, to purify it, and to dump it into waterways already burdened by other waste disposal facilities (12). The higher the purification efficiency of the treatment procedure, the greater is the mass and volume of retained sludge to be handled and removed for final disposal. There are many procedures available for intermediary treatment to change the mass or volume of the sludge, but there are only two alternatives for the ultimate removal - land or ocean dumping or delivery to agriculture for spreading onto cropland, Figure 14 (9). (Pyrolysis may become the third alternative, although requiring the use of substantial quantities of auxiliary fuels (4)).

Evaluation as a Fertilizer

Sludge is used on cropland in a liquid or sticky or crumbly state, the liquid is the most popular form today. The manuring effect of sewage sludge is good, but different from that of rotted animal manure. The latter is nearly 'foolproof'; the nutrients are in a good balance, and in the soil their availability to plant nutrition proceeds slowly, according to the progress of decomposition and transformation. In sewage sludge, the ratio of nutrients is unbalanced, and the variation is great, Figure 7. There is usually a deficiency in potassium, and a greater portion from the total nitrogen content is at once available, table 6. However, the yield efficiency of sludge nitrogen is still less than that of nitrogen in ammonium nitrate, Figure 9. These differences from stable manure and inorganic fertilizer must be taken into consideration in order to reach maximum effects. Balancing the ratio of nutrients in sludge and corresponding to additional nitrogen fertilizer application by potassium increases the crop yield very distinctly, that means more complete uptake and better utilization of the applied nutrients, thus decreasing a possible pollution potential in run-off or leachate (Figure 10 to 12, and 8).

Table 6. Municipal Sewage Sludge Characteristics

As an example: City of Peine, activated sludge, 69 samples 1971 to 1973

Constituent	kg in 10 mm = 100 m^3/ha
Total solids	4 100
Ignition loss	2 100
N	210
P	60
K	13
Na	11
Ca	200
Mg	15
Fe	120
Cu	1,4
Pb	0,1
Ni	0,6
Zn	5,1

High-rate Application by Sheet Composting

The application of sludge in amounts which surpass the nutritive demand of the crop means enriching the soil with nutrients and raising the fertility level, usually with a lasting effect on crop yield increase.

Such a procedure is possible only without damage to the crop and without unwelcome groundwater contamination. By applying small amounts of sludge at short intervals, adjusted to sludge water infiltration and evaporation, combined with a mixing and aerating soil cultivation so that moisture and air are kept in good balance makes high-rate sludge application feasible.

In a field experiment on loamy sand, 10, 93 and 366 mm of municipal sludge were sprayed in 10 mm rates over several months. Ten mm sludge influenced the nitrogen content of soil, soil water and crop (kale and sugar beet) only in a very small scale; 366 mm sludge increased the ammonia content in the upper soil layer for three months. Soil water collected by suction cells in the depths of 1 and 2 m was enriched with nitrate up to 600 ppm for a long period of observation. Thus sludge application in great amounts must be restricted on sites with a great depth of the groundwater table and a slowly permeable soil (5).

Predominantly Toxic Compounds

Solid and liquid municipal waste contain not only essential or useful plant nutrients, but also always toxic or noxious compounds. When waste is delivered to farmers for the use on cropland, it should be regarded as an inevitable condition that the waste is unobjectionable for crop production. That means that the contents of toxic and noxious compounds must be very low in comparison to the essential nutrients. Limitations of application rates should only be possible by high concentrations of nutrients, never by high concentrations of predominant toxic or noxious compounds.

The most important sources for these unwelcome substances are industrial waste and waste-water. If it is impossible to exclude these wastes from the public collection and from being mixed with harmless municipal waste, special attention must be given to those pre-treated wastes which are delivered for land application and crop production. Reliable analyses are necessary in order to calculate the admissable application rate.

Crops are no good indicators for the presence of higher amounts of predominantly toxic substances. Evidently, with regard to growth and yield, crops are more tolerant than a low level in the food chain would permit.

Knowledge of those substances in waste which are not nutrients, about their behaviour in soil is still incomplete. Most of them, especially heavy metals, are found to accumulate in the upper layer of the soil (6). Thus no groundwater contamination will occur, but the continuing enrichment in the root zone must be controlled. We do not know enough about the crop damaging level under different soil conditions, thus the list of 'Tolerable Amounts' must be accepted preliminarily as a proposal, table 7 (3).

Table 7. Tolerable Amounts of Some Elements in Soils with Regard to their Plant Compatibility

	Total amounts ppm		
	Range	Most frequent	Tolerable (proposal)
Be (a)	0.1 - 10	1 - 5	10
Bo	2 - 100	5 - 30	100
F	10 - 500	50 - 250	500
Cr	1 - 100	10 - 50	100
Ni	1 - 100	10 - 50	100
Co	1 - 50	1 - 10	50
Cu	2 - 100	5 - 20	100
Zn	10 - 300	10 - 50	300
As	1 - 50	2 - 20	50
Se	0.1 - 10	1 - 5	10
Mo	0.2 - 10	1 - 5	10
Cd (a)	0.01 - 1	0.1 - 1	5
Hg (a)	0.01 - 1	0.1 - 1	5
Pb	0.1 - 10	0.1 - 5	100

(a) special reservation

Health Considerations

Sewage and sewage sludge, and also compost from solid waste treated together with sludge, are usually regarded as potentially hazardous to human health or living organisms if the treatment was insufficient. According to Figure 14, there are many treatment steps available for sludge, but only two alternatives for the final removal - dumping or spreading onto farmland. While many treatment steps deliver still a hazardous product, special considerations are necessary about admissable and inadmissable sludge application to cropland, Figure 13 (15). Sanitary regulations inform how to apply the different kinds of sludges, i.e. upon cropland or grassland, in vineyards or orchards, in nurseries or gardens, in the growth period or in winter.

Composts from solid waste mixed with sewage sludge are unobjectionable, if the composting operations are well managed. The major factors in the destruction of pathogenic organisms in the compost process are heat and antibiotic reactions (7).

The effectiveness of land treatment in removing contaminators from wastewater is regarded high. Data indicate nearly complete removal of BOD, pathogenic bacteria, viruses, phosphorus. High levels of removal are effected for nitrogen, sulfates, chlorinated hydrocarbon pesticides. Land treatment offers a safer means of treating wastewater than any other general method now available (12).

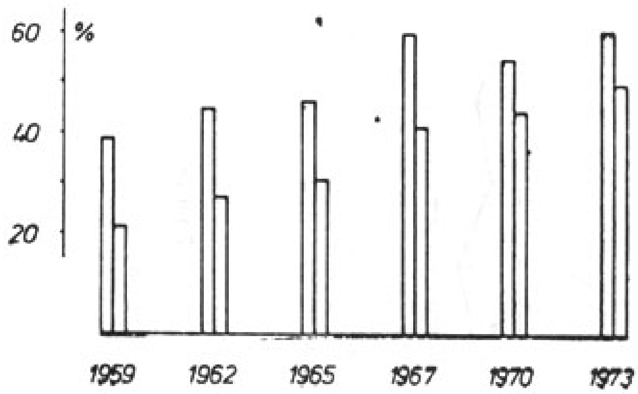


Figure 1

Organic Matter Content in Municipal Refuse Compost (% in dry matter) Bad Kreuznach 1959-1973
Fresh Compost (1 week): Left Column
Rotted Compost (6-9 months) Right Column

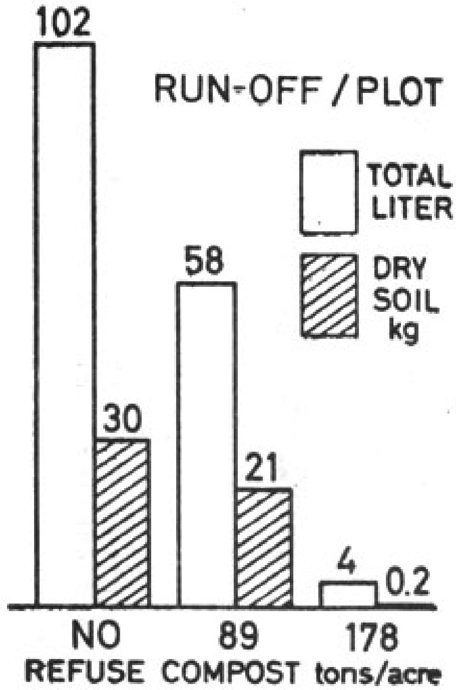


Figure 2

Decrease of Soil Erosion in a Vineyard by Compost (Slope 58%, Plot 24 m^2)

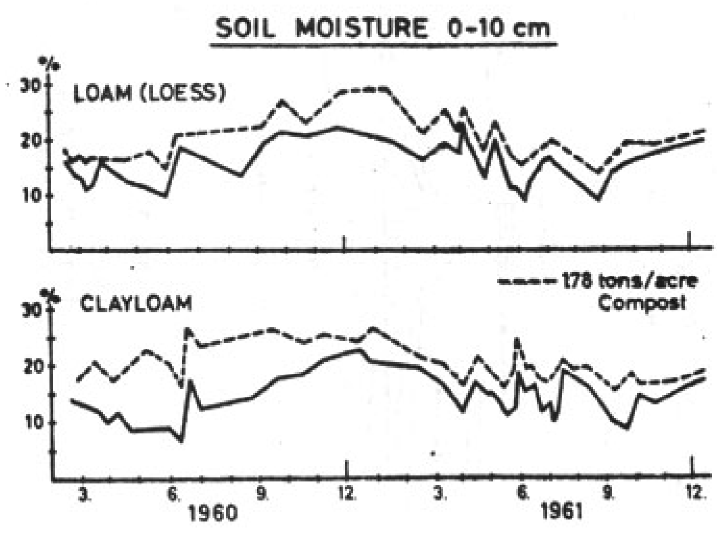
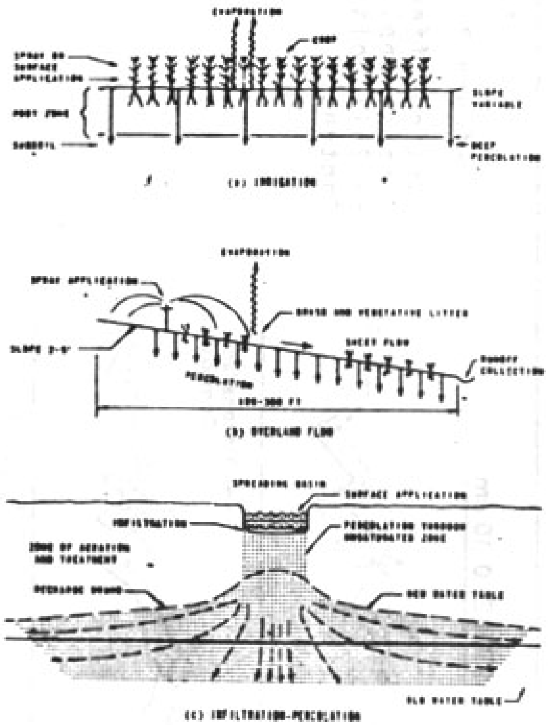
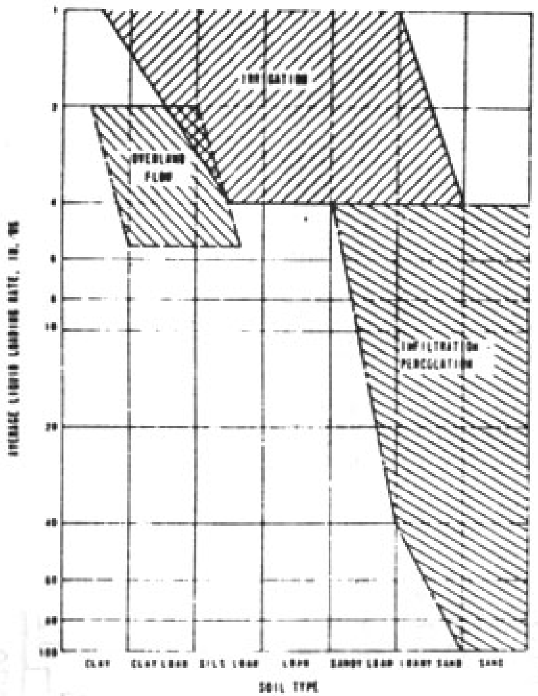


Figure 3

Lasting Effect of Compost Application on Soil Moisture Content



LAND APPLICATION APPROACHES



SOIL TYPE VERSUS LIQUID LOADING RATES
FOR DIFFERENT LAND APPLICATION APPROACHES

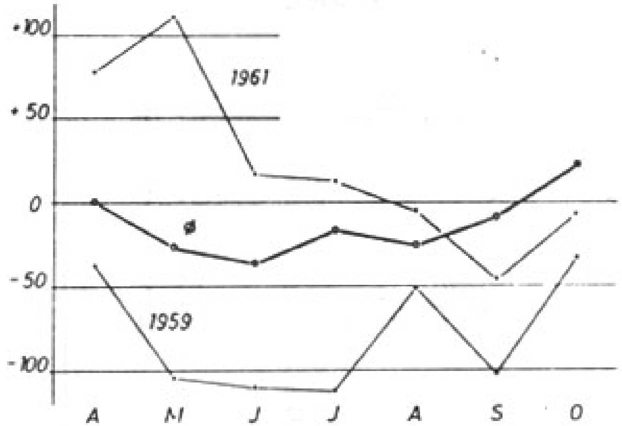


Figure 4

(Ref.: Ch.E. Pound; R.W. Crites; R.E. Thomas: Wastewater Treatment and Reuse by Land Application. - U.S. Environmental Protection Agency, 1973)

Figure 5

Figure 6

Climatic Water Balance at the Site of the Sewage Utilization Association of Braunschweig

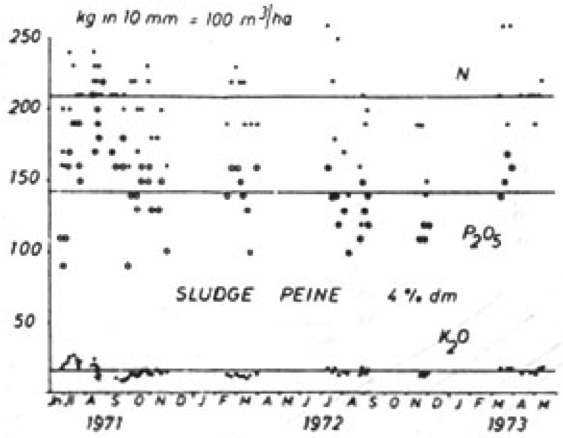


Figure 7

Variation of Plant Nutrient Contents in Sewage Sludge of the City of Peine over 2 Years

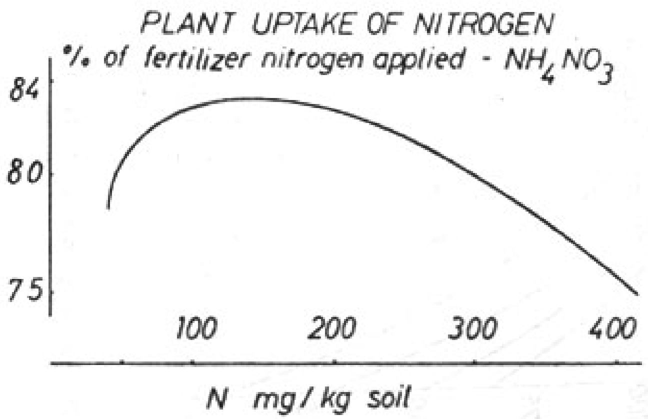


Figure 8

Uptake of Nitrogen by Oats (Grain + Straw) Pot Experiments Average of 11 Years

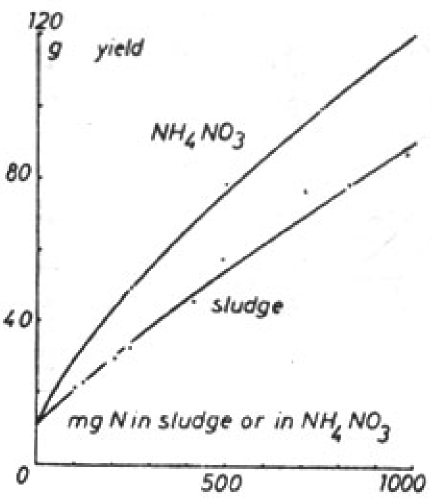


Figure 9

Yield Effect of Nitrgen in Sewage Sludge and in NH_4NO_3 Pot Experiment with Oats

Figure 10

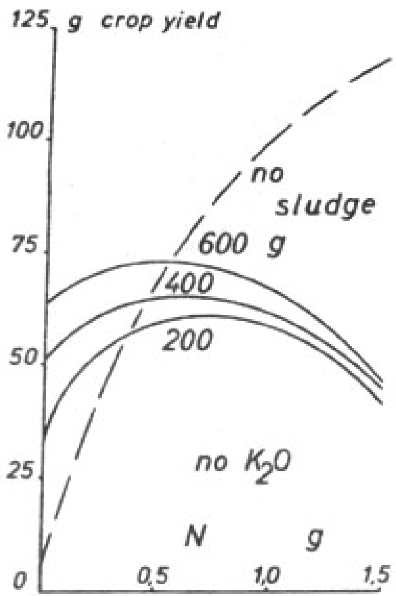


Figure 11

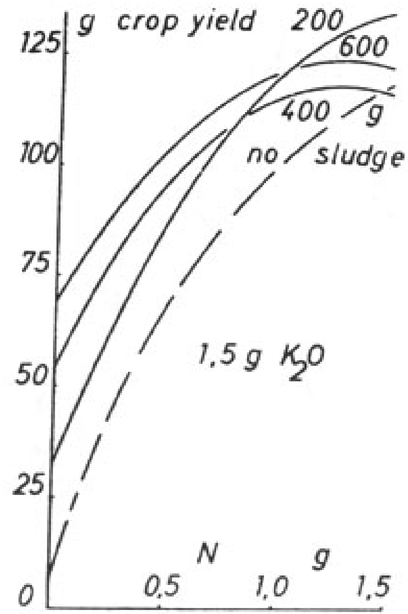


Figure 12

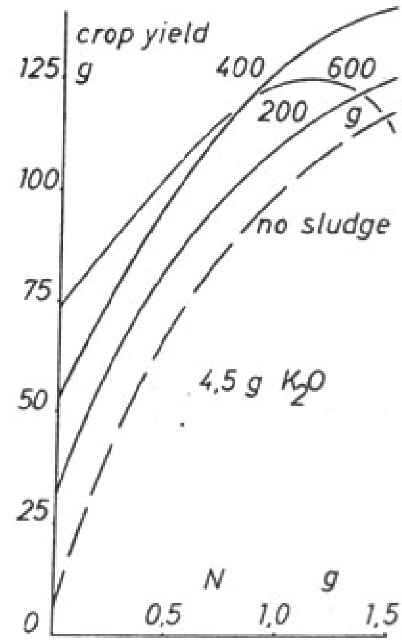


Figure 10 to 12: Potassium Effect on Balancing and Utilizing of Nutrients in Sewage Sludge

		Reserve area	Crop land No GS	Crop land GS	Grass land Forage crop No GS	Grass land Forage crop GS	Vineyard No GS	Orchard no filler No GS	Nursery	Garden Vegetable land
Raw sludge	h	*	-	-	-	-	-	-	-	-
Sludge from premises treatment plants and earth basins	h	*	*	-	-	-	-	-	*	-
Liquid / drained / natural / dried } anaerobically or aerobically stabilized sludge	h h h	*	*	-	*	-	*	*	*	-
Chemically / by heat } conditioned sludge	h									
Artificially dried sludge pasteurized sludge (raw, stabilized, chem. cond.) composted sludge		*	*		*		*	*	*	*

h = hazardous * admissible - inadmissible GS growth season

Figure 13
Admissable and Inadmissable Sludge Application to Cropland

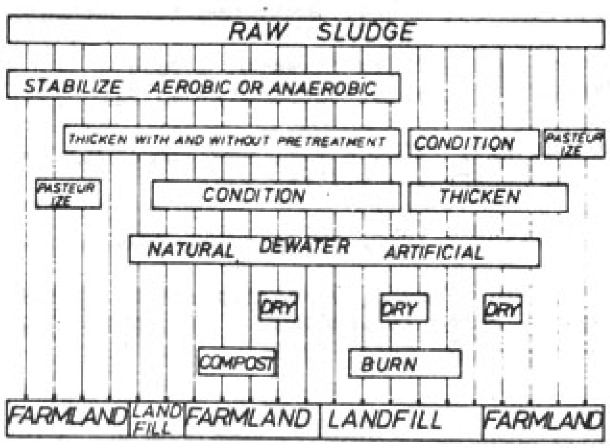


Figure 14
Scheme of Sludge Treatment Procedures

LITERATURE

(1) Banse, H.J.: Beeinflussung der physikalischen Bodeneigenschaften durch Kompostgaben. - Informationsblatt der IAM Nr. 13, 1961

(2) Bosse, I.: Erosionsbekämpfung durch Müllkompost. - Garten und Landschaft 8, 1969

(3) Bundesgesundheitsamt, Institut für Wasser-, Boden- und Lufthygiene: Fachliche Unterlagen für Rechtsverordnung nach § 15, Abfallgesetz, 1974

(4) Colonna, R.A., C.McLaren: Decision-Makers Guide in Solid Waste Management. - U.S. Environmental Protection Agency, 1974

(5) El-Bassam, N., C. Tietjen, F. Mertens: Nitrat-, Nitrit- und Ammoniak-N im Boden und Bodenwasser sowie Aufnahme durch Markstammkohl und Zuckerrüben bei Zufuhr hoher Klärschlammgaben. - Landwirtsch. Forschung 30/II, 1974

(6) El-Bassam, N., P. Poelstra, M.J. Frissel: Chrom und Quecksilber in einem seit 80 Jahren mit städtischem Abwasser berieselten Boden. - Z. Pflanzenernähr., Bodenkunde, im Druck

(7) Golueke, C.G.: Composting. - Rodale Press, Inc., Emmaus, Pa., 1973

(8) Kick, H.: Die Anwendung von Müllkomposten und Müllklärschlammkomposten in der Landwirtschaft. - Hdb. Müll- und Abfallbeseitigung, Kumpf, Maas, Straub, 6710, 1971

(9) Möller, U.: Schlammbehandlungs- und Beseitigungsanlagen. - Techn. Mitteil. 9, 65, 1972

(10) Peyer, E.: Versuch zur Verhütung von Schwemmschäden im Rebbau und deren Messung. - Schweiz. Z. Obst- und Weinbau 1958

(11) Pound, E.Ch., R.W. Crites, R.E. Thomas: Wastewater Treatment and Reuse by Land Application. - U.S. Environmental Protection Agency, 1973

(12) Stevens, R.M.: Green Land - Clean Streams. - Centre for the Study of Federalism, Temple University, Philadelphia, Pa., 1972

(13) The Solid Waste Disposal Act, 1970. - U.S. Environmental Protection Agency, Solid Waste Management Office, 1971

(14) VAM. Amsterdam: Mededelingen 1960, 1964, 1968, 1972

(15) Zentralstelle für Abfallbeseitigung, Umweltbundesamt: Merkblatt 7, Verwertung von Klärschlämmen im Landbau. - Hdb. Müll- und Abfallbeseitigung, Kumpf, Maas, Straub, 6854, 1972.

13. CHEMICAL AND BIOLOGICAL CONSIDERATIONS FOR LAND APPLICATION OF AGRICULTURAL AND MUNICIPAL WASTES

by

J.F. Parr[1]

Introduction

Concepts and considerations for land spreading of organic wastes have changed dramatically in recent years. Where animal wastes have been traditionally applied at rates ranging from 5 to 10 tons per acre, these and other materials, including sewage sludges and processing wastes are now often applied at rates 10 to 50 times higher. The actual rate of application would depend on the specific objectives involved; i.e., (i) whether to utilize the wastes for their plant nutrients in crop production or (ii) to use the land only as a disposal site. Rapid decomposition of organic wastes and mineralization of their organic nitrogen by the soil microflora depend on an adequate supply of molecular oxygen. However, the high biochemical oxygen demand (BOD[2]) of many wastes, high loading rates, and the mode of application often create anaerobic environments which lead to significant changes in microbial metabolism. The chemical nature of the end products of microbial metabolism under anaerobiosis is quite different than that found in a highly aerobic or oxidized system. Excessive loading rates can result in a period of extended anaerobiosis and the production of toxic metabolites in sufficient concentration to inhibit seed germination and retard plant growth for some time, even after aerobic conditions are resumed.

In view of the present world energy crisis and the resulting increased costs and deficits of nitrogen fertilizers, the proper utilization of agricultural and municipal wastes as sources of crop nutrients, particularly N, has become one of our most urgent research priorities. If such wastes are to be properly utilized their immediate and long-term effects on certain chemical and biological processes in soil must be considered.

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[1]Microbiologist, Agricultural Research Service, U.S. Department of Agriculture, Baton Rouge, Louisiana.

[2]Biochemical oxygen demand is the oxygen consumed by microorganisms in the process of decomposing organic wastes under standard conditions and during a specific period of incubation. It is expressed in terms of mg O_2/liter or ppm and is an indication of the readily oxidizable materials present.

FACTORS AFFECTING THE RATE AND EXTENT OF DECOMPOSITION OF CROP RESIDUES AND ORGANIC WASTES IN SOIL

A number of factors can affect the decomposition of various organic substrates when applied to soil. These can be grouped into substrate factors and soil factors. Substrate factors would include (a) chemical composition, (b) C:N ratio, (c) lignin content, (d) particle size or state of subdivision, (e) nature of the indigenous microflora, and (f) BOD. Soil factors would include (a) temperature, (b) oxygen supply, (c) moisture, (d) pH, (e) available nutrients (N, P, K, S), and (f) soil texture and structure. The rate of decomposition of a waste or residue will depend primarily on its chemical composition, and on the chemical and physical properties of the soil which determine the nature of the environment for microbial growth and metabolism. The exact physico-chemical nature of this environment will determine the specific types and numbers of soil microorganisms available to decompose the substrate. It should be recognized that those factors which have the greatest effect on microbial growth and metabolism will have the greatest potential for altering the rate and extent of substrate decomposition in soil.

A brief discussion of just how some of these factors can affect residue or substrate decomposition follows:

a. The C:N Ratio -- Because crop residues contain about the same amount of carbon (40% on a dry weight basis), their N contents are often compared on the basis of C:N ratios. Thus, a low N content or wide C:N ratio is associated with slow decomposition. Although the N content or C:N ratio of crop residues or other organic wastes can be useful in predicting decomposition rates, they should be used with some caution since the C:N ratio says nothing about the microbial availability of the carbon or nitrogen.

b. Lignin Content -- The rate of decomposition of crop residues and some animal wastes is often proportional to their lignin content. Wastes having a high lignin content decompose more slowly than those containing a small amount of lignin. Some researchers have suggested that the lignin content of some wastes may be a more reliable parameter for predicting the rate of decomposition than the C:N ratio.

c. Temperature -- Changes in temperature can alter the species composition of the soil microflora. Different organisms have different temperature optima for maximum growth and activity. Maximum decomposition rates for residues and wastes in soil are generally obtained in the range 30° to 35°C.

d. O_2 Supply -- Maximum decomposition rates are dependent upon an adequate supply of molecular O_2. While many soil bacteria can grow under anaerobic conditions, though less actively, most fungi and actinomycetes do not grow at all. Thus, residues decompose more slowly and are subject to incomplete oxidation under conditions of soil anaerobiosis.

e. Soil Moisture Content -- Soil microorganisms are affected differently depending on the moisture regime, which may greatly influence the rate and extent of residue decomposition. For example, maximum bacterial growth and activity occurs in soils at high water potentials (wet soils), but is noticeably decreased at about -3 bars (drier soils) and markedly so at -15 bars (very dry soils; i.e., the wilting point). However, fungi tend to grow and survive in soils at much lower water potentials (dry soils) where bacteria are less active. In wet soils where bacteria tend to flourish, fungal growth is often suppressed because of the greater competitive and antagonistic advantage of bacteria under these conditions.

f. Soil pH -- While different types of soil microorganisms have different pH optima for maximum growth, the optimum pH range for rapid decomposition of wastes and residues is 6.5 to 8.5. Bacteria and actinomycetes have pH optima near neutrality and do not compete effectively for nutrients under acidic conditions, which would explain why soil fungi often become dominant at lower pH values.

CHEMICAL COMPOSITION AND NITROGEN RELATIONSHIPS

Most of the waste and residue materials applied to soil consist of a water-soluble fraction and a water-insoluble fraction with vastly different rates of decomposition. The water-soluble fraction is comprised of sugars, starches, organic acids, pectins, tannins, and some protein, which are subject to early, rapid utilization as carbon and energy sources by the soil microflora. At a less rapid rate, compounds in the water-insoluble fraction consisting of hemicellulose, cellulose, fats, waxes, resins, and oils would be utilized. Lignin, the constituent least susceptible to degradation would tend to persist and accumulate in the soil organic matter or humus.

During decomposition of wastes and residues low in N, the C:N ratio tends to decrease with time. For example, the C:N ratio of undecomposed corn stalks is about 50:1, but after 6 to 8 months this residue would approach a C:N ratio similar to that reported for most native soil organic matter; i.e., about 10:1 or 12:1. The decrease in the C:N ratio results from the net loss of carbon as CO_2 during decomposition, while most of the N (including available inorganic soil N) is quickly assimilated and immobilized in microbial cellular material until the C:N ratio is sufficiently narrowed. Thus, the percentage of N in residual plant material steadily increases as decomposition proceeds (Fig. 1).

The total N content of some characteristic organic wastes and residues is shown in Table 1. Those materials which contain more than 1.5% N would ordinarily need no supplemental fertilizer N or soil N to meet the demands of soil microorganisms during decomposition. Although there is some variation, depending on the chemical composition of a particular waste and the rate of decomposition, the 1.5% figure is a guideline which is generally accepted. Since the N content of most mature crop residues, some cattle feedlot manures, municipal waste composts, some paper mill sludges, and most cannery wastes are considerably less than 1.5%, there is immediate concern that their application to soil could induce an N deficit during decomposition, leading to microbiological immobilization of inorganic soil N for extended periods. The addition of supplemental inorganic fertilizer N in such cases will actually accelerate the rate of residue decomposition. Ultimately, however, after 6 months or a year, there would be little difference in the extent of decomposition whether N is added or not (Fig.2). The total residual carbon which enters the humus fraction would be about the same, with or without N. Thus, supplemental inorganic N can be added to some wastes and residues of low N content to accelerate their decomposition or, in the case of some crop residues, to ensure against any deficiency of soil N if another crop is soon to be planted.

On the other hand, wastes such as poultry manure and sewage sludges contain much higher levels of N and would be expected to release inorganic N, probably as ammonia, soon after application to soil. The single most important consideration which may limit the loading rates for land spreading of these wastes is their high N content. Excessive loading rates (>50 tons of dry waste/acre) of these wastes on land could soon result in the pollution of surface and ground waters by nitrate-N, through runoff and leaching, respectively.

THE INDIGENOUS MICROFLORA OF WASTES AND BOD RELATIONSHIPS

It is often overlooked that most organic wastes and residues inherently contain populations of indigenous microorganisms including bacteria fungi, actinomycetes, and protozoa. For example, in fresh animal manures microbial cells and cells from the intestinal lining of the animal make up about 40% of the feces. A fresh cow manure slurry may contain 10^6 anaerobic bacteria, 10^5 coliform bacteria, 10^6 enterococci bacteria, and 10^5 fungi per ml of suspension. Coliform bacterial counts as high as 18 billion excreted per animal per day are not unusual. This, along with the high percentage of digestible materials involved,explains why animal manures are characterized by such high BOD values, which may run as high as 100,000 mg O_2/liter (i.e., ppm), respectively, in a fresh cow manure slurry of feces and urine. Animal wastes carried in runoff from feedlots are considerably lower in BOD, ranging from 100 to 10,000 mg O_2/liter, depending on the extent of dilution and degree of deterioration of the waste. Decomposition of animal manures during extended periods of storage results in the loss of carbon as CO_2, concentration of inorganic nutrients, loss of N as NH_3, and denitrification of nitrate and nitrite. This would explain why the N content of cow manure from some cattle feedlots is little more than 1% (Table 1).

Other wastes such as sewage sludge, cannery wastes, and green or mature crop residues are also known to have rather high indigenous populations of microorganisms. The exact role of these organisms in the decomposition of wastes and residues following application to soil is not known. Hopefully, this will be the subject of some future research investigations.

NUTRITIONAL REQUIREMENTS AND TYPES OF MICROBIAL METABOLISM WHICH INFLUENCE OXYGEN RELATIONSHIPS

The rate and extent of organic waste decomposition and the rapid reduction of BOD depend on a continuous supply of available oxygen. Diffusion of molecular O_2 into soils subjected to excessive loading rates is often impeded because of excess moisture associated with the waste or physical restrictions from heavy surface applications. Thus, conditions which exist in waterlogged soils are often similar to those where upland soils are amended with heavy loadings of high BOD wastes.

The development of more efficient and effective methods for spreading of organic wastes and residues on land depend on a clear understanding of the nutritional requirements and types of microbial metabolism which influence O_2 relationships, a brief discussion of which follows:

Aerobic respiration by soil microorganisms involves oxidation-reduction reactions in which molecular O_2 serves as the ultimate electron acceptor, while an organic substrate (i.e., the waste or residue) functions as the electron donor or energy source. If O_2 is available for active decomposition the system will be dominated by an array of different soil microorganisms, including bacteria, actinomycetes, and fungi.

Anaerobic respiration by soil microorganisms includes biological oxidation-reduction reactions in which inorganic compounds, rather than molecular O_2, serve as the ultimate electron acceptor. Here again, the organic waste or residue serves as the electron donor or energy source. Thus, if O_2 is depleted during active decomposition, as is often the case, the system will be dominated by facultative anaerobic bacteria. Most soil bacteria are in this category; that is, they can readily utilize molecular O_2 as an electron acceptor in aerobic respiration, but under anaerobiosis they are capable of utilizing nitrate (NO_3^-), manganic (Mn^{4+}), and ferric (Fe^{3+}) ions as electron acceptors, thereby reducing them to nitrite (NO_2^-), manganous (Mn^{2+}), and ferrous (Fe^{2+}), respectively. Under strict anaerobic conditions, obligate anaerobic bacteria of the genus *Desulfovibrio* utilize sulfate (SO_4^{2-}) as an electron acceptor, reducing it to sulfide (S^{2-}). These organisms are capable of utilizing organic acids as electron donors in this reduction. Most soil actinomycetes and fungi are obligate aerobes and would not be active under soil anaerobiosis.

Fermentation includes energy-yielding reactions performed by select groups of obligate and facultative anaerobic bacteria in which organic compounds serve as both electron donors and electron acceptors. Fermentation occurs mainly in anaerobic, substrate-amended soils, particularly under extremely reduced conditions. These reactions result in the accumulation of incompletely oxidized organic compounds, including an array of organic acids and alcohols. A special example of fermentation is performed by the *methane bacteria* which are obligate anaerobes capable of degrading organic acids to yield methane. This type of reaction might be expected to occur in soils amended with excessive loadings of high BOD wastes or in sanitary landfills.

SUCCESSION OF REDUCTIVE PROCESSES IN SOILS AMENDED WITH ORGANIC WASTES AND RESIDUES

There is great similarity in the events which occur in poorly drained or waterlogged soils compared with soils receiving heavy loadings of high BOD wastes. As the level of molecular O_2 steadily decreases during waste decomposition, the type of microbial metabolism changes successively according to the oxidation-reduction state (i.e., redox potential or Eh[3]) involved, ranging from aerobic respiration in the presence of molecular O_2 to methane fermentation under complete anaerobiosis. The succession of types of microbial metabolism occurring in a soil after waterlogging relative to the soil Eh (Table 2) is the same that is likely to occur when wastes are applied to soils at excessive loading rates.

Two stages are evident in the transition of microbial metabolism governing the reductive processes. During the first stage, which occurs early in the incubation period, oxidative decomposition of wastes and residues proceeds through the activity of aerobic and facultative anaerobic microorganisms. Carbon dioxide and NH_3 are evolved rapidly with little or no accumulation of incompletely oxidized organic compounds. Soon after waterlogging, or the application of excessive loadings of high BOD wastes, molecular O_2 disappears from the system and the Eh begins to decline. In fairly rapid succession nitrates disappear,

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[3]Eh is an expression of the electron density of a system. As a system becomes increasingly reduced there would be a corresponding increase in the electron density, resulting in a progressively increased negative potential.

mainly as a result of biological denitrification, and the formation of manganous (Mn^{2+}) and ferrous (Fe^{2+}) ions follows. During the first stage, Eh drops from +600 to about +100 millivolts (mV).

The second stage in the reduction process may occur somewhat later in the incubation period and is characterized by the reduction of sulfate (SO_4^{2-}) to sulfide (S^{2-}), which can result in the formation of H_2S. Sulfide formation is followed by the appearance of products of incomplete organic matter decomposition; i.e., organic acids, molecular hydrogen, and methane. Organic acids accumulated at this time soon disappear due to their utilization as electron donors and as a source of carbon by sulfate-reducing and methane-producing bacteria. The amount of molecular hydrogen produced varies greatly while the amount of sulfide and methane continues to increase as the Eh drops to -200 mV.

THE POSSIBLE CONSEQUENCES OF EXTENDED SOIL ANAEROBIOSIS FROM LAND SPREADING OF WASTES

The maximum amount of a particular waste or residue which can be applied to a soil without serious environmental consequences is not known. We do have, however, considerable information which suggests that when wastes are applied to land at more reasonable or acceptable loading rates (10 to 30 tons/acre of dry waste), as compared with excessive loading rates (>50 tons/acre), and providing the soils are well drained but not sandy, there have been few problems concerning nitrate runoff and leaching or subsequent impairment of the soil for crop production. Where researchers have attempted to establish maximum loading capacities for soils using loading rates often far in excess of 50 tons/acre, there is evidence of associated environmental problems, particularly that of excess nitrogen, although heavy metals are also of some concern in the case of sewage sludges.

The data in Table 2 provide a good indication of what we can expect when a soil is loaded beyond its capacity for sustained aerobic decomposition. Possibly a more helpful understanding of the consequences which can develop from excessive loadings of a high BOD waste compared with lower, acceptable loadings is shown in figure 3. With acceptable loadings, O_2 balance is maintained as rapid aerobic decomposition is ensured. Thus, the end products of decomposition are inorganic carbon, nitrogen, and sulfur compounds. However, with excessive loadings of wastes, rapid O_2 depletion occurs, and there is an equally rapid transition to a highly reduced anaerobic state where the rate and extent of decomposition is slowed considerably, and where undesirable chemical changes occur resulting in the production of obnoxiously odorous compounds (amines, mercaptans, and H_2S) and compounds having pronounced phytotoxic effects (NH_3 and H_2S). Depending on the extent of overloading, the soil may remain in an anaerobic condition for an extended period.

The relationship between loading rate and application frequency relative to the probable period of soil anaerobiosis is shown in figure 4, which illustrates the effects of frequent, successive applications of wastes at acceptable loading rates, compared with single slug applications at an excessive loading rate, on changes in the soil redox potential. Excessive loading rates of high BOD wastes often lead to a rapid depletion of O_2 and equally rapid decrease in soil Eh to an undesirably reduced state where it remains for a matter of months, after which a slow upward trend may occur. On the other hand, a proper balance of loading rate and application frequency can maintain the soil Eh within a more desirable range, where extensive reduction does not occur and where the likelihood of odorous and phytotoxic end products arising is minimal. While some downward deflection of Eh can be expected even with acceptable loading rates, the system will tend to recover rapidly because it has not been loaded excessively or beyond its limits. Thus, the cyclical Eh pattern allows successive and more frequent applications as the Eh moves back into the aerobic range.

In summary, most soils have a tremendous capacity to decompose organic wastes. The soil provides (i) a medium for dilution of waste concentrates, (ii) a highly important buffering system, and (iii) a potentially active microflora for rapid and sustained decomposition. Where wastes are applied at acceptable loading rates (10 to 30 tons/acre, dry weight basis), the problems associated with waste decomposition including extended anaerobiosis and undesirable end products are indeed minimal. However, soils do have some limits as to how much waste they can accomodate at any one time, and if loaded excessively (>50 tons/acre) there will be certain deleterious effects of rapid O_2 depletion, extended anaerobiosis, extensive reduction, and the accumulation of odorous and phytotoxic end products which could impair the soil for crop production for some time.

SPECIFIC GUIDELINES

1. The maximum amount of a waste or residue that a soil will accommodate for sustained aerobic decomposition without serious environmental hazard or impairment of the soil for crop production is not known.

2. There is considerable information which suggests that when wastes are applied to land at acceptable loading rates (10 to 30 tons/acre, dry weight basis), and providing the soils are well drained and not sandy, there are few problems concerning nitrate runoff and leaching.

3. Where researchers have attempted to establish maximum loading rates for the disposal of wastes (rather than utilization as a source of nutrients), problems of excess inorganic nitrogen have often occurred.

4. The single most important consideration in the land spreading of high BOD wastes is the N content. Approximately 50% of the total N (mainly organic N) contained in the waste will be mineralized during the first year; 25% the second year; and 12% the third year. Thus, environmental problems related to nitrate runoff and leaching are predictable based on the N content.

5. Excessive loading rates (>50 tons/acre for many soils) often lead to a sealing of the soil surface, thereby impeding O_2 movement into the profile. The result is rapid O_2 depletion and equally rapid lowering of Eh to an undesirable range where it may remain for extended periods.

6. In view of energy shortages for agriculture and increased costs as well as probable deficits of fertilizer N, research should be initiated which asks the question, "How much waste of a particular N content should be applied to land in conjunction with other N inputs and the N requirement of the crop?"

7. We must begin to think in terms of acceptable loading rates rather than maximum loading rates; that is, loading rates that are compatible with specific wastes, soils, management practices, and which consider the N content of the waste relative to the N requirements of the crop.

8. The mode or method of application of a waste or residue on land will directly influence its rate and extent of decomposition. Wastes that are soil incorporated would, under most conditions, decompose more rapidly than surface-applied or semi-incorporated wastes. However, there is some indication that some wastes (e.g., fresh animal manures) applied to soil in slug applications (i.e., in trenches or other localized placements) may actually decompose more rapidly than when thoroughly mixed with the soil. This rather unexpected phenomenon can probably be attributed to the nature and activity of the indigenous microflora associated with the waste. There is need for additional research in this particular area.

9. The rate and extent of decomposition of wastes and residues would be more rapid in neutral to alkaline soils than in very acid soils.

10. At a given loading rate high BOD wastes would tend to deplete the available soil O_2 and induce soil anaerobiosis more rapidly than low BOD wastes.

11. Poorly drained soils of a high clay content would undergo more rapid soil anaerobiosis from waste applications than lighter textured soils (i.e., sandy loams and silt loams) with good drainage. Extremely sandy soils would have a higher aeration potential but would be associated with nitrate leaching problems.

12. Loading rates and application frequencies may have to be balanced to maintain adequate soil O_2 levels for sustained aerobic decomposition and to prevent extensive and prolonged soil reduction.

REFERENCES

Alexander, M. 1961. Organic matter decomposition, Chapt. 9. *In* Soil microbiology, p. 139-162. John Wiley & Sons, Inc., New York.

International Symposium on "Livestock waste management and pollution abatement" held at Columbus, Ohio, April 19-22, 1971. Proceedings publ. by American Society of Agricultural Engineers, St. Joseph, Michigan, 360 p.

Mathers, A. C. and B. A. Stewart. 1970. Nitrogen transformations and plant growth as affected by applying large amounts of cattle feedlot wastes to soil. *In* Relationship of agriculture to soil and water pollution, p. 207-214. Cornell Univ. Conf. on Agr. Waste Mgmt. Proc., Rochester, New York.

McCalla, T. M., L. R. Frederick, and G. L. Palmer. 1970. Manure decomposition and fate of breakdown products in soil, Chapt. 17. *In* Agricultural practices and water quality, p. 241-255. T. L. Willrich and G. E. Smith [Eds.]. Iowa State University Press, Ames, Iowa.

McCalla, T. M. and F. A. Haskins. 1964. Phytotoxic substances from soil microorganisms and crop residues. Bacteriol. Rev. 28:181-207.

McKinney, R. E. 1970. Manure transformations and fate of decomposition products in water, Chapt. 18. *In* Agricultural practices and water quality, p. 256-264. T. L. Willrich and G. E. Smith [Eds.]. Iowa State University Press, Ames, Iowa.

Parr, J. F. 1969. Nature and significance of inorganic transformations in tile-drained soils. Soils and Fertilizers 32:411-415.

Peterson, J. R., T. M. McCalla, and G. E. Smith. 1971. Human and animal wastes as fertilizers, Chapt. 18. *In* Fertilizer technology and use, 2nd Edition, 671 p. R. A. Olson, T. J. Army, J. J. Hanway, and V. J. Kilmer [Eds.]. Soil Science Society of America, Madison, Wisconsin.

Wadleigh, C. H. 1968. Wastes in relation to agriculture and forestry. U.S. Dept. Agr., Misc. Publ. No. 1065. 112 p.

Waksman, S. A. 1938. Humus. 2nd Edition. Publ. by The Williams and Wilkins Co., Baltimore, Maryland.

Wilson, C. E. and F. E. Beckett [Eds.]. 1968. Proceedings of a Symposium, "Municipal sewage effluent for irrigation," publ. by Louisiana Tech. Univ. Alumni Foundation, Ruston, Louisiana.

Allison, F.E. and R. G. Cover. 1960. Rates of decomposition of shortleaf pine sawdust in soil at various levels of nitrogen and lime. Soil Science 89:194-201.

van den Hende, A. Cottenie, and R. de Vlieghere. 1952. Trans. Intl. Soc. Soil Sci., Comm. II and IV. 2:37-47.

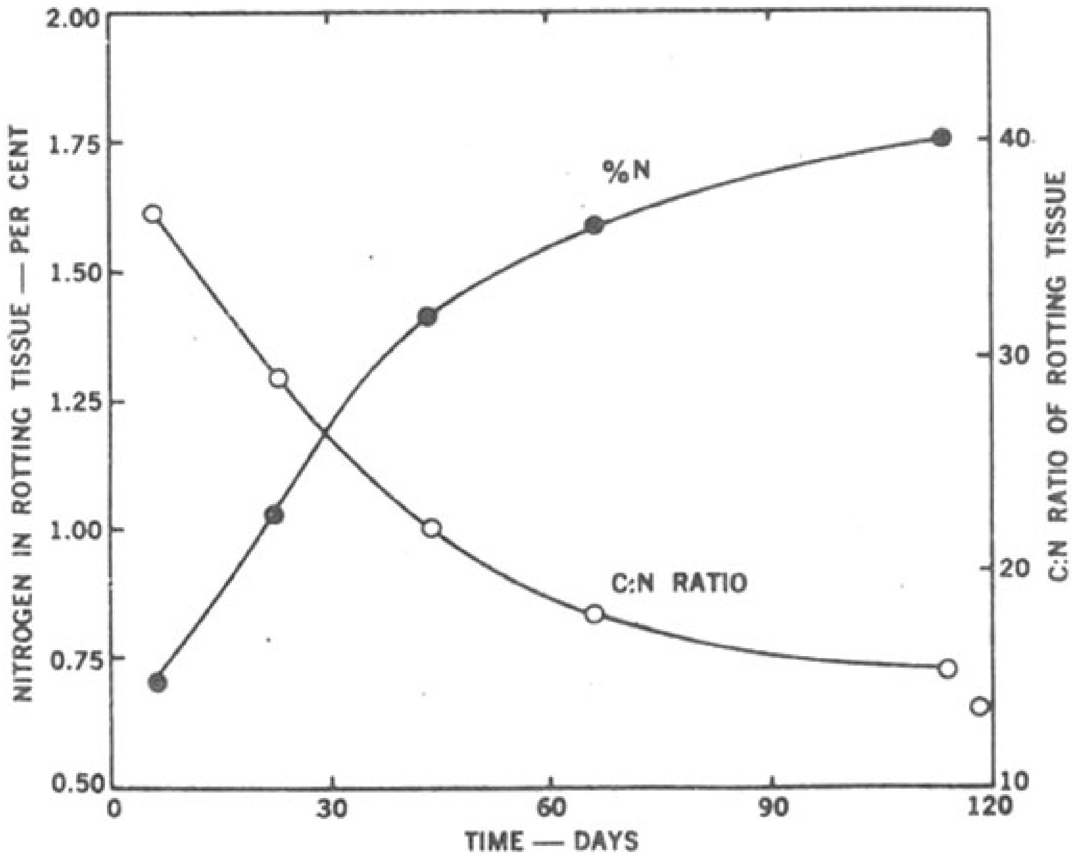

Figure 1. Changes in the nitrogen content and C:N ratio of barley straw during decomposition (van den Hende <u>et al</u>, 1952).

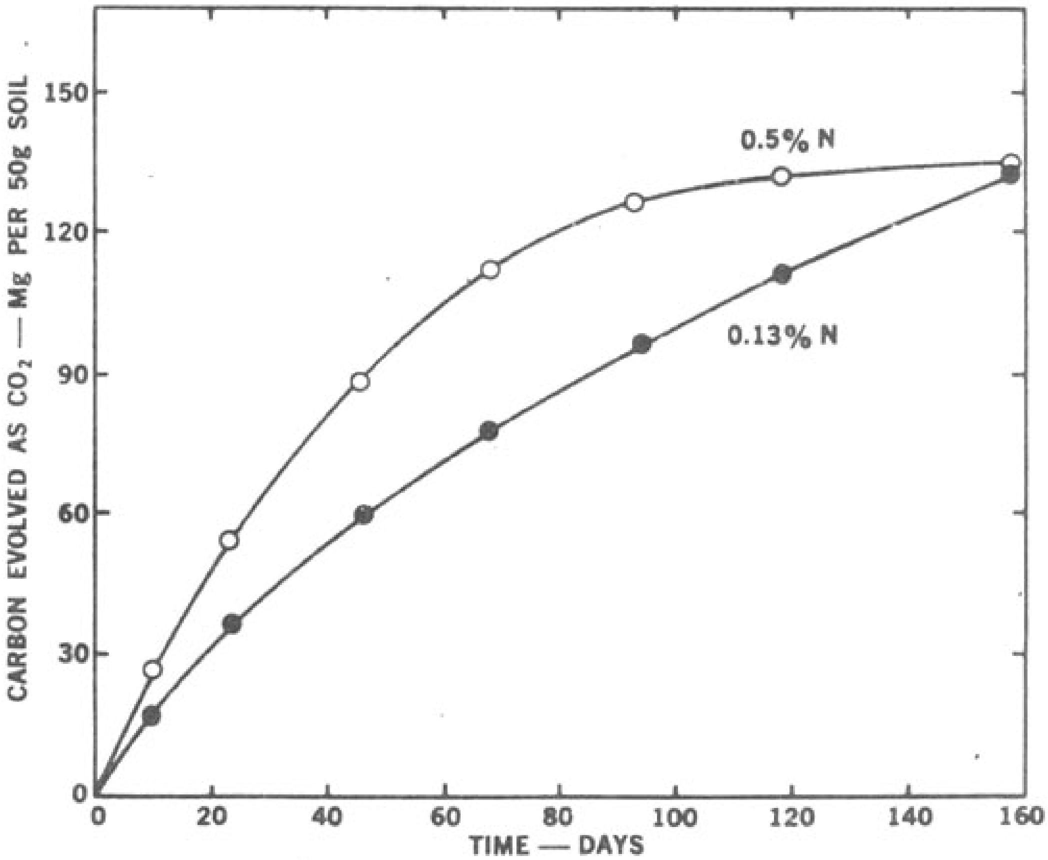

Figure 2. Extent of decomposition of sawdust in soil at two nitrogen levels (Allison and Cover, 1960).

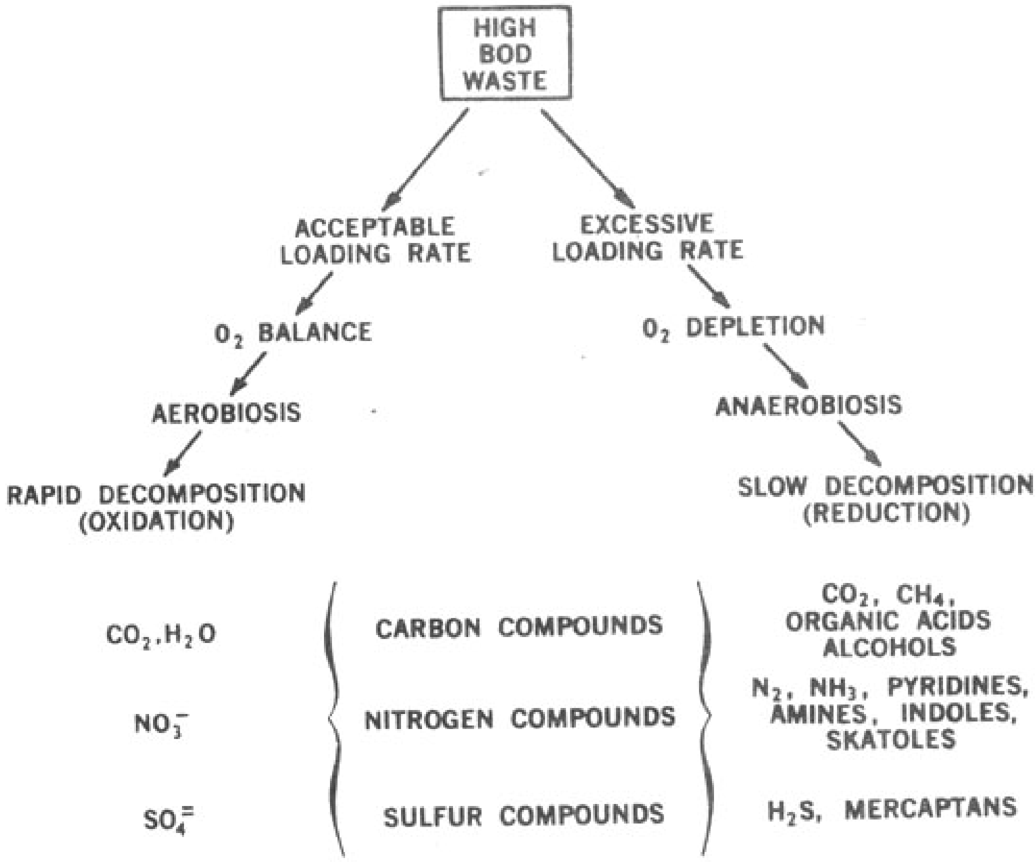

Figure 3. A flow diagram illustrating the possible consequences which might develop from the application of a high BOD waste to soil at an excessive loading rate compared with an acceptable loading rate.

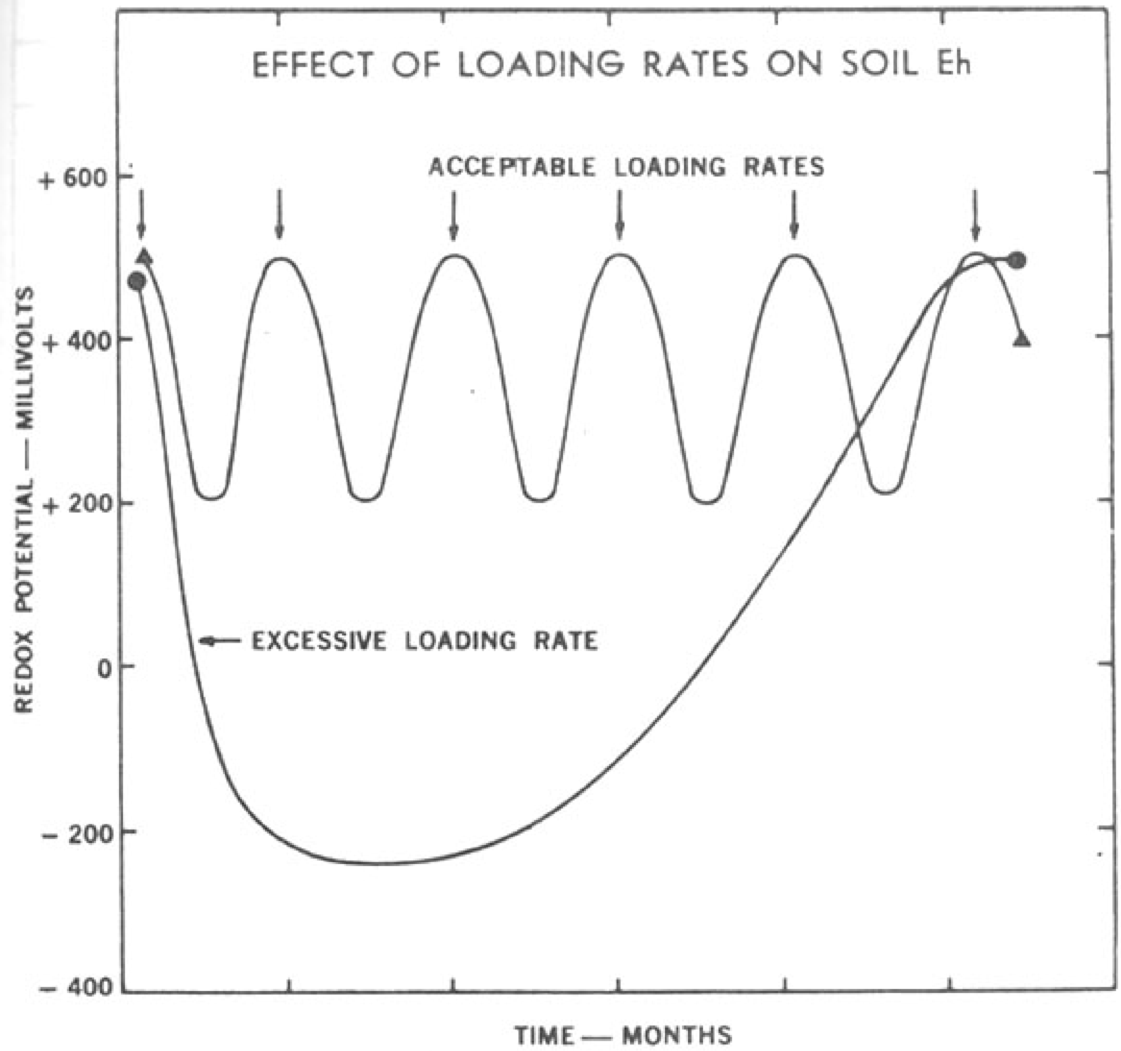

Figure 4. A hypothetical illustration of the relative effects of frequent, successive waste applications at acceptable loading rates compared with a single slug application on changes in the soil redox potential.

Table 1--Total nitrogen content of some organic wastes and residues

	N--percent of dry material
Cattle feedlot manure	1.2 - 2.0
Fresh cow manure, litter free	2.4
Poultry manure	3.5 - 5.0
Municipal waste compost	1.0
Paper mill sludges	0.2 - 2.3
Sewage sludges	2.0 - 6.0
Cannery wastes	0.5 - 1.8
Corn stover	0.9
Wheat straw	0.5

Table 2--Succession of events related to the redox potential which may occur in a waterlogged soil or a soil receiving excessive loading rates of organic wastes.

Period of incubation	Stage of reduction	System	Redox potential (millivolts)	Nature of microbial metabolism	Formation of organic acids
Early		Disappearance of O_2	+600 to +400	Aerobes	None
	First stage	Disappearance of NO_3^- Formation of Mn^{2+} Formation of Fe^{2+}	+500 to +300 +400 to +200 +300 to +100	Facultative anaerobes	Some accumulation after addition of organic matter
Later	Second stage	Formation of S^{2-}	0 to -150		Rapid accumulation
		Formation of H_2 Formation of CH_4	-150 to -220 -150 to -220	Obligate anaerobes	Rapid decrease

Summary of discussion

The three papers by D. Stickelberger, C. Tietjen and J.F. Parr respectively were discussed as a group. On the question of capital investment and running costs of processing organic materials experience in U.S.A. and Japan suggested the returns in monetary terms were low, but in Spain the need for processed organic materials was so great that it should develop into a lucrative enterprise. Where large quantities of materials have to be processed as in the U.S.A., it seems necessary to reduce costs by devising means to cut down the number of times the material is handled.

Regarding toxic effects, there had been trouble in the U.S.A. due to ash of boron mixed with waste, but this has now been overcome, and it was found that toxic effects from metals could be eliminated by keeping the pH at 6.5. Not much was known on pathogenes, except that if composting was well done, pathogens did not seem to develope. Nothing much was known about viruses, but they could be killed by heavy chlorination.

A question was raised as to who should pay for the cost of disposal of wastes. In densely populated areas it was suggested that the urban population should pay for it, and the farmer should pay only for the effect of the waste on his crops. How to avoid mixing urban and rural wastes appeared to be a problem.

Some speakers from developing countries were alarmed at the possible dangers of toxic effects, pathogens, viruses etc. which apparently could only be overcome by expensive and sophisticated methods, and thus posed a real problem in finding the necessary finance.

D. EXPERIENCE AND NEW DEVELOPMENTS

1. UTILIZATION OF ORGANIC MATERIALS AS FERTILIZERS IN JAPAN

Tomoji EGAWA†

INTRODUCTION

In view of the current world-wide shortage of chemical fertilizers and its anticipated adverse effect on food production, the endeavour to discover and develop efficient techniques of utilizing organic materials as fertilizers is urgently needed. Japan has a long-standing and traditional history of this issue, though some of those practices were abolished nowadays in accordance with the tremendous breakthrough of chemical industries.

The present paper deals with a historical review as well as some recent information on the utilization of organic materials as fertilizers in Japan.

HISTORICAL REVIEW

(1) In the days of old, Japanese people attached much importance to agriculture, and respected hard working people. Japanese farmers were forced to work particularly hard in the feudal age. They had to exert their utmost efforts to apply every self-sufficient substances available to fertilize crops. Plowing-under of twigs and wild grasses mowed in the mountain areas became popular among farmers more than 1000 years ago.

In Japan's feudal age, the main manures were produced on the farms, and included weeds and wild-grasses, feces and urine of humans and domestic animals, grass and wood ashes, etc. Oil cakes from rape, sesame and cotten seeds and fish manures of sardine and herring were used mainly for commercial crops such as cotten, sesame and vegetables in the feudal age. In the Meiji era (1868–1912), these cakes and fish manures were used more commonly for ordinary cereal crops, and imported soybean cake was at the zenith of its utilization from late Meiji to Taisho era (1912–1926). As shown in Table 1 and Table 2, these organic fertilizers* have been gradually replaced by chemical fertilizers in the past 40 years, but the application of bulky organic materials such as compost** and stable manure has been strongly believed by farmers to be the most important practice to maintain and improve soil fertility.

Until recently, this practice of applying compost and stable manure had been continued even with the increasing supply of cheap chemical fertilizers. This practice had been encouraged under the Government leadership, and the leading farmers, who were awarded prizes in the lowland rice yield contest, applied large amounts of composts on their fields without exception as shown in Table 3.

(2) Owing to the recent tremendous development of chemical industries in Japan, relatively cheap chemical fertilizers have been available in ample amounts, and their prices have remained at almost the same

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† Director General, National Institute of Agricultural Sciences, Tokyo, Japan

* The term "Organic fertilizers" is used in contrast with "Inorganic Fertilizers". This is defined in the Fertilizer Control Law in Japan as follows: "Organic materials to be applied to the land for agricultural production, containing fertilizer components in available forms for plant growth."

** The term "Compost" is used in this paper as a general term for heaped and partially rotted materials from cereal crop residues such as rice and wheat straw. It is used here in distinction with "stable manure", or "farmyard manure", which is partially rotted straw containing urine and feces of domestic animals. Composts are now produced from other organic materials such as town garbage and industrial waste as described later in this paper. In those cases, some commercial products containing various types of microbes and inorganic minerals are often added to promote decomposition process.

level in spite of remarkable increase in rice price and labour income in the past more than 10 years, and the percentage of chemical fertilizers in the rice production cost has been showing a declining tendency. In the last 40 years, there has been a great increase in productivity of lowland rice. Taking the country as a whole, whereas there has been little change in the total area of paddy fields, which in 1930 approximated three million hectares, there has nevertheless, since that time, been an increase in total production in the order of something like 40 percent–from nine million tons to over twelve million tons per annum. Over the period, output per hectare has jumped from about 3 tons to 4.5 tons. The most satisfactory explanation for the recent continuous high yielding of lowland rice in Japan, seems to be the recent advancement of techniques in rice cultivation, particularly the increase and betterment of application method of chemical fertilizers linked closely with other technical improvements. The upward trend in chemical fertilizer consumption for paddy field is shown in Table 4.

Table 1. Consumption Trend of Inorganic and Organic Fertilizers in Japan (as Nitrogeneous Fertilizers)

Unit: 1,000 mt N

Year	NH_4-Sulphate	Ca-Cyanamide	Urea	NH_4-Chloride	NH_4, Na -Nitrate	Sum (Inorg.)	Sum (Org.)	Percentage of Org. Fert. in Total (%)
1912	18.4	0.9			2.9	22.2	62.2	73.7
1916	8.9	6.0			6.9	21.8	69.2	76.0
1921	34.1	17.8			2.6	54.5	97.4	64.1
1926	79.9	25.8			9.5	115.2	124.8	52.0
1930	97.6	41.8			4.3	143.7	106.3	42.5
1935	162.5	40.2			9.5	212.2	94.1	30.7
1940	240.4	40.4			29.9	310.7	67.7	17.9
1945	56.5	14.0			–	70.6	20.9	22.8
1949	236.9	61.1	2.7		64.9	362.9	23.1	6.0
1957	352.2	79.8	94.2	22.7	8.3	557.2	38.1	6.4
1960	357.8	70.0	161.3	55.0	9.8	653.9	38.3	5.5
1965	256.5	55.5	174.3	52.0	8.2	554.6	35.9	5.1
1970	201.5	56.8	249.3	55.2	8.5	641.6	36.6	5.3

Table 2. Consumption Trend of Some Organic Fertilizers in Japan

Unit: 1,000 mt

Year	Fish Manures	Soybean Cakes	Rape seeds Oil Cakes	Cotton seeds Oil Cakes	Other Org. Fert.	Total
1903	108	177	87	23	17	412
1908	75	474	82	22	38	691
1913	210	722	140	49	64	1,185
1918	114	1,273	78	55	100	1,635
1923	137	1,526	118	59	145	1,985
1928	240	1,162	116	53	131	1,702
1938	160	943	93	45	55	1,296
1943	46	519	42	11	12	630
1948	16	64	15	–	0	96
1957	94	266	174	22	30	586
1962	95	185	163	37	35	515
1967	92	83	161	90	67	493
1971	138	95	211	11	78	533

Table 3. Rice Yields and Amounts of Compost or Stable Manure Applied by the Farmers who were Awarded First Prizes in the Rice Yield Contests

(t/ha)

Year	Farmer's Name	Location (Prefecture)	Rice Yield (Brown)	Amounts of Applied Composts
1949	T. Maezawa	Nagano	7.7	7.5
1950	J. Nishimura	Kagawa	7.8	7.5
1951	T. Dohi	Toyama	8.6	11.3
1952	Y. Ohkawa	Kagawa	9.2	22.5
1953	I. Tarumi	Fukuoka	8.8	26.3
1954	S. Kawahara	Toyama	9.9	30.0
1955	K. Joraku	Toyama	10.1	11.3
1956	K. Momose	Nagano	8.7	11.3
1957	E. Fujimori	Nagano	8.6	11.3
1958	N. Kitahara	Nagano	10.2	18.8
1959	K. Kato	Akita	9.6	30.0
1960	Y. Kudo	Akita	10.5	22.5

Table 4. Upward Trend in Chemical Fertilizer Consumption for Paddy Field

(Kg/ha)

Element	1950	1953	1954	1957	1960	1963	1966
N	81.8	87.4	84.0	101	112	105	115
P_2O_5	41.4	51.6	54.9	67.2	82.9	86.2	103
K_2O	23.5	54.9	66.1	82.9	95.2	93.0	98.6

Drastic changes, that have been brought into Japan's agriculture keeping pace with the high rate of growth of economy, are enough reflected in the problem of the utilization practices of cereal crop residues. The remarkable transfer of labour from agriculture to other industries, in particular, and the alteration of draft animals to machinery, has brought the remarkable decline of production and application of compost or stable manure as shown in Table 5.

Table 5. Change in Amount of Compost and Stable Manure Applied for Paddy Fields in Japan

(mt/ha)

Region / Year	Whole country	Northern district (Tohoku)	Central district (Tōkai)	Southern district (Kyūshū)
1955	6.50	10.10	3.55	2.79
1960	6.30	10.28	3.18	3.08
1965	5.45	8.74	2.77	3.07
1970	4.51	7.48	1.30	2.22
1972	3.49	5.54	1.19	1.81
'72/'55 (%)	53.6	54.9	33.5	64.9

The declining tendency is much more noticeable in the industrialized central districts. On the other hand, the amount of rice straw plowed in paddy fields, which was very scanty in 1955, has considerably increased and has reached as high as 0.5 tons per hectare in 1972. (Table 6)

Table 6. Changes in Amount of Rice Straw Applied for Paddy Fields in Japan

(mt./ha)

Year \ Region	Whole country	Northern district (Tōhoku)	Central district (Tōkai)	Southern district (Kyūshū)
1955	0.001	–	0.005	–
1960	0.10	0.01	0.25	0.08
1965	0.32	0.05	0.91	0.29
1970	0.54	0.13	1.38	0.43
1972	0.49	0.19	0.81	0.32

The low increasing tendency in northern districts can be ascribed to the difficulties of application in winter and the instability of succeeding rice growth due to the slower decomposition of applied straw in the soil.

Crop residues, mostly rice straw, are now competitive in their demand for various purposes. Some examples showing the present situation of the utlization of rice straw for various purposes are presented in Table 7.

Table 7. Situation of Usage of Rice Straw in Two Prefectures

(%)

	Incorporation into the soil	Compost	Feed & bedding	Application to upland fields	Burning	Sale & manifacture	Total
Aomori Pref. (Northern district)	4	34	17	–	32	13	100
Saga Pref. (Southern district)	40	15	–	22	4	19	100

It is worthy of note that burning is becoming popular these days even in the main rice-producing area with labour shortage. Rice straw is now used as litter for domestic animals, feedstuff for livestock, soil ameliorating or mulching materials for horticulture and also for some cottage industries.

As the preparation of composts is labourconsuming, it is becoming more and more difficult to persuade farmers to make composts even in main rice-producing areas. On the other hand, excrements of domestic animals and fowls, as well as various organic wastes produced as a result of industrialization and urbanization, are bringing about many serious environmental problems. They are now potential pollutants and at the same time potential resources for manure and fertilizers. In other words, there is both surplus and deficit of organic materials to be utilized for crop production at present moment in Japan. (Table 8)

Table 8. Estimated Amounts of Feces and Urine Discharged by Livestock and Poultry

Items	Numbers in 1000	Fresh Feces in 1000 mt	Urine in 1000 mt	Total in 1000 mt
Poultry	Hen 164,034 Broilers 67,922	10,188		10,188
Swine	6,985	4,917	5,763	10,680
Milch Cow	1,817	17,945	3,847	21,792
Beef Cattle	1,749	9,200	2,124	11,324
Total	242,507	42,250	11,734	53,984

(3) Quite recently, importance of agriculture has been reconsidered in Japan. The intensification of serious environmental pollution as a result of industrial and urban activities promoted under the recent economic policy of high growth rate has reminded Japanese people of the important role of agriculture to conserve natural eco-system.

Besides, evet increasing world-wide food crisis induced by energy crisis is enough for Japanese agriculturists to reconsider the present unstable status of Japan's agriculture. As is well known, the degree of food self-sufficiency of Japan has been remarkably declined in the past 10 years. Needless to say, the increase of food production is quite needed for secure food supply.

Under the circumstances, not a few of Japanese agriculturists are worrying about the possible reduction of soil fertility caused by diminished return of organic materials to the cultivated fields in these years. Major rice producing prefectures have started active campaign for promoting soil fertility. Generally speaking, however, it is not easy to persuade individual farmers to prepare composts under the present condition of rapidly increasing labour charge. Recently, some trials to establish a new cooperation system between stockbreeder groups and crop farmers have gradually pervaded several rural areas in Japan, and it has made it possible to exchange rice straw and stable manure between rice farmers and stockbreeders. As for preparation and storage of compost or farmyard manure, some associations of new types have been established in some districts through intimate cooperation between rice farmers and beef cattle breeders. In all cases, both spiritual and financial supports of agricultural cooperative societies as well as prefectural authorities are seemed to be indispensable to promote a new campaign for rehabilitation of agriculture and conservation of soil fertility.

(4) As already mentioned, cereal crop residues, mostly rice straw, are now competitive in their demand for various purposes. New resources of organic materials to be utilized as fertilizers should be searched and developed. Studies are now being done in Japan to produce new organic fertilizers from various industrial wastes and sewege sludge. Some of them will be described more precisely later in this paper.

UTILIZATION OF CEREAL CROP RESIDUES

Compost and Stable Manure

(1) In Japan, the typical organic materials most popularly used as fertilizers hitherto are compost and stable manure produced from cereal crop residues, particularly rice straw. Needless to say, the utilization of cereal crop residues is one of the most effective countermeasures to meet the present situation of tight supply of chemical fertilizers. Under intensive condition of fertilization, however, it is also the most important way of recycling of plant nutrients, because the contents of plant nutrients remained in the residues usually increases with the application of chemical fertilizers.

As already described in the previous chapter, the position of compost or stable manure in agriculture has been gradually changed in recent Japan, these organic materials are still used most commonly throughout Japan.

(2) The composition of composts and stable manures vary naturally as affected by the composition of original straw and also by the process of preparation. Some data on the chemical compositions of 105 samples of composts and stable manures are shown in Table 9. As shown in this Table, the samples produced in the areas where the contents of some elements in the soil are low, contain low contents of those elements.

(3) Chemical studies on the rotting process of plant remains have been conducted by several researchers. Changes of organic and inorganic constituents during composting are illustrated in Table 10. (Kumada et al, 1972) In this study, the compost was prepared by heaping a moist mixture of rice straw and calcium cynamide (100 : 2) for 2 or 3 months.

Table 9. Chemical Compositions of 105 Samples of Composts and Stable Manures

(Hashimoto, 1965)

(on the basis of fresh matter)

Component	Highest Value	Lowest Value	Mean Value
H_2O	93.2 %	39.6 %	75.1 ± 12.2%
pH(H_2O)	9.4	5.9	7.9 ± 0.8
C	13.3	1.4	7.9 ± 2.1
N	1.07	0.07	0.39 ± 0.17
C/N	46.0	4.7	20.3 ± 6.5
P_2O_5	0.57	0.03	0.19 ± 0.09
K_2O	2.22	0.09	0.70 ± 0.45
CaO	1.49	0.08	0.45 ± 0.22
MgO	0.49	0.02	0.13 ± 0.05
Na_2O	0.45	0.01	0.13 ± 0.03
MnO*	600	41	248 ± 111
B*	11.9	0.3	1.9 ± 1.3
SiO_2	16.4	0.01	4.5 ± 1.4

* : ppm

Table 10. Changes of Organic and Inorganic Constituents during Composting Process of Rice Straw

(Kumada et al. 1972) (Percentage, oven dried matter basis)

Sample		pH	Ash	T-C	T-N (Nt)	C/N	NH_4-N*	NO_3-N*	Pigments + lipid	Sugars + starch	Pectin + hemi-celluloses	Cellulose	Protein**	Lignin***	H_2SO_4-insoluble N (Ni)	H_2SO_4-insoluble C	H_2SO_4-insoluble C/N	Ni/Nt × 100
Rice straw		7.58	17.8	39.9	0.624	63.9	6.13	0	3.82	3.85	26.3	36.8	3.28	7.95	0.098	5.16	52.7	16
Compost	4 weeks	8.30	32.5	34.6	1.65	21.0	8.19	12.3	3.07	4.27	13.7	24.5	7.08	16.8	0.518	10.9	21.1	31
Compost	6 weeks	8.48	39.3	32.3	1.85	17.4	6.84	9.6	2.55	3.73	12.9	23.0	7.76	17.8	0.609	11.5	18.9	33
Compost	12 weeks	8.78	52.9	26.6	2.05	13.0	3.43	23.6	1.23	1.93	7.31	10.2	6.35	21.5	1.03	14.0	13.5	50
Compost	16 weeks	8.80	52.2	26.5	2.05	12.9	3.44	33.7	1.64	3.07	6.78	8.78	6.68	22.1	0.981	14.4	14.6	48

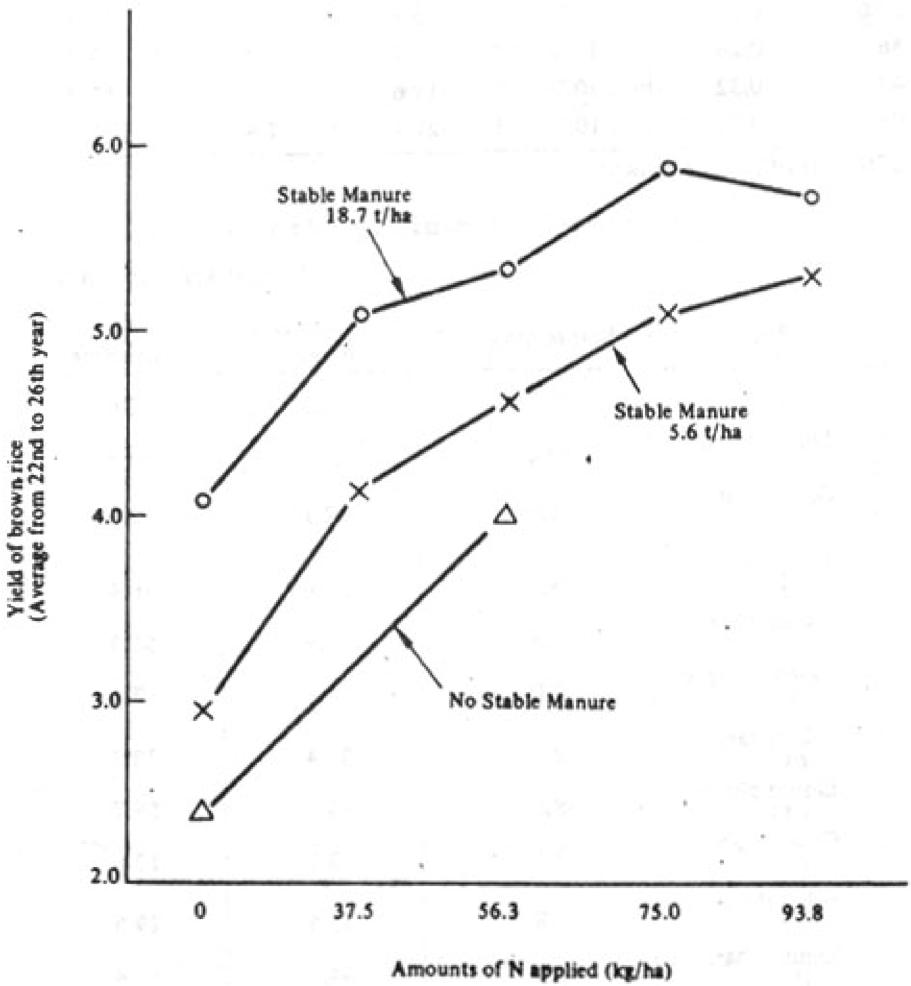
Remarks:
- * N mg per 100g oven dried matter
- ** (Nt − Ni) × 6.25
- *** H_2SO_4 insoluble C × 1.45

(4) Quite a lot of experiments and investigations have been conducted on the effects of the application of compost or stable manure for the yields of lowland rice and upland crops during the past 100 years in Japan. Generally speaking very high valuation has been given to the fertilizer responses of compost or stable manure. The merits of these materials as fertilizers are considered to be : 1) They contain almost all of the plant nutrients in available forms for plant growth, 2) They can supply nutrients slowly and gradually keeping step with the plant growth, 3) Some organic constituents contained inherently or formed secondarily are believed to play an important role as chelating agents to accelerate absorption of some nutrient elements, and 4) In case of these well-decomposed materials, there is no likelihood of retarded growth of the plant being caused by nitrogen immobilization or by harmful decomposition products, that are often found in case of plowing-under of fresh rice straw into the soil as stated later.

(5) Cumulative effects of continuous application of compost or stable manure on the yields of lowland rice as well as upland crops have been studied by many researchers in Japan, and generally speaking, the positive valuation has been given.

For example, the result of a long term experiment carried out at Aomori Prefectural Exp. Station, northern district of Japan, was shown in Figure 1. In this experiment, no positive effect of stable manure application was observed for the first 5 years. However, there was difference of about 0.7t/ha in yield between no-manure plot and 5.6t/ha manure plot and difference of 0.5 – 1.1t/ha between 5.6t/ha plot and 18.7t/ha plot in average yield of 22nd – 26th year. The relation of the effect of stable manure to the amount of N application shows the tendency that the effect of manure is larger when the applied N level is low. The highest yield was obtained in 18.7t/ha manure plot when the amount of applied N was 75Kg/ha. Though the yield of no-stable manure plot and 5.6t/ha plot increased with the amount of applied N, the yield of these plots did not exceed the maximum yield of 18.7t/ha manure plot. It is supposed that further increase of N application in no-manure plot would not result higher yield than that of 18.7t/ha manure plot.

Figure 1. Effect of Application of Stable Manure on the Yield of Lowland rice (Aomori Pref. Agr. Exp. Stat.)



(6) Studies on the cumulative effect of continuous application of compost or stable manure on the soil properties have been intensively studied in Japan. Changes in soil chemical properties due to the continued application of stable manure are presented in Table 11 as an example. The values are obtained by the chemical analysis of surface soils of paddy fields to which manure has been continuously applied for 27 years. Total-C and total-N content of soils increases proportionally to the amount of applied manure. These increase of humus content in soils also bring about the increase of CEC. Available K, P and Si content in soils shows an increasing tendency too. These increase in nutrients content in soils may contribute to a great extent towards the increase of the yield.

The application of organic manures promotes the development of granular structure of surface soil. The development of granular structure promotes percolation of the water from rain and irrigation, makes the operation of machinery easy, and improves the efficiency of puddling and pulvertizing as seen in Table 12.

Table 11. Cumulative Effect of Application of Stable Manure on the Properties of Paddy Soil*
(Aomori Pref. Agr. Exp. Stat.)

Amounts of Stable Manure	Total C	Total N	C/N	C.E.C.	K_2O (exch.)	SiO_2 (solu.)
t/ha				me/100g	me/100g	mg/100g
0	2.63%	0.22%	10.7	15.5	1.4	13.4
5.6	2.86	0.26	11.0	17.2	1.4	12.0
11.2	3.43	0.32	10.7	19.6	1.4	12.0
18.7	3.95	0.37	10.7	21.1	2.4	11.0

* Analyzed at 27th year of the experiment.

Table 12. The Effect of Different Kinds of Fertilization on the Soil Porosity
(Central Agr. Expt. Stat.)

Treatment	Phases	Before plowing	Under rice cultivation	After harvesting
No fertilizer	Solid phase (%)	50.7	36.2	42.6
	Liquid phase (%)	40.4	61.7	53.4
	Gaseous phase (%)	8.9	2.1	3.6
Chemical fertilizer	Solid phase (%)	43.2	34.6	36.4
	Liquid phase (%)	47.8	63.9	56.0
	Gaseous phase (%)	9.0	1.5	7.6
Compost	Solid phase (%)	38.9	31.4	28.9
	Liquid phase (%)	48.0	65.5	58.7
	Gaseous phase (%)	13.1	3.1	12.4
Green manure	Solid phase (%)	37.8	32.5	29.6
	Liquid phase (%)	41.5	64.2	51.8
	Gaseous phase (%)	20.7	3.3	18.6

(7) Under the condition of moderate temperature, one of the most important effect of the continuous application of organic materials on the improvement of the soil properties is undoubtedly the accumulation of organic nitrogen. This is quite important if we put the high yielding of rice into question, because about 70% of nitrogen absorbed by rice plants is estimated to come from nitrogen reserved in the soil. On the contrary, mere increased fertilization does not always result in a high yiled. It is well known that too much application of nitrogenous fertilizers often causes heavy mutual shading of leaves, lodging, damages from diseases and insect pests and the decrease of the yield due to inferior maturity of grains. As already mentioned, the farmers, who were awarded prizes in the rice yield contest in Japan, exerted their utmost efforts to improve the soil ferility by applying much amounts of farmyard manures or composts, keeping it in mind that rice plants must be supplied with much nutrients from the soil,but not from chemical fertilizers, to avoid the dangers mentioned above.

As the decomposition of the accumulated organic nitrogen in the soil proceeds gradually, the rate of nitrogen release is naturally very slow, and the released nitrogen is homogeniously distributed within the whole soil layer, whereas nitrogen supplied by top dressing of chemical fertilizers is concentrated in the surface layer. It is necessary to keep the concentration of NH_4-N in the soil at a higher level in order to promote the tillering of rice plants. This can be achieved by the basal dressing of nitrogen fertilizer. The high yielding of rice plants, however, is characterized by the ample absorption of nitrogen after the stage of young panicle formation. It is necessary to carry out a frequent top dressing if one wants to meet these requirement by the application of chemical fertilizers. This is, however, practically impossible. And furthermore, as nitrogen is released very slowly and is distributed homogeniously throughout the layer at this period, the soil nitrogen is more effective than the applied nitrogen in maintaining the tillered stems and in promoting the ripening. Figure 2 shows the effect of the amount and the time of top dressing on the yield of rice in two soils of different fertility. The yield of rice in highly fertile soil is influenced only a small extent by the amount and the time of the top dressing and is kept constantly in high levels of 7 – 8t/ha. On the contrary, in less fertile soil, the yield increases with the amount and the number of top dressings, but does not exceed that of highly fertile soil.

Accordingly, the evaluation of soil nitrogen differs markedly depending on the period of its release. The soil that releases greater part of its nitrogen during the period of reproductive growth is considered to be the most desirable one for the high yielding of lowland rice under the condition of moderate temperature. Of course, such a high valuation of cumulative effect of organic manures as maintainers of soil fertility may be unwarrantable in tropical countries, where the decomposition pattern of applied organic materials in the soil, not to speak of the growth pattern of rice, is quite different under high temperature.

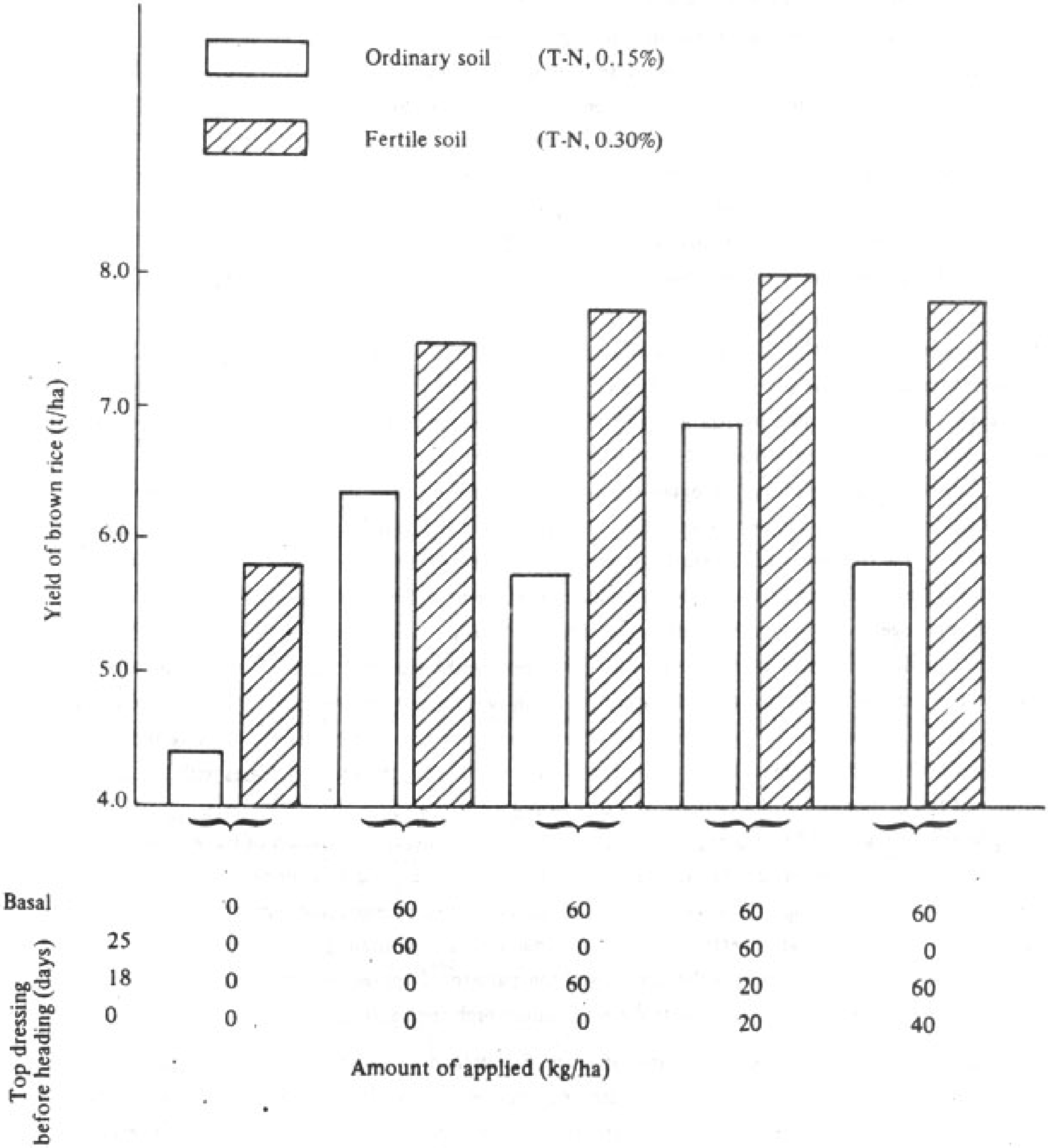
(8) Fertilizer responses of compost or stable manure for upland crops are always very high, and the cumulative effects of continuous application of these manures on the upalnd soil properties are generally distinct. Table 13 shows the result of a long term experiment carried out in Kyushu Agricultural Experiment Station, in which the application of stable manure was continued for 10 years.

Rice Straw

(1) As described in the previous chapter, the practice of plowing-under of fresh rice straw has been becoming popular recently in the rice-producing areas, contrary to the declining tendency of application of composts to the rice fields.

Since rice straw is applied to the soil in an undecomposed condition and immediately plowed under, the decomposition which subsequently takes place in the soil has an important influence on the growth of the following rice crop. This decomposition process is influenced mainly by the temperature and moisture content of the soil. In the first stages of the decomposition process, the soluble carbohydrates in rice straw are

Figure 2. Relation between the Soil Fertility and the Effect of Top Dressing on the Yield of Paddy rice



decomposed rapidly (within 30 to 40 days after application)if weather conditions are warm: The cellulose and lignin are more slowly decomposed. An experiment designed to study the processes which take place during the decomposition of rice straw in the soil and the effects of soil moisture conditions and added nitrogen showed that decomposition progressed more rapidly under higher soil moisture conditions and that the addition of nitrogen considerably accelerated the decomposition of straw during the early stages. (Table 14)

Table 13. Cumulative Effect of Continuous Application of Stable Manure on the Upland Soil Properties

(Hashimoto et al., 1971)

Amounts of Stable Manure	Total C	Total N	CEC*	Exch. Bases*			Degree of Base Saturation	Truog's* P_2O_5
				Ca	Mg	K		
mt/ha	%	%	me	me	me	me	%	mg
0	7.19	0.58	36.6	24.0	0.92	0.30	68.9	tr.
7.5	7.36	0.58	36.9	23.0	1.34	0.40	67.2	0.5
15	7.40	0.64	39.6	25.6	1.30	0.49	69.2	2.1
30	7.74	0.67	42.4	29.3	1.95	0.74	75.5	1.1
60	8.00	0.70	41.4	26.5	2.17	1.14	71.9	3.0

* per 100g dry soil

Note : The Soil of this experiment field is Andosol in Kumamoto Prefecture, Kyushu District. Green-cut oats and Green-cut maize were cropped in winter and summer respectively.

Table 14. Decomposition Process of Rice Straw in the Soil as Affected by Soil Moisture Condition and Nitrogen Addition (at 15°C)

(Sakai, 1970)

Soil-Moisture	** Nitrogen added	Start (g)	Dry Matter (g)					Decomposition Ratio (%)				
			15 days	30 days	60 days	100 days	150 days	15 days	30 days	60 days	100 days	150 days
*	None	5	4.25	3.91	2.95	2.35	1.76	15.0	21.8	41.0	53.0	64.8
80%	Urea	5	4.06	3.64	2.74	2.04	1.66	18.8	27.2	45.2	59.2	66.8
PF1.10	Ca-cyanamide	5	4.23	3.96	2.71	2.18	1.79	15.4	26.2	45.8	56.4	64.2
*	None	5	4.33	3.95	3.40	2.74	2.62	13.3	21.0	32.0	45.2	54.8
60%	Urea	5	4.14	3.68	3.12	2.15	2.06	17.2	26.4	37.6	57.0	58.8
PF2.8	Ca-cyanamide	5	4.36	3.92	3.32	2.33	2.34	12.6	21.6	33.6	53.4	53.2
*	None	5	4.40	4.15	3.65	2.95	2.90	12.0	17.0	27.0	41.0	42.0
40%	Urea	5	4.23	3.85	3.23	2.90	2.24	15.4	23.0	35.4	42.0	55.2
PF3.2	Ca-cyanamide	5	4.43	4.14	3.39	2.97	2.61	11.5	17.6	32.2	40.6	47.8

Notes
* Percentage to the Maximum Water Holding Capacity
** N 26.3 mg/one vessel (11 × 11 × 11 cm)

(2) Generally speaking, rice straw, when applied to a paddy field, fixes nitrogen in the soil during the early stages of the decomposition of soluble carbohydrates, and the rice plants suffer for a short time from nitrogen starvation. The first step to be taken to prevent this temporary nitrogen deficiency is the application of nitrogenous fertilizer to promote the decomposition of the straw at the time of plowing-in. An increased application of nitrogen fertilizer as a basal dressing is also recommended. The fixed nitrogen taken into the rice straw is returned to the soil after decomposition has passed its peak. Consequently the application of rice straw tends to prolong the period of effectiveness of nitrogen applied as a basal dressing; when rice straw is plowed into a paddy field, topdressing must be applied with due consideration of the leaf color to avoid over-fertilization.

As the decomposition of rice straw is influenced mainly by the temperature of the soil, application methods vary between cold and warm districts. In a cold district such as Hokkaido, rice straw must be spread over the surface of the paddy fields in autumn and immediately plowed into the soil; the amount of rice straw applied must be strictly limited. In a warm district, even if the rice straw is plowed under in spring it will still give beneficial results (Table 15).

Table 15. Effect of Rice Straw Application

(Average Values of Brown Rice, ton/ha) (Shizuoka Agr. Exp. Stat.)

Plot / Year	No Straw	Applied in Winter	Applied in Early Spring	Applied in Spring*		Compost
					with Increased N	
5 years (1952~56)	2.61 (100)	3.91 (108)	3.72 (103)	3.85 (107)	3.93 (109)	3.87 (107)
3 years (1957~59)	3.88 (100)	4.11 (106)	4.03 (104)	4.05 (104)	4.61 (119)	4.23 (109)

Notes (1) The amounts of rice straw applied:
1952~56 : 3.78 ton/ha
1957~59 : 5.76 ton/ha
(2) *Nitrogen as basal dressing
1952~56 : 30kg/ha + 11kg/ha
1957~59 : 30kg/ha + 17kg/ha

(3) The cumulative effect on soil properties of yearly applications of rice straw has been studied in many experimental stations. The results show that there is an accumulation of organic nitrogen, which will be mineralized during the later growth stages of the rice crop, while some physical properties such as porosity and moisture-holding capacity are also improved; exchangeable bases such as Ca and Mg are sometimes leached down in well-drained paddy fields.

The cumulative effect of applications of rice straw compared with compost on the physical properties of upland soils has been illustrated in Table 16. The benefits derived from applications of rice straw are superior to those obtained from compost in increasing soil porosity and decreasing soil strength.

Table 16. The Effect of Applications of Organic Matter on the Physical Properties of Upland Soils

(Miki & Mori, 1966)

		No Compost	Compost 1t/ha	Straw 1.5 t/ha
Three phase composition (Vol. %)	solid	57.3	57.6	51.6
	liquid	22.9	24.9	21.7
	air	19.8	17.5	26.8
Total porosity (vol. %)		42.7	42.4	48.5
Apparent density (g/ml)		1.52	1.52	1.36
pF-moisture contents (vol. %)	pF 0.7	30.4	30.9	34.6
	pF 1.7	26.1	26.3	25.2
	pF 2.7	20.2	19.8	17.8
	pF 3.1	18.5	18.4	16.3
	pF 4.1	14.7	14.4	13.1
Available water (mm/25 cm soil)	pF 1.7–4.1	28.5	29.8	30.3
	pF 1.7–3.1	19.0	19.7	22.2
Soil strength (penetr. resis. kg/cm)		5.2	4.2	3.2
Water-stable aggregates (weight %)	2.4mm	5.0	8.3	10.0
	2.4 – 0.5	24.7	25.7	27.1
	0.5 – 0.1	15.7	11.1	13.3

Notes: (1) Soil : Reddish-Yellow Earth (diluvial)
(2) Cropping : Oats – Sorghum (3 years. 6 crops)

The cumulative effects of the application of plant residues instead of compost or stable manure on the maintenance of the fertility of upland soils have also been intensively studied over recent years. The results obtained show, almost without exception, that the application of fresh organic materials is very effective in increasing the supply of plant nutrients in the soil and in improving some of its physical properties, even though the rate of decomposition of organic materials in the soil and the release of mineral nutrients are different, as they are affected by factors such as the C/N ratio of the plant residues and soil conditions.

DISCOVER AND DEVELOPMENT OF POSSIBLE SOURCES FOR ORGANIC FERTILIZERS

The total production of fertilizers in present Japan amounts to about 18 million tons per annum, in which about 6 million tons are products prepared from industrial byproducts or wastes. The utilization of such industrial byproducts or wastes for fertilizer production has been limited hitherto only for few materials of relatively high contents of fertilizer components. Recent aggravation of water and soil pollution due to wastes of various industries, however, has aroused public attention to the necessity of strict control of waste water quality, and consequently the new enterprises to industialize fertilizer production from such wastes have started in various kinds of industries.

The total amounts of industrial waste is now estimated to be more than 1 million tons per day in the whole country. These organic wastes are undoubtedly considered to be the potential resources for fertilizer production, though there are many limiting factors and processing difficulties to be overcome in future development. The limiting factors are : 1) Low contents of plant nutrients, 2) Non-available forms of plant nutrients, 3) Inadequate contents of trace elements, 4) High contents of injurious ingredients and 5) High carbon/nitrogen ratio. Needless to say, the common difficulty in treatment and processing is found in their large amounts of water of low concentration of plant nutrients. The care should be taken in the contents and chemical forms of ntureint elements in these wastes. As for tracer elements, in particular, the problem should be stricity considered, because the allowable latitude in the contents of tracer elements for causing injurious effects due to either deficiency or excess is very narrow. For reference, analytical data of trace elements in some organic fertilizers are presented in Table 17.

Table 17. Contents of Trace Elements in Some Organic Fertilizers

(Fertilizer & Feed Inspection Office)

(ppm, dry matter basis)

	Numbers of Samples	Mn	Fe	Zn	Cu	B	Mo
Oil cakes	24	44	359	57	22	18	3
Wastes of Agr. Ind.	19	117	678	43	24	14	3
Fish cakes	7	–	268	86	11	–	2
Bone meal	5	–	266	120	6	–	1
Streamed Leather meal	4	–	556	27	13	–	I

The contamination of injurious ingredients including both inorganic heavy metal elements such as Cd and Hg and organic compounds such as biuret, sulfanic acid (ASA) or some carcinogens should be strictly checked and the future studies on the methods of both qualitiative and quantitative analysis of such compounds in the organic fertilizers are urgently needed.

Organic materials tentatively considered to be the possible sources for fertilizers are : 1) Wastes of wood and paper-pulp industries, 2) Waste water of various food and brewing industries, 3) town garbage and sewage sludge and 4) feces and urine of domestic animals. Among these materials, only a small amount of the waste of wood and pulp industies (bark compost, saw dust compost, pulp-waste compost), the waste of some food industries (sludge cakes) and town garbage and sewage (town garbage compost, calcined sludge) are utilized for the production of organic fertilizers. As the development studies of the new techniques are now eagerly promoted, however, there is a possiblity that the industrialization on the utilization of these waste materials will meet with success in the near future.

Night Soil

In prewar Japan, night soil (feces and urine of human beings) had been used very commonly as one of the most important self-supplying fertilizer. Urine was found particularly useful for leafy vegetables because of its instant effect. After the War, this practice was nearly abolished from the sanitary viewpoint.

The chemical compositions of night soil are diversified as affected mainly by age and diets of human beings. Table 18 shows the average figures of several samples.

Table 18. Chemical Composition of Night Soil

Moisture	Organic Matter	Ash	N	P_2O_5	K_2O	NaCl
95%	3.4%	1.6%	0.57%	0.13%	0.27%	1.02%

Prior to application of night soil, it should be set aside for about 3 – 4 months in a manure sink built in the shade. Addition of a small amount of superphosphate (about 3%) into the night soil is effective to prevent volatilization loss of gaseous ammonia formed by the decomposing process of protein or urine during the storage period.

As the salt concentration of night soil is considerablly high (about 0.3%), the direct application of fresh night soil should be avoided to protect crop roots against concentrated salt injury. So the dilution is indispensable for application of night soil. The amount of water needed for dilution is twice or three times as much as that of night soil.

The surface of the soil dressed with night soil should be quickly covered by soil to prevent bad smelling as well as volatilization loss of gaseous ammonia.

Bark Compost

Bark is one of the new organic resourses to be utilized as raw material for compost preparation.

Owing to high carbon-nitrogen ratio of bark, the process of heaping and fermentation is indispensable for bark compost. Addition of adequate amounts of poultry manure or urea is needed to promote fermentation. Sometimes cellulose decomposing bacteria is added.

An example of chemical composition of bark compost is shown in Table 19.

Table 19. Chemical Composition of Bark Compost
(Average Value of Several Samples)

Moisture	Organic Matter	C/N	pH	N	P_2O_5	K_2O
65.0%	30.0%	30	7.0	0.5%	0.3%	0.2%

Because of high price and low content of fertilizer components, bark compost is not used commonly at present time. It is used only as soil-amendment matter for nursery of some horticultural crops and trees. Optimum application amounts of bark compost is 20 – 30 kg per a. Excessive application is liable to induce mitrogen starvation.

Town-Garbage Compost

Since about 15 years ago, the big plants for producing compost rapidly from town garbage had been equipped in 32 cities in Japan. Some of them were imported from European countries and others were constructed in some Japanese factories. The principle is that the collected town garbage is fermented by incubation in a big rotary kiln for about one week under warmed aerobic condition.

In the past 5 years, however, most of these plants were scrapped one after one, and only 5 or 6 plants are now in operation. The reason why most of the plants were forced to be scrapped is economical imbalance between the increasing wages and cheap prices of the products. In spite of the apparently mechanized process, the first operation for sorting-out of various materials contained in town garbage, such as broken pieces of glass, cans and vinyl film etc, requires many hands and is unexpectedly labor-consuming. As the compost-making using town gargabe was planned originally to solve the disposal problem of town gargabe from the sanitary viewpoint, the compost was considered to be byproduct and was sold at very cheap price.

It is quite natural that the plants are in full operation only in the cities, where these unnecessary mixtures are almost completely sorted out from kitchen garbage through the cooperation of inhabitants in advance of the garbage gathering. Some data of chemical compositions of town-garbage composts are shown in Table 20.

Table 20. Chemical Compositions of Town-Garbage Composts

(%)

Sample No.	Moisture	Total C	Total N	C/N	P_2O_5	K_2O	CaO
1	44.0	28.0	1.0	28.0	0.56	0.90	7.20
2	43.7	–	1.2	–	0.60	1.17	–
3	56.0	–	0.7	–	0.40	1.00	–
4	36.1	–	1.1	–	0.54	1.29	–
5	38.4	–	1.3	–	0.51	1.34	–

A field experiment on the fertilizer response and aftereffect of application of town-garbage compost was continued from 1965 to 1968 in Toyohashi upland field of Aichi Prefectural Experiment Station. The result obtained showed clearly the high fertilizer response of newly applied compost. The aftereffect of the compost heavily applied in the first year was still observed for both summer and winter crops of 4th year.

The author consideres that the utilization of town garbage for preparation of compost is promising, provided that the financial aid from Government or Prefectural Government is given to the city purse. It contributes not only to the recycling of plant nutrients, but also to the solution of the increasing environmental pollution due to town waste.

Sewage Sludge

The production of sewage sludge is supposed to increase with the gravitation of population towards cities. Only a few case of the production of organic fertilizer from sewage sludge (activated sludge) has been reported hitherto in Japan. Calcined ash (at about 900°C) of sewage sludge was produced in some cities. It contains considerable amounts of plant nutrients. But the careful pretreatment for removal of injurious heavy metals contaminated in sewage by sedimentation method is needed for further industrialization of this processing.

Sludge Cakes of Industrial Waste

Waste water of food and brewing industries must be treated in the first step by physical, chemical or biological processing to concentrate organic materials contanined in the waste water. The activated sludge method is most commonly used to purify waste water by means of biological activity, and is considered to be most suitable for the present purpose. Table 21 shows the estimated amounts of waste water in various food and brewing factories in Japan, and possible amounts of sludge cakes to be produced from waste water.

The compositions of sludge cakes produced in some beer factories are presented in Table 22.

The fertilizer responses of these sludges are diversified as affected by the source and the process. An example of the pot experiment on the effects of sludges is shown in Table 23.

Table 21. Possible Amounts of Sludge Cakes to be Produced from Industrial Waste Water

(Ohhashi, 1972)

Factory	Production per annum	Nubmers of Factories	Amounts of Waste Water		Amounts of Sludge	Possible Production of Sludge Cakes
			m^3		dry matter	dry matter t/year
Beer	2,000,000 kℓ	21	3,000/Beer	200 kℓ	0.93	9,300
Ethanol	133,000 kℓ	65	200/Ethanol	19 kℓ	2.5	18,000
Bean Jam	250,000 t	1,500	1,800/source	30 t	3.5	29,000
Glucose	206,000 t	33	5,000/sugar	80 t	1.8	4,600
Starch	670,000 t	1,686	1,250/starch	15 t	1.5	67,000
Beet Sugar	220,000 t	9	16,500/Beet	1,500 t	95.0	14,000
Yeast	25,000 t	10	100/yeast	10 t	0.82	2,100
Orange Juice	330,000 t	414	500/orange	25 t	0.13	2,700
Milk	1,974,000 Heads	1,070	2,000/milk	70 kℓ	0.17	4,800
Meat Processing	310,000 Heads	312	1,890/500 heads		0.60	370

Table 23. Effect of the Application of Sludges on the Yield of Rice

(Sanpei, 1974)

	Applied Amounts			Yield			
	N	P_2O_5	K_2O	Unhulled Rice	Index	Straw	Index
No Nitrogen	0g	0.6 g	0.6 g	6.4 g	15	7.4 g	14
Ammonium Sulphate	0.7	0.6	0.6	41.7	100	53.6	100
Sludge (Food Ind.)	0.7	0.6	0.6	23.2	56	30.0	56
Sludge (Beer Ind.)	0.7	0.6	0.6	22.1	53	25.7	48
Sludge (Oil Ind.)	0.7	0.6	0.6	29.5	71	29.6	55
Sludge (Food Ind.)	0.7	0.6	0.6	30.9	74	34.8	65
Sludge (Food Ind.)	0.7	0.6	0.6	22.5	54	24.8	46
Sludge (Beer Ind.)	0.7	0.6	0.6	22.5	54	22.3	42

Notes: (1) Phosphorus and Potassium were applied as super-phosphate and potassium sulphate respectively.

(2) Rice plants were grown in 1/4000 a pots.

Table 22. Chemical Compositions of Sludge Cakes Produced in Beer Factories in Japan

(Fertilizer & Feed Inspection Office) (%)

	"Kirin" Beer				"Asahi" Beer	"Sapporo" Beer
	Factory A	Factory B	Factory C	Factory D		
Moisture	50.61	84.08	7.86		88.02	89.85
Crude Ash	12.01	51.52	12.95	14.1	44.58	17.79
Total – N	4.85	4.96	6.46	7.01	4.51	6.93
Total – P_2O_5	2.85	1.48	3.02	3.21	2.11	3.50
Total – K_2O	0.21	0.16	1.55	1.69	0.16	0.37
CaO	2.34	0.35	0.71	0.84	3.05	1.88
MgO	0.26	0.14	0.28	0.33	0.18	0.41
Fe	1.38	1.25	3.08	3.3	6.62	2.81
Na			0.15	0.2		
Total – SiO_2			4.00			
Cu			13.4ppm	14.5ppm		
Crude Protein			40.4	43.0		
Carbohydrate			12.4	13.5		

R E F E R E N C E S

HASHIMOTO, H. (1965) : Bull. Ibaragi Pref. Agr. Exp. Stat., No.6, 1. (in Jap.)

HASHIMOTO, H. et al. (1971) : Bull. Kyushu Agr. Exp. Stat., 16, 25. (in Jap.)

KUMADA, K. et al. (1972) : Jour. Soc. Soil Manure, Japan, 43, 13. (in Jap.)

MIKI, K. and MORI, T. (1966) : Bull. Tokaikinki Agr. Exp. Stat., No.15, 112 (in Jap.)

OHHASHI, O. (1972) : cited from "Problems of Organic Fertilizers in Japan" compiled by Hayase, T. p.186 (in Jap.)

SAKAI, H. (1970) : "Studies on the Problems of Rice Straw Application" (Res. Council Agr. Fores. Fish.) p.122 (in Jap.)

SANPEI, M. (1974) : unpublished.

Summary of discussion

This paper endorsed the compelling need to increase the availability of organic fertilizers, borne out by the experiments described and by the fact that average yields of paddy in Japan were already around 4.5 tons per hectare and 8 to 10 tons/ha were being aimed at.

In one of the experiments it was noted that the lignin content rose to only 17% which was very low and it was suggested that this figure be checked. The terms "nitrogen starvation" was commented upon (Table 19) due to incorporation of rice straw; it was suggested that this might be due to phototoxic substances rather than nitrogen deficiency.

E R R A T A

Page	Line	Wrong	Correct
1	4 from the bottom	resicues	residues
4	(in Table 7.)	Sale & manifacture	Sale & manufacture
4	6 from the bottom	labourconsuming	labour-consuming
5	2 from the bottom	cynamide	cyanamide
7	bottom	result	result in
8	5	increases	increase
9	5	yiled	yield
9	8	farility	fertility
9	13 & 20	homogeniously	homogeneously
9	18	requirement_	requirements
13	(Title)	DISCOVER_	DISCOVERY
13	3 & 4 from the bottom	tracer	trace_
13	(in Table 17.)	Stream	Steam
14	2	sulfanic	sulfamic
14	3	qualitiative	qualitative
14	11 from the bottom	considerablly	considerably
15	4	mitrogen	nitrogen
15	15	gargabe	garbage
16	7	contanined	contained

2. THE USE OF ORGANIC FERTILIZERS IN INDIA*

CHAPTER I

RURAL COMPOST

Farm yard manure or cattle dung manure is by far the most commonly used manure in Indian agriculture. And yet, the production level of cattle dung manure has been quite low vis-a-vis potential and its quality very poor. This is largely due to: (a) failure to utilize all the vegetable refuse and cattle dung that could be collected on the farm for purposes of farm-yard manure making: (b) the complete neglect of cattle urine which though much richer in nitrogen than the cattle dung is not properly collected and added to the manure heap; and (c) the defective method of preparation in exposed heaps which lead to rapid drying in summer, improper decomposition and considerable loss of nitrogen into air. In the rainy season, the available nitrogen fraction and a good portion of soluble humus are lost by leaching action. In the end only a small quantity of manure of poor quality is obtained.

In the present situation when prospects of obtaining enough chemical fertilizer to feed the crops has become remote it has become imperative that all-out efforts on a national level are made to step up production and use of rural compost to the maximum possible extent to release pressure on demand of chemical fertilizers. Composting of farm wastes with animal wastes would save crores of Rupees worth of manure and increase food production correspondingly. For the farmer, it would mean a substantial cut in his fertilizer bill. In addition, collection of waste materials and conversion of these into compost would keep the villages clean and promote healthy life.

A. Objective: The efforts should be directed to raise the present level of rural compost production so that each field gets manures every alternate year and the quality of the manure improved by raising the nitrogen content from 0.5% to 1.0%.

In the Fifth Plan, it is proposed to implement an integrated programme in the States aiming at utilisation of all conceivable manurial resources in rural areas viz. cattle dung and urine, farm wastes, water hyacinth, leaves, etc. for raising rural compost production to 350 million tonnes a year.

To achieve the above target, the following measures need be taken:-

(i) A manuring schedule should be worked out for each village and its requirements met through exploiting manurial resources suited to local conditions.

(ii) Panchayats should be made over-all responsible for the rural compost production activity in the villages. As an incentives to the panchayats, a system of awarding prizes to the panchayats doing excellent rural compost work should be introduced on block, district and State levels.

(iii) In the past, compost campaign weeks arranged sporadically were none too promising and it is rarely that there has been a sustained follow-up. Such campaign weeks should form a regular feature of the rural compost programme and arranged twice a year as a 'Peoples' Programme'. Panchayats organizing these campaigns should be given suitable bonus on the quantity of compost produced and distributed under its own management.

(iv) Intensive promotional propaganda/publicity should be organized through All-India Radio, T.V. and Press.

(v) In-service training refresher courses should be arranged by the State Agriculture Departments in collaboration with Agricultural Universities for the staff engaged in the operation of compost scheme not only to keep them in touch with the up-to-date techniques and methods of efficient conservation and utilization of local manurial resources but also to build up confidence and competence in the staff.

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* Ministry of Agriculture, New Delhi

(vi) Training of farmers in the techniques of composting should also be arranged at the farmers' training centres. These trained farmers will prove instrumental in demonstrating correct methods of composting to their fellow farmers and will also assist compost staff in promoting rural compost programme.

(vii) Special Staff for Compost Work:

The State Governments had in the past appointed special staff for compost schemes. Subsequently the compost staff was either disbanded or curtailed in several States while in other States it was put on other jobs.

To carry out the comprehensive programme for development of local manurial resources envisaged for the Fifth Plan, it is of the utmost importance to have a well-knit staff organisation at State, regional and block levels. The State Governments should, therefore, provide requisite staff where there is none and suitably strengthen it where there is some.

To augment rural compost production, special programme which could bear definite result, need also be drawn up and implemented. There are:-

(a) Construction of improved cattle-sheds permitting collection of cattle urine also.

(b) Night-soil conservation on community basis in selected villages-provision of Wardha type latrines and movable latrines.

(c) Construction of suitable latrines/urinals in schools to conserve and utilize night-soil and urine for manuring school fields/vegetable plots.

(d) Construction of urine and compost pits and manure sheds in goshalas and pinjrapolls for better conservation of cow-dung and urine.

(e) Construction of manure sheds in coastal areas.

(f) Construction of roofed pits/heaps for storing manure under severe cold climate.

(g) Compost making by landless labourers as an ancilliary occupation to supplement their income.

(h) Preparation of poultry manure as an adjunct to poultry development.

For the execution of the above programmes, adequate funds should be provided in the State Plan. The programmes at (a), (e), (f), (g) and (h) can best be taken up under the aegis of SFDA/MFAL agencies.

(viii) In case of dearth of sufficient land for compost pits, panchayats should be empowered and assisted to acquire the required land for the common good and develop the same as model compost yards. In villages where consolidation of holdings has been completed and land for compost pits earmarked, the revenue patwaris should give demarcation of area to each farming family in the village.

(ix) Planting of Ipomea-carmea and Glyricidia maculata and incorporation of leafy material into compost pits should be popularized.

(x) Farm forestry programmes may be undertaken in village common lands and also in the fields of the farmers by planting suitable trees recommended by the forest authorities for use as fuel wood with a view to diverting dung for manurial purposes.

B. Award of Prizes to Gram Panchayats-Central Sector

The scheme is one measure among various other development aspects to step up compost production. The scheme will be implemented with the twin objective of increasing compost production and bringing about improvement in its quality by giving encouragement to the outstanding gram panchayats through incentives in the shape of prize awards and by involving more number of panchayats in the programme by creation of competitive spirit amongst them.

The competition will be held at four levels viz. block, district, State and all India levels. The prizes to be awarded shall be according to the following schedule:

Prize at	Amount of each prize		Amount for all the prizes	
	First	Second	For 1 year	for 5 years
	Rs	Rs	Rs	Rs
Block Level (5,000)	250	-	12 50 000	62 50 000
District Level (35)	400	200	21 000	10 50 000
State Level (30)	2 000	1 000	90 000	4 50 000
All-India Level	5 000	3 000	8 000	40 000

While the funds for award of prizes at the block level and district level will be provided by the State Governments themselves, the award of prizes at the State level and all-India level will be taken as a Centrally sponsored scheme, the entire cost (Rs. 4.90 lakhs) being treated as grant-in-aid to the States.

C. Organisation of Demonstration-cum-Training Camps by the Farmers' Associations - Central Sector.

Rural compost programme being a programme of the masses, the training of farmers in the techniques of better and larger conservation of manurial resources for compost production forms the back-bone of this programme. The objective of the proposed scheme is to secure active cooperation and involvement of various Farmers' Associations with national standing in the implementation of the programme for better and larger conservation of manurial resources for manure production in the rural areas. These Associations will organize campaigns, exhibitions, seminars and demonstration-cum-training camps with a view to educating, motivating and mobilizing the farmers for maximizing the production and use of organic manures. Every year, 200 demonstration-cum-training camps of 1-day duration will be organized and for each camp a grant of Rs.250/- would be made available by the Government of India to the Farmers' Associations. The total amount of grant required for 5 years works out to Rs. 2.50 lakhs.

CHAPTER II

Green Manuring

Green manuring offers a very effective way of meeting fertiliser shortages. It requires no investment of money and can be carried out by the farmer with his own labour. In the long run, fertility of the soil is increased by the addition of green materials. Some or all of the following effects are also likely to result:

(i) The humus may be increased and with it the physical characteristics of the soil improved.

(ii) Mineral nitrogen already present in the soil may be protected against loss.

(iii) The availability of other nutrients than nitrogen may be increased.

It is, therefore, highly desirable that green manuring practices be popularized as far as possible. It is however generally felt that by adopting the practice of green manuring there is every likelihood of losing a crop. Another constraint in the adoption of this practice is the lack of adequate water supply for sowing of green manure crop and for its decomposition in the soil. Under such conditions, it will be a good practice to follow a crop rotation including a leguminous crop so that there is no loss of any crop while the beneficial effect of nitrogen fixed by the leguminous crop will be available to the succeeding crop. Even where the growing of green manure involves a loss of kharif crop, it should be possible for the farmer to put 1/5 of his land in the first year under green manure. The increase in yield that he would get from the 1/5 green manure area will Compensate him for the loss of the kharif crop. In the second year he can green manure 1/4th of his land and one third in the third year.

A choice of a particular green manure crop has to be made in relation to the soil, the time available to raise green manure crop and the facilities for irrigation.

The State Governments should ensure that the farmers get green manure seeds which are suited to their conditions. The multiplication of green manure seeds should be arranged within the block and preferably within the village so that the supply of seeds does not operate as a limiting factor. Irrigation water for growing of green manuring crops will also have to be provided free as has been the practice in several States.

CHAPTER III

MECHANICAL COMPOST PLANTS

Whilst towns and medium cities in general have adopted conventional method of composting with success as a system of disposal of urban wastes, it is in big cities that this method poses several problems like costs, availability of land for composting, labour requirements for composting operations which involve human contact with filthy and obnoxious materials, haulage of refuse materials to distantly located composting grounds, marketing of compost etc. The result is that the municipal corporations/committees of these cities resort to disposal of their urban wastes by methods other than by composting thereby wasting completely a great deal of urban garbage which could be usefully converted into organic manure through composting. The use of urban wastes as manure would have a number of advantages,the chief being a source of income which could be set off against the cost of disposal and service.

Advantages of mechanical composting:

Mechanical composting offers a solution to the various problems of disposal of wastes in big cities. It is particularly suited for cities in which population growth has taxed the capacity of existing sites for dumps or land-fill. Mechanised composting can be undertaken at a central location and in small compact areas thus avoiding long haulage and constant search for new land. If composting has to be encouraged in the larger cities, the traditional method of composting will not be suitable. It is only mechanised composting which may prove effective in not only serving as a means of disposal of the urban wastes but also of providing the country with large quantities of high quality organic manure to supplement the supply of chemical fertilizers. The other advantages of mechanized composting are:-

(a) sanitary control with odour-proof devices;

(b) working both in dry and wet seasons;

(c) recovery of discarded materials, like metal, glass, rags, etc. is more economical because of the plants design;

(d) high grade compost quality in a very short time;

(e) a well designed compost plant can handle sewage, sullage into a safe valuable product when mixed with ground refuse and completely eliminates large anaerobic digesters sludge drying beds, thus effecting saving cost of treating sewage (It is estimated that the cost of treating sewage by composting is about one half of the conventional disposal method in a modern sewage plant;

(f) compared with land-fill, a centrally located compost plant would reduce hauling costs from Re. 1/- to Rs. 5/- per tonne.

Experiences of other countries

European countries and America are devoting considerable efforts to mechanize the composting process. These efforts have resulted in various successful mechanized innovations. There are now available several types of compost plants which have been set up in foreign countries. whose economy is based on agriculture. Israel has built what is known to be the largest compost plant in the world. The plant is to cater to the manurial needs of horticulture. It is designed to cope with all the domestic refuse from Tel-Aviv (500 tons in one shift of 8 hours). The second biggest plant has been built in Bangkok. The plant is planned to play an important part in increasing susbstantially the yield of rice in that country.

Necessity of setting up of compost plants:

In our country, the drive for raising vegetables and short duration crops to meet consumers' demands is assuming increasing importance. The growing of vegetables and short duration crops is mainly confined to the vicinity of big cities. Large application of organic manure is required for raising these crops in comparison to other crops. Compost from urban wastes will meet, in full measure, the manurial requirements of these crops. It is high time that such plants are set up in the selected cities/towns in India where the problem of disposal of urban wastes and night-soil has assumed greater importance due to progressive growth of urbanization and has also become a source of health hazard.

The Committee on 'Urban Wastes' constituted by the Ministry of Health under the chairmanship of Shri B. Sivaraman, Vice-Chairman National Commission on Agriculture, which is seized of the problem of disposal of urban wastes both in the interest of agriculture and sanitation has strongly felt that compost plants should be set up in large cities/towns in the country.

In the Conference of State Agriculture Ministers and State Ministers of Urban Development and Local Self Government on utilization of organic manures and efficient use of inputs, held at Vigyan Bhavan, New Delhi, on the 4th January 1974, under the chairmanship of the Union Minister for Agriculture, it was also decided that 45 compost plants in cities/towns of population of 3 lakhs or above might be set up in the country to manufacture good quality compost out of the city wastes to meet the demand of organic manures, the need of which is being increasing felt particularly in the present context of shortage of chemical fertilizers.

Benefits accruing from the compost plants:

With the commissioning of 45 plants, it is estimated that 1.5 million tonnes of good quality compost would be available per annum for agricultural production purposes. The monetary value of the plant nutrients (N, P, K & Lime) contained in the above quantity would be about Rs.10.5 crores. Apart from this, application of compost will result in the availability of huge quantities of organic matter which is responsible for keeping the soil in proper physical condition and for building up soil fertility. Compost turned out by the plants will contain plant nutrients more or less in a balanced proportion and also meet the micronutrients requirements of the soil. The other specific benefits which would be achieved are as under:-

(i) Cleanliness of the cities/towns and environmental pollution control through a well designed and equipped system of collection, removal and disposal of garbage; and

(ii) Eradication of degrading practice of manual handling of night-soil and other urban refuse by provision of suitable handling equipment to the sanitary staff.

Economics:

Cost of manufacturing one tonne of compost mechanically has been assumed as Rs. 30/- and necessary distribution charges at Rs. 5/- per tonne. These figures are hypothetical because of the fact that no compost plant has so far been set up in the country and therefore no cost data on the actual working of a compost plant are available in the country. Taking the composition of compost as 1.3% N, 1.1% each of P205 and K_2O, including lime the market value of compost comes to Rs. 75/-. Therefore, the balance i.e. Rs. 40/- can be spent on transportation. Assuming transportation charges at Re.1/- per km per tonne, economic haul distance would be 40 km.

The farmers by using compost in conjunction with the chemical fertilizers shall be getting additional yield to the extent of 25% of the crop that he would have got with the use of chemical fertilizers and 0.625 tonne with fertilizers and compost; the value of additional rice (0.125 tonne) at Rs. 1500/- per tonne comes to Rs. 185 per acre.

One tonne of compost will contain 13 kg of N, 11 kg of P_2O_5 and 11 kg of K_2O. One tonne of compost will be equivalent to 65 kg of ammonium sulphate, 66 kg of superphosphate and about 22 kg of sulphate of potash. It will cost about Rs. 30/- to produce the above quantity of plant nutrients contained in one tonne of compost, whereas the pool price of ex-factory price of the same plant nutrients contained in chemical fertilizers comes to Rs. 67/-. Thus it is cheaper to manufacture compost mechanically than chemical fertilizers on equal plant nutrient basis even if transport aspect is taken into account.

Thus the need for setting up of compost plants has been recognized at all hands.

Fifth Plan Programme and financial assistance:

It is planned to set up 45 compost plants under the integrated scheme of urban wastes disposal during the Fifth Plan period. A list of such cities/towns which offer scope is appended. As compost plants are first of their kind and huge capital investment is required on the part of the municipalities/municipal corporations/agro-industries corporations setting up these plants, the Ministry of Agriculture has decided to give grant-in-aid to the extent of 33% of the capital cost. The remaining cost will have to be met by the agencies setting up the plants either from their own resources or by raising loans from the nationalized banks.

The Ministry of Works and Housing has also provided Rs.10.0 crores during the Fifth Plan in the Central sector for the following purposes which will be given as non-recurring grants to the municipalities/corporations ranging from 25% to 50% of their computed deficiencies for implementing the multi-objective scheme intended to integrate the cleanliness of selected cities with the production of enriched manure:-

(a) Financial support for technical personnel in the integrated scheme;

(b) Non-recurring grant for purchase of trucks, wheel barrows, etc;

(c) Non-recurring grant for improvement of workshop facilities.

(d) Non-recurring grant for construction of collection sites;

(e) Non-recurring grant for providing mechanical sieves and other equipment to the remaining 95 class I towns; and

(f) Setting up of Project Formulation Group/Project Management Group, Survey/investigation and field studies.

Preparation and submission of project reports

The Ministry of Agriculture has requested all the State Governments, Union Territory of Delhi and Municipal Corporations of all the cities having population 3 lakhs or above to undertake survey, conduct field studies and send us concrete proposal for approval so that the project could be started right from the beginning of the Fifth Plan period.

The Gujarat Agro-Industries Corporation which has taken a lead in formulation of a project have also offered their services for rendering consultancy service, conducting of field studies and for preparation of project reports. The services of the Agricultural Finance Corpn., National Industrial Development Corporation and CPHERI of CSIR could also be availed for consultancy service, conducting surveys.

Action to be taken by the States and municipal corporations:

The project for setting up of compost plants involves huge task and requires urgent action on the part of the State Governments and the Corporations on the following lines:-

(i) The State Governments may identify the cities where the integrated scheme of urban wastes disposal may be implemented during the 5th Plan period. These cities should forthwith be notified about the broad outlines of this scheme.

(ii) The selected municipalities should take the following steps:-

a. To have analysis of the refuse done quickly if it has not been done. For this purpose, they can enlist the services of CPHERI, Nagpur. The CPHERI would be in a position to carry out the investigations in this regard and give them the requisite report.

b. To prepare a list of the deficiencies in matters of transport, workshop facilities, properly constructed garbage bins, equipment needed for handling the urban wastes e.g. wheel barrows, clothing items, etc. They should separately prepare estimates for seeking assistance for these items under the scheme. The proposed assistance will not exceed about 50% of the computed deficiencies.

c. To compute deficiencies in man power involved in the collection, transportation and disposal of urban wastes and prepare suitable schemes for strengthening the organization for efficient handling.

d. To take steps for initiating the process of obtaining institutional finance for mechanical composting plants. The State Governments should issue guidelines to the local bodies in this regard.

e. To take steps for sewage disposal so that it is available for enriching the compost.

Urban Compost - State Sector

It has been observed that the schemes for the development of local manurial resources were accorded a low priority and most of the State Governments did not allocate and provision in the Fourth Plan specifically for these schemes. Even those States which had allocated funds for these schemes in the draft 4th Plan, either withdraw the provision subsequently or cut it drastically. Even the special staff appointed for implementing these schemes has been disbanded in several States, while in some States it has been put on other jobs. For these reasons, the progress under these schemes has not been to the desired extent.

While discussing the approach to the Fifth Plan, it has been strongly felt that the programme for development of local manurial resources should not only be further intensified but made more comprehensive aiming maximum exploitation of all conceivable manurial resources. Recently, the programme has assumed special importance in the context of shortage of chemical fertilizers now and in years to come. In view of this, the State Governments have been requested to take advance action for drawing up suitable programme pertaining to development of local manurial resources and make adequate provision in the States' Fifth Plan for their implementation.

The approach to urban compost programme in the Fifth Five Year Plan should be on the lines indicated below:-

The objective should be:-

(i) to achieve urban compost production to potential at the urban centres already covered under the scheme.

(ii) to start urban compost work in new urban centres not covered under the scheme so far, in aphased programme during the plan period.

The urban population of the country (as per 1971 census) is 10.8 crores. The urban compost that can be prepared from the wastes of this population is estimated at 10.8 million tonnes. The gap between the present level of compost production (4.8 million tonnes) and the potential (10.8 million tonnes) indicates that there is an enormous scope for increasing urban compost production in the country. (Statement showing State-wise Fourth Plan targets/ achievements and the urban centres covered is appended) Annex I-A.

It is proposed to prepare 7.5 million tonnes of urban compost a year by the end of Fifth Plan period which would yield 0.075 million tonnes each of N, K_2O and P_2O_5.

To achieve the above targets of compost production and coverage of all the urban centres, it would be necessary to take the following measures:-

(i) States should take immediate steps for starting urban compost work in all the towns/urban centres in the States so that all the towns and urban centres are fully covered under this programme and compost is made available to the farmers for increased agricultural production.

(ii) In places where urban compost production is much below the potential due to limited local demand, suitable transport subsidy to carry the manure to distantly located areas of demand should be provided to the farmers. If the quantity involved is huge, it would be justified to maintain departmental trucks at these centres for supply of manure to the indenting farmers on subsidized rates.

(iii) Necessary legislation should be passed by all the State Governments making it obligatory for local bodies to subject their refuse to composting. In States where such legislation already exists, steps should be taken to enforce it strictly. As an alternative, a directive may be issued to the Municipal committees/local Bodies that no

Government loan or non-statutory grant will be sanctioned to them for undertaking any plan, or non-plan scheme unless they take up a regular compost making scheme. Such directives have already been issued by the State Governments of Karnataka and Maharashtra.

(iv) Composting is inter-related with refuse collection and removal arrangements. The municipalities/local bodies should strengthen these arrangements. Since the expense on refuse collection and removal arrangements is a legitimate charge on sanitation, the Ministry of Health/State Departments of Local Self Government/Urban Development/Municipal Administration should provide liberal assistance for strengthening of these arrangements.

(v) A State compost development officer assisted by 2-3 regional officers should be appointed to organize urban compost work in the State. He should also be made responsible for imparting training to sanitary inspectors in the techniques of composting to enable them to carry out composting work at their respective places on efficient and sound lines.

(vi) In schemes of town planning, specific areas should be earmarked for composting grounds.

Award of prizes to Municipalities-Central Sector

Under the existing Central sector scheme for award of an all India prize to the municipality adjudged best in urban compost work, a cash prize of Rs. 5000/- is awarded every year. This is not considered sufficient incentive to the competing urban compost centres at the all India level. Even some of the State Governments are giving Rs. 25,000/- either in cash or in kind (tractor) to the local body adjudged best at the State level competition.

In the Fifth Plan, it is proposed to increase the amount of the first prize to Rs. 25,000/-. It is also proposed to award a prize of Rs. 10,000/- to the municipality adjudged second best.

CHAPTER IV

POPULARIZATION OF GOBAR GAS PLANTS

It has been recognized that the rightful use of cow-dung in our economy is as manure and its use as domestic fuel is wasteful. In the context of the urgent need to increase agricultural production. The desirability and need to conserve cow-dung as manure has assumed great importance, more so in the situation arising from shortage of chemical fertilizers in the country- The replacement of cow-dung as fuel by some alternative out cheap source of fuel in the villages with a view to releasing the cow-dung for use as manure is a very desirable objective to be worked for.

Need for the cow-dung Gas Plants

The cow-dung when processed through a cow-dung gas plant yields enough gas for cooking and lighting and a good quality manure. The cow-dung gas plant is thus a veritable boon for the farmer because of several benefits accruing from it. These are:-

(i) The manure obtained from cow-dung gas plants is richer as it contains about 1.5% nitrogen as against 0.753% in farm yard manure.

(ii) The heat efficiency of the cow-dung burnt in usual manner is not more than 11% while cow-dung gas burnt in properly designed burners has heat efficiency of 60%.

(iii) The dung gas manure is far more rich in humus which is important for improving the physical characteristics of soil, namely waterholding capacity, prevention of water logging, good aeration, etc.

(iv) The dung gas manure is in such finely divided condition that it gets mixed with the soil very easily.

(v) It helps in improving the village sanitation by preventing fly breeding, etc.

(vi) The manure is free from offensive odour normally associated with manure pits.

Working principle of the gas plant

The gas plant operates on the simple principle that when dung or any other organic material is fermented in absence of air, the combustible gas, methane is produced. In the Gobar Gas Plant this fermentation is carried out in a brick lined well which is filled with dung made into a liquid slurry with water. This is then covered with an iron drum introduced upside down in the well which serves to cut off air and provide the necessary conditions for fermentation. The gas produced bubbles inside the drum which gradually fills up and begins to float and rise. The gas is taken through a wheel cock on the top of the drum and led to the kitchen by pipes and burned through suitable burners. Maintenance of gas production is achieved by feeding about 50 kg fresh dung daily through a funnel pipe which carries the slurry to the bottom of the well. The spent slurry overflows from the top of the well and collects in a pit from where it is periodically removed and added to the compost pit.

Pre-requisites for setting up a Gas Plant

The individual or the institution must have sufficient number of animals. The animals preferably be stable bound. Weight of fresh dung every day should be at least 45 kg. This will enable establishment of a two cubic meter (60 c.ft.) gas plant. On an average the daily droppings expected from a medium size cow, buffalo or bullock, can be taken to be 10 kg (green weight). Besides this, it is possible also to establish gas plants fed entirely on night soil. In that case for the smallest size gas plants at least 60 adult persons are essential. This is normally possible only in case of hostels, public latrines etc. Roughly about 5 animals or 60 persons are essential for establishing a 2 cubic metre gas plant.

2. Sufficient space must be available for constructing the gas plant and for location of pits for outlet slurry. This space again must be very near the stable on the one hand and close to the place where gas is to be used. Normally the distance should be within 20 meters.

3. Sufficient quantity of water must be available Normally the cattle dung is mixed with equal quantity of water before feeding to gas plant.

4. Besides cattle dung and night soil, it is also possible to establish a gas plant where waste from flaying centre is available in sufficient quantity. Piggery and poultry droppings if available in sufficient quantity, can also be employed for this purpose.

Installation of the gas plant

The site for installation of the gas plant should be near the kitchen, in open space and away from any wall or tree so as to be under sunshine as much as possible. This will ensure better fermentation and better gas production.

Construction

(i) IARI Model:

Diagram 1 explains the details of the family sized gas plant which yields about 3 cubic metres of gas by daily feeding 50 kg fresh dung, sufficient for the cooking requirements of a family of about 6-8 members.

To start with a well P,2 metres in diameter is dug to a depth of 4 metres. A sloping channel E, of 15 cm. diameter is dug to a horizontal distance of 60 cm from well and carried to a depth of 65 cm above the bottom of the well. The bottom is then brick floored and plastered with cement. A well one-brick thick is now raised from the bottom, keeping an internal diameter of 1.65 metre of the well. The feeding pipe E is then fixed in position in the channel and burried, with one end projecting 10cm inside the well and the other about 35 cm above ground level. Brick lining of the well is then continued to a depth of 1 metre from the top. At this point 3 brick cornices (R) projecting 15 cm inside the well are constructed for supporting the gas holder. Alternatively 3 stone slabs or angle iron pieces each 40 cm long, can be fixed projecting 15 cm inside the well. The brick wall is then continued and finally raised 30 cm above ground level. A channel F, 10 cm wide is taken from the top for carrying the overflowing digested slurry to the compost pit W.

Where the feeding pipe E emerges out of the ground, a square brick structure 60x60x60 cms (G) is constructed about the pipe. This is filled with earth and then floored with bricks and plastered with cement, flush with the open end of the pipe. This construction serves as a funnel for daily feeding of dung slurry flowing down the pipe to the bottom of the well.

N is a small brick lined pit, 30 cm square and 30 cm deep, just outside the well which serves as a water catch to remove the condensed moisture from the gas pipe. By opening the tap periodically, once a week, the condensed water is let out and the pipe line for gas kept clear. The gas outlet pipe J with the wheel cock S is then connected as shown in the diagram and the pipe line taken to the kitchen where a suitable gas tap is fixed to take off gas for burning. The drum is then carefully introduced into the well so as to rest on the three projecting supports (R). Three 240 cm long black iron pipes (I) 4.2 cm in diameter, with pulleys (D) on the top are then fixed at equidistant points outside the well, emerging 180 cm above ground level. Three iron buckets (B) are tied to lingths of twisted wire rope of iron chain (C), with the other end tied to each of the handles of the gas drum. The wires are then passed over the pulleys so that the buckets keep hanging 45 cm from the ground level. The pipe line (J) is fixed as shown in the diagram to one of the supporting pipes, with a hand at the upper end to which is attached one end of a 240 cm long hose pipe (V) and the other end is connected to the nipple (T) in the drum.

(ii) Khadi and Village Industries Commission Model

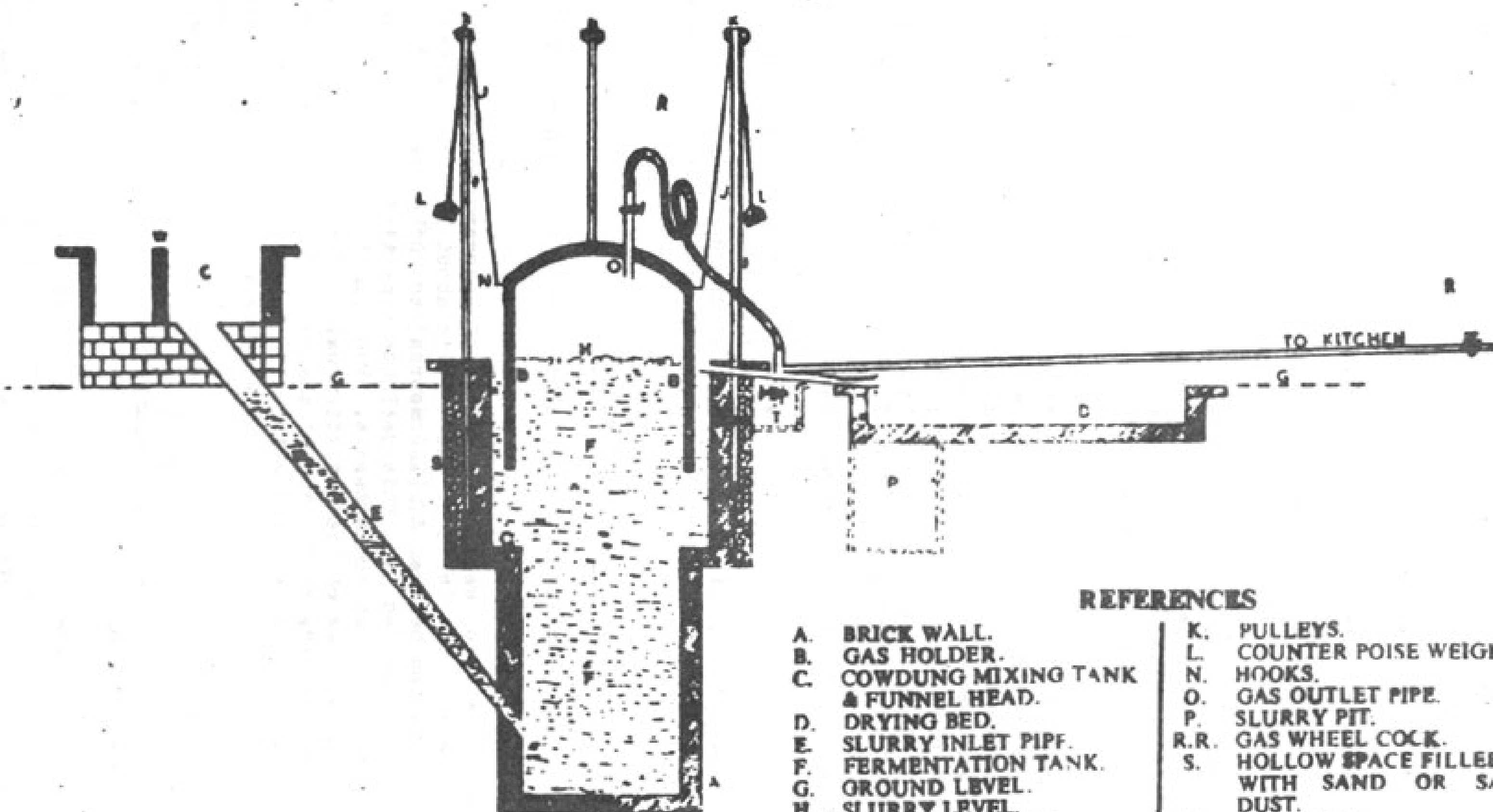
The construction of the gas plant can be understood broadly from Diagram 2. It mainly consists of two parts:

a. Digester: It is a sort of well, constructed of masonary work, dug and built below the surface of ground level. The depth of the well is about 12 (3.5 metres) to 20 ft (6 metres) and diameter varies between 4 ft (1.2 metres) to 20 ft (6 metres) depending upon the quantity of material to be fed in. This well has a partition wall in the middle dividing it into two semi-circular compartments. Two slanting cements pipes reach the bottom of the well on either side of the partition wall and have their opening on the surface of the ground by the side of the top of the well. One pipe serves as inlet and the other as outlet. Cattle dung is mixed with water in the proportion of 4:5. This mixture is led down in the inlet pipe and as the well gets filled up equal quantity of dung slurry flows out through the outlet pipe, outlet opening being lower than inlet. The partition wall stops short of the top of the well and thus it remains submerged in the dug slurry. It may be noted that the well is so designed that it can hold 50 days material. Initially it is filled up so that whenever any material is put up from one side equal quantity goes out from the other.

b. Gas Holder: It is a drum constructed of mild steel sheets. It fits like a cap in the mouth of the well where it dips in the slurry and rests on a ledge constructed inside the well for this purpose. The drum collects the gas which bubbles out from the cattle dung slurry put in the digester. The drum rises as the gas is collected in the gas

Diagram - 1

Sketch Plan of 'Utility Gobar Gas Plant'



REFERENCES

A. BRICK WALL.
B. GAS HOLDER.
C. COWDUNG MIXING TANK & FUNNEL HEAD.
D. DRYING BED.
E. SLURRY INLET PIPE.
F. FERMENTATION TANK.
G. GROUND LEVEL.
H. SLURRY LEVEL.
I. ANGLE IRON POST.
J. IRON WIRE ROPE.
K. PULLEYS.
L. COUNTER POISE WEIGHTS.
N. HOOKS.
O. GAS OUTLET PIPE.
P. SLURRY PIT.
R.R. GAS WHEEL COCK.
S. HOLLOW SPACE FILLED WITH SAND OR SAW DUST.
T. WATER TAP.
W. WOODEN PARTITION.

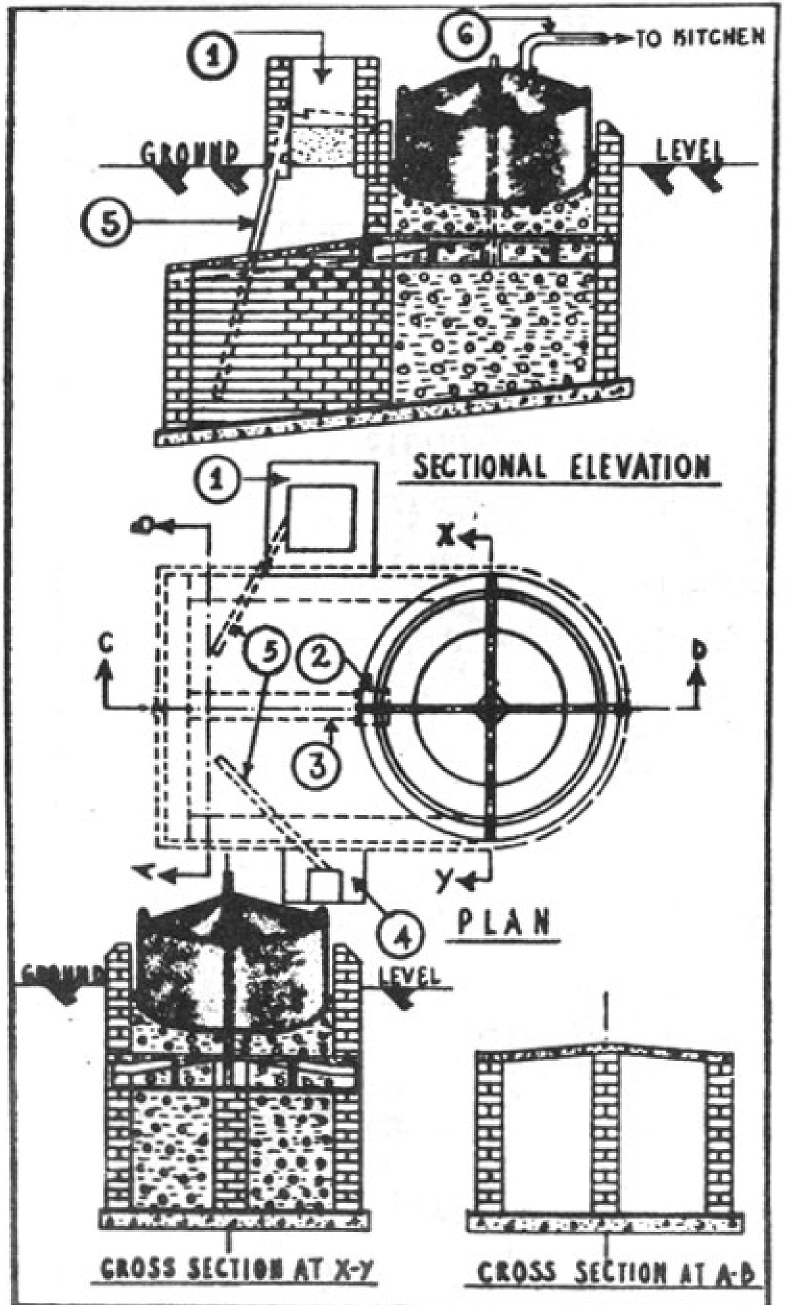


Diagram 2/1

LEGEND

(1) INLET TANK

(2) 13½" SUPPORT

(3) 9" PARTITION WALL

(4) OUTLET TANK

(5) 4" ø A. C. PIPES

(6) GAS OUTLET

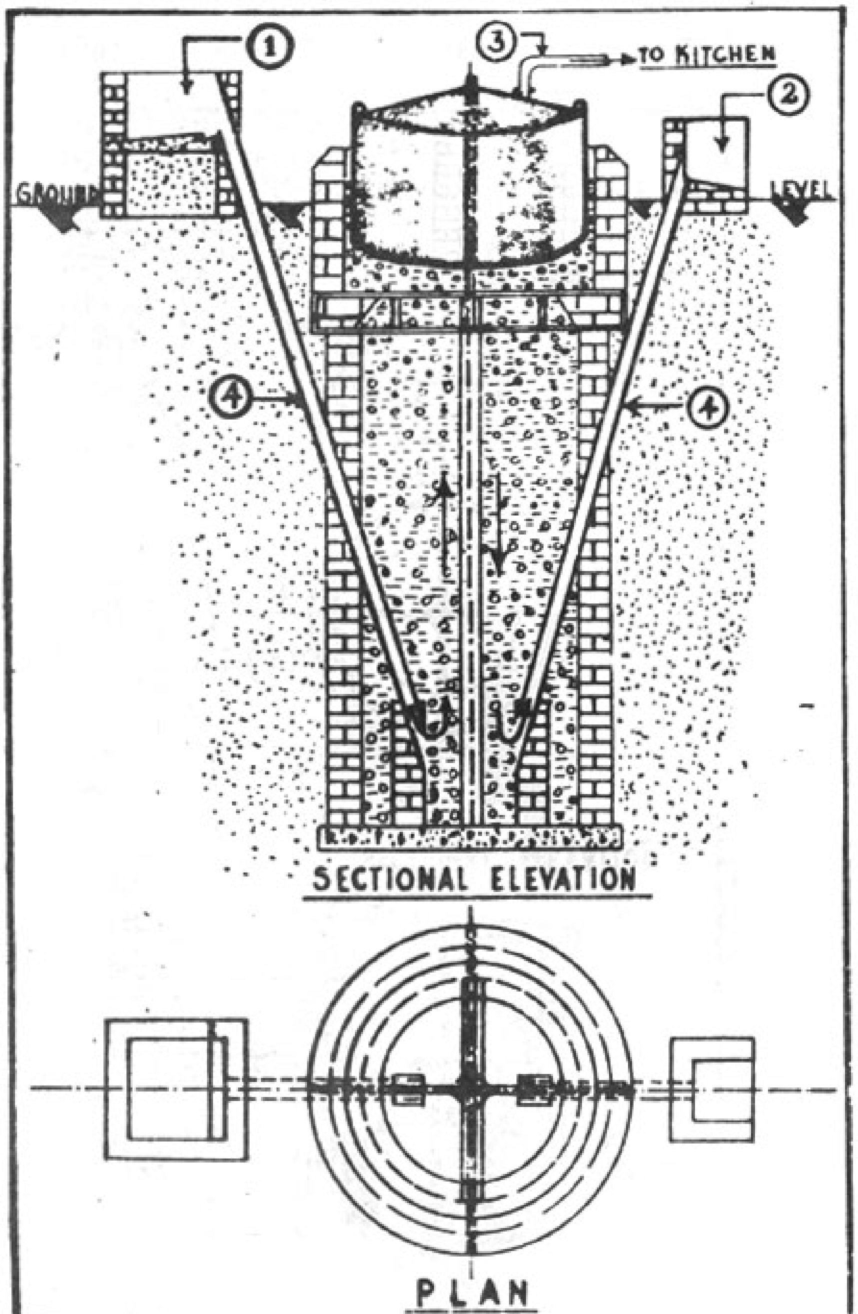


Diagram 2/2

LEGEND

(1) INLET TANK

(2) OUTLET TANK

(3) GAS OUTLET

(4) 4" ø A. C. PIPES

holder drum. The gas so accumulated flows out through the pipe provided at the top, whenever the top is opened. This gas can be led to the kitchen or can be used for gas lamps whenever required within a distance of about 100 ft (30 metres). In its up and down movement, the drum is guided by a central guide pipe fitted in a frame which is fixed in masonary work. Gas formed is otherwise sealed from all sides except at the bottom. The gas which accumulates inside the drum is under pressure equivalent to the weight of the drum. The pressure is no doubt very small 3 in (7.5 cm) to 6 in (15 cm) water column, but it is adequate to press the gas into the kitchen stove or gas lamp.

Operation of the Plant

The gas plant is now installed and ready for operation. Dung is frist made into a slurry with an equal proportion of water and introduced in the fermentation well through the funnel until it is completely full. This may take a week or more and require about 1000kg fresh dung to fill. The wheel cock of the gas holder should be kept open during this to allow the air to escape. When the fermentation well is full, the wheel cock is closed and the gas pipe line (J) and the bend (T) on the gas holder are connected by means of the rubber hose (V).

Production of gas normally starts within a week, the gas accumulating inside the holder causing it to float and rise. The first gas after installation may not burn due to a large proportion of carbon dioxide in it. If so, detach the rubber hose and open the wheel cock to release the gas. The drum will settle down and again rise with fresh gas which may be similarly tested. When the gas is required for use, open the wheel cock on the drum and burn the gas through a suitable burner.

After the gas has first formed, production is maintained by daily feeding about 50 kg fresh dung made into a slurry with an equal proportion of water. This produces about 3 cubic metre of gas daily, sufficient for the cooking requirements of an average sized family.

Larger sized gas plants can be constructed on the same principle by increasing the dimensions of the fermentation well upto 2.55 metres diameter and 4.5 metres depth with a gas holder of 2.4 metres diameter and 1.2 metres height, to yield about $9m^3$ of gas daily.

Maintenance

The gas plant can be maintained in working condition by attending to the following points:

(i) The gas collecting in the drum contains water vapour which gradually condenses in the rubber hose and the pipe line leading the gas to the kitchen. The pipe lines should, therefore, be laid with a small slope from the pit N so that all condensed water may collect here. For proper maintenance remove this water periodically by disconnecting the hose pipe and opening the water tap in the pit.

(ii) In summer the slurry on the top of the fermentation well is apt to become so thick that the drum does not easily sink when released for using the gas. The flame obtained is good to begin with but later becomes low. To remedy this, add a few buckets of water directly in the fermentation well and stir all round with a bamboo pole until the slurry is sufficiently thin. Give a few shakes to the drum and test the flame.

(iii) The gas drum should be taken out and given a coating of a protective paint at least once a year.

Disposal and use of the digested slurry

The digested slurry overflowing from the top of the well daily when fresh dung is fed, is led by means of a channel directly in a compost pit (W) filled with leaves, straw etc, where it promotes the decomposition of these materials and yields a large quantity of manure.

If space for a compost pit near the gas plant is not available, the liquid slurry may be collected in a smaller pit from where it may be cleared periodically and either applied to land directly or put in a compost pit. Liquid slurry can also be dehydrated quickly by absorbing it in leaf powder, paddy husk, saw dust and such other waste materials and further dried in the sun and stored for use when required.

Stimulating gas production in winter

In the north, the yield of gas obtained in winter is reduced to about one-third, due to the effect of low temperature on the activities of the micro-organisms. This difficulty can be overcome by the following measures to stimulate bacterial activity:

(i) Incorporation of about 10 litres of cattle urine with 50 Kg. daily will considerably increase the yield of gas by stimulating fermentation. Arrangements can be made for collecting the urine fraction in cattle sheds as such or by absorbing it in suitable litters, which can then be immersed in water and the extract incorporated in the well.

(ii) The water for preparing dung slurry may be kept exposed to the sun for the day and used in the evening for mixing with dung and introducing this in the well.

(iii) About 1 Kg of powdered leaves or wheat straw mixed with 50 Kg dung will give increased yield of gas by providing simpler energy material for the fermenting microorganisms.

(iv) Cover the gas plant with wood or polythene structure to maintain higher temperature inside.

Use of Gobar Gas

(i) Cooking

The gas is excellent for cooking purposes since the blue and smokeless flame provides a neat and efficient fuel. Suitable ring gas burners of different sizes are available in the market for this purpose. The Indian Agricultural Research Institute has also designed the following cheap and simple burners which can be easily fabricated. (a) Tin burner: This can be made from an empty cigarette tin by boring a 0.7 cm hole in the side, about 2 cm from the bottom, and soldering a 7 cm long tube of this diameter with 3 cm inside and 4 cm from outside. The lid is perforated with a 2 mm nail in a circle of 4 holes with one hole in the centre. The tin is filled with a few stones for distribution of the gas. Gas passing inside the tin through the tube burns from the perforations of the top and yield a good flame for cooking. The burner is introduced in an earthen chula on which is placed the cooking pot. (b) Angithi burner: This can be fabricated from flat tins of the size of the usual boot polish tin or larger flat tins. A 0.7 cm metal tube bent at sight angles is soldered in a hole made in the bottom of the tin. The cover of the tin is perforated with 2 mm holes along the circumference with a space of 2.5 cm between holes. This is fitted up in the usual iron angithi.

(ii) Lighting

Gobar gas can be used for lighting purposes for which suitable gas mantle lamps are available in the market. The consumption of gas in these is about $0.12m^3$ per hour per mantle.

(iii) Power

The usual petrol, kerosene and diesel oil engines of any horse power can be adopted to run on gobar gas and the power generated utilized for pumping irrigation water, grinding flour, generating electricity etc. Adapted diesel oil engines are available in the market. the consumption of gas in these is about $0.45m^3$ per horse power per hour. For this purpose large capacity gas plants according to requirements can be constructed.

Past Development Work relating to the Establishment of Cow-Dung Gas Plants in the Country

A number of agencies namely, Ramakrishna Mission, Khadi and Village Industries Commission, Indian Agricultural Research Institute and Planning Research and Action Institute, Lucknow as well as States and Central Governments have been working for popularising the installation of cow-dung gas plants in the past.

Setting up of cow-dung gas plants on a wider sclae started in 1955-56, when the Government constructed about one hundred plants in Saurashtra. The Planning Research and Action Institute, Lucknow also undertook construction of gobar gas plants in U.P., somewhat later and put up about 200 plants.

Khadi and Village Industries Commission started setting up of the gobar gas plants in the country in 1962, provided financial and free technical help to those interested in having the gas plants. There are now about 7000 gas plants in the country set up by K.V.I.C. (Annexure II).

Till now, the KVIC has been channelizing the funds in the form of subsidy and loan for installation of gobar gas plants through the State K and VI Boards and some institutions engaged in the development of K and VI Programmes.

Agencies involved in the development of the Cow-dung Gas Plants

Various agencies, viz. ICAR, Khadi and Village Industries Commission, I.A.R.I., Ministry of Agriculture are involved in the development of cow-dung gas plants. ICAR has requested its institutes and the universities to submit programmes of research to the council which would cover engineering aspects for improving burners, cylinders, drums, paints etc. A design engineering group with industrial micro-biologists and a representative of I.S.H. has been constituted, by the ICAR and has been assigned with the task of standardization, and improvement in increasing the efficiency of burners and digesters. The ICAR has also constituted a Technical Committee to undertake a survey and assessment of the different models of cow-dung gas plants now in use in the country. Khadi and Village Industries Commission has already installed 7 thousand gas plants in the country and a Statewise distribution of these plants is given in Annexure I. The Commission proposes to take up a massive programme of installing such plants during the Fifth Plan, with the Collaboration of Union Ministry of Agriculture .

National Council of Science and Technology have also taken up projects on devising gobar gas burners of more than 60% thermal efficiency and the development of alternative materials and design of gas plant to improve its working.

Indian Agricultural Research Institute has taken up studies concerning the fermentation chemistry, micro-biological studies and the studies pertaining to engineering aspects.

The Ministry of Agriculture has taken up a massive programme of setting up 50 thousand cow dung gas plants during the Fifth Five Year Plan in the collaboration with Khadi and Village Industries Commission.

Besides, the various agencies mentioned above, the banks have agreed to finance such plants in the various States.

Current Programme pertaining to the Installation of Cow Dung Gas Plants

(1) The programme for setting up of cow-dung gas plants has been taken up in a big way by the Khadi and Village Industries C mmission. The Commission renders technical as well as financial assistance for this purpose (i) to institutions and cooperatives (loan varying from Rs. 300/- to Rs. 7500/- for plants varying from 60 c.ft per day to 3000 c.ft. per day capacity), (ii) to individuals (loan varying from Rs. 300/- to Rs. 7500/- for plans varying from 60 c.ft. to 250 c.ft. per day capacity); and (iii) weaker sections and hill and border areas (100% grant for institutions and Rs. 450/- grant for individuals, the remaining amount as loan to be repaid in 10 years in 9 equated instalments). So far, about 7000 cow-dung gas plants are reported to have been set up in different States through the Commission's efforts. This number is insignificant as compared to the total number of villages in the country.

(2) Recently, the Syndicate Bank and Canara Bank have in collaboration with the Khadi and Village Industries Commission drawn up a scheme for financing the setting up of cow-dung gas plants by individuals and forwarded the same to its branches for giving wide publicity. Other banks have also agreed to extend financing assistance for this programme.

(3) Copies of the Syndicate Bank Scheme have also been forwarded by the Ministry of Agriculture to all the State Governments for wider publicity in the villages so that interested farmers other individuals/parties could avail of the financial assistance for setting up of cow-dung gas plants.

(4) In the meeting held at Bombay on 30th November 1973, with the representatives of the nationalized banks, all the banks have agreed to finance gobar gas plants in the States where it has proved very successful.

It is proposed to take up a scheme for construction of 50.000 Gobar Gas Plants during the 5th plan, jointly by the Ministry of Agriculture and Khadi and Village Industries Commission. During the first two years of the plan i.e. 1974-75 and 75-76, it is proposed to install 20,000 plants under a seeding programme. Under this scheme it is proposed to set up 2000 gas plants in each of the States of Andhra Pradesh, Bihar, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu and Uttar Pradesh, Pubjab, Haryana, etc. The estimated expenditure on this scheme is Rs. 5.60 crores which will be met by the nationalized banks by way of loans to the beneficiaries on the recommendations of Khadi and Village Industries Commission. The Government of India will give 25% subsidy on capital cost, which will be released directly to the banks after completion of gas plants. The total amount of subsidy required is Rs. 1.40 crores which will be met out of the provision of Rs. 9.0 crores agreed to by the Planning Commission for the integrated scheme for development of local manurial resources. If necessary, more funds will be sought for.

Points of Action

1. The States should assist the Khadi and Village Industries Commission to set up these plants in the States as early as possible.

2. The Khadi and Village Industries Commission will expand their organization to meet the growing demand of the farmers for setting up of gobar gas plants, take necessary steps for fabrication of gas holders and other equipments on priority basis in each region and provide necessary maintenance and service facilities for the gobar gas plants.

3. The Khadi and Village Industries Commission will also in collaboration with the State Departments of Agriculture take up immediately intensive programme of training of the farmers who will install the gobar gas plants in their homes so that they can take the best use of gas as well as manure.

4. Agro-service Centres under the State Agro-Industries corporation should also be involved in fabrication, installation and maintenance of the plants.

5. As all the banks have agreed to finance the installation of the gobar gas plants by giving loans to the farmers and others they should be given all facilities in carrying out their programme.

6. State Governments should ensure that cement and M.S. sheets/angles/flats required for the construction of gobar gas plants are made available on priority basis.

7. Necessary research work should be taken up to find out how production of gas can be increased in winter and also how cost of the plant can be reduced so that small farmer can take it up.

CHAPTER V

UTILIZATION OF SEWAGE/SULLAGE FOR IRRIGATION

Sewage is the used water supply of a community carried through an under ground sewerage system. It contains human, household and industrial wastes. It normally carries 0.1 per cent solids, two-thirds of these are in colloidal suspension and one-third in solution.

In India some 100 cities and towns are having complete or partial sewerage system. Besides these places there are some 700 towns which have surface drainage system (open drains). The sewage and sullage available in these cities and towns is estimated at about 800 million gallons per day. Sewage or sullage is disposed of in two ways: (i) by broad irrigation on the land with or without any treatment; and (ii) by discharge into the nearest river or stream either throughout the year where no sewage farm exists or at least some part of the year, even when there is one. The practice of discharging sewage or sullage into the river or stream not only causes pollution of water with consequent danger to the people and animals who use this water for drinking but also deprives the agricultural land of good manure and water for which our soils are in dire need. The information received from the State Governments indicates that at present about 200 million gallons of sewage or sullage is being utilized daily for irrigation in about 220 cities and towns. The area receiving sewage irrigation is about 24 000 hectares. (Vide Annexure V).

The benefit derived by the crops from sewage irrigation is due to the additional supplies of water as well as to the plant nutrients and organic matter content. The fertilizing as well as irrigational value is estimated below:

VALUE OF SEWAGE AND SULLAGE

Ordinary domestic sewage contains 15 to 30 p.p.m. of nitrogen 4 to 6 p.p.m. of phosphoric acid and 10 to 20 p.p.m. of potassium and an average of 400 p.p.m. of organic matter. Taking an average of 25 p.p.m. of nitrogen, 5 p.p.m. of phosphoric acid and 15 p.p.m. of potassion the manurial nutrients in 800 million gallons of sewage in a day would be as under or as in Table 1:

N 91.0 tonnes per day or 33215 tonnes a year.
P_2O_5 18.2 tonnes per day or 6943 tonnes a year.
K_2O 54.6 tonnes per day or 19929 tonnes a year.
O.M. 1456 tonnes per day or 531 440 tonnes per year.

The total value of the sewage works out to about Rs. 12.00 crores annually.

<u>Irrigation value</u>: The discharge of 800 million gallons of sewage per day can irrigate an area of 100 000 hectares or about double the area can be benefited by this source, on biennial rotation. Extra produce in terms of foodgrains from this acreage would be to the extent of six lakh tonnes. The value of this produce would be over Rs. 60 crores.

Table 1 POTENTIAL AVAILABILITY OF PLANT NUTRIENTS THROUGH LOCAL MANURIAL RESOURCES

Manurial Resources	Potential				Fourth Plan Achievement				V Plan Targets			
	Quantity	Plant nutrients content (million tonnes)			Quantity	Plant nutrients (million tonnes)			Quantity	Plant nutrients (million tonnes		
		N	P_2O_5	K_2O		N	P_2O_5	K_2O		N	P_2O_5	K_2O
1. Urban compost	10.8 million tonnes	0.108	0.108	0.108	4.8 million tonnes	0.048	0.048	0.048	7.5 million tonnes	0.075	0.075	0.075
2. Rural compost	657.5 million tonnes	4.935	3.290	3.290	170.0 million tonnes	1.270	0.850	0.85	350 million tonnes	2.620	1.750	1.750
3. Sewage/sullage	800 m.g.d.	0.033	0.007	0.020	200 m.g.d.	0.008	0.002	0.005	400 m.g.d.	0.016	0.004	0.010
4. Sludge	0.3 million tonnes	0.012	0.009	0.003	0.1 million tonnes	0.004	0.003	0.001	0.2 million tonnes	0.008	0.006	0.002
TOTAL		5.088	3.414	3.421		1.330	0.903	0.904		2.719	1.835	1.837
		Total N.P.K. = 11.923				Total N.P.K. = 3.137				Total N.P.K. = 6.391		

Composition:

		N	P_2O_5	K_2O
(i)	Urban Compost	1%	1%	1%
(ii)	Rural Compost	0.75%	0.5%	0.5%
(iii)	Sewage/Sullage	25 ppm	5 ppm	15 ppm
(iv)	Sludge	3.5%	2.5%	0.5%

Eight hundred million gallons of sewage per day is equivalent to a flow from 1600 tubewells. Sewage irrigation which supplies both the plant nutrients and water has thus a great potentiality for increased food production. This will be of increasing importance when more and more drainage schemes are completed under the national water supply and drainage programme in the various States.

Need for sewage irrigation: It is well known that the Indian soils are deficient in nitrogen and organic matter. As a result of the low nutrient content and organic matter, the average yields of food and other crops in our country are much lower than those of other countries. The lack of sufficient rain or irrigation is another problem in our country. In many areas crops cannot be raised because of the complete lack of irrigation facilities or of the limited supply of water. As a result, supplementary water needs are to be provided to meet the water requirements of crops. The correction of these conditions requires: (a) not only the full use of all known conservation practices applied so that rain will be caught and held where it falls but the tapping of all available irrigation sources; and (b) the return of all organic matter of our waste to the soil to increase productivity of our soils. There is, therefore, a great need to properly collect and utilise sewage after appropriate treatment for agricultural production and to stop the colossal waste that occurs through other means of its disposal.

Irrigation and farm management: The quantity of sewage that can be applied on land will depend on its character and upon the climatic conditions including temperature, evaporation and rainfall and the farming plan which has to be designed. The sewage may be weak, medium or strong. Weak sewage may be used without dilution while concentrated sewage will have to be suitably purified or diluted to make it fit for agricultural use. The quantity to be applied also depends on the nature of soils and may be between 4 000 to 30 000 gallons per acre per day although higher rates have been used with the effluent from treatment plants and on favourable soils. The sewage should be applied intermittently, the time between the applications varying from one to three weeks, depending on weather and on the condition of the soil. The sewage may be applied to the land in any of the following ways which are known as (1) flooding, (2) surface irrigation, (3) ridge and furrow irrigation.

SEWAGE FARM LAYOUT

A preliminary soil survey should be made. It will be necessary to examine the ground contours with reference to place or places of outfall works, the water tables from the existing wells or bore wells, relief i.e. sub-soil drainage conditions, etc. The selected site should not ordinarily be on the windward side of the city or town.

A sewage farm may be divided into different blocks for irrigation purposes. Adequate provision should then be made for distributing channels and outlets with grades sufficient to maintain a proper oxygen balance during the transit of sewage. It is undesirable to convey sewage in open, unprotected channels because of the danger of its use by cattle. Fences may give some protection. It will also be necessary to give a controlled supply of sewage irrigation by providing for standing wave flumes or Gibbs Modules.

Farm management: Cropping pattern may be adopted according to soil and local conditions. Provision of proper crop rotations and of simultaneous cultivation of green manure crops are prerequisites of a successful sewage farm as this will maintain tilth of the soil under intensive cultivation. With continued sewage irrigation under conditions of inadequate drainage, crop yields diminish steadily, indicating the gradual development of 'sewage sickness' of soil. Treatment of such soils with burnt lime followed by rest is found useful. In some soil types, sub-surface drainage must be employed to ensure proper aeration.

Sewage irrigation promotes considerable weed growth. The remedy consists in giving more space to crops so as to allow bullock cultivation operations to be carried out in standing crops.

Properly managed sewage farms have been operated successfully without reported effect on the farm workers or neighbouring residents. The management and control of sewage farms is not an amateur undertaking and should be directed by an officer of the agricultural agency.

Crops suited for sewage irrigation: Under favourable conditions, almost all crops respond well to sewage or sullage irrigation. The leafy crops, however, do better. From a sanitary viewpoint, no crops which are eaten raw should be grown on a sewage farm. The crops most suited to sewage irrigation are fodder crops and other forms of hay, grains, industrial crops such as sugarcane may also be grown successfully.

The major hazard is, however, to the farm worker. Everything possible should be done to protect him by providing safe water for drinking, from undue exposure to sewage effluents by providing gloves, gum boots, etc.

Factory effluents: Sometimes domestic sewage may become unsuitable for irrigation on account of the effluents from factories which may be let into it. Acids, alkalies, tarry matters, other toxic substances depending upon the products of the factory render the sewage unsuitable for irrigation. Methods of purification appropriate to each case are required to be adopted before letting the effluents to pass into domestic sewage.

PROBLEM OF USING SEWAGE

The following conditions are necessary for utilizing sewage/sullage potential:

(1) In all towns already having some underground drainage system, the local body should make serious efforts to extend the lines so as to cover the entire town. The same applies to open drainage systems also carrying sullage. Generally one-half or one-third of these drains are 'kutcha'. There should be a phased programme to make surface drains 'pukka' at the earliest.

(2) Most of the funds out of the allotment for the National Water Supply and Drainage Scheme are spent on Water Supply schemes and meagre provision is left for drainage schemes which are inadequate. Consequently, the drainage schemes remain uncompleted. A specific amount must be earmarked for the underground or open drainage schemes separately.

(3) In the implementation of the National Water Supply and Drainage Programme by the Ministry of Health, the initial planning and estimating of sewage schemes under the programme should include a self-contained disposal of the sewage on land. In preparing such schemes, it is essential that the Public Health Engineering Department works in close collaboration with the Agriculture Departments of the States so that the selection of the site and soils for sewage farming is made on proper lines.

(4) Sewage irrigation requires large area of land which it is difficult for a municipality to acquire. Acquisition also leads to dislocation of cultivators who own the land. Therefore the land should not be appropriated by municipal committees, but the sewage should be applied on farmers' fields after their payment of reasonable charges. In schemes of town planning, specific areas should be earmarked for setting up of sewage farms by the local bodies. To meet hygienic requirements, the Central Ministry of Health may lay down standards regarding sewage farming practices.

(5) In places where available sewage or sullage is not being utilized or is being used partially for irrigation, special survey should be undertaken jointly by the State Public Health Engineering Department and the Department of Agriculture to study the scope of its full utilization and suitable schemes framed wherever feasible.

(6) Sewage utilization scheme should not suffer for want of loans and for this purpose it is recommended that State Governments may make adequate provision in their State Plans for grant of long-term loans to local bodies. Under the pattern of Central financial assistance, sewage utilization schemes are eligible for subsidy to the extent of 33 per cent of the recurring cost of the schemes.

SEWAGE UTILIZATION DURING THE PAST PLAN PERIODS

During the Second Plan Period loans were provided to the State Governments for implementing sewage utilization scheme. But in the Third Plan no provision was made even by the State Governments under Agriculture sector of their plans with the result that practically no scheme could be taken up as Plan scheme. Realizing the financial limitation of the State, the Ministry of Agriculture, provided cent per cent funds (25% as grant and 75% as loan) for sewage utilization schemes under the special Development Programme for Agriculture (Crash Programme) launched during the last two years of the Third Plan. The response from the State Governments had been very encouraging. Thirty-nine schemes costing about Rs. 150.0 lakh were sanctioned for implementation in various States.

During the Fourth Plan Period most of the State Governments did not allocate any provision specifically for the sewage utilization schemes. Even in the case of these which had allocated funds for these schemes in their draft 4th Plan, the provision was either withdrawn or drastically cut subsequently. Though the State Governments prepared cost estimates for a number of sewage utilization schemes for places which offer immediate scope, unfortunately in view of their tight financial position, sewage utilization programme could not be given effect as it was no longer a Centrally sponsored one and thus received a great set-back.

FIFTH PLAN APPROACH

During the Fifth Plan, it is proposed to take up sewage/sullage utilization scheme in 200 cities/towns benefiting an area of 24 000 hectares and giving an additional yield of 1.5 lakh tonnes in terms of foodgrains. For executing these schemes, it is proposed to give central assistance by way of grant-in-aid to the municipalities to the extent of 33% of the capital cost of works, such as connecting sewers, pumping equipment, rizing mains, construction of irrigation channels and lay-out of sewage farms. The remaining cost will be met by the municipalities through loans.

As an advance action, the State Governments have been requested to frame economically viable sewage/sullage utilization schemes and send the same to the Ministry of Agriculture for scrutiny and approval so that the actual execution could be taken up right from the beginning of the Fifth Plan.

The criteria for grant of Central assistance will be as under:-

(i) The cost of a scheme should not exceed Rs. 2 500/- per hectare benefited;

(ii) Items of work will include only laying of connecting sewers primary treatment, pumping equipment, laying of rizing mains, distribution channels and well for diluting the sewage, wherever needed; and

(iii) Only such schemes will be considered as are framed by the State Public Health Engineering Department in consultation with Department of Agriculture and Completed and commissioned within two years.

The financial assistance will be provided to the concerned municipalities through the State Governments. The municipalities will in turn place the funds at the disposal of the State Public Health Engineering Department for execution of the schemes. The Municipalities will be responsible to operate the schemes and ensure their proper maintenance and working. The municipalities will levy irrigation charges from the farmers, receiving sewage irrigation. The income accruing from this levy could be set against operating cost. In course of time, the municipalities are expected not only to meet the operating cost but also make handsome profit from the supply of sewage water for irrigation to the farmers.

POINTS FOR SPEEDY IMPLEMENTATION

1. The State Goverments should immediately submit schemes to Ministry of Agriculture for utilizing of sewage in the State on the criteria laid down for preparation of these schemes.

2. Highest priority should be given for completion of these schemes so that the benefits can be earned by the farmers within the financial year.

3. The States should take necessary steps for providing necessary loans to the municipalities/Corporation or raising loans from the financial institutions like L.I.C., Commercial Banks, etc.

4. A positive step in the direction of ensuring full utilization of sewage/sullage for irrigation would be to lay down a condition that unless the municipalities utilize the available sewage/sullage for irrigation, no Government loan or non-statutory grant will be sanctioned to them for undertaking any plan or non-plan scheme.

5. It should be ensured that the initial planning and estimates of sewerage schemes should include provision for disposal of the sewage through irrigation. Failure to make such provision has resulted in non-utilization of sewage in several cases. In planning such schemes, it is necessary also that the Public Health Engineering Departments work in close collaboration with the Departments of Agriculture of the States so that selection of sites and soils for sewage farming is made on proper lines.

6. Sewage irrigation requires large areas of land which is difficult for municipalities to acquire. Acquisition also loads to dislocation of cultivators owning the lands. Therefore, acquisition of land should be avoided to the extent possible and sewage should be applied on cultivators' fields on payment of reasonable charges. To meet hygienic requirements, the Central Ministry of Works and Housing should lay down standards regarding sewage farming purposes.

7. In schemes of town planning, suitable areas should be ear-marked as 'sewage farming zones' and these should not be built upon.

8. Suitable schemes for distribution of sludge at places where it is available, may also be implemented.

Summary of discussion

The description of simple and cheap processes for the production of organic manure and bio-gas in India was noted with interest and compared with the much higher costs of sophisticated and large scale methods and equipment used in the U.S.A. and other western countries. These plants needed highly skilled and trained operators and a question was raised as to whether there were any difficulties in obtaining the necessary trained operators in India. The speaker pointed out that the simple methods used in India had been developed over a long period of time, they were well known and only about 15 days of intensive training was required. Design and manufacture of the equipment was also easy, and the parts could be made by local blacksmiths.

There was a lull in interest in bio-gas plants around 1965 when the high yielding variety programme resulted in an intense fertilizer programme, but the present deficit in the energy-fertilizer-food complex is motivating the farmers to intensify and develop bio-gas plants.

ANNEXURE I-A

Statement showing targets and achievements of urban compost production and coverage of urban centres during the 4th Plan

(000 tonnes)

S. No.	State/U.T.	Potential	4th Plan Target (1973-74)	Achievement (1971-72)	Total number of urban centres	Number of working centres
1.	Andhra Pradesh	839	500	325*	806	403 **
2.	Assam	125	50	10*	80	16
3.	Bihar	585	250	92	1	65
4.	Gujarat	751	500	177	301	226
5.	Haryana	177	100	106	2	55
6.	Himachal Pradesh	24	6	6	20	10
7.	Jammu and Kashmir	84	50	9	6	2
8.	Kerala	346	40	20	9	20
9.	Madhya Pradesh	677	300	149	10	152
10.	Maharashtra	1570	1000	710	909	733
11.	Mysore	711	600	302	308	270
12.	Orissa	181	150	42	1	60
13.	Punjab	321	260	207	6	87
14.	Rajasthan	453	350	64	645	82
15.	Tamil Nadu	1245	1050	620	647	541
16.	Tripura	12	6	2	1	1
17.	Uttar Pradesh	1237	950	699	440	430
18.	West Bengal	1093	200	39	88	50
19.	Delhi	363	100	45*	1	1
20.	Goa, Daman & Diu	N.A.	6	-	3	-
21.	Pondicherry	30	30	24	2	2
22.	Cantonments			100		
23.	Miscellaneous			350		
	Total	10804	6498	4098	4286	3206

* Anticipated ** Includes bigger panchayats N.A. - Not available.

SPECIFICATIONS OF MATERIALS REQUIRED FOR INSTALLATION

(IARI MODEL)

S. No.	Materials	Quantity
1.	Gas holder 1.5 diameter, 1.2m height of 20 G.M.S. sheet, open at one end, with three handles fixed at equal distances along the circumference of the closed end. An iron rod 1.3 cm diameter welded all round the open end. One hole 13cm diameter bored on the closed end, about 23cm from the edge and a nipple 1.3 cm diameter and 8cm long welded in the hole. Another hole of 4cm diameter to be bored on the other side and 4cm cock fitted in it.	1
2.	G.I. pipes 4.2cm diameter, 240cm long with a 10cm iron sheet welded in the centre to serve as a base and a 10cm diameter pully between two 15cm long shafts welded at the other end at a tilt of about 35 degrees.	3
3.	Iron bucket 45cm diameter X 45cm height	3
4.	G.I. twisted flexible 8 ply wire (or alternatively iron chain)	25m
5.	Cement feeding pipe 3.5m. long and 10cm diameter	1
6.	Hose pipe 1.9cm diameter	3m
7.	G.I. pipe 1.3cm diameter	6m
8.	G.I. elbows, sockets, bend and tee, as required	1
9.	Wheel cock 1.3cm	1
10.	Gas tap 1.3cm	1
11.	Anti-corrosive paint	5 lit.
12.	Bricks second quality	2000
13.	Sand and cement (one bag)	

STATEMENT OF GAS PLANTS COMPLETED UPTO JANUARY '74

S. No.	States and Union Terrs.	Plant completed upto March '73	Total plants upto Jan. '74
1.	Andhra Pradesh	361 Nos.	534 Nos.
2.	Assam	17 "	27 "
3.	Bihar	85 "	100 "
4.	Gujarat	2 694 "	2 944 "
5.	Haryana	175 "	180 "
6.	Himachal Pradesh	6 "	7 "
7.	Karnataka	234 "	524 "
8.	Kerala	93 "	108 "
9.	Madhya Pradesh	191 "	106 "
10.	Maharashtra	1 350 "	1 530 "
11.	Orissa	15 "	17 "
12.	Punjab	91 "	99 "
13.	Rajasthan	40 "	45 "
14.	Tamil Nadu	198 "	248 "
15.	Uttar Pradesh	416 "	470 "
16.	West Bengal	22 "	22 "
17.	Delhi	3 "	3 "
18.	Goa, Daman & Diu	7 "	7 "
19.	Pondicherry	4 "	4 "
	Total	6 002 "	6 975 "

The Banks have agreed to finance for Gobar Gas Plants in the following States:-

a)	Gujarat	1. State Bank of India Group. 2. Bank of India. 3. Bank of Baroda. 4. Union Bank. 5. Dena Bank. 6. Central Bank of India. 7. United Commercial Bank.
b)	Maharashtra	1. State Bank of India. 2. Bank of India. 3. Bank of Baroda. 4. Union Bank. 5. Dena Bank. 6. Central Bank of India. 7. United Commercial Bank. 8. Bank of Maharashtra.
c)	Andhra Pradesh	1. State Bank of India. 2. Indian Bank. 3. Andhra Bank. 4. Punjab National Bank. 5. Indian Overseas Bank. 6. Union Bank. 7. Central Bank of India.
d)	Tamil Nadu	1. State Bank of India. 2. Indian Overseas Bank. 3. Indian Bank. 4. Canara Bank. 5. Syndicate Bank. 6. Central Bank of India. 7. Union Bank of India. 8. Bank of India. 9. United Commercial Bank.
e)	Karnataka	1. State Bank of India Group. 2. Syndicate Bank. 3. Canara Bank. 4. Union Bank. 5. Central Bank of India. 6. Vijya Bank. 7. Indian Overseas Bank. 8. Corporation Bank.
f)	Kerala	1. State Bank of India Group. 2. Syndicate Bank. 3. Canara Bank. 4. Indian Overseas Bank. 5. Vijaya Bank. 6. Federal Bank. 7. Union Bank of India.

Contd....

g)	Madhya Pradesh	1. State Bank of India Group. 2. Central Bank of India. 3. Bank of India. 4. Bank of Maharashtra.
h)	Uttar Pradesh	1. State Bank of India Group. 2. Bank of Baroda. 3. Union Bank. 4. Punjab National Bank. 5. Central Bank of India. 6. Allahabad Bank. 7. United Commercial Bank. 8. Bank of India. 9. Canara Bank.

LIST OF INTENSIVE DISTRICTS IN THE STATES UPTO MARCH 1973

S. No.	Name of States/Intensive districts		No. of plants already working
1.	ANDHRA PRADESH		
	i) Chittoor	-	93
	ii) Krishna	-	92
	iii) Warangal	-	38
	iv) Nizamabad	-	18
2.	BIHAR		
	i) Patna	-	19
	ii) Gaya	-	14
	iii) Champaran	-	11
3.	GUJARAT		
	i) Surat	-	602
	ii) Bulsar	-	468
	iii) Broach	-	344
	iv) Baroda	-	342
	v) Bhavnagar	-	185
4.	KARNATAKA		
	i) North Kanare	-	54
	ii) Dharwar	-	50
	iii) Shimoga	-	35
	iv) Chiskmanagalur	-	26
	v) Belgaum	-	22
5.	KERALA		
	i) Palghat	-	32
	ii) Mallapuram	-	13
	iii) Kottayam	-	10
	iv) Trivandrum	-	9
6.	MADHYA PRADESH		
	i) Narsing hpur	-	78
	ii) Ratlam	-	37
	iii) Ujjar	-	19
	iv) Raipur	-	9
7.	MAHARASHTRA		
	i) Sangli	-	403
	ii) Ratnagiri	-	229
	iii) Satara	-	122
	iv) Amravati	-	81
	v) Wardha	-	50
	vi) Kolaha	-	47

Contd.....

S. No.	Name of States/Intensive districts		No. of plants already
Contd.....			
8.	RAJASTHAN		
	i) Bhilwara	-	17
	ii) Jaipur	-	7
	iii) Bikaner	-	5
	iv) Ajmer	-	3
9.	TAMIL NADU		
	i) Tirunelveli	-	67
	ii) Coimbatore	-	51
	iii) Madras	-	21
	iv) Ramanathpuram	-	12
10.	UTTAR PRADESH		
	i) Varanasi	-	234
	ii) Jaunpur	-	27
	iii) Ghazipur	-	23
	iv) Allahabad	-	10

ANNEXURE V

STATEMENT INDICATING NO. OF CENTRES UTILIZING SEWAGE/SULLAGE FOR IRRIGATION PURPOSES

(in million gallons per day)

S. No.	Name of State	No. of Centres	Total quantity of sewage available (m.g.d.)	Area receiving (Hectares)
1.	Andhra Pradesh	8	29.02	876
2.	Bihar	3	6.50	171
3.	Gujarat	16	98.32	2 300
4.	Haryana	20	10.10	612
5.	Kerala	3	1.8	82
6.	Jammu and Kashmir	1	-	120
7.	Maharashtra	17	23.94	1 176
8.	Madhya Pradesh	16	10.20	1 324
9.	Karnataka	6	0.70	392
10.	Orissa	3	-	160
11.	Punjab	45	11.95	7 797
12.	Rajasthan	6	0.70	418
13.	Tamil Nadu	28	14.84	569
14.	Uttar Pradesh	40	75.35	5 021
15.	Himachal Pradesh	3	-	10
16.	Delhi	1	-	1 100
17.	Goa, Daman and Diu	1	-	111
18.	West Bengal	1	-	1 200
19.	Chandigarh	1	-	800
20.	Pondicherry	1	-	80
	Total	220	284.42	24 319

3. THE AGRICULTURAL USE OF ORGANIC MATERIAL IN BRAZIL

by

C.A. Burnett*

The recent sudden rises in the price of chemical fertilizers as a result of new international rates for petroleum have profoundly affected agricultural production throughout the world and has had a violent impact on Brazil.

Fertilizer is fundamental to substantial increases in the productivity per unit of area. The average prices of the major nutrients in the fertilizers used in Brazil before and after the price increase were: CR $

	N	P_2O_5	K_2O
1972	2.20	2.00	0.50
1974	7.20	7.00	2.00

The use of fertilizers is an investment and until a few years ago the cost of chemical fertilizers rarely exceeded 20% of the expense of farming. Now, however, fertilizers represent almost half the costs. The cultivation of wheat in the State of Rio Grande do Sul is a specific example. Mineral fertilizers used to vary between 15% and 25% of the total cost and for the 1974 crop represented more than 50% of the total investment.

The use of fertilizers obviously depends on the ratio between increased productivity and the cost of fertilizers (valor/custo). Until a few years ago this ratio was normally approximately 3 to 1 but now, owing to high prices of fertilizers, the ratio has gone down to between 1.3 to 1 and 1.8 to 1 in many cases. This is regrettable because the minimum acceptable ratio is 2 to 1. In other words, every dollar invested in fertilizers should produce an increase in the value of the crop of at least 2 dollars.

It is hoped that present technological advances will provide economical solutions to the problem of large scale production of organic fertilizers and that these fertilizers can be conveniently spread by machines on the land.

Manure

Manure is the most plentiful organic fertilizer and the most readily available in Brazil. It is obtained by collecting and treating the droppings of domestic animals, with or without the use of technological processes.

Where cowsheds are used the residue is much greater in volume because of the straw which absorbs liquids. In the more advanced farms the residue is kept in appropriate containers where great advantage can be taken of the organic material as a result of decomposition which makes the manure richer in nitrogen and more valuable as a fertilizer.

The properties of manure are well known. Some of the advantages of using it are:

1. Production of fertilizers near the areas to be cultivated;
2. the presence in balanced quantities of primary and secondary major nutrients and minor nutrients;
3. greater solubility phosphates and other minerals;
4. substratum for the development of micro-organisms and lower animals;
5. improvement in the structure of the soil.

* DICOF (Fertilizer Unit), Ministry of Agriculture, Brazilia, D.F., Brazil

In the past the correct processing and the general use of organic material were limited because of:

1. The farmer's lack of knowledge;
2. the precariousness of the infrastructure of farms;
3. the absence of sufficient government assistance.

Although these obstacles have largely been removed, there haven't been sufficient economic advantages to encourage farmers to process and to use manure more efficiently. Advertising and distribution of chemical fertilizers have increased enormously. Excellent transport is available as well as a large variety of financing schemes.

Now, however, the situation has changed considerably to favour the parallel use of organic fertilizers, because of the disproportionate increase in the price of mineral fertilizers whereas the price of manure has only risen slightly.

Great changes have occurred in the sale of chemical fertilizers:

1. Difficulties in obtaining certain products;
2. lack of delivery guarantees;
3. rises in prices, which force the farmers to reduce the amount of fertilizer per hectare since the use of fertilizer depends on the value/cost ratio.

Normally the farmer uses the manure himself and sells the surplus to his neighbours. The price is in the region of US$ 6.00 per load, about 6 or 7 tons.

Manure is used chiefly on pasture land, gardens, orchards but it is clear that if it were enriched with mineral fertilizers it could be used for the intensive cultivation of cereals and root crops.

To have an idea of the current Brazilian production of cattle manure we have only to remember that there are approximately 100 000 000 heads of cattle of which 12% are dairy cattle. Of these 25% are kept under cover and thus are effective producers of manure (approximately 8 tons per animal per year) which comes to an annual total of 24 000 000 tons.

Moreover, other domestic animals are also producing manure as the following table shows.

Animals	Total number	Percentage under cover	Manure per animal - PA
Cattle	100 million	3	8 tons
Pigs	45 "	20	2 "
Horses	14.25 "	10	2 "
Sheep and goats	36 "	10	300 kg
Fowl	281 "	30	12 kg

Compost

Compost, which is regarded in Brazil as an excellent fertilizer for gardens, orchards and hay fields, is similar in nature to manure. It comes from the transformation of various residues from agricultural land to which fresh manure has been added to activate the natural bio-chemical process.

Organic residues are transformed by the decomposing and digestive action of fungi and bacteria and lower animals, within a few weeks into a dark, friable substance which is rich in humus. It can and should be produced on a large scale as soon as the technology is available.

Compost requires some investment, for example, levelling of the land, wire fences and plentiful water. It is prepared by piling the material in lairs, each of which is covered with a lair of fresh manure. The piles are long and straight and not very high: five to ten metres in length, three to four metres in width at the bottom, narrowing to about two metres at the top. They should not be more than one-and-a-half metres in height.

It is up to the farmer to take economical measures as to the use of labour in making and maintaining the piles, in the rationalization of transport and in the spreading of the compost on the land.

The compost can be very advantageously enriched with lime, natural phosphates and potassium chlorate because it can then be used in smaller quantites per hectare. The production of this traditional type of compost in Brazil is still insignificant. It is estimated to be little more than 50 000 tons. The quantity used per hectare varies between 10 and 30 tons, depending upon the natural fertility of the soil and the crop to be grown.

Green fertilization

Brazilian technicians regard green fertilization as an efficient means of increasing the quantity of nitrogen in the soil although it is not used very much because it is considered uneconomical. Nevertheless some farmers in a few of the Southern States do practice it occasionally. In the State of Rio Grande do Sul, in the wheat producing area, this type of fertilization was increased thirty years ago. Cowpea was planted at the end of November and ploughed into the soil in March in order to improve its fertility for the growing of wheat which was planted in June and July and harvested in the middle of November. In the case of maize lupine, it was planted in June and ploughed in September. The maize was planted from October onwards.

Nowadays, in the South of Brazil, wheat is rotated with soybeans in the same year, so the land is occupied for the whole year and green fertilization cannot be employed. Nevertheless, since one of the crops is leguminous, it fixes the nitrogen from the atmosphere and thus fertilizes the soil naturally.

Studies show that sales of seeds for green fertilization have fallen drastically and probably do not exceed one hundred sacks whereas in past years thousands of sacks were sold per year.

In a few words, the factors which limit its use are as follows:

1. Occupation of land at the expense of crops.
2. Cost of planting, and mixing operations of the leguminous fertilizer.
3. The difficulty of acquiring seeds on a large scale and/or multiplying them.
4. The necessity for lime and even for mineral fertilizers.
5. Investment which is considered counter-productive on rented land.
6. The relative lack of proportion between the cost of green fertilization and the loss of the crop for which it is substituted and the increase in the value of the crop which benefits from this type of fertilization.
7. Finally, the absence of data which indicate exactly

    7.1 - the regional technology to be used and
    7.2 - the economic advantages of this practice.

The advantages can be listed as follows:

1. The production of organic material in the area in which it is to be used.
2. The availability of species and varieties for planting at different times of the year.
3. The possibility of attaining a high yield of green fertilizer per hectare.
4. The absorbency of the soil increased by the rapid decomposition of organic material.
5. The ease of mechanical ploughing in.
6. The fixity of nutrients from chemical fertilization.

This suggests that green fertilization depends entirely upon the rationalization of its use according to regional conditions and upon a balancing of the positive and negative results which it offers.

Peat

There are a number of peat bogs in Brazil of which the best known are in the states of Rio Grande do Sul, Paraná and São Paulo. There is evidence of large quantities of peat in other states, on the coastal plains, on the banks of streams and in ciliary forests of Central Brazil.

Peat is not much used as a fertilizer but it can be studied and developed in the future.

Fertilizer factories in the States of Rio Grande do Sul and Paraná use it to support nitrogen fixing bacteria.

We believe that it will be possible to use peat enriched with concentrated fertilizers such as urea, amonium phosphate, concentrated superphosphate and potassium chlorate. These mixtures should be properly tested in advance by experimental farms to discover their value as fertilizers.

Brazilian reserves of peat are estimated at more than 200 000 000 tons.

Urban Waste

Very few Brazilian cities process their waste industrially. Most collect it and tip it on unused land to fill depressions or marshes. Mountains of waste are obviously a danger to the health of the city. To put waste in the wrong places merely increases pollution.

In São Paulo, a city of 5 000 000 people, the Public Cleansing Department collects 4 000 tons of waste per day - 1 460 000 tons per year. Of this only 700 tons per day are treated and this yields 53% organic compost or 371 tons. There are two plants, one with a daily capacity of 400 tons and the other treating 300 tons per day. The equipment in these plants is of Danish design, manufactured in Brazil under the supervision of Danish experts.

Basically, there are four parts to the plants:

1. Conveyor belts to receive the waste.
2. Screens for sorting useful material.
3. A rotating cylindrical bio-stabilizer.
4. Vibrating screens for final separation of compost from what is to be rejected.

The organic substances which go through the bio-stabilizer undergo an aerobic fermentation process. The rotation homogenizes and aerates them. The internal temperature is kept at between 55° and 60° C.

From each 100 kg of waste are obtained:

- 53 kg of partly decomposed compost
- 30 kg of coarse waste
- 5 kg of fine waste

  1.5 kg of ferrous metals

  10.5 kg of glass, plastic and rags.

The partly decomposed compost is turned occasionally to mature it and to make it less dense.

The prices of the products from the São Paulo plants are:

Partly decomposed compost	(d=0.85)	- Cr $20.00/m3	- US $2.74
Mature compost	(d=0.50)	- Cr $50.00/m3	- US $6.85
Coarse waste		- Cr $ 4.00/m3	- US $0.54
Fine waste		- Cr $ 4.00/m3	- US $0.54
Compressed metals		- Cr $260.00/ton	- US $35.60
Glass		- Cr $285.00/ton	- US $39.04
Rags		- Cr $ 65.00/ton	- US $ 8.90

The demand for compost from waste has been increasing annually and the Department of Public Cleansing plans to build other plants next year.

In Porto Alegre - RS, a city of about 1 000 000 people, approximately 400 tons of waste are collected per day and are used as filler on a nearby uninhabited island. The city plans to build a type plant in 1975 to treat 150 tons per day. If all the waste were treated, more than 60 000 tons of compost could be extracted per year.

There are other cities in other states with population of more than 200 000 people which are planning to build waste processing plants. So Brazil will soon be producing significant quantities of compost from urban waste.

Other sources of organic material

The Sugar Industry

Factories are in rural areas. The cane fibres, after the extraction of the sugar, have been extensively used as fertiliser but now they are used more advantageously as fuel in the factories themselves. What is left over goes to paper and cardboard factories.

There is, however, another by-product which is being used on a large scale to fertilise the cane fields near the factories. This is the watery substance which is left over from the distillation of alcohol and cane spirit (called in Portuguese: vinhaca, restilo, vinhoto ou calda). In the past the value of this residue was not appreciated and it was poured away into streams near the factories. Present Brazilian legislation forbids this in order to prevent pollution. For this reason the residue was investigated and its value as a fertiliser was discovered. It contains 7% of solids which are rich in potassium and proteins. It is now being used by means of the irrigation system in the cane fields at a rate of 50 000 litres per hectare. One ton of cane yields 90 kg of sugar and 30 kg of syrup which is the by-product of crystallization. The thirty litres of syrup can be diluted with water to produce 10 litres of alcohol and 100 litres of residues (vinhaca).

The Brazilian production of alcohol from the harvest of 1974/75 will be 740 000 000 litres and the production of residue will probably be ten times as much as that.

The rice processing industry

Brazilian production of rice husks, which are generally discarded, is estimated at 200 000 tons. However, rice husks can be transformed into excellent compost when mixed with the waste from abbattoirs, canning factories, etc.

The timber industry

There is a large output of waste from wood processing which, like rice husks, having no special use, has been used as filler or simply burnt. However, like rice husks, it can be made into compost for organic fertilization if it is properly mixed.

Nitrogen fixing bacteria

The use of bacteria in Brazil has increased appreciably because of the general increase in the cultivation of soya beans in various states.

Four laboratories are producing bacteria in larger quantities every year. The quality is good. The innoculation of soya beans in Brazil is a practice which is being extended to other leguminous plants, in particular feed crops for animals. These are being innoculated with cultures containing specific bacteria.

The production of some Brazilian firms:

LEIVAS LEITE		800 000 doses
TURFAL		1 200 000 "
NITRAL		750 000 "
INOSODA		100 000 "
	Total	2 850 000 "

The researches of agricultural research organizations have shown the efficiency of "innoculating" soybeans, in terms of increased production.

The quantity of "innoculating agents" normally used per hectare is on standard dose (300 gms) for each 60 kg sack of beann. Each dose costs US $0.50.

It is known that the cultivation of soya beans leaves 60 kg of nitrogen per hectare in the soil. This quantity of nitrogen at a cost of US $1.00 per kg comes to US $60.00. The innoculation stimulates the fixing of nitrogen and the cost of the cultures per hectare is insignificant.

In the United States the following average figures for the fixing of nitrogen have been obtained on experimental forms with the following leguminous plants:

Plant	Average quantity of nitrogen fixed in kg/ha/year
Alfalfa	from 126.67 to 332.94
Crimson clover	" 84.07 to 191.69
Peas	" 80.71 to 147.97
Soya Beans	" 63.90 to 117.70
Cowpea	" 63.90 to 131.16
Broad beans	" 88.56 to 156.94

Conclusions

The difficulties of agricultural economy are becoming extremely complex in all countries. Agricultural production is not only linked to internal distribution but also to international trade and is thus subject to the law of supply and demand. This demands extreme care in the planning of regional production programmes as well as in the establishment of commercial agreements on exportation and importation, to avoid negative impacts, overproduction, shortages, collapse or running down in rural areas.

The exaggerated rise in the price of fertilizers has made us realise immediately the value organic materials has in merely economic terms.

Brazil has so many potential sources of organic material and residues with which to fertilize the soil that we believe we should set up a National Commission to study the subject.

Moreover we emphasize the following priorities:

1. Research projects on experimental farms.

2. The study of new technological processing.

3. The enriching of organic materials with major nutrients.

4. Intensive programmes to encourage the use of organic fertilization as well as mineral fertilizers.

5. A policy of subsidies and incentives.

Summary of discussion

The paper stressed that the present high cost of chemical fertilizers resulting from the sudden increase in the price of petroleum products was having a marked impact on Brazil. It was noted however that organic manure and peat is plentiful and readily available in that country. Present production of cattle manure alone is estimated to be in the region of 24 million tons. In line with experience in other countries, green manuring is regarded as uneconomical by the majority of farmers. The processing of urban waste for manuring is still in its infancy and at present most of the waste is tipped on unused land and could become a health hazard, but two small compost processing plants are in operation in São Paulo and more are planned for other cities.

The production of inoculants for soybeans was on the increase due to a general increase in the production of that crop. The statement that 60 kg of nitrogen per hectare was fixed in the soil by the cultivation of soybeans was regarded as excellent and probably due to very favourable conditions.

E. SOIL MANAGEMENT AND ORGANIC FERTILIZERS

1. ORGANIC MATTER AND BIOCHEMICAL PROPERTIES OF SOIL IN THE DRY TROPICAL ZONE OF WEST AFRICA

by

C. Charreau

1. Introduction

"It has been rigorously established by experimental study that plants develop fully and normally in sterile conditions and without addition of organic compounds. The role of organism and organic matter in plant nutrition is therefore indirect, although growth can be stimulated by injection of certain hormones into plants. The indirect influence that biological and organic factors have on plant nutrition is, nevertheless, of great importance, particularly in relation to the continuing ability of soils to sustain vigorous plant production (Greenland, 1972)".

We will try here to identify those functions of organic matter which are essential to the continuing usefulness of tropical soils for crop production; then, we will discuss the levels and evolution of organic matter and organic nitrogen in soils of the dry tropical area.

2. Effects of organic matter on soil properties

These effects of organic matter on soils are multiple and concern physical as well as chemical and biochemical properties of soils. From the combination of these effects on soils properties results an integrated effect of organic matter on yields, which we shall try to measure.

2.1. Effects of organic matter on soil physical properties

2.11. Macrostructure

The effects on macrostructure in an agricultural environment result mainly from the ploughing under of vetative matter, such as straw, green matter, dung, or compost. The residual effects of ploughing on soil macrostructure are more lasting when vegetative matter is incorporated in the soil.

All kinds of vegetative matter do not have the same effects on soil macrostructure. This was shown in an experiment in small lysimeters (64 dm^3) carried out in Senegal in 1972 (Ganry, Nicou, 1973). In this experiment, five kinds of vegetative matter were compared at two levels (15 t/ha and 30 t/ha as dry matter) with and without 200 kg/ha of nitrogenous fertiliser. The five kinds of vegetative matter were: (a) green stems and leaves of pearl millet, (b) roots of pearl millet, (c) straw of pearl millet, (d) composted straw of pearl millet, and (e) dry tops of groundnuts.

The vegetative matter was incorporated at the end of the dry season in the coarse loamy surface layer of a leached ferruginous soil over clayey sandstone. Then the soil in the lysimeters was kept bare during the rainy season, as the experiment had as a main objective the study of biodegradation of harvested residues. By the end of the following dry season, measurements of resistance of the soil to penetration were made in the lysimeters. Significant differences appeared among the treatments. Soil compaction was in the following order:

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* Ingénieur de Recherche, I.R.A.T., Paris

NOTE: This paper is taken from a series of 13 lectures on the soil management in the dry tropical zone given by C. Charreau, Visiting Professor at Cornell University, USA. (Spring Semester, 1974). Supported by a Grant from the US Agency for International Development under Section 211 (d) of the Foreign Assistance Act of 1961 as amended in 1966.

Straw < Roots ≃ Composted Straw ≤ Green Matter

Straw maintained the soil macrostructure better than the other forms of vegetative matter. Furthermore, addition of nitrogenous fertilizer significantly increased soil compaction in all of the treatments. It is thought that this results from biodegradation of organic components (polysaccharids or humic acids?) that contribute to soil structure (Dommergues, 1973).

These effects of vegetative matter on soil macrostructure are closely related to increases in rooting and in yields for most crops. These effects are thought to be general and of great agronomic significance for the soils of the dry tropical area of West Africa. That may be compared with the effects observed in soils of the temperate zone, as reported by Bunting (1963). This author studied comparative information from 113 experiments which were conducted on 56 sites in England for eight years (1942-49). These experiments studied the composition and agronomic effects of farmyard manure, sewage sludge, composts of straw with sewage sludge or inorganic N-sources, and straw ploughed in with sludge or inorganic N-sources. Among various conclusions, Bunting states that where organic manure is incorporated in soil its effects on yields can generally be ascribed simply to the increase in the total amount of plant nutrients supplied. He points out that in only ten experiments on nine sites effects of organic manure on yields cannot be explained by this chemical factor alone. He notes that "all of these nine sites have light soils, and some tendency to become compact in dry weather." He assumes that in these cases the complex effects of organic manure must be physical. Finally, he states that "there is little justification for ploughing in straw except on soils containing a high proportion of fine sand and silt.".

Bunting's conclusions do not conflict with our own experimental observations in the French-speaking countries of dry West Africa. Simply, what is an exception in England (and, generally speaking, in Western Europe) must be considered as the general rule in dry West Africa where sandy to coarse loamy textures prevail in the surface layers. Eventually, Bunting himself recognized the importance of physical effects of incorporating vegetative matter" ... in the developing countries, particularly in the tropics, where equilibrium contents of organic matter in arabic soils are naturally low, and many soils compact severely in dry weather (Bunting, 1965)".

Where vegetative matter is not incorporated in the soil by ploughing but is left on the surface as mulch, effects on soil macrostructure are negligible in the sandy to coarse loamy soils of the dry tropical area. This has been found in many experiments (Charreau, Nicou, 1971). On the contrary, under other tropical conditions these effects may be important. Such is the case, for instance in Ibadan, Nigeria, under an equatorial climate where textures of the surface layers are mostly fine loamy and organic matter ranges from 1.5 to 2.0 percent. Under these conditions, straw mulch has proven to have beneficial effects on soil macrostructure due to both protection against erosion and increased activity of earthworms (Lal, 1972).

2.12. Water storage

Two effects of organic matter on water storage in soil have to be distinguished: (a) the immediate effect of vegetative matter incorporated at the end of the rainy season, which is a short-term effect and (b) the effect of decomposed organic matter (or humus in a broad sense) in soil on water retention characteristics, which is a long-term effect.

Ploughing at the end of the rainy season when water content in soil is not far from field capacity may conserve most of the water stored in the soil through the dry season. This results from reducing evaporation. When rainfall is inadequate at the beginning of the following rainy season, which has happened often recently, the water conserved may result in increases of yield and, in some cases, in avoiding total loss of crops by drought. It seems also that incorporation of vegetative matter has an additional effect compared to that of ploughing bare soil. Experimental data on this practice are still limited, but some measurements made at Bambey, in Central Senegal, in the very dry year 1972 indicate that the effect may be significant (Nicou, Dancette, 1973).

The effects of humus on water retention characteristics of soil are well known. Increases in organic matter increase the water held both at the wilting point and at field capacity, but the latter is usually increased more. Thus the total available water in soil is usually increased, and the increase is at tensions at which plants can most easily withdraw water. Greenland (1972) reports, for example, that "the water holding capacity of a coarse sandy loam at Kwadaso, Ghana, was 57 percent when the organic matter content was 5 percent, and 37 percent when it had fallen to 3 percent after several years of cultivation."

Similar results were obtained in Southern Senegal where field capacity in the coarse loamy surface layers fell to 40 percent of its initial value when organic matter content decreased from 1.2 percent under forest to 0.7 percent after clearing and seven years of cultivation (Cointepas, 1958).

Although increases in water storage resulting from increases in organic matter content mainly affect the soil surface layers, they can be very important in the dry tropical area by buffering soils against the periods of water shortage that frequently occur at the beginning or at the end of the rainy season even in "normal" years.

2.13. Aggregation and soil stability

From previous experience it has been shown that structural stability and permeability measured by the Darcy method on sieved soils decreased when soils under forest were cropped in Southern Senegal (Chauvel, 1966). They also were greater in soils under long-lasting perennial grass fallow than in soils which were cropped continuously to groundnuts in Central Senegal (Poulain, 1960). These variations are closely linked to differences in organic matter content. Organic matter usually increases and strengthens aggregates in tropical soils. That not only improves water infiltration but also helps to control erosion, according to data of Combeau and Quantin (1964) in Central Africa. Multiple correlation, however, has thus far failed to show a conspicuous direct influence of soil aggregation on crop yields. As pointed out by Greenland (1972), "there is a lack of critical evidence to show that the changes induced are important in increasing crop yields."

2.14. Prevention of soil hardening

Greenland (1972) reports that humic and fulvic acids are strongly absorbed by hydrous oxides of iron and aluminium, resulting in the development of a negative charge and the peptisation of these hydrous oxides. Sorption of organic anions by amorphous iron hydroxides inhibits their crystallination and the hardening of soils. That can be important in ferruginous and ferrallitic soils, which have a high content in iron and aluminium oxides. Little information is available in French-speaking countries about this. Agronomic implications of these processes should be understood better.

2.2. Effects of organic matter on soil chemical properties

2.21. Retention of cations in soils

In most soils of the dry tropical areas, inorganic colloids consist of kaolinitic minerals and iron-and aluminium oxides. The content of inorganic colloids is low or very low in the sandy to coarse loamy soil surface layers. As a result, the exchange capacity due to inorganic colloids is low. It ranges in most surface layers from 1 to 5 meq/100g of soil. Moreover, it decreases with decreasing pH, and the latter varies in these soils between 6.5 and 4.5.

In such soils, the contribution of organic matter to the exchange capacity may be very important. It is essentially due to the carboxyl groups of the organic compounds.

"Organic matter normally has about 200 meq of carboxyl groups per 100 g, and although their degree of dissociation decreases with pH, the P_{K_a} values are in the range 4 to 6. Thus this pH range of 4 to 6, half of the carboxyl groups carry a negative charge. Thus 4 percent organic matter in a soil of pH 5 can contribute 4 meq of cation exchange capacity per 100 g of soil (Greenland, 1972)." Although this is a low value, it is usually greater than the negative charge on the inorganic colloids in most soils of the dry tropical area.

This principle can be illustrated by one example among many from data of Siband (1972) in South Senegal. Measurements were made in the soil surface layers (0-10 cm) under forest and in fields that had been cropped for various times after clearing. Values of organic matter content, clay content and exchange capacity, under forest and about 90 years after clearing were as follows:

Table 1

	O.M. (%)	Clay (%)	C.E.C. (meq/100 g of soil)
Under forest	2.85	11.1	7.80
90 years after clearing	0.86	7.5	2.50

The decrease of clay content, expressed as percent of the initial content, is 33 percent. Organic matter decreased 70 percent compared to 68 percent for the exchange capacity.

2.22. Release of inorganic nutrients

Most of the nitrogen and sulphur and an appreciable fraction of phosphorus (about one quarter to one half) are in organic forms in tropical surface soils. Moreover, organic matter readily forms complexes with heavy metals, so it can act both as a source and as a sink for trace elements in soil, thus controlling to some extent their uptake by plants.

The progressive release of these elements by mineralization of organic matter is, therefore, essential for plant nutrition in traditional systems of cropping where little or no inorganic fertilizer is used. Even in improved systems where large amounts of fertilizers are used, the fact that the release from organic matter mineralization is progressive is very important as it decreases losses by leaching.

When there is no uptake of nutrients by plants, losses of soluble forms by leaching depend mainly on the rate of mineralization of organic matter. In the lysimeter experiment quoted in item 2.11, amounts of mineral nitrogen leached were found to increase in the order:

Roots of pearl millet < straw of pearl millet ≃ composted straw of pearl millet ≃ tops of groundnuts < green matter of pearl millet

Roots of pearl millet appear to be specially resistant to mineralization. Additions of nitrogenous fertilizer generally favoured mineralization of organic matter in this experiment (Ganry, 1973).

2.23. Prevention of phosphorous fixation

Bhat and Bonyer (1968) showed that organic matter can play an important role in preventing fixation of phosphorus and other nutrients by hydrous oxides of iron and aluminium. Organic matter is strongly adsorbed by oxides, resulting in a decrease of fixation of phosphorus added.

Bhat (1970) and Oliver (1972) quoted by Pichot and Roche (1972) studied the effects of organic matter added as composted straw or dung to pots of various tropical soils, including sandy ferruginous soils. The soils were later treated with solutions containing isotopically labelled phosphorus. Where no phosphorus was added to the soil, organic

organic matter increased the phosphorus in the solution in equilibrium with soil. Where phosphorus fertilizer was added to the soil, incorporation of organic matter maintained a significant amount of phosphorus in solution and markedly increased the isotopically labelled fraction of phosphorus adsorbed on the solid phase. It seems that organic matter prevents or delays the fixation of soluble phosphates added.

This favourable action of organic matter on phosphorus dynamics in soil was confirmed by pot experiments with plants. Positive effects on growth and uptake of phosphorus by ray grass were observed. Also the L (Larsen) value was increased above that which could be attributed to phosphorus added in organic matter.

2.3. Effects of organic matter on soil microbiology and soil biochemical properties

Most soil microorganisms are dependent on the supply of decomposable organic material in soil. This is of peculiar importance for the sandy to coarse loamy surface soils of the dry tropical zone in which numbers of microorganisms are relatively low and the equilibria between populations seem very fragile. That will be illustrated by two examples from soils of Senegal.

2.31. Influence of "free" organic matter on mineralization of nitrogen

"Free" organic matter as defined by Turc (1949) is the organic matter freshly incorporated in soil and on the way to decomposition. Unlike the "linked" organic matter, vegetative tissues can be identified by use of a microscope. Both "free" and "linked" organic matter are components of soil humus (in a broad sense). Free organic matter is distinguished from linked organic matter by its density, which is less than 2.0 when separated by heavy liquids.

It was suspected that free organic matter plays an important role in mineralization of nitrogen in soils of Senegal. To test this hypothesis, a study was undertaken in two steps (Blondel, 1971). The first step was a field investigation using correlations between contents of free organic matter in the soils and tests for nitrogen nutrition of cereals. Positive and significant correlations were found. The second step used experiments, the results of which are shown on graph 1. In one experiment, "normal" soils were compared with soils enriched with free organic matter and soils on which all free organic matter had been removed. The soils were uncropped. The samples were incubated, and measurements of mineral nitrogen were made after 0, 8, and 15 days. Results on graphs 1a and 1b show that mineralization of organic nitrogen was increased by addition of free organic matter. For the soil from Nioro, increases in mineral nitrogen were more than proportional to the amount of free organic matter added. In a second experiment, controls and soils enriched with free organic matter were seeded, in vitro, to pearl millet. Measurements made after 0, 8 and 15 days are shown on graphs 2a and 2b. Levels of mineral nitrogen are low for all treatments, but mineralization of nitrogen appears to have been induced by the plants themselves and addition of organic matter significantly increased mineralization, by 36 percent for the soil from Nioro and 20 percent for that from Bambey. This fraction of humus seems to have special importance for mineralization of nitrogen and nitrogen nutrition of crops in the sandy to coarse loamy soils of the dry tropical zone.

2.32. Specific effects of dung on microbial activity

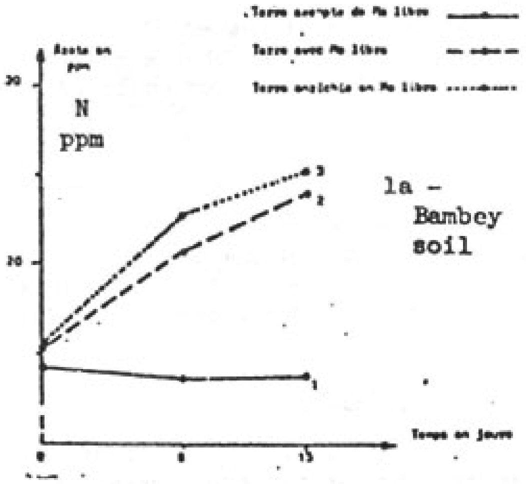
In sandy to coarse loamy soils, dung seems to have a specific influence on the balance of microbial populations and on microbial activity, resulting in important agronomic implications. Two examples from Senegal are given as illustrations.

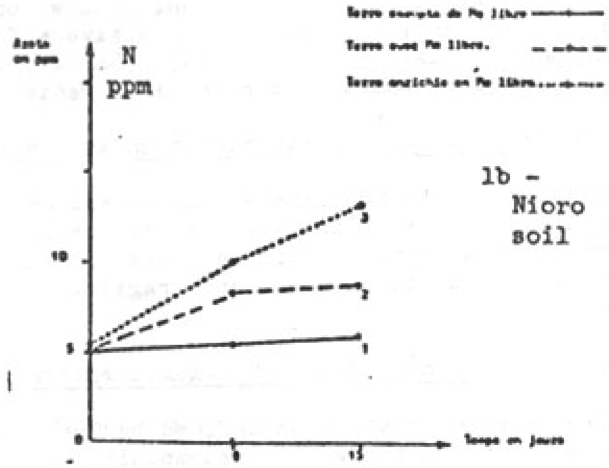
The first example concerns the correction, by dung, of depressive effects induced by repeated crops of sorghum on yields of the following crops, including cotton and sorghum itself. At Nioro in Central Senegal, for example, a two-year rotation (groundnut-sorghum) and a four-year rotation (green manure-groundnut-sorghum-groundnut) were compared. Yields of sorghum in kg/ha in these rotations follow:

GRAPHS 1 and 2

Influence of "Free" Organic Matter in Soil on Mineralization of Nitrogen

Source: D. Blondel (1971)



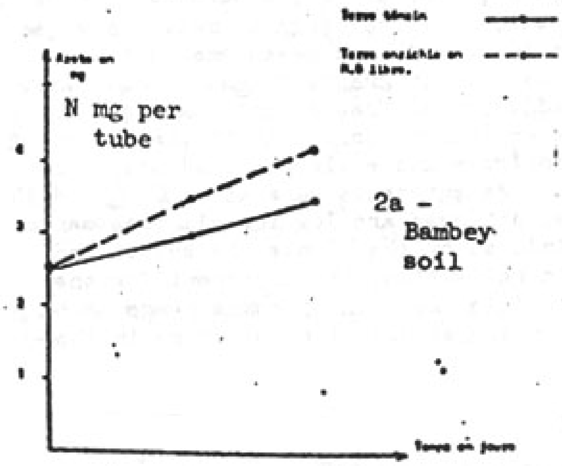


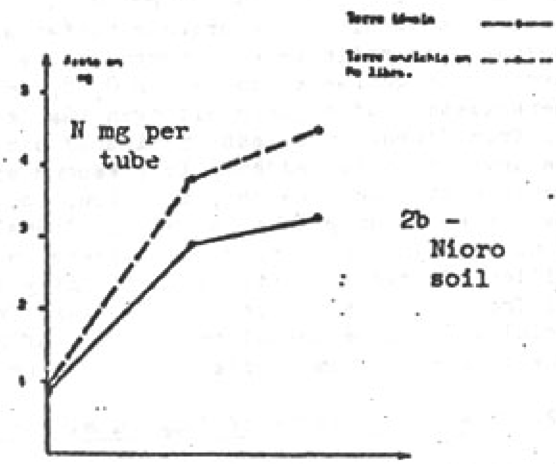
1. Experiments on uncropped soils

——— Soil without free O.M.

------- "Normal" soil

.... Soil enriched in free O.M.





2. Experiments on cropped soils

——— "Normal" soil

-------- Soil enriched with free O.M.

Table 2

	2-year rotation	4-year rotation
1968	1 877	2 642
1969	926	4 411

The plots were ploughed every two years, and large amounts of fertilizers were added in both rotations. No significant differences between the yields of groundnuts cropped in the two rotations were found, but depressive effects like those for 1969 were accentuated with time for sorghum in the two-year rotation. Various experiments in pots and in the field were carried out to check three hypotheses that might account for this despressive effect: (a) Mineral deficiencies, (b) Toxicity resulting from products of decomposition of the sorthum roots, and (c) Modification of bacterial activity with development of a pathogen flora after a crop of sorghum (Chopart, Nicou, 1972). Mineral deficiencies proved to be of secondary importance. Supplementary additions of K, Ca, and S resulted in positive but limited effects on yields. The validity of hypothesis (b) was proven by several experiments in pots. The results are illustrated for one of them in table 4. Hypothesis (c) was tested in another experiment in pots using seedlings of sorghum as a test plant. The control soil, after cropping with sorghum, was compared to (a) sterilization (autoclaved at 120° C for three hours), (b) thiabendazol (anti-*Fusarium*) 2 percent, and (c) dung (7 g per pot), alone and in various combinations. Effects on growth of aerial parts of young sorghum were the following, expressed as g of dry matter per pot:

Table 3

	0	NPK
Control	0.19	1.16
Thiabendazol	0.07	1.13
Sterilization	1.10	3.20
Dung	0.15	3.16
Dung + thiabendazol	1.13	3.39
Dung + sterilization	1.08	3.74

In this experiment, the effects of sterilization and dung are large while those of thiabendazol are small, but the dung is effective only in the presence of mineral fertilization, in contrast to sterilization.

Results of this experiment seem to support the assumption of development of a pathogen flora other than *Fusarium* after cropping with sorghum, but they do not conflict with the assumption of a toxic product (like coumaric acid). Such pathogens would be destroyed by sterilization and their biodegradation would be accelerated by addition of dung. Research is still going on to clarify this point. Whatever the final result, it is important to note the specific effect of dung where problems of microbial equilibrium are involved in soils and its practical importance from an agronomic viewpoint.

Another illustration of this point is given by the effect of dung on acidified sandy soils. It has been shown by Blondel (1970) that excessive leaching of exchangeable Ca and Mg resulted in acidification and development of aluminium toxicity where pH was less than 5.0 to 4.5, depending on the kind of soil. This toxicity decreased rhizobium activity, nitrogen nutrition, and the growth and yield of groundnuts. Similar effects were also observed for pearl millet and ascribed to abnormalities of the rhizosphere. Effects of liming to correct acidity resulted in increases of yields but these effects were enhanced greatly when dung was added in the case of pearl millet. This is illustrated by experimental data in table 5. In this experiment, effects of dung cannot be dissociated from those of calcium, but comparisons with other experiments show that the additional effect of dung on yields of pearl millet is important and may be explained by modification of microbial activity in the rhizosphere.

Influence on growth of sorghum of addition
of sorghum residues to soil in pots

Sorghum	Soil after cropping with groundnut		Soil after cropping with sorghum	
	Control	Enriched with roots of sorghum	Sampling between rows	Sampling beneath the sorghum plant
Height (cm)	32	18	20	18
Dry weight of aerial parts (mg)	332	73	117	98
Dry weight of roots (mg)	255	99	132	94

Table 5

Influence of dung, associated with lime, on yields of pearl
millet and groundnut, on acidified soils in the center of Senegal
(Yields in kg/ha)

Crop	Rotation	Without fertilizers		Light fertilization		Heavy fertilization	
		Control	Dung + lime	Control	Dung + lime	Control	Dung + lime
Pearl Millet	4 years	215	1 883	704	1 958	783	1 900
	2 years	88	1 723	363	1 720	459	1 721
Ground-nut	4 years	1 491	1 809	1 487	2 125	1 740	1 880
	2 years	1 390	1 841	1 481	1 914	1 417	1 935

Source: IRAT/Senegal, 1971-72

2.4. Integrated effects of organic matter on yields

So far we have tried to separate the effects of organic matter into physical chemical and biological effects on the soil. Now we will attempt to measure their synthesis in the effects of organic matter on yields. Two methods can be used to measure these effects on yields: (a) Correlation techniques and (b) field and pot experiments.

2.41. Correlation

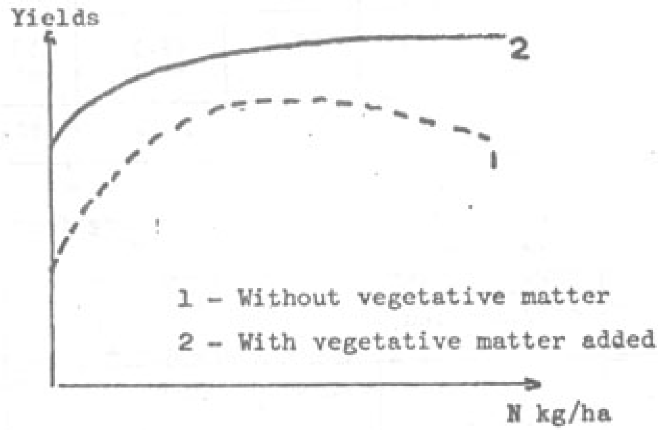
Simple multiple correlations between organic matter contents in soil and yields of crops are difficult for the sandy to coarse loamy soils of the dry tropical zone because the range of variation of organic matter content is often narrow in cropped fields, and where large variation is found, it is often linked to variation in clay content and, hence, in exchange capacity and exchangeable cations. There are, however, some examples where the effect of organic matter could be isolated. Such is the case for the variations induced by Acacia Albida in Central Senegal (Charreau, Vidal, 1965). Organic matter ranges from 0.5 percent to 1.1 percent in the soil, depending on the distance from the tree. Yields of pearl millet have been found to increase by 145 kg/ha when organic matter content of the soil increases by 0.1 percent.

2.42. Experiments

A series of pot and field experiments have been conducted by IRAT to study the effects of organic matter on crop yields. The basic experiments compared the response curves of graminae to mineral nitrogenous fertilizers in the presence or absence of vegetative matter incorporated in the soil (Chaminade, 1958). The objective was not only to measure the specific effect of organic matter on yields but also to study the possibilities of biological storage of nitrogen in soils and the effects of simultaneous additions of carbon on this storage.

The kinds of vegetative matter incorporated were: straw, composted straw, green matter and dung. Large amounts of mineral nutrients were added, so they were not limiting factors for yields. Many analyses of soils and crops were carried out to determine the role of organic matter, ^{15}N was used. About 30 field experiments were started in 1970 at about 20 sites in Africa and Madagascar. Test plants in these experiments were cereals. The experiments are expected to run at least five years, and final results will not be available before 1975, but preliminary response curves are mainly shaped like this example.

GRAPH 3



Examples of the data are given in table 6. This experiment on pearl millet was carried out on sandy soils in Central Senegal in 1972 (Ganry, 1973; Guiraud, 1972).

Table 6

Experiment on the Specific Role of Organic Matter (Bambey, Senegal, 1972)

Source: Dommergues (1973)
After: F. Ganry (1973); G. Guiraud (1972)

A - Yields of early pearl millet (kg/ha)

	Addition of composted straw	Mineral nitrogenous fertilizer (N, kg/ha)					
		0	30	60	90	120	150
Grain	11 t/ha (D.M.)	1 959	1 971	2 179	2 241	2 192	2 061
	0	1 608	2 017	1 956	2 039	1 959	1 922
Straw	11 t/ha (D.M.)	6 325	6 600	7 250	7 025	7 210	7 480
	0	4 825	6 375	6 375	6 040	6 925	6 170

B - Distribution in % of fertilizer nitrogen stored in the various parts of the soil-plant system (calculations from ^{15}N)

Fertilizer	Addition of composted straw	Straw	Grain	Straw + Grain	Soil (0-90 cm)	Soil + Straw + Grain	Losses
90 N	11 t/ha (D.M.)	18.8	17.6	36.4	37.7	74.1	25.9
	0	18.0	21.2	39.2	43.3	82.5	17.5
150 N	11 t/ha (D.M.)	16.5	11.1	27.6	29.5	57.1	42.9
	0	14.9	12.7	27.6	25.0	52.6	47.4

C - Percentage of total nitrogen in grain and straw coming from fertilizer (calculations by usual methods)

Fertilizer	Addition of composted straw	Straw	Grain	Straw + Grain
90 N	11 t/ha (D.M.)	22.9	21.7	22.2
	0	16.4	26.5	20.6
150 N	11 t/ha (D.M.)	22.3	28.3	24.3
	0	33.4	37.0	35.3

Table 6A shows the yields of pearl millet, as influenced by various additions of N-fertilizers in the absence or presence of composted straw.

The year 1972 was a very dry year in the whole Sahelian zone; at Bambey (Central Senegal) annual rainfall was only 377 mm, compared to the average of 659 mm. Nitrogen fertilizer had little effect; only the addition of composted straw had a positive, statistically significant effect on yields. Pearl millet used mainly the nitrogen released from the straw.

Use of ^{15}N in this experiment allowed calculation of the percentage of nitrogen in the plant which came from fertilizer in the various parts of the soil-plant system (Table 6B). Only 28 to 39 percent of the fertilizer N was in the above-ground parts of pearl millet. Losses were important, ranging from 17 to 47 percent of the nitrogen applied. They were probably due to leaching because (a) the layer from 60 to 90 cm had a high content in ^{15}N and (b) in an adjacent experiment in lysimeters where the balance of nitrogen could be measured, losses by denitrification were found to be nill. Immobilization of nitrogen in organic forms was important, not only in the surface layers but also in the deep layers.

Table 6C presents calculations of percentage of total nitrogen coming from fertilizer in grain and straw. These were made by comparing the uptake by plants with or without addition of fertilizers and computing the ratio of additional uptake of nitrogen to the amount of N-fertilizer added to the soil ("apparent" coefficient of use). As would be expected, the percentage of nitrogen in the plant (grain + straw) coming from fertilizer in Table 6C is higher than the percentage of fertilizer added which was in the plant by ^{15}N in Table 6B ("real" coefficient of use). The former ranges from 20 to 35 percent compared to 28 to 39 percent for the latter. It will be noticed that the percentage of nitrogen in grain coming from fertilizer decreased when organic matter was added to soil.

2.5. Conclusions about the influence of organic matter on soil properties and yields of crops

Although soil organic matter has no direct effect on plants, it has many indirect effects that are of great importance for crop production. In the traditional systems of cultivation the chemical effects of organic matter are predominant and essential since no mineral fertilizer is used and supplies of nitrogen and sulphur come mainly from the mineralisation of soil organic matter. The stability of crop production systems depends on the replenishment of soil organic matter by allowing vegetation to regenerate naturally for several years (Nye and Greenland, 1960).

Where plant nutrition is dependent on soil organic matter, it is essential to understand the changes that are induced by the practices of the agricultural system. This is particularly important in the dry tropical zone where high temperatures and, for a short time, high humidity permit vigorous biological activity. Changes in organic matter levels are more rapid in these regions than in temperate countries.

In modernized systems where mineral fertilizers and mechanical soil tillage are used, chemical effects of organic matter are less important but remain appreciable: physical and biological effects become relatively more important and can be essential in some cases.

In both systems, replenishing soil organic matter is a major concern for the agronomist, and cultural practices must take into account the need to maintain and, if possible, to increase the levels of organic matter in soils.

3. Levels of organic matter in soils

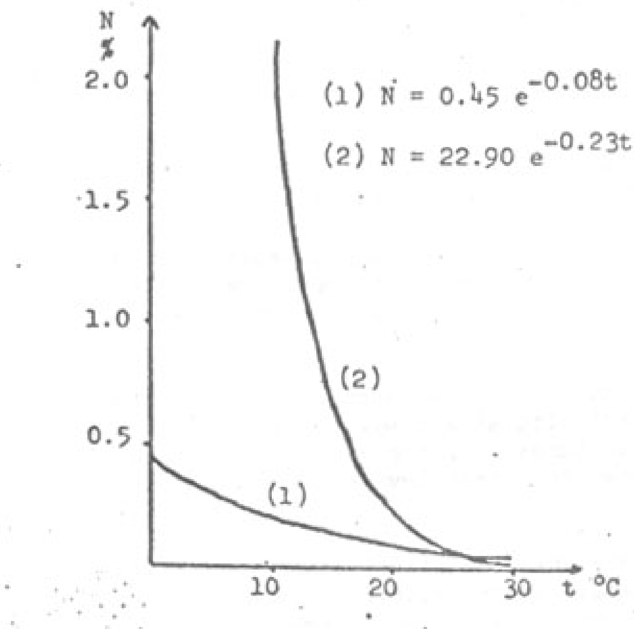
Variations of organic matter levels will be discussed in relation to two factors: (a) temperature and (b) time.

3.1. Variations with temperature (after Laudelout, Meyer and Peeters, 1960)

A quantitative relationship between soil organic matter content and climate as characterized by mean annual temperature and humidity (Meyer's NS quotient) was developed by Jenny (1941) for temperate climates. Within areas of homogeneous humidity, the relation between N, total nitrogen content in soil, and 6, mean annual temperature, is $N = Ce^{-kt}$ where C and k are constants. For the American Middlewest, values of C and k were found to be 0.45 and 0.08, respectively, when N is expressed in percent of soil and t in °C.

Extrapolating this equation to tropical soils should give values of organic nitrogen much lower than those actually observed. Further studies carried out mainly by Jenny et al. (1948, 1949, 1950) and Laudelout et al. (1960) showed that the relationship between organic nitrogen and mean annual temperature for tropical regions was always a negative exponential function, but that parameters C and k were different than in temperate regions.

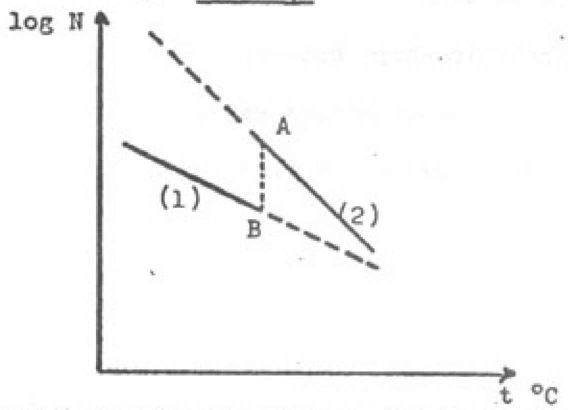
GRAPH 4A



Curves (1) for temperate soils (Jenny, 1941) and (2) for soils of Central Africa (Laudelout et al., 1960) are compared on the diagram. The curves intersect at 27°C.

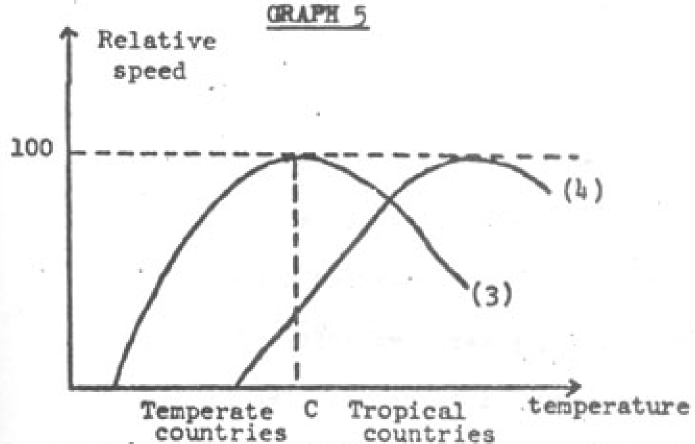
If log N is used instead of N, curves (1) and (2) become straight lines, as diagrammed here.

GRAPH 4B



One of the most likely hypotheses to account for the discontinuity AB and the limit B for extrapolation of the Jenny's equation seem to be "the frost free line." In temperate countries, frosts stop the synthesis of organic matter for a long time while decomposition by microflora is reduced but for shorter periods. On the contrary, under tropical conditions synthesis of organic matter goes on throughout the year if moisture permits. Differences in the slopes of the straight lines (1) and (2) would be explained by differences in relative speeds of synthesis and decomposition of organic matter, as illustrated in the following diagram.

GRAPH 5



(3) Synthesis of organic matter

(4) Decomposition of organic matter

Laudelout et al. (1960) theorize that in temperate countries a decrease in temperature results in decreases in rates of both synthesis and decomposition of organic matter. They suggest that in tropical countries, a decrease in temperature decreases the rate of mineralization but increases the rate of synthesis of organic matter. Thus, organic matter content would increase more rapidly with a decrease in temperature in the tropics. This would account for the steeper slope for straight line (2) than for straight line (1).

The fact that organic matter levels in many tropical soils are higher than anticipated by extrapolation from relationships between climatic factors and organic matter levels for temperate countries may also be due to interaction of organic matter with hydrous oxides of iron and aluminum (Greenland, 1972).

3.2. Variations with time

3.21. A general mathematic model

Various mathematic models have been proposed to describe the changes in soil organic matter with time. The most commonly used of them is

$$\frac{dH}{dt} = -kH + A \qquad (1)$$

where: H = humus content in soil

A = addition of humus to soil per unit time

t = time

k = decomposition constant

H, A and k refer to a defined depth of soil.

Three assumptions are made for this equation: (a) There is continuous formation of humus in soil, (b) A is a constant, and (c) k is a constant fraction of the humus content. Although A and k are not really constant over short intervals of time, general validity of the equation can be accepted provided a long enough interval of time is considered (one or several years).

At equilibrium, changes in humus content are null and $\frac{dH}{dt} = 0$

Hence: $A = kH_{\infty}$ (2)

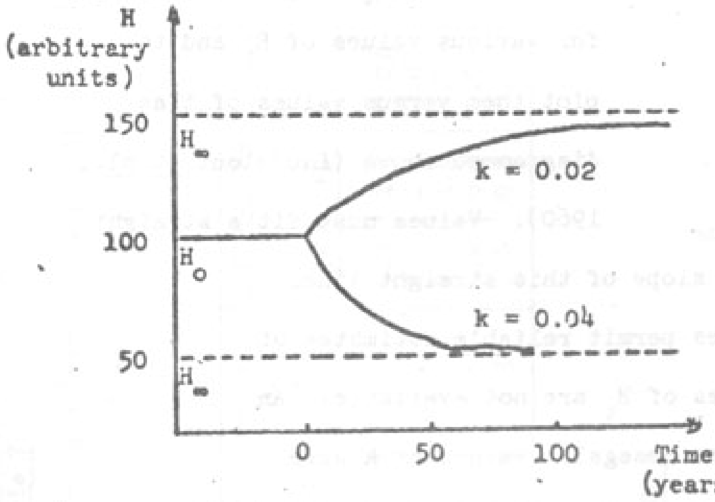
Integrating equation (1), it becomes:

$$H = \frac{A}{k} - (\frac{A}{k} - H_o) e^{-kt} \qquad (3)$$

Replacing $\frac{A}{k}$ by H_∞, from equation (2), it becomes:

$$\frac{Ht - H_\infty}{H_o - H_\infty} = e^{-kt} \qquad (4)$$

GRAPH 6



This can be diagrammed as illustrated here (Laudelout et al., 1960). The diagram illustrates effects of different decomposition constants and shows for both that the difference between the organic matter content at time t and the level of equilibrium decreases as an exponential function with time. The farther from equilibrium, the greater will be the rate of change in organic matter content. The diagram also illustrates that the higher the values of k, the more rapid will be the changes in humus, either in the sense of decreasing or increasing values (compare steepness of curves k = 0.02 and k = 0.04).

3.22. Discussions of k, the decomposition constant

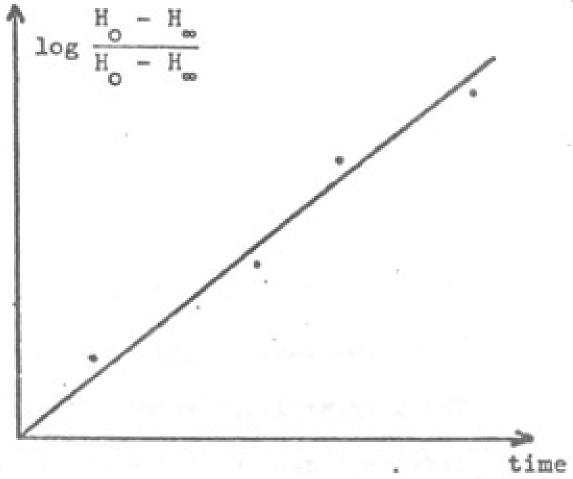
Knowledge of k enables one to calculate the time required to reach a defined level of organic matter content. It also allows one to calculate A as annual addition of soil organic matter from equation (2), when H_∞ is known.

The value of k can be determined from equation (4), knowing H_o and H_∞.

Taking the logarithm of the two members of equation (4), it becomes:

$$\ln \frac{H_t - H_\infty}{H_o - H_\infty} = -kt \qquad \text{or:} \quad \log_{10} \frac{H_o - H_\infty}{H_t - H_\infty} = \frac{kt}{2.303} \qquad (5)$$

GRAPH 7



A convenient method to measure k in a given situation is to calculate $\log \frac{H_o - H_\infty}{H_t - H_\infty}$ for various values of H_t and to plot them versus values of t as diagrammed above (Laudelout et al., 1960). Values must fit a straight line going through the origin; k is the slope of this straight line.

Few situations in tropical countries permit reliable estimates of k. Most of the time, intermediate values of H_t are not available. An example is given on Graph 8 for Southern Senegal. Values of k were computed for carbon and nitrogen. As can be seen, experimental values fit straight lines, but these do not go through origin. Values of k during the first three years were higher than later. In this example, values of k for carbon and nitrogen are about 4 percent. Greenland (1972) mentions for the humid tropical zone values of k of 3 percent under a forest canopy where nitrogen is held in a closed cycle between soil and vegetation. When forest is cleared and the soil cropped, k increases to as much as 6 percent. Much higher values have been reported by other investigators in the forest zone, but their results do not seem entirely reliable.

In the savannah zone, few measurements are available for estimating k. In Senegal, estimates of k range from 2 percent to 9 percent depending

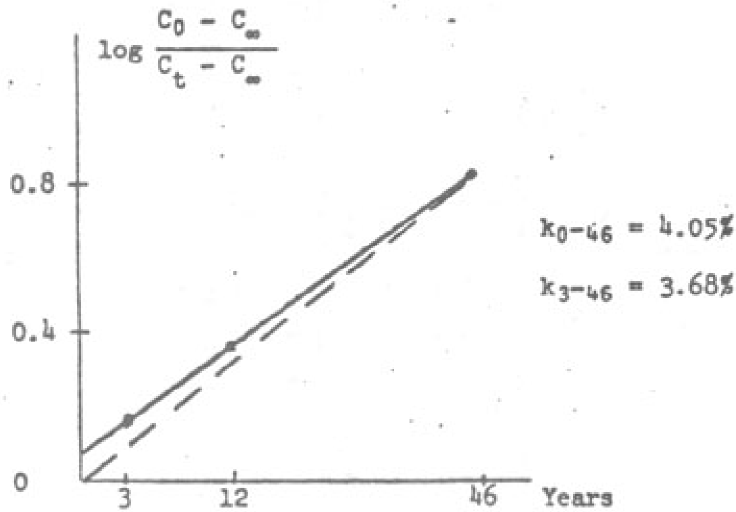
Table 7

Evolution of analytical characteristics in the surface layer (0-10 cm) of a cropped soil in South Senegal.

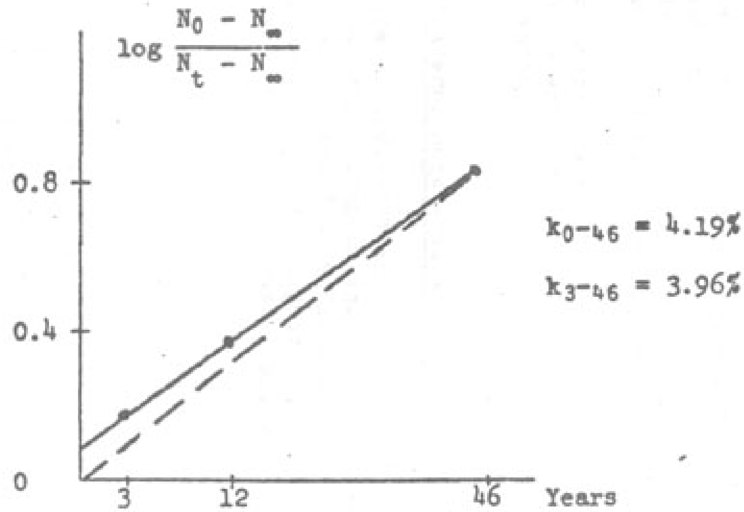
Source: P. Siband, 1972

Time after clearing (years)	Organic Matter			Particle-size		Available water	Exchangeable cations (meq/100 g of soil)						pH
	Carbon %	Nitrogen %	C/N	Clay %	Fine silt %	%	Ca	Mg	K	Sum	C.E.C.	Saturation %	
0 (Forest)	1.65	.090	18.3	11.1	5.0	4.1	5.0	1.7	0.07	6.8	7.8	87	6.3
3	1.38	.079	17.5	10.2	4.7	4.7	2.7	1.2	0.07	4.2	5.2	81	6.0
12	1.16	.068	17.0	10.5	4.7	3.7	2.2	1.0	0.04	3.2	3.7	86	5.9
46	0.68	.043	15.8	9.0	4.3	2.8	1.4	0.5	0.04	2.0	3.8	53	6.0
90	0.50	.035	14.3	7.4	4.2	3.3	1.0	0.5	0.04	1.6	2.5	64	5.9

GRAPH 8



Determination of coefficient "k" for carbon



Determination of coefficient "k" for nitrogen on kinds of soils and vegetation (Charreau, Tourte, 1967).

Values of k are influenced by climatic, soil and biologic factors. High temperature and high moisture are the main climatic factors leading to high rates of mineralization. For this reason, values of k are generally higher in tropical zones than in temperate ones, so the changes in humus content are expected to be more rapid.

Soil aeration and tillage increase k; other soil properties, such as texture, structure, and mineralogy of clays, influence k, but their roles are not fully understood. Generally high clay content and a high proportion of hydrous oxides in the clay fraction seem to lead to lower k values (Greenland, 1972).

3.23. Discussion of A, the accession constant

The limiting factor for humus formation in soil is not carbon. The supplies of carbon through photosynthesis are abundant enough. Nitrogen is the limiting factor. Thus, the value of A can be discussed practically in terms of the additions of nitrogen to the soil. These additions come from rainfall, nitrogen fixation, mineral fertilization and organic additions from vegetation. Only the latter will be discussed here.

According to Dommergues (1963) annual production of litter in the open deciduous forests of the dry tropical zone in Southern Senegal ranges from 4.0 to 5.0 t of dry matter per ha. Measurements for isolated trees (Acacia albida) in cropped fields in Central Senegal gave mean values of 4.2 t/ha (Jung, 1967). These values are about half of those reported by Greenland and Nye (1959) from various authors for the forests of the equatorial and humid tropical zones: These range from 8 to 12 t/ha. Values for the dry tropical forests, however, are similar to, if not greater than those recorded in forests of the temperate zone (Jenny, 1950).

The annual growth of roots cannot be measured directly, but they may be estimated from the ratio of production of shoots to roots. Assuming that the latter is about two to one (Greenland and Nye, 1959), annual production of vegetative matter as roots would range from 2.0 to 2.5 tons of dry matter per ha. Thus, the total addition of vegetative matter to soils would range from 6.0 to 7.5 t/ha in the forests of the dry tropical zone.

For grass fallows and crops, some estimates of amounts of dry matter, carbon, and nitrogen in straw and roots are shown in Table 8. Although the production of dry matter may be similar to, if not greater than it is under forest, the contribution to soil organic matter is low in traditional systems due to regular burning ofstraw. Only the roots contribute to the formation of humus. As can be seen, amounts of dry matter, carbon, and nitrogen are from three to seven times larger in straw than in roots. Carbon and nitrogen, as well as sulfur, are nearly entirely lost by burning.

As a result humus contents in the topmost 30 cm layers of soils in cropped fields or under grass fallows are low and range from 10 to 25 t/ha. That is 1/3 to 1/2 lower than they are under forests or wooded savannahs, where humus contents usually range from 20 to 40 t/ha (Cointepas, 1958; Poulain, 1961; Charreau, Vidal, 1965).

Organic matter maintenance is essential for an intensive and permanent agriculture in the savannah zone. The nitrogen and organic matter balances in soils can be improved greatly by replacing burning with ploughing.

Table 8

Some estimated values for harvest residues for the main crops in Senegal

After: C. Charreau and R. Tourte, 1967; C. Charreau and R. Nicou, 1971

A - Straw

Crops	Straw (D.M.) t/ha			Nitrogen		Amount of carbon kg/ha			Amount of nitrogen kg/ha		
	Minimum	Maximum	Mean	% of D.M.	C/N	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Grass fallow	1.0	10.0	3.0	0.8	70	550	5 500	1 650	8	80	24
Pearl millet, as a forage	0.5	15.0	5.0	1.0	55	275	8 250	2 750	5	150	90
Pearl millet, as a cereal	2.0	18.0	9.0	0.6	90	1 100	9 900	4 950	12	108	54
Sorghum	1.8	18.0	7.0	0.3	180	990	5 500	3 850	5	30	21
Maize	0.5	6.0	3.0	0.8	70	275	3 300	1 650	4	48	24
Rainfed rice	0.5	6.0	3.0	1.1	50	275	3 300	1 650	6	66	33
Groundnut	1.5	5.0	2.5	2.8	20	825	2 750	1 375	42	140	70
Cowpea	0.5	4.0	1.5	1.4	39	275	2 200	825	7	56	21
Cotton	0.6	6.0	3.0	--	--	--	--	--	--	--	--

B - Roots

Crops	Rooting			Weight of roots kg/ha			Nitrogen		Amount of carbon kg/ha			Amount of nitrogen kg/ha		
	Depth cm	% of surface exploited	Action on soil struc.	Minimum	Maximum	Mean	% of D.M.	C/N	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Grass fallow	10-20	90-100	+	200	7 000	1 000	0.7	70	110	3 800	550	1	49	7
Pearl millet, as a forage	15-25	80-100	+	200	3 000	1 700	0.7	80	110	1 650	930	1	21	12
Pearl millet, as a cereal	20-40	10-40	++	400	3 000	1 500	0.7	80	220	1 650	820	3	21	11
Sorghum	20-40	25-40	++	400	4 000	1 000	0.6	90	220	2 200	550	2	24	6
Maize	20-40	35-70	++	300	4 000	2 000	0.8	70	165	2 200	1 100	2	32	16
Rainfed rice	15-30	50-90	++	300	3 000	1 000	0.9	60	165	1 650	550	3	27	9
Groundnut	20-40	50-80	0	400	1 500	800	1.8	30	220	820	440	7	27	14
Cowpea	20-40	50-80	0	150	1 300	500	1.8	30	80	715	275	3	23	9
Cotton	50-80	50-80	0	150	1 500	750	--	--	--	--	--	--	--	--

Summary of discussion

The paper reviewed the physical, chemical and biological processes taking place in the soil under traditional farming systems practised in the past, and the changing pattern of events resulting from increased pressure on the land and the need for increased food production.

Under present conditions, it has been found through the results of extensive experiments, that deep ploughing of these soils (20 to 25 cm) with incorporation of vegetative material produces the best results and highest yields. This statement elicited questioning and comment from speakers who supported minimum tillage, but the author insisted that deep ploughing for these particular soils was necessary because the structure and porosity is poor. There was of course the problem of completing the ploughing in time during the short season available when the soil is soft, and the need to develop short season cereals. Beneficial results of deep ploughing with incorporation of residues were obtained in the Middle East but this was due to improved soil macrostructure rather than to an increase in pH.

On the question of biological effects of organic matter in these soils, it was admitted that some of the effects could not be explained in spite of thorough observation and measurements on soils, plants and plant nutrition.

References

Bhat, K. K. S. 1970. Contribution à la dynamique du phosphore dans les sols tropicaux et de ses conséquences sur l'alimentation phosphorique des végétaux. Thèse. Fac. Sciences, Orsay.

Bhat, K. K. S. and S. Bouyer. 1968. Influence de la matiére organique sur le phosphore isotopiquement diluable dans quelques types de sols tropicaux. C.R. Coll. AIEA: Isotopes and radiation in soil organic matter studies, Vienna, pp. 229-313.

Blondel, D. 1970. Relation entre le "nanisme jaune" de l'arachide en sol sableux ("Dior") et le pH; definition d'un seuil pour l'activité du Rhizobium. L'Agr. Trop., XXV, 6-7, 589-595.

Blondel, D. 1971. Rôle de la matière organique libre dans la minéralisation en sol sableux; relation avec l'alimentation azotée du mil. L'Agr. Trop. XXVI, 12, 1372-1377.

Bunting, A. H. 1963. Experiments on organic manures, 1942-1949. J. Agric. Sci., 60, 121-140.

Bunting, A. H. 1965. Effects of organic manures on soils and crops. Proc. Nutr. Soc. 24, 29-38.

Chaminade, R. 1958. Influence de la matière organique humifiée sur l'efficacité de l'azote. Ann. Agro., 9, 167-192.

Charreau, C. 1972. Problèmes posés par l'utilisation agricole des sols tropicaux par des cultures annuelles. L'Agr. Trop., XXVII, 9, 905-929.

Charreau, C. and R. Nicou. 1971. L'amèlioration du profil cultural dans les sols sableux et sablo-argileux de la zone tropicale sèche ouest africaine et ses incidences agronomiques. L'Agr. Trop., XXVI, 9, 903-978; 11, 1184-1247.

Charreau, C. and R. Tourte. 1967. Le rôle des facteurs biologiques dans l'amèlioration du profil cultural dans les systèmes d'agriculture traditionnels de zone tropicale sèche. Coll. sur la Fert. des Sols Trop., Tananarive (Madagascar), Nov. 1967, II, 120, 1498-1517.

Charreau, C. and P. Vidal. 1965. Influence de l'Acacia albida Del. sur le sol, la nutrition minèrale et les rendements des mils au Senegal. L'Agr. Trop., XX, 6-7, 600-625.

Chauvel, A. 1966. Etudes physiques des sols à Séfa. ORSTOM-Dakar, mimeo, 56 pages.

Chopart, J. L. and R. Nicou. 1972. Effect dépressif des cultures répètées de sorgho dans les sols sableux du Senegal. African Soils, XVII, 181-188.

Cointepas, J. P. 1958. Bilan des études chimiques et pédologiques entreprises à la station expèrimentale de Séfa. ORSTOM-Dakar, mimeo, 110 pages.

Combeau, A. and P. Quantin. 1964. Observations sur les relations entre stabilité structurale et matière organique dans quelques sols d'Afrique Centrale. Cah. ORSTOM, série Pedol., II, 1, 3-11.

Dommergues, Y. 1963. Les cycles biogéochimiques des éléments minéraux dans les formation tropicales. Bois et Forêts des Tropiques, 87, 9-25.

Dommergues, Y. 1973. Rapport sur la mission effectuée au C.R.A. de Bambey du 17 au 27 Juillet 1973. IRAT/Senegal, mimeo, 22 pages.

Ganry, F. 1973. Rapport d'activité 1972. IRAT/Senegal, mimeo, 42 pages.

Ganry, F. and R. Nicou. 1973. Personal communication.

Germain, R. and C. Evrard. 1956. Etude écologique et phytosociologique de la forêt à <u>Brachystegia laurentii</u>. INEAC, ser. scient., no. 67.

Greenland, D. J. 1972. Biological and organic aspects of plant nutrition in relation to needed research on tropical soils. Com. Sem. on Tropical Soils. IITA (Ibadan, May 1972).

Greenland, D. J. and P. H. Nye. 1959. Increases in the carbon and nitrogen contents of tropical soils under natural fallows. The Journal of Soil Science, 10, 2, 284-299.

Guiraud, G. 1972. Rapport au Gouvernement du Senegal. AIEA, Vienne, Assistance technique, rapport no. 820.

IRAT-Senegal. 1971-72. Rapport annuel d'activité.

Jenny, H. 1941. Factors of soil formation. McGraw Hill, New York.

Jenny, H. 1950. Causes of the high nitrogen and organic matter contents of certain tropical soils. Soil Sci., 69, 63-75.

Jenny, H., F. Bingham, and B. Padilla-Saravia. 1948. Nitrogen and organic matter contents of equatorial soils of Colombia. Soil Sci., 66, 173-196.

Jenny, H., S. P. Gessel, and F. T. Bingham. 1949. Comparative study of decomposition rates of organic matter in temperate and tropical regions. Soil Sci., 68, 419-432.

Jung, G. 1967. Influence de l'<u>Acacia albida</u> sur la biologie des sols "Dior." ORSTOM-Dakar, mimeo, 63 pages.

Lal, R. 1972. Personal communication.

Laudelout, H., J. Meyer, and A. Peeters. 1960. Les relations quantitatives entre la teneur en matière organique du sol et le climat. Agricultura, 8, 103-140.

Nicou, R., and C. Dancette. 1973. Amélioration du stockage de l'eau par le labour de fin de cycle. In Synthèse des activités et résultats 1972 de l'IRAT au Senegal. IRAT/Senegal, mimeo, 130 pages.

Nye, P. H. and D. J. Greenland. 1960. The soil under shifting cultivation. Tech. Com. No. 51, Commonwealth Bureau of Soils, Harpenden, England.

Oliver, R. 1972. Etude du statut phosphorique des sols de Madagascar (3[e] partie). IRAM, mimeo, doc. no. 313.

Pichot, J. and P. Roche. 1972. Phosphore dans les sols tropicaux. L'Agr. Trop., XXVII, 9, 939-965.

Poulain, J. F. 1961. Observations sur certaines caracteristiques des sols ferrugineux tropicaux (sol "Dior"). Les principaux facteurs de leur fertilité. ORSTOM, mimeo, 21, 175 pages.

Siband, P. 1972. Premiers résultats de la recherche sur riz pluvial en Casamance, en agropédologie, pour l'annee 1971. IRAT/Senegal, mimeo, 15 pages.

Turc, L. 1949. Sur la matière organique des sols fractionnée par densité. C. R. Acad. Sci. 229, 227-228.

2. INTERRELATIONS BETWEEN ORGANIC AND MINERAL FERTILIZERS IN THE TROPICAL RAINFOREST OF WESTERN NIGERIA

by

Akinola A. Agboola, G.O. Obigbesan
and A.A.A. Fayemi *

The maintenance of soil humus constitutes one of the most serious soil fertility problems in the tropics. The high crop yields in Central Europe, for example are largely due to the fact that by the use of animal and green manure, mineral fertilizers and judicious soil cultivation, the farmer succeeds in promoting the build-up of clay-humus complex. When the soil organic matter dwindles as a result of poor soil management, so also does the yield decline. However, a total destruction of the soil fertility may not set in in the temperate region because the clay minerals present possess high sorption properties and therefore, even without humus, they still maintain a remarkable absorption capability for water and nutrients.

In the humid tropics on the other hand the dominant kaolinitic clay minerals possess low sorption capacity and are fully effective only in combination with humus. The rate of humus degradation on the equator is five to six times greater than in the temperate latitudes (Andreae, 1966) and while in the temperate region the clay still remains as absorption sites after the degradation of humus, almost all the absorption power of the tropical soil is at this stage totally destroyed. Since the soil organic matter seems to furnish most of the exchange sites in soils of low buffer capacity (Agboola and Corey 1973) it follows that the concentration, rate of release and the amount of nutrients absorbed by plants are influenced by the level of soil organic matter. Loss of soil organic matter therefore is mainly responsible for the decline in crop yield as a consequence of rapid deterioration in the nutrient status of the soil. This forces the peasant farmer to leave his piece of land to natural regeneration under fallow after a few years of cropping.

The use of mineral fertilizers alone had not solved the problems of crop production in the tropics and the adverse side effects of continuous application of acidifying fertilizers like sulphate of ammonia on acid soils are known (Bache & Heathcote 1969). In seeking a solution to these problems, the Department of Agronomy at the University of Ibadan, Nigeria, has been carrying out field and greenhouse experiments over a number of years, on the interrelations between organic and mineral fertilizers in crop production.

Interrelation between organic manure, mineral fertilizer and soil nutrients

In one of these investigations a number of legumes, namely, cowpea (*Vigna sinenis*), *Calopogonium mucunoides*, and green gram (*Phaseolus aureus*) were interplanted with maize and N.P.K. fertilizers were applied at the rate of 50 kg N, 9 kg P and 50 kg K to evaluate the effect of intercropping legumes with maize under fertilization on the major soil nutrients.

The results of these investigations indicate that the total N was not increased (Table 1), rather there was acceleration of the rate of decomposition of soil organic matter. After cultivating the land for a period of four growing seasons the control (no legume, no fertilizer) lost 2.5% of its total N per growing season while the plots with interplanted legumes without fertilizer lost 2.6% under greengram and 2.0% each under cowpea and calopogonium. In the plots where legumes and fertilizer were used the loss went up to 4.8%, 4.7% and 5.4% per growing season under cowpea, calopogonium and greengram, respectively. Even if the 200 kg N/ha applied as fertilizers were not considered, the losses from the fertilised plots with interplanted legumes, were still considerably greater than unfertilized plots.

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* Department of Agronomy, University of Ibadan

The addition of fertilizer thus resulted in a greater decline in total N in plots planted to legumes. It was also observed that the amount of N loss was related to the foraging capability of the legumes or to the amount of forage incorporated into the soil. The combination of mineral fertilizer and green manure therefore seemed to increase the soil nitrogen reduction. This increase in reduction could be due to mineralization of soil organic matter. The increased nitrate-nitrogen accruing from the mineralization of soil organic matter could be utilized by the subsequent crop following the legume to produce higher yield. This, therefore, provides good reason to advocate the use of green manure plus fertilizer to improve soil organic matter.

With respect to phosphorus fertilizer, intercropping with legume seemed to suppress the rate of loss of P (Table 2). The unfertilized plots carrying no legume intercrop showed a greater loss of available P than the fertilized plots without legumes. During the four growing seasons the fertilized plot had a reduction of 27.7% of its initial available P while the control had 30.8% loss. The systems that had legumes interplanted lost only about 15.2% of their initial available phosphorus. This result suggests that legumes seemed to minimize the rate of phosphorus fixation. Close observation will show that the fertilized plots were losing as much phosphorus as the unfertilized plots in all the system but part of the available phosphorus utilized in fertilized plots were replaced by addition of phosphorus fertilizer (9 kg P/ha per growing season).

The results of these experiments indicated that the interplanting with legumes in a cropping system would serve a useful purpose as a means of conserving soil and fertilizer phosphorus.

Losses of phosphorus due to leaching are generally insignificant in the temperate regions, even after heavy fertilization with superphosphate (Fried and Broeshart, 1967). But in this experiment, phosphorus loss appeared rather high, ranging from 5 kg P/ha per growing season in the plots interplanted with legume to 11 kg P/ha per growing season in the no-legume plots. It therefore seems that phosphorus leaching under tropical conditions might be a problem requiring further investigations.

Similar to the effect on phosphorus, the legume intercrops seemed to suppress the rate of loss of exchangeable potassium. This effect did not show up till after the second cropping (Table 3). The control plot having no legume and no fertilizer lost a highly significant amount of exchangeable K when compared with the loss in plots interplanted with legumes. The loss from the control plot averaged 6.0% during each cropping season followed by plots interplanted with greengram, cowpea and calopogonium with losses of 2.6, 1.8 and 1.5% respectively, per growing season. It was observed that the loss of exchangeable K in the legume plots correlated with the maturity of the legumes. The greengram was early while calopogonium was late maturing. When fertilizer was applied, the loss of exchangeable potassium increased by one and a half times in the plots interplanted to calopogonium, cowpea and greengram which showed increase from 1.5% to 6.8% to 7.1% and 2.6% to 5.3% per growing season respectively. The increase was about 3 times in the legumes plots without fertilizers.

In general, legume fallow as well as legume intercropping appeared to reduce the rate of loss of exchangeable potassium. This could be due to the fact that the legume tissues contain a high amount of potassium which was returned when the legume was ploughed into the soil. The legume also seemed to reduce the amount of soil erosion, thereby reducing losses from this source.

A greenhouse experiment was designed to elucidate the effect of liming, organic manure and mineral fertilizer on crop yield and nutrient status of some selected soils from locations in Mid-Western State of Nigeria, notably low in pH ranging from 3.10 to 3.70.

Lime was applied to 3 kg of soil per bucket at the rate of 5.45 gm/bucket which is equivalent to 2 tons of lime per hectare, N.P.K. fertilizer at the rate of 100-40-100 kg/ha and compost manure at 136.2 gm/bucket (50t/ha). The test crop was maize and yield was evaluated on the basis of the dry weight of top growth (foliage). The results, which are summarized in Table 4 brought out some salient points vividly.

Firstly, the application of organic manure plus fertilizer produced a yield which was up to 700% more than the control. Although by the addition of lime or fertilizer alone the yields almost doubled the yield of the control plots, still they were less than half of the yields from plots which received manure plus fertilizer. Moreover, the combination of organic manure with fertilizer did not only enhance the uptake of phosphorus and calcium it significantly reduced the iron and manganese content to non-toxic levels. That the organic manure had liming effect was clearly evident (Table 5). Consequently it would appear that the use of organic manure plus mineral fertilizer would be the most appropriate treatment to improve the production of maize in acid soils.

The interaction between organic manure (dung) and mineral fertilizer (ammonium sulphate) was excellently demonstrated by the work reported for the savannah area of Northern Nigeria by Bache and Heathcote (1969). Here also the acidifying character of ammonium sulphate and the liming effect of dung were convincingly demonstrated (Table 6).

Effect of organic manure (farmyard manure), lime and P fertilizer on the yield of cowpea

On a soil that has been cultivated continuously for ten years with annual application of about 100 kg N/ha in the form of sulphate of ammonia, the effect of farmyard manure, lime and P fertilizer on the yield of cowpea, (Vigna sinensis) was investigated in field experiments.

The farmyard manure had a composition of 0.60% N, 0.42% P, 0.55% K and 0.73% Ca and the soil pH was 3.17, available P was 2.14 ppm. Phosphorus was applied at the rates of 0,6,7, 20.2 and 30.2 kg P/ha while organic manure (FYM) was applied at 25t/ha.

The forage weight and cowpea grain yield as affected by these treatments are shown in Figs. 1 and 2, respectively. There was no significant response to P fertilizer when organic manure was not used on this acid soil. The yield obtained almost doubled the yield on plots which received only P. When farmyard manure and P fertilizer were used there was considerable response to P application.

The result as contained in figs. 1 and 2 reflect the liming effect of farmyard manure which also improved soil physical structure. Indeed the combination of farmyard manure with fertilizer increased the yield even more than when lime plus fertilizer was applied to this soil.

Influence of organic manure and nitrogen fertilizers on yield of Chinese yam (Dioscorea esculenta)

Constant reference has often been made to the beneficial effect of organic manure on the yield of root and tuber crops (Amon, 1964, Ferguson and Haynes 1970). Tuber crops are peculiarly known to respond very well to organic manures (Stephen, 1960, Djokoto and Stephens, 1961). Undoubtedly this response to organic matter by root crops is partly due to its effect on the supply of nutrients. Yams for example grow over a period of eight to ten months depending on the cultivar. Such a crop might not be able to make maximum use of readily mobile nutrients, such as nitrogen when applied in a single large dose. In the decomposition of organic matter, nutrients are more slowly released, and consequently when it is applied, a more uniform supply of nutrients such as nitrogen, potassium and phosphorus can be expected to be available to these crops slowly and continuously throughout the growth period.

In an experiment on the interaction of farmyard manure and nitrogen fertilizer, it was observed that N alone hardly gave any significant increase in the yield of Chinese yam, Dioscorea esculenta. The maximum yield obtained in this experiment was 12.5 t/ha with 20 kg N/ha compared with 11.0t/ha fresh tuber on the control plots. But when farmyard manure (FYM) having a composition of 1.75% N, 1.53% P_2O_5, 1.85% K_2O and 4.26% CaO was applied to this soil of 0.08% total N and pH of 4.5, there was an increase in yield from

11 t/ha in the control (no farmyard manure and N fertilizer) to about 20 t/ha in the plots which had received 5t FYM/ha plus 20 kg N/ha (Fig. 3).

The use of organic manure alone was as effective as using N alone. It should be noted that there must be a time lag between the application of FYM and planting of the crop since immediate planting caused yield depressions. Besides the higher tuber yield obtained, correct combination of FYM and mineral fertilizer increased the crude protein content of the tuber by about 3% over the plots without farmyard manure (Table 7). The improvement of the quality of the tuber by combination of organic matter and mineral fertilizer was therefore demonstrated by this work.

Effect of continuous land use with organic manure and mineral fertilizer on soil nutrients

To study further the resultant effect of organic manure (farmyard manure) plus fertilizer on the one hand and inorganic fertilizer (N.P.K.) alone on the nutrient changes of arable land under continuous use on the other, soil samples were taken from two fields, which belong to Iwo soil series (Smyth and Montgomery, 1962) and under the same bioclimatic influences, but which had been subjected to different cultural practices.

The first, which was the University arable field had been under a seven year rotation consisting of a four year cropping system of maize, yam, cassava and legumes with three years of elephant grass fallow. This rotation had existed for 18 years before the investigation was carried out in 1971 and the field was regularly treated with farmyard manures and N.P.K. fertilizer.

The second field was the Rockefeller research field, which was subjected to 10 years continuous cropping to mainly maize and cowpeas with the regular use of only N.P.K. fertilizers.

The samples were analysed for organic matter, available P, exchangeable K and soil pH (Table 8).

Estimated total amount of fertilizer used in kilograms per hectare in the two fields were University arable field, 1 000 kg N, 560 kg P and K and Rockefeller field, 1 000 kg N, 500 kg P and 600 kg K.
The results of soil analyses gave higher values for the University arable field than for the Rockefeller field. Since the two soils belong to Iwo soil series, a typical Iwo soil series as stated by Smyth and Montgomery was used as a basis for comparison. A typical Iwo soil series from virgin land is estimated to have 3 to 4% organic matter, pH range of 6.5 to 7.5, 40 ppm of available P and 400 ppm exchangeable K on the top 0.15cm. This not withstanding a reference soil sample, was taken from the Botanical Garden which was adjacent to these fields and which had not been cultivated. The only recorded disturbance was due to the reduction in the vegetation cover. This soil had 3.2% organic matter 44 ppm of available P, 350 ppm of exchangeable K and a pH of 6.8 in the top 0-15 cm layer.

These results indicate that the University arable field lost about 50% of its organic matter in about 19 years, while the Rockefeller field lost about 75% in about ten years even with the addition of almost the same amount of nitrogenous fertilizer. The pH of both fields declined to pH 6 for the University arable field and to a pH of 5.4 for the Rockefeller field indicating the buffering effect of organic manure and elephant grass fallow, on the pH of the University arable field.

The exchangeable K was reduced to about 25% of the original value after 19 years of continuous land use of the University farm which included fallow and the addition of organic manure, while on the Rockefeller field it was reduced to about 13% of the original value. Despite the fact that almost the same amount of P had been used in both fields the P content was reduced to one half on the Rockefeller field while the P on the University field had increased by about 30%. This information suggests therefore that the inclusion of fallow in a rotation together with the returning of possible crop residue to the soil and the application of farmyard manure maintains soil fertility better than the exclusive use of inorganic mineral fertilizers.

Summary and conclusion

In general, it was observed from these investigations that any addition of organic material to the soil would increase the level of readily decomposable humus. However, raw organic material added to the soil decomposes very rapidly under tropical conditions and only a fraction of it is converted to humus as a result of losses due to oxidation. It might not be practicable to maintain fertility by green manuring alone in the tropics as the effect on crop yield is short-lived and does not prevent a gradual decline in soil nitrogen. A greater problem is the unavailability of organic manure (farmyard manure) in most humid areas where mixed farming is not practised.

Interplanting with legume plus fertilizer application increased the rate of decomposition and mineralization of soil organic matter, reduced the fixation of phosphorus and leaching losses of potassium. Organic manure has liming effect on acid soils. Whereas the combination of farmyard manure and nitrogen fertilizer increased the yield and quality of tuber crops.

Since it was evident from the data discussed in this report that the best way of continuous use of tropical soil is by combination of organic manure (farmyard or compost manure) and fertilizer, there exists the great handicap of producing these organic manures because the cost of production of compost manure is very high and may not be feasible for large scale crop production.

Summary of discussion

The paper stressed the rapid loss of humus content in the soil under poor management in the humid tropics compared to soils in temperate areas. This was largely due to the absorption capacity of the clay minerals present in the soils of the temperate areas. In the humid tropics the dominant kaolinitic clay minerals had low absorption capacity and were only fully effective in combination with humus. This required the use of organic fertilizers on a large scale to maintain soil fertility. The problem was how to mobilize resources to obtain the amount of organic manure necessary. There seemed to be no doubt that mixed farming together with mixed cropping, minimum tillage and fallowing seemed to provide the only answer in these areas.

Questioned on why he used only ammonium sulphate as a source of nitrogen the author explained that it was the only N fertilizer readily available to farmers and he believed in simulating practical conditions in the field in his experiments. It was suggested that N-labelled materials might be of help in the authors experiments. So far he had not been able to obtain any and it was noted that he should receive assistance in this respect.

Table 1 : Effect of soil management systems with green manure and mineral fertilizers on soil nitrogen (kg/ha)

SAMPLING TIME	CONTROL		COWPEA		CALOPOGONIUM		GREEN-GRAM	
	No Fertilizer	N.P.K. 50-0-50	No Fertilizer	N.P.K 50-0-50	No Fertilizer	N.P.K 50-0-50	No Fertilizer	N.P.K 50-0-50
Initial N	2697	2933	2740	2990	2673	2840	2749	2833
After 1st Cropping	2880	2770	2640	2313	2867	2800	3009	2863
After 2nd Cropping	2483	2250	2433	2440	2793	2147	2100	2780
After 3rd Cropping	2287	2160	2213	2160	2333	2383	2397	2893
After 4th Cropping	2100	2360	2340	2260	2247	2047	2184	2340
DIFFERENCE	597	573	400	730	426	793	493	893
% CHANGE	19.4%	19.5%	14.6%	24.4%	15.9%	27.9%	17.9%	28.9%

N addition was 50 kg N/ha per growing season

Table 2: Effect of soil management systems with green manure and mineral fertilizers on soil available phosphorus (kg P/ha)

	CONTROL		COWPEA		CALOPOGONIUM		GREENGRAM	
	No Fertilizer	N.P.K 60-0-60	No Fertilizer	N.P.K 60-0-60	No Fertilizer	N.P.K 60-0-60	No Fertilizer	N.P.K 60-0-60
Initial P	143	186	123	103	103	87	121	121
Soil P + Fert. P	143	191	123	139	103	123	121	167
P in soil after 4 seasons	81	106	68	84	49	67	78	94
P in maize grain in 4 seasons	18	32	23	28	30	20	28	28
Estimated P in 4th crop of legume	-	-	9	8	8	9	6	6
Available P lost in 4 seasons	44	53	23	19	21	19	9	26
P loss in each season	11	13	6	5	5	5	2	6
% P loss in 4 seasons	30.8%	27.7%	18.7%	13.7%	20.4%	15.4%	7.4%	16.8%

• The unfertilized plots carrying no legume intercrop showed a greater loss of available P than the fertilized plots. During the four growing seasons the fertilized plot had a reduction of 27.7% of its initial available P while the control had 30.8% loss. The systems that had legumes interplanted,

Table 3: Effect of soil management systems with green manure and mineral fertilizer on soil exchangeable potassium (kg/ha)

SAMPLING TIME	CONTROL		COWPEA		CALOPOGONIUM		GREENGRASS	
	No Fertilizer	N.P.K. 50-9-60	No Fertilizer	N.P.K. 50-9-60	No Fertilizer	N.P.K. 50-9-60	No. Fertilizer	N.P.K. 50-9-60
Initial K	700	666	617	613	606	575	666	600
After 1st Cropping	825	650	606	533	683	666	633	700
After 2nd Cropping	642	517	517	492	478	533	576	567
" 3rd "	393	436	506	466	537	520	484	483
" 4th "	472	458	442	449	446	440	448	468
DIFFERENCE	228	208	178	164	102	135	218	132
REDUCTION %	32.6%	31.2%	28.4%	26.8%	26.0%	23.4%	32.7%	22.0%

K addition was 60 kg K/ha per growing season

Table 4: Effect of Bime, Organic Manure and Fertilizer on soil pH, top growth, and mineral element concentration in soil low in pH

Treatments	Initial soil pH in 1.2 $CaCl_2$	Final Soil pH 1.2 $CaCl_2$	Top growth in gm/pot	NUTRIENT CONCENTRATION				
				% P	% K	% Ca	Mn (ppm)	Fe (ppm)
CONTROL	3.10	3.20	3.6e	0.03	3.30	0.22	1026	2630
Organic Manure	3.10	4.90	17.44b	0.28	2.40	0.26	425	700
Fertilizer	3.10	3.20	6.36d	0.21	1.95	0.18	1175	2700
Lime	3.10	5.50	6.40d	0.10	2.75	0.38	600	1600
Fertilizer	3.10	5.00	16.20b	0.32	2.75	0.30	425	1000
O.M. + fertilizer	3.10	4.00	26.13a	0.22	1.90	0.21	600	2120
O.M. + Lime	3.10	5.00	14.20b	0.11	2.30	0.36	400	1200
O.M. + Lime + Fertilizer	3.10	5.00	12.40bc	0.28	2.60	0.33	300	1200

* Means having the same value are not significantly different from each other

Table 5: Liming effect of Organic Manure on acid soils

Location	Initial pH	pH after Liming	pH after applying organic manure
Agbaro	3.40	6.10	5.20
Effurum	3.10	4.90	4.70
NIFOR	3.70	6.20	5.20
Olukwu	3.10	6.20	6.40

Table 6: Effect of dung and ammonium sulphate treatments on soil acidity factors (Bache and Heathcote (1969)

	pH ($CaCl_2$)			Al (M X 10^4)			Mn (M X 10^4)		
	N_o	N_1	N_2	N_o	N_1	N_2	N_o	N_1	N_2
No Dung (Do)	4.20	4.06	3.76	0.13	0.60	1.61	0.15	0.25	0.08
Dung (D_1)	4.08	4.22	4.00	0.06	0.19	0.53	0.08	0.15	0.33
Dung (D_2)	4.70	4.43	4.19	0.05	0.07	0.21	0.06	0.09	0.20

Table 7: Influence of farmyard manureand N-fertiliser on crude protein content (%) of Chinese yam tuber

	Control	20 Kg N	40 Kg N
No FYM	7.44	7.91	9.00
20 t FYM	10.62	10.36	10.31
40 to FYM	10.34	10.79	11.59

Table 8 : Effect of land use on soil nutrients status

Location soil characteristics	ROCKEFELLER FIELD				UNIVERSITY ARABLE FIELD			
	N.P.K. fertilizers only				N.P.K. fertilizers only			
	pH (H_2O)	Organic matter %	Available P (ppm)	Exchangeable K (ppm)	pH (H_2O)	Organic matter %	Available P (ppm)	Exchangeable K (ppm)
Plot No. 1	5.3	1.03	23.70	34.58	5.5	1.02	7.40	76.84
" 2	6.4	0.96	26.74	43.06	5.5	1.26	111.80	64.60
" 3	6.0	1.26	26.36	77.13	5.9	1.80	24.42	100.20
" 4	5.0	0.91	24.54	70.02	5.0	1.92	30.50	57.61
" 5	5.5	0.91	12.44	52.54	6.5	2.18	130.00	148.10
" 6	5.6	0.88	25.60	52.02	6.3	1.40	34.00	87.60
" 7	5.4	0.95	26.37	70.23	6.6	1.82	40.60	62.80
" 8	5.6	0.86	24.11	82.66	7.0	2.33	47.82	91.12
" 9	4.9	0.78	11.82	43.48	6.9	1.91	46.00	134.90
" 10	5.0	0.71	5.82	35.06	6.6	2.00	45.90	97.80
Mean	5.4	0.93	20.06	37.96	6.0	1.77	52.71	92.10
Ref soil	6.8	3.2	44.00	350.0	6.8	3.2	44.00	280.00
Typical Iwo Series	7.0	4%	40.00	40.00	7.0	4%	40.00	40.00

Estimated total amount of fertilizer used in kilograms per hectare

University arable field:- 1000 kg N, 500kg P and 1000kg K

Rockefeller field :- 1000 kg, 800kg P and 800 kg K

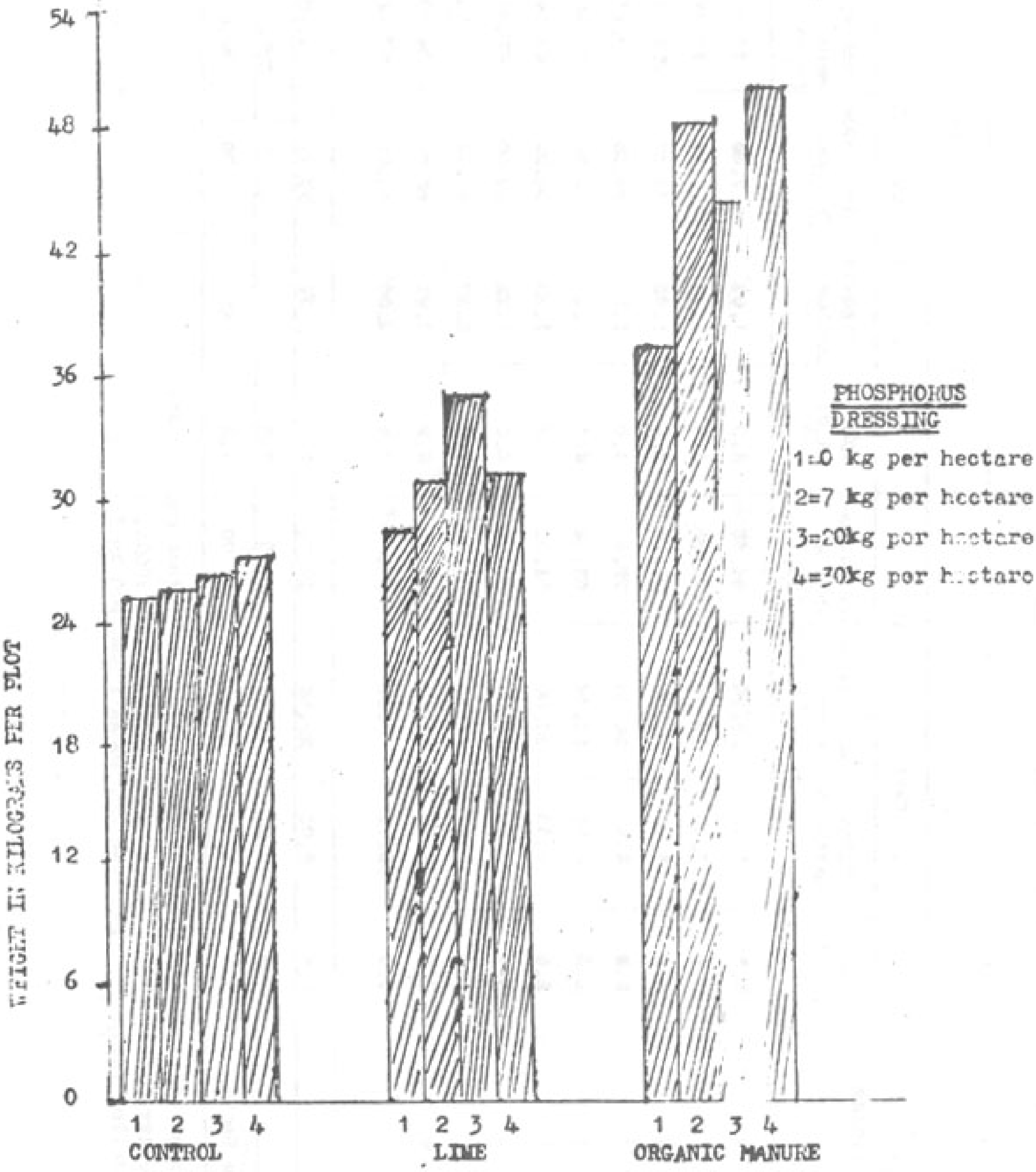

Fig. 1 : FORAGE WEIGHT AS AFFECTED BY LIME, ORGANIC MANURE AND PHOSPHORUS FERTILIZER IN A SOIL LOW IN pH.

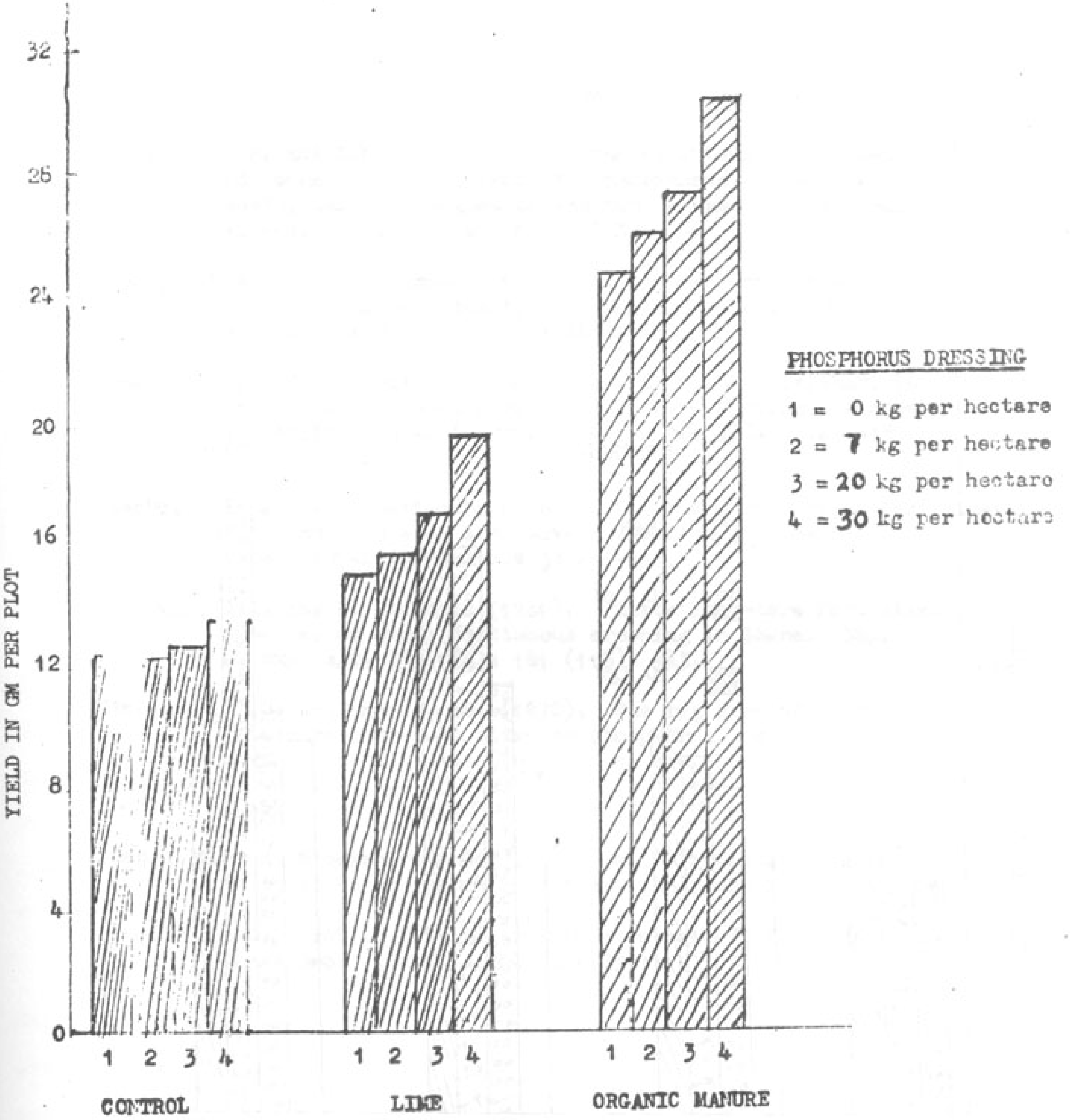

Fig. 2 COWPEA GRAIN YIELD AS AFFECTED BY LIME, ORGANIC MANURE AND PHOSPHORUS FERTILISER IN A SOIL LOW IN pH.

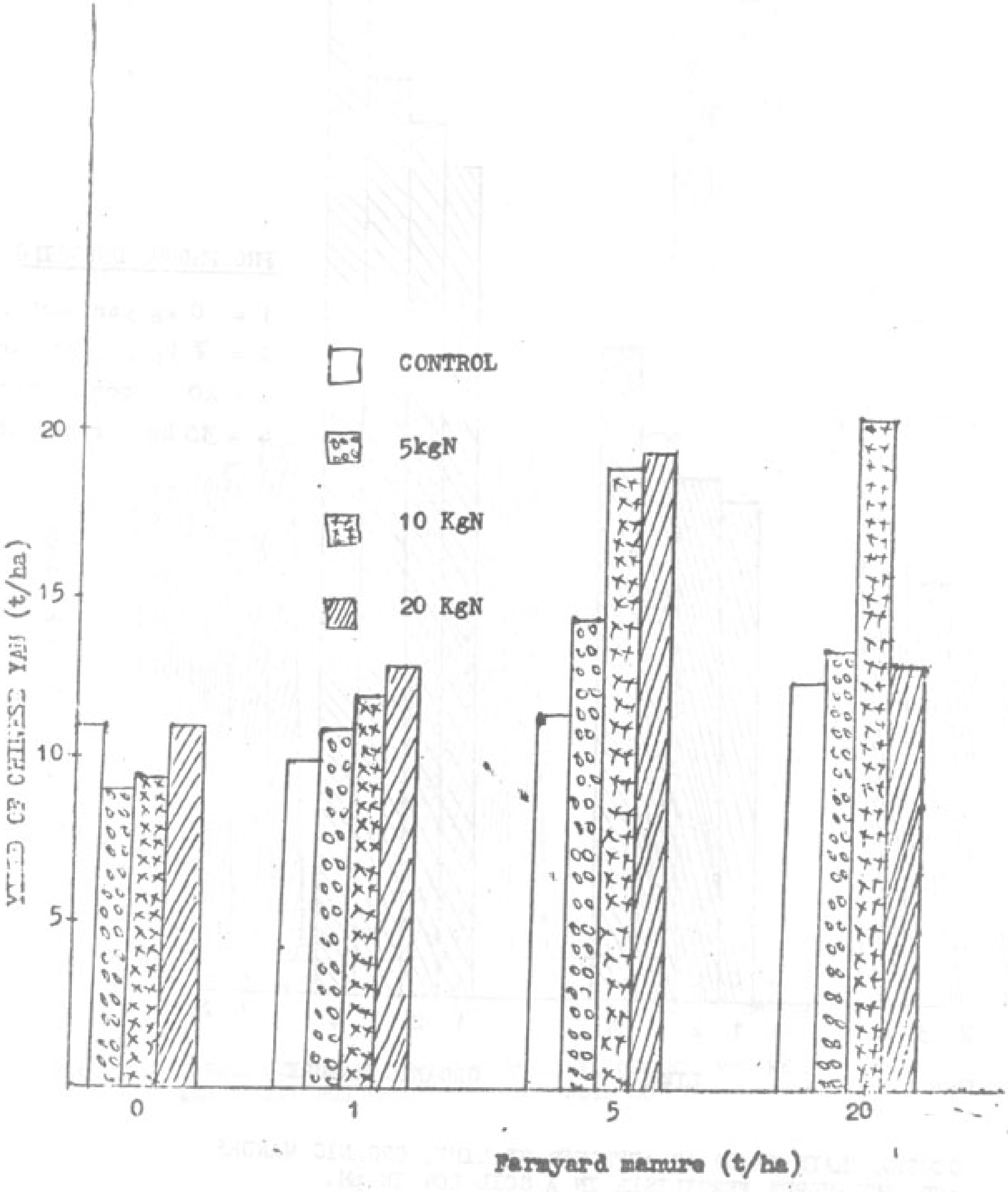

Fig. 3 The effect of different levels of farmyard manure Nitrogen fertiliser on the tuber yield of Chinese yam.

REFERENCES

Agboola, A.A. and R.B. Corey (1973). The relationship between soil pH, organic matter, available phosphorus, exchangeable potassiu, calcium, magnesium and nine elements in the maise tissue. Soil Science 115, 367-375.

Amon, B.O.E. (1964). Response to N.P.K. in soils of Western Nigeria. Annual Report, Crop Husbandry section. Min. of Agric. & Natural Resources Ibadan.

Andreae, B. (1966). Die Uberwindung der Waldbrand wirtschaft in den feuchten Tropen durch produktivere Wirtschaftaformen. In: Berichte uber Landwirtschaft. Bd. XLIV. H.4, p684. P. Parey-Verlag.

Bache, B.W. and R.G. Heathcote (1969). Long term effects of fertilisers and manure on soil and leaves of cotton in Nigeria. Experimental Agriculture 5: 241-247.

Djokoto, R.K. and D. Stephens (1961). Thirty long-term fertiliser experiments under continuous cropping in Ghana. Emp. J. Exp. Agr. 29 (114): 181 (115): 245.

Ferguson, T.U. and Haynes, pH. (1970). The response of yams (Dioscorea spp.) to nitrogen phosphorus, potassium and organic fertilisers. In Tropical Root and Tuber Crops Tommow Vol. 1p. 93. Proc. 2nd Int. Symp. Trop. Root & Tuber Crops. Howaii.

Fried, M. & A. Broeschart (1967). The soil plant system in relation to inorganic nutrition. Academic Press New York.

Stephens. D. (1960). Fertilizer trials on peasant farms in Ghana. Emp. J. Exp. Agri. 28 (109): 1.

F. ECONOMICS

ECONOMIC ASPECTS OF THE USE OF ORGANIC MATERIALS AS FERTILIZERS

by

A. Duncan

1. Introduction.

The term 'organic fertiliser' is used here to refer to human and animal wastes and plant matter deliberately applied to the soil to raise its productivity.

The use of organic matter as fertiliser in less developed countries has received much less attention from economists than its importance deserves. With the exception of urban wastes, the subject does not lend itself to straightforward economic analysis. There are two main sources of difficulties. First, organic fertilising practices are necessarily closely woven into a farming system which has major economic and social importance in the people's lives. Any change, especially in labour-demanding practices, may therefore entail unexpected additional costs in the pattern of other activities. Second, many of the costs and benefits involved may not be accorded a market value by the decision-maker. Particularly where the main costs are his own family's time and energy, and where the main benefits are unmarketed foodstuffs, imputed prices may not provide a clear guide to real value.

But despite these problems for the economist, the farmer's decisions are economic since they involve the allocation of scarce productive resources. The employment of a factor of production for one purpose generally entails foregoing an alternative; the value of the most profitable alternative is the opportunity cost. We should aim to understand the farmer's true costs and benefits; it may then be possible to recommend changes which make a fuller use of his limited resources.

2. The economic value of organic fertilisers to less developed countries.

2.1. The efficient use of available productive resources.

The development path followed by a society should make full use of its abundant resources --- those with a low social cost --- while economising on those which are scarce. Less developed countries are characterised by rapid population growth and to varying degrees by limited cultivable land and foreign exchange reserves. Their aims should therefore be to employ techniques which raise the productivity of the land using the energy of human beings and other domestically available resources rather than inputs, particularly capital and equipment, that impose net demands on foreign exchange.

Under these circumstances, organic fertilisers have an important economic role. They raise returns to land by increasing yields, using labour and waste materials with a low social cost; the foreign exchange requirement is insignificant and the investment needed can often be provided simply by labour.

The factors commending organic fertilisers as socially desirable are moreover likely to become more significant over time. As the man:land ratio declines under the influence of population growth and to a lesser extent soil erosion and the spread of cities, yield-increasing and labour-using techniques will become more desirable. At the same time deficit trading positions will restrict imports of inorganic fertilisers or of the means to manufacture them domestically.

In general terms then there is a strong economic case to be made for the fuller use of organic materials as fertilisers in less developed countries, particularly those which lack unused cultivable land.

2.2. The current price of mineral fertilisers.

The discussion of the possible role of organic fertilisers is of course given urgency by the current scarcity and high cost of the main alternative, mineral fertilisers. Less developed countries are more vulnerable than developed countries to these conditions.

The present state of the world fertiliser market is in part due to cyclical production factors, in part to raw material and energy costs. Insofar as cyclical factors are responsible, we should be over the peak by the late 1970s. But this does not significantly reduce the need to make fuller use of plant nutrients from organic sources in less developed countries, which were short of fertilisers even before recent price rises.

2.3. Overall potential use of organic fertilisers.

The approximate annual availability of crop nutrients from different organic materials in less developed countries is presented in table 1. The 1971 totals for N, P and K of 48, 16 and 39 million tonnes respectively may be compared to 13.2 million tonnes of nutrients in mineral fertilisers used in less developed countries in 1970/71 (van Voorhoeve, 15*, p.6). Table 2 from the same source suggests a value of US $16.000 million for 1971 production.

The usefulness of these rough calculations is to indicate the technical scope for the use of organic fertilisers; even a modest percentage increase in utilisation could contribute significantly to total food production. The level of use will be determined by individual decisions, mainly by farmers and government officials who will be affected by a wide range of technical, economic, social and political considerations; it is to these that we now turn.

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* Refers to the list of references.

Table 1. Total annual production of soil nutrients (N, P, K) through organic wastes in the developing world, 1971 (actual) and 1980 (estimated)*

(million metric tons of nutrients)

Source		N	P	K
Human:	1971	12.25	2.87	2.61
	1980	15.26	3.57	3.25
Cattle:	1971	17.80	4.91	14.12
	1980	22.25	6.14	17.65
Farm Compost:	1971	9.54	3.34	9.54
	1980	11.93	4.18	11.93
Urban Compost:	1971	.48	.38	.57
	1980	.60	.48	.71
Urban Sewage:	1971	1.43	.29	.86
	1980	1.79	.36	1.08
Other**	1971	6.63	4.44	11.35
	1980	8.29	5.55	14.19
TOTAL:	1971	48.13	16.23	39.05
	1980	60.12	20.28	48.81

* excludes Central America and Oceania, includes Socialist Asia

**Bone-meal, poultry litter, bagasse, sheep/goat litter, oil cake, press-mud. (Several other sources were not included due to small potential for all developing world.)

This table was calculated on the basis of various publications, especially Organic Manures, Indian Council of Agricultural Research, Technical Bulletin No.32, as well as FAO's Production Yearbook 1971 and IBRD's Trends in Developing Countries(1973). The LDC total for human excrement is based on the Indian calculation of 0.0047 metric tons N/person/yr., 0.0011metric tons P205/per./yr., 0.0010 metric tons K/per./yr., multiplied by a total LDC population estimate for 1971 and 1980. Cattle estimates are based on Indian figures of 8.6 metric tons/cow/ur. excrement (liquid and solid) x number of LDC cattle (FAO Production Yearbook, 1971, p.303) x the respective percentages of N, P, and K of .0029, .0008 and .0023, likewise based on Indian findings. Assuming that cattle production will rise at least as rapidly as human population growth rates, the 1980 estimated cattle population was based on the human growth factor of 1.25. All other categories are based on a similar methodology, i.e. an extrapolation of Indian findings. As waste production increases sharply with income per capita and feed/animal, an extrapolation of Indian experiences is bound to be a conservative estimate.

Source of Table 1: Van Voorhoeve (15) p.5.

Table 2: Value of N, P and K found in wastes of the developing world as compared to chemical fertilizers (at 1973 world f.o.b. prices)*

(in millions of US$)

	N	P	K	Total
1971	9 626	4 058	2 499	16 183
1980	12 024	5 070	3 124	20 218

*The individual farmer pays, of course, local prices, which are higher than world prices because of transport, storage, and commercial costs. He may also benefit from government subsidization of fertilizer costs, however. In Table 2, the value of N is based on the world f.o.b. price of urea (45% N) at US$70-105 metric ton, which means a price of $155-233 per ton of pure N. The average value was set at a median of US$200/metric ton. P2O5 value is based on triple super-phosphate (48% P2O5) at $ 120 / metric ton which means $ 250 per ton of P. The K-value is based on potassium chloride (62% K) at $40/metric ton which means $64/metric ton of K.

Source of Table 2: Van Voorhoeve (15) p.7

3. Factors determining the use of organic fertilisers.

3.1. Hypothesis on the scope for organic fertilisers.

Farmers will be prepared to adopt organic fertilising practices where the ratio of perceived costs to benefits is favourable.

It is suggested that in relatively unmodernised farming systems, there is scope for the use of organic matter as a major source of crop nutrients in the three following situations:-

(i) Where no alternative can provide basic necessities.

(ii) Where organic fertilising will contribute to adequate and fairly secure returns from a cash crop.

(iii) Where the costs of organic fertilisers are exceptionally low.

(i) As a function of high population density and a low state of technological development, there may be no other way to produce the family's basic requirements. The need to employ yield-increasing techniques will be communicated to the farmer through two main channels. (a) Holdings may subdivide between generations reducing cropped area per head to the level at which yields must rise to fulfil basic needs. (b) Land will become increasingly expensive as a factor of production relative to labour; least-cost combinations will tend to substitute labour for land, leading to the use of organic fertilisers and other labour-intensive land-saving practices.

On Ukara Island in Lake Victoria, naturally rather infertile soils have been densely populated for a long period; highly labour-intensive techniques to maintain fertility are employed despite low returns per hour of labour because they have offered the only means to provide food, short of emigration (Ludwig, 9; Rounce and Thornton, 11). More generally the shortening cycle of land use under shifting cultivation, owing to the increase of population and cash-cropping, leads to rapidly declining average returns to labour over time. When these returns fall below those possible under a permanent cropping system, a precondition exists for the adoption of more intensive practices.

(ii) The costs of organic fertilising will be more acceptable if it leads to a cash income. Cash has a high value to small farmers as the means to investment and consumer goods, and as a convenient method of saving. Increasing the output of foodstuffs above the family's needs may be of limited use where market value is low and storage facilities inadequate. Market demand for cash crops is likely to be stronger and storage problems are less.

(iii) In some cases, the costs of organic fertilisers are low owing to specific local factors. The village of Gata at Zaria, Nigeria, has supported a high level of permanent cropping for some decades due to its lying on a major cattle route (Hill,6, p.158). Similarly farms near urban areas may use low-cost city wastes, or organic by-products from a processing plant may be easily available.

If this hypothesis can be confirmed it would provide guidelines for a strategy to increase the use of organic fertilisers.

3.2. Farmers' decision-making.

Farming systems result from the evolution of techniques in response to the rational pursuit of objectives by farmers within the context of the constraints upon them and the possibilities open to them. The lower the standard of living and the more unpredictable the natural environment the more decisions will be governed by the need to avoid risk. The farmer's priority will be to ensure the production of minimum subsistence requirements and thereafter he may be concerned to maximise net returns. Insofar as these considerations apply, production decisions will not be based on the principle of equality at the margin. Instead, after satisfying basic needs, the farmer may not be prepared to produce after the point, say, at which marginal returns to his family's labour begin to decline. In this case there will be little opportunity for labour-intensive practices to raise the production of subsistence foods. More extensive farming is likely with a low return per unit land but a high marginal return on the limited labour input.

Theoretically distinct, but in practice closely related, is the point that average costs of labour may be high. Where calorific food is scarce, the energy available for productive purposes from family members or draft animals may be limited. Particularly where seasonal scarcities occur, as in parts of Africa before the harvest, or when harsh climatic conditions make any work demanding, inactivity on the part of people and animals may represent a careful husbanding of energy needed for future crucial tasks. Such slack periods may therefore not present opportunities for introducing the labour-demanding practices associated with organic fertilisers. To perform these operations may actually reduce output by lowering the efficiency of other critically important tasks. The opportunity costs of labour would in such cases be high.

At the same time the value of increased output may be reduced by technical or social factors of which the following two may be identified. (i) Inadequate storage facilities; reliable estimates of losses due to pests and mould do not exist but they are widely agreed to be considerable; moreover in percentage terms they are likely to be higher the lower the income of the farmer (Lipton et al., 8, p.3). (ii) Where sharecropping and other tenancy arrangements are in force, the tenant will be less likely to adopt output-raising techniques the more the benefits accrue to the landlord.

3.3 The use of different organic sources of plant nutrients.

3.3.1. Farmyard manure.

Farmyard manure is the greatest organic source of plant nutrients available to less developed countries (see table 1) but of course the full technical potential is not used. In India it has been estimated that only one-third of the 1,335 million tonnes annually available is used as fertiliser (ICAR, 7, p.9.)

An upper limit on the use of manures is set by the state of the livestock economy, particularly the number of animals and their nutrition; in much of Africa where there are no cattle, the scope for manuring is limited. Further, intensive manuring generally requires that livestock and crop husbandry be closely integrated and that there be no geographical and social separation of pastoralists and cultivators.

(a) Costs

The costs of manure must be assessed in the context of the livestock economy. To identify them, it is necessary to estimate the extent to which the costs of the whole livestock system have been increased by the use of manure. At one extreme lies Ukara island where the need for manure provides the sole rationale for keeping cattle; in this case all costs may be ascribed to manure. At the other extreme, observed more frequently in developed countries, manuring the fields may be the least-cost method of disposing of an unwanted by-product; manure is therefore costless.

Between the two extremes lie the many systems in which manure imposes demands of varying severity on productive resources. The main costs to the farmer will be the labour required for transporting and processing a considerable volume of manure. Particularly where wheeled vehicles are not available and traction power is limited, labour costs will in many cases prove a deterrent to the intensive use of manure. The pattern of fluctuations through the year in the demand for and supply of labour will be crucial in determining the opportunity costs involved; farmers will be unwilling to adopt practices which increase pressure on seasonal bottlenecks.

Other costs rise with the complexity of techniques employed. Skills must be developed, and where animals are stabled, fodder and litter provided. Transport costs may be high if these originate outside the farm or if the farm is fragmented. Where the manure is processed anaerobically, capital costs will be higher, but this may be offset by the greater value of the product.

The use of manure as fertiliser competes with its use as fuel where there is insufficient firewood. It has been estimated that in India roughly one-third of available dung is burned. This practice which is known also in Africa represents a constant drain on the fertility of the land; in the face of rising populations and continuing exploitation of woodland, it is unlikely to come to an end. Two long-term partial solutions exist: first reafforestation with fast-growing trees, and second the wider use of methane plants producing both gas and high-quality manure. Some 7 000 of these plants had been completed in India by January 1974 and a target of 50 000 has been set for the Fifth Five-Year Plan (Brochure, 2, p.20; Annexure II). No social cost-benefit analysis of methane plants appears to be available; they would however be likely to show fairly high returns.

Financial analysis using Indian market prices suggests that even a small plant with a three cubic metre per day capacity taking the wastes from eight cattle would be viable. For an annual expenditure of Rs.395 (including interest and depreciation but excluding labour), manure and gas worth Rs.858 can be produced (Gober Gas, 4, p.11). Capital costs of the plant per unit output decline with increasing size, which suggests that larger plants would also be feasible.

(b) Benefits

The benefits of manure will vary according to its quality, to the method and timing of application to the soil and to the value of the additional output it generates. In tropical climates benefits will be lessened by the rapid decomposition of organic matter and leaching of nutrients. But despite these variations, estimates may be made of the value of manure. Where necessary for budgeting purposes, a financial value may be accorded on the basis of major crop nutrients plus an allowance for micronutrients and organic matter. In a study of the role of livestock in the farming system of Sind, Pakistan, the following method was adopted. The nutrient content of the manure was estimated as 0.41, 0.14 and 0.14% for N, P and K respectively; on this basis the market value of the nutrients per maund(37kg) was Rs.0.52. This was doubled to provide an estimate of the total value (McConnell, 10, p.20) The alternative to this rather arbitrary valuation is to omit altogether a significant element of the farming system.

When measuring the effect of manuring on output, a range of crop responses can be determined (see e.g. ICAR,7, tables 1-33); but results should be interpreted with caution unless they were pbtained under constraints similar to those which limit farmers' freedom of action. Moreover there are considerable difficulties in estimating the actual value to the farmer of this increased output.

The most useful approach to assessing the benefits of manuring involves measuring gross returns on farms which do, and on farms which do not, use manure but which are in other respects similar. The value of this method is to treat manuring as part of a complete system. It was employed in a study of coffee and banana holdings near Bukoba, Tanzania, (Friedrich, 3.) The ownership of cattle was used as a proxy for the application of manure and farms were categorised on this basis. The key assumption is that the observed variations in gross returns were due to the manure. On the farms under study, the assumption is probably justified; the value of meat and milk produced was very low and the cattle were neither a source of prestige, nor a form of security. It is stated that the purpose of livestock husbandry was in the first place the production of manure to increase the fertility of the banana holdings which provided the bulk of gross returns. The weak spot in the approach is the possibility of a correlation between skill in cultivation and the purchase of cattle.

The study found that family incomes on the 37% of farms with cattle were 450/- shillings, or 33%, higher than on farms without cattle (table 3). Figure 1 suggests that the difference in output exists irrespective of farm size. If all the difference is attributed to the manure, the annual value of each livestock unit is 130/- shillings. This would account for the importance attached to the ownership of cattle by the farmers.

In this case the costs of producing manure were acceptable for two reasons. First, the production of the staple food, bananas, required an investment in the fertility of the soil, and was given priority in the allocation of manure. Second, a marketable crop, coffee, produced a valuable cash income. The cultivation of both these crops showed a high gross return to labour.

It is probably widely true that where these conditions hold, farmers will be prepared to commit resources to organic fertilisers.

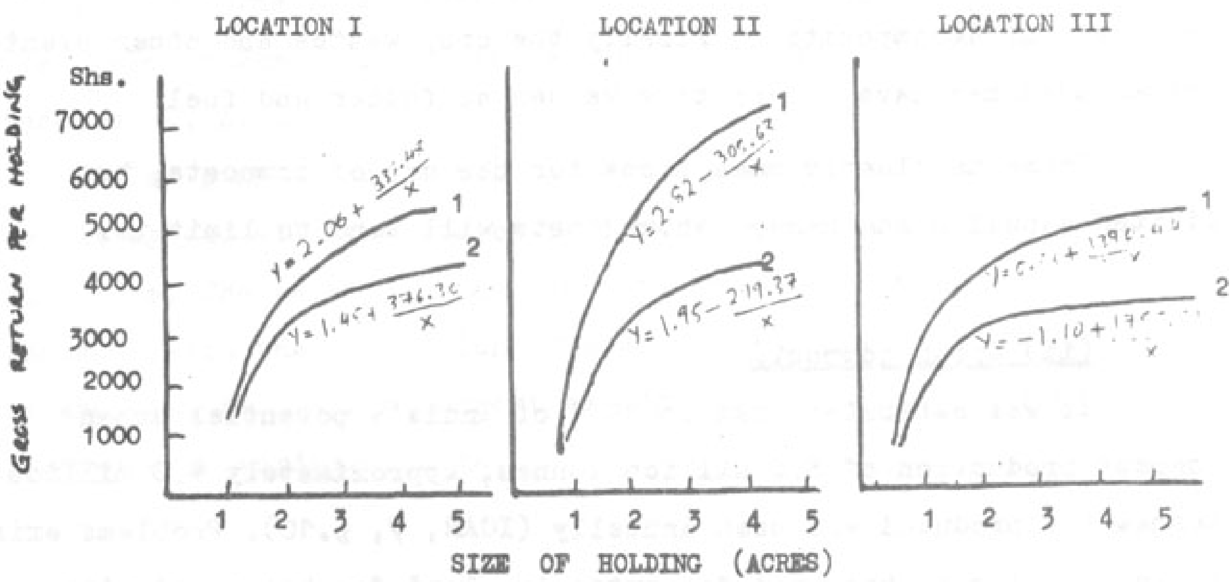
Table 3. Family Incomes according to Farm Size in coffee-banana holdings, Bukoba.

Cultivated area in acres	Full-time farms without cattle shs	Full-time farms with cattle shs
under 1	662	892
1-2	928	1 247
2-3	1 294	1 567
3-4	1 713	1 230
4-5	1 260	2 515
5-6	2 066	2 513
6 and over	2 272	3 020
Ø	1 352	1 840

Source: Friedrich, 3, p.203

Figure 1. Gross returns on farms with and without cattle in three locations.

	Location I	Location II	Location III
Cattle	1. R^2= 0.98 n=16	1. R^2= 0.11 n=13	1. R^2= 0.23 n=7
No cattle	2. R^2= 0.51 n=18	2. R^2= o.45 n=26	2. R^2= 0.47 n=10



Source: Friedrich, 3, p.204.

3.3.2. Rural and urban compost.

(i) Rural compost.

In almost every farming system some use is made of the fertiliser value of household wastes. But composting, defined as the deliberate decomposition of plant matter with or without some human or animal wastes, is characteristic only of rather intensive systems.

The extent of benefits to be derived from compost will depend largely on the method of preparation; being generally less rich in nutrients than manure, a larger volume of compost is needed for a similar effect. However high-quality compost as prepared under the Indore or Bangalore methods (ICAR, 7, p.20) can greatly increase the fertiliser value of the animal wastes used.

Particular advantages of compost are that it requires neither cash inputs nor livestock. But there are obstacles to its wider use. The supply of materials necessary to maintain high levels of composting is generally not available on the farm, and the scope for importing from outside will decline as population density increases. Labour costs for transport and processing will be high except where composting is limited to household wastes. In drier areas water may have to be provided for decomposition. Finally the crop wastes and other plant matter used may have alternative values as fodder and fuel.

There is clearly some scope for the use of composts; but limited supplies and heavy labour costs will tend to limit it.

(ii) Urban compost.

It was estimated that in 1971 of India's potential urban compost production of 8.0 million tonnes, approximately 4.0 million tonnes are produced and used annually (ICAR, 7, p.10). Problems exist however, owing to the need for extensive land for heaps and pits near cities, to health risks and to compost marketing difficulties. As a result other methods of disposal are adopted which are wasteful and cause pollution (Brochure, 2, p.6). The growth of cities compounds the problems whose solution is becoming increasingly costly. Larger Indian municipalities are therefore beginning to develop mechanical compost plants; 45 have been commissioned under the Fifth Five-Year Plan. Their advantages include:- (i) The reduction of health risks and offensive smells. (ii) Less land, so they may be sited to minimise transport costs. (iii) The salvage of saleable materials. And (iv) the use of the plants to process human wastes. Social cost-benefit analyses should be carried out to determine the most socially desirable of the technically feasible alternatives.

Under Indian conditions, it is estimated that the financial cost of producing one tonne of compost mechanically is Rs.30 with a necessary transport charge of Rs.5. This estimate is subject to revision when the first plants begin operation. Assuming the plant nutrient content is 1.3% N, 1.1% P_2O_5, and 1.1% K_2O, the ex-factory price of the nutrients, including lime, is Rs.67 with a market price of some Rs.75. The balance of Rs.40 per tonne between cost and market value suggests such plants can be financially viable (Brochure, 2, p.8).

The purchase of urban compost by farmers will require a cash outlay and will tend to be used only on crops which provide a cash income. The sale of urban compost may therefore be usefully integrated with the production of high-value crops destined for city markets. Existing transport systems may then perform a two-way service to minimise costs.

3.3.3. Green manure, fodder crops and mulch.

(i) Green manure.

Long-term experimental evidence reviewed by Webster and Wilson (16, pp.184-188) suggests that green manure crops can play an important role in fertility maintenance. They raise the organic content of the soil, they act as a cover crop, they hold plant nutrients and they may fix nitrogen. Economic advantages over other methods of fertilising include the following:- first, no cash is generally involved; second, no transport costs are incurred; and third, livestock husbandry is not necessary.

However there are major difficulties which have so far limited the acceptability of green manures to farmers. It has been estimated that in West Africa some 20 - 30 tonnes of green manure/hectare are necessary to maintain permanent cultivation (Guinard, 5). This requires faster growth than is often possible. Moreover green manure crops cannot greatly supplement a nutrient in which the soil is deficient; it may have to be complemented by external inputs.

There may be heavy costs involved in green manuring; these are compounded by the frequency with which these crops must be grown since their beneficial effects are short-lived in tropical climates. (a) The provision of water for the growth of green manure crops and for their decomposition in the soil will prove costly where water is a constraint. (b) Considerable energy, human or animal, is necessary to plough in green manure shortly before the planting of the crop that is to benefit. Where this has to be performed at the end of the dry season, animals may be weak. (c) The land under the green manure will have an opportunity cost unless it would in any case have been fallow; the requirement for land, particularly where population is dense and agriculture intensive, may prove unacceptable to farmers. In traditional Chinese agriculture green manure is said to have been little used; almost any crop was too valuable to plough in before it had been consumed by man or animal (Allison, 1, Ch.1).

It is a further disadvantage of green manure that ploughing it in demands precise timing that may be beyond the capacity of a small farmer operating under other constraints. If ploughed in too soon with a low C:N ratio, benefits for succeeding crops will be limited; if the ratio is too high the resulting nitrogen deficiency may depress yields.

Technological advance over recent decades has increased the profitability of green manuring. The mechanisation of draft operations and the improvement of bullock equipment may relieve the constraint of inadequate power at critical periods. In addition a wider range of green manure crops are now available to suit specific local conditions; research and extension services should seek to extend this range.

There is however a psychological obstacle to the wider acceptance of green manuring. All farmers, but especially those near subsistence, are generally unwilling to commit resources to crops which do not show an immediate return. It has been suggested a propos of the economics of introducing inorganic fertilisers to small farmers that even the most progressive require a value:cost ratio of 2:1 (and less progressive up to 4:1) before they will be prepared to adopt fertiliser (Ruthenberg, 12, p.182). To make green manure sufficiently attractive, technological changes will be necessary that radically improve the value:cost ratios.

In the long-established farming methods on Ukara Island, green manure formed one element of the system of fertility maintenance. But the steady migration from the island suggests that where possible farmers will seek less labour-demanding means of fulfilling their needs.

(ii) Fodder crops.

Where livestock are kept, fodder crops in a rotation will be more immediately productive than green manure and therefore more acceptable to farmers; if suitable manuring techniques are employed, the nutrient loss sustained through feeding the crop to cattle need not be great.

The superiority of fodder crops over grass fallows will depend largely on their value for livestock and their efficiency in nitrogen-fixing. Research efforts should concentrate not only on improving these characteristics in general, but should also seek to provide varieties which suit specific local conditions.

(iii) Mulch.

The highest returns to mulch occur in dry areas owing to its role in moisture conservation; it has value also in providing crop nutrients and in reducing soil temperature fluctuations and weed growth. In decomposition, however, it can lead to nitrogen deficiency if the C:N ratio is too high (Webster and Wilson, 16, p.235).

The rather limited use of mulch in less developed countries is due in part to its opportunity cost as fuel or fodder and in part to the labour costs of cutting and transporting. The scope for mulching will be limited by the supply of crop wastes or grass on or near the farm; extension services should encourage the cultivation of suitable mulch grass in the place of unregulated fallows.

3.3.4 Night soil and urban sewage.

(i) Night soil

A recent account of farming practices in China states: "In Chekiang province, night soil collection is almost a passion. We saw literally thousands of roadside privies, placed there to lure passers-by into depositing valuable fertiliser within reach of the farmer. On one heavily-travelled country road there were as many as ten in a one-block stretch." (Soil Association,14,p.4.) China shares important characteristics with other Asian countries, including a dense population and strong unfulfilled demand for fertiliser. This suggests that technically and economically there is scope elsewhere for a fuller utilisation of night soil as a source of crop nutrients.

In India, there is very little use made of night soil in urban areas and practically none in villages (ICAR, 7, p10). Some idea of the potential value of the nutrients forgone by this neglect is provided by Table 4.

Table 4: Total N, P_2O_5 and K_2O in human wastes in India. (million tonnes)

	N	P2O5	K2O
Solid	0.383	0.299	0.133
Liquid	2.207	0.319	0.404
Rounded Total	2.60	0.62	0.54
Approx. value* (Million US$)	520	155	35

Total value - $ 710 million

*Nutrient prices as calculated by Van Voorhoeve (see Table 2)

Sources of Table 4: ICAR, 7, p.10
Van Voorhoeve, 15, p.7

The $710 million total value may be interpreted as the foreign exchange cost to India of importing the nutrients that are actually available domestically in human wastes. The value of the higher output depends upon crop responses and prices but would certainly be several times greater than the market value of the nutrients.

There appears to be no systematic work available on the social costs and benefits involved in the alternative methods of collection, processing and distribution of night soil. It is probable, however, that the least-social-cost systems will be rather labour-intensive, using little capital and providing employment; this will only be feasible, however, where humans are prepared to perform the necessary tasks.

The extent to which the potential is used will be influenced by the farmer's costs, by health risks and by culturally-determined attitudes. Night-soil is rich in nutrients compared to other organic sources of fertiliser; its use may be acceptable particularly near cities where supplies may be abundant and cheap. Health risks may be reduced by suitable processing but appropriate techniques may spread only slowly. The greatest single obstacle may prove to be the distaste felt by many people for the use of night soil; such attitudes may be slow to change.

(ii) Urban sewage

Water-borne city wastes are used for irrigation in the vicinity of urban areas in several less developed countries. Some 47 000 hectares of farmland near Mexico City have been irrigated by waste water for many years at a rate of 1 900 million litres per day. In 1971, 1.5 million tonnes of foodstuffs were grown worth US $26.7 million. The 30 000 farmers who rent the land from the government pay the sewage irrigation costs at rates of US $1.60 - 2.40 per hectare. No health problems are reported. (Source: Van Voorhoeve, 15, p.10).

Smaller schemes operate in India where 100 cities and towns have sewage systems and 700 have open drainage. 24 000 hectares are irrigated from some 220 centres using 1 300 million litres per day. The value of the nutrients in the sewage at market prices is estimated at Rs. 40 million while the additional production of foodgrains is valued at Rs. 200 million (Brochure, 2, p.22; Annexure V;) information on the structure of costs is not available. The capacity of the existing sewage and drainage systems is thought to be some 3 640 million litres, per day - nearly three times the currently used volume. This level of use however may represent the economic optimum; distribution costs rise with distance, and marginal returns begin to tail off above a certain level of application.

There appears to be economic scope for the integration of public health programmes and sewage irrigation, given the urgent needs of growing cities to dispose of their wastes. The rate of increase of the use of sewage on farms, however, will be limited particularly by the rate at which new urban areas are provided with sewage systems. All else equal, sewage irrigation in new areas will show higher marginal returns than increased irrigation where it already exists; this is due to the shape of crop response curves which tend to level out.

3.4 Summary of factors limiting the use of organic fertilisers

Socio-economic characteristics of farming in less developed countries impose constraints on the use of organic fertilisers which are substantially different from those operating in developed countries. The following may be identified.

(i) The need to adjust the whole farming system.

(ii) The heavy labour requirement.

(iii) The low level of technological development

(iv) The lack of opportunities for profitably raising output.

(v) The need to develop skills.

(vi) Cultural attitudes.

(vii) The lack of mixed livestock and crop husbandry

4. The wider use of organic fertilisers.

At the start of the last section it was suggested that farmers will be more prepared to use organic fertilisers in the following cases:-

(i) Where they are necessary to produce basic requirements.

(ii) Where they lead to a cash income.

(iii) Where their costs are exceptionally low.

If this hypothesis is accepted, efforts to spread organic fertiliser practices should be directed for maximum effect to areas in which these pre-conditions hold. It may be a cause for optimism that population pressure has historically led to the adoption of intensive cultivation in many areas. Over time, price ratios are likely to favour the fuller use of organic fertilisers owing to the rising prices of food and land, the continuing scarcity of inorganic fertiliser, and labour whose wages are unlikly to rise. But at best the use of organic fertilisers will increase only slowly. They do not have the dramatic appeal of mineral fertiliser; moreover skills must be learned and farming systems adapted to accommodate them.

Extension services should recognise that organic fertilising practices are necessarily elements of an interwoven system; the strategy to encourage their use must involve wider changes including better livestock and crop husbandry, better irrigation, better draft equipment, and above all better transport. The pace of change will inevitably be rather slow.

More immediate progress is possible in the disposal and processing of urban wastes which may usefully be integrated with farming near the cities.

But overall, while there is certainly scope for using organic fertilisers more fully, they will not contribute dramatically to the present fertiliser scarcity in less developed countries.

5. Economic research into organic fertilisers

5.1. The state of economic research

A paper on economic aspects of organic fertilisers inevitably suffers from the lack of systematic data, though some work has been done in India. In contrast to agronomists, economists have tended to overlook this element of farming systems, partly because it has been overshadowed by the greater economic appeal of mineral fertilisers which have been seen as substitutes.

What has been the effect of this neglect? Perhaps it partly explains the apparent gap between the rotations and fertilising practices developed by scientists and the generally far less productive techniques used by farmers. Economists, and to a lesser extent sociologists, should have been on hand to advise on the specific requirements of the farmers in the light of their objectives and the resources available to them. Failure to do this has inevitably led to researchers developing systems which have proved unacceptable to the farmers themselves who perceive acutely the costs and benefits involved.

5.2. Suggested directions for the future

The urgent need for small farmers to raise food production in less developed countries demands that this neglect be put right. Attention should be turned in two main directions.

First, social cost-benefit analyses should be carried out of technically feasible alternatives to determine which systems of collecting, processing and distributing organic fertilisers make the best use of society's scarce resources.

Second, at the farm level, attempts should be made to understand the economic and social pressures on decision-makers which lead to the evolution of particular production patterns. In particular, much greater attention than hitherto should be directed to the costs to the farmer and his family of different fertilising practices. The constraints on the wider use of organic fertilisers, whether land, labour, markets, water, transport, or a combination or these, should be identified; technical research may then be directed to their resolution.

As a useful first step, FAO might bring together data from its farm management projects to provide a basis for systematic economic analysis.

Summary of discussion

It was noted that the use of organic fertilizer in the developing countries had not received the attention it deserved from economists. Problems were that it did not lend itself to straightforward economic analysis and it was often difficult to accord a market value to many of the costs and benefits involved. The aim should be to understand the farmer's true costs and benefits in relation to possible changing patterns of farming resulting from making the best use of limited resources in the context of balancing increased pressure on the land with increased production, conservation, and availability of foreign exchange reserves.

The importation of sophisticated farm machinery developed for different conditions under which they were to work, with the consequent drain on foreign exchange, had not always led to the beneficial results expected, and the time had come to take a hard look at less sophisticated but effective aids to production, such as improved land and animal operated equipment.

At both the administrative and research level there was still too much isolation of for example crop production and animal husbandry functions, and it was stressed that there must be an integrated and multidisciplinary approach to agricultural development in the developing countries.

REFERENCES

1. Allison, F.E. "Soil organic matter and its role in crop production." Elsevier Publishers. 1973.

2. "Brochure on organic manures." Ministry of Agriculture (Department of Agriculture.) Government of India. 1974.

3. Friedrich, K.H. "Coffee-banana holdings at Bukoba." In "Smallholder farming and smallholder development in Tanzania," ed. H.Ruthenberg. IFO-Institut fur Wirtschaftsforschung Munchen. Afrika-Studien 24. 1968.

4. "Gobar Gas - Why and how." Khadi and Village Industries Commission, Bombay. Undated.

5. Guinard, A. "Conservation and improvement of soil fertility in Africa". Part 2. World Crops 19(6). December 1967.

6. Hill, P. "Studies in rural capitalism in West Africa." African Studies Series 2. Cambridge University Press. 1970.

7. Indian Council for Agricultural Research. "Organic manures." Technical Bulletin (Agric.) No.32. By Garg, A.C., Idnani, M.A., and Abraham, T.P. New Delhi. 1971.

8. Lipton, M., Cook, I., and Nair, N."Cost-benefit analysis of crop storage improvements: a south Indian pilot study." Discussion Paper no.56. Institute of Development Studies, University of Sussex, England. 1974.

9. Ludwig, H.D. "Permanent farming on Ukara." In "Smallholder farming and smallholder development in Tanzania," ed. H.Ruthenberg. IFO-Institut fur Wirtschaftsforschung Munchen. Afrika-Studien 24. 1968.

10. McConnell, D.J. "The place of livestock in the farming system of Sind (Mirwah) Farms." Report to the Government of Pakistan. Rome,1972. UNDP, Report No. TA 3069.

11. Rounce, N.V. and Thornton, D. "Ukara Island and the agricultural practices of the Wakara." Empire Cotton Growing Review XXXIII. October 1956.

12. Ruthenberg, H. "The Economics of introducing fertiliser." Proceedings of the VIIth Colloquium of the International Potash Institute, Berne.

13. Ruthenberg, H. "Farming systems in the tropics." Clarendon Press, Oxford. 1971.

14. Soil Association Journal. "Living on the land in China today." By Robert Rodale. Vol.1(7). October 1973.

15. van Voorhoeve, J.J.C. "Organic fertilisers: problems and potential for developing countries." World Bank Fertiliser Study. Background Paper No.4. I.F.C. Office of the Economic Adviser. 1974.

16. Webster, C.C. and Wilson, P.N. "Agriculture in the tropics." Longmans. 1966.

G. RECOMMENDATIONS AND GUIDELINES

PROPOSALS FOR SHORT TERM RESEARCH, LONG TERM RESEARCH, EXTENSION, EDUCATION AND INTERNATIONAL COOPERATION

by
B.R. Nagar

In the light of the present world food crisis, it need hardly be emphasised that a large number of developing countries do not have money either to purchase costly food from abroad or to buy inputs, fuel and fertilizers needed in sufficient quantity for modern agriculture. Therefore, the situation demands that they do serious rethinking on their agricultural research, education, and extension with a view to evolve a 'New Agricultural Strategy' to utilise organic materials as fertilizers on a large scale.

New Agricultural Strategy: Maximum Food Production with Minimum Cost and with the Least Possible Utilization of Energy

The salient features of this new agricultural strategy should be as follows:

(1) There should be maximum agricultural production with the least possible utilization of energy;

(2) Organic materials should be utilized in considerably larger amounts as fertilizers and thus reduce the consumption of mineral fertilizers (consequently the consumption of energy will be reduced). Furthermore, the efficiency of the use of mineral fertilizers should be increased to very great extent.

(3) Steps should be taken to organize short term as well as long term research on soil organic matter and organic manures, including cooperative research with the assistance of the developed countries and international agencies.

(4) Effort should be made to create the right type of manpower for research, education and extension work on soil organic matter and organic materials as fertilizers.

(5) Steps should be taken for extension work to propagate the use of organic materials as fertilizers on a large scale.

(6) International cooperation should be organized for soil organic matter and organic manures research, education and extension.

Research

In order to use organic materials as fertilizers on a large scale, it is absolutely essential that research work on soil organic matter and organic manures be carried out on a number of problems under different climatic conditions and for different crops. I have classified this research effort under 'short term research' and 'long term research'. Under short term research such problems for research are suggested, the solution of which may help us in extensive use of organic materials as fertilizers within 3 to 4 years. On the other hand, for long term research problems it will take more time to obtain useful results.

Short Term Research

In order to obtain fruitful results for the extensive use of organic materials as fertilizers within 3 to 4 years, the research work should be carried out on the following problems:

1. Studies on the economics of the use of mineral fertilizers in combination with various dosages of organic materials such as crop residues, compost, bones, animal manure, and peat, night soil and sludge, etc.

2. Studies on the efficient method of preparation of biogas and manures from the animal manures, farm residue, town refuge, sludge and night soil etc.

   It may be mentioned here that in order to popularize the use of Biogas Plants on a large scale, research work is needed on the following problems: (a) studies on the designing of very low cost Biogas Plants (b) studies to design such plants in which CO_2 can be separated very efficiently from CH_4; and (c) studies to find out a suitable catalyst which may maintain the release of gas from the plant during the winter season.

3. Green manures and crop rotation

   3.1 Studies on the economics of mineral fertilization in combination with crop rotation with legumes, especially pulses and fodder legumes.

   3.2 Studies on the economics of mineral fertilization in combination with green manures, including inter-cropping whereever possible.

   3.3 Studies on the economics of the growth of green manuring plants, including fodder leafy plants on the fallow land from where subsequently they should be transferred to the field and ploughed in the soil.

4. Nitrogen fixation

   4.1 Studies on the development of legume inoculation.

   4.2 Studies on the non-symbiotic fixation of nitrogen.

   4.3 Studies on the role of organic matter in symbiotic and non-symbiotic nitrogen fixation.

   It is significant that currently 30 million tons of nitrogen per year are obtained from industrial 'N' fixation. On the other hand, Rhizobium bacteria alone fixes 14 million tons nitrogen per year throughout the world in root nodules of food and fodder legumes. In order to increase considerably the quantity of 'N' fixed by Rhizobia, investigations should be carried out on the following problems: (a) studies on the development of the right strains for the different leguminous crops under different ecological conditions; (b) studies to establish the efficient carrier media for inoculation.

5. Studies on the efficient methods of production of compost with optimum properties such as C/N ratio 10 from the various plant residues, animal manures, sludge and night soil etc.

6. Studies to evolve very quick growing and fuel yielding trees which can be used as fuel so that cow dung may be conserved for manuring purposes.

7. Studies on the nitrogen balance sheet in soils

In order to increase the efficiency of the use of nitrogenous fertilizers it is desirable that research work should be carried out on problems such as (a) studies to control the rate of nitrification in soils, including the use of suitable organic materials; (b) studies to reduce the movement of nitrate in lower layers of soils by applying organic manures; and (c) studies to develop methods for retarding hydrolysis of urea in soils and to reduce its volatilization as ammonia etc.

8. Studies on the recycling of plant nutrients in soils from natural resources, including studies on decomposition of organic materials in the soil.

It is desirable that extensive work should be carried out on the nitrogen transformations in soils such as amount of biological nitrogen fixation, ammonification, nitrification, denitrification etc. so that the data thus obtained can be utilized for system analysis, subsequently on the basis of these data models of the nitrogen cycle may be prepared which can be used for predicting the values of nitrogen transformation by computers.

9. Studies on the efficient hygienic methods of handling, storage and utilization of animal manure, sewage, sludge and night soil

10. Studies on the use of natural and synthetic slow nitrogen releasing fertilizers prepared from industrial waste products (including N-Lignin) during plant growth

11. Studies on the economics of the use of mulching under humid and hot climate conditions

Long Term Research

For efficient and extensive use of organic materials as fertilizers during the next 20 years it is desirable that research work may be carried out on the following problems:

1. Studies on the characterization of soil organic matter

1.1 Systematic studies on the characterization of soil organic matter of the different types of soils of the world with a view to prepare soil organic matter maps of the world.

1.2 Studies on the characterization of the dynamics of soil organic matter in relation to the soil productivity.

1.3 Studies on the characterization of soil organic matter with a view to establish the influence of high dosages of mineral fertilizers and pesticides (which are necessary for the high yielding varieties) on the dynamics of soil organic matter.

2. Studies on the recycling of plant nutrients in soils from organic materials

2.1 Studies on the decomposition of plants and other organic materials in soils in relation to the availability and uptake of nutrients - including trace elements - by plants. For these studies multi-labelled plant materials have to be used.

2.2 Studies on the dynamics of soil organic matter formed under long term treatments of organic manures, fertilizers, fertilizers plus manures and crop rotation.

3. Studies on the role of soil organic matter in soil fertility, especially in sub-tropical and tropical climatic conditions.

In order to establish the role of soil organic matter in soil fertility in tropical and sub-tropical climatic conditions, studies should be carried out on the rate of turnover and persistence of soil organic matter under these climatic conditions. For these studies the decomposition of C^{14} and N^{15} labelled organic materials should be carried out in the soils over a period of several years with a view to establish the rate of turnover and persistence of soil organic matter and to determine the level of N in relation to organic carbon.

4. Studies on the processes of humification and on the structure of constituents of soil organic matter

4.1 Studies on the processes of humification and on the structure of constituents of soil organic matter formed under sub-tropical and tropical climatic conditions.

4.2 Studies on the possible difference of the physical and chemical properties of constituents of soil organic matter produced from different plant materials, city refuge and organic industrial waste products.

4.3 Studies on the effect of clay minerals on the formation and stabilization of soil organic matter.

4.4 Studies on the effect of mulching on the physical and chemical properties of constituents of soil organic matter

5. Studies to find out new leguminous green manuring plants which can fix nitrogen very efficiently and very quickly

6. Studies to explore the possibilities to find out very cheap organic industrial waste products which may be used for the following purposes: (a) as a source of biogas and manure, and (b) as a base for slow releasing N-fertilizers

7. Studies on the possible effects of constituents of soil organic matter on plant production

7.1 Studies on the influence of constituents of soil organic matter on the metabolic pathways in plants.

7.2 Studies on the effect of constituents of soil organic matter on checking the incidence of plant diseases.

8. The following studies should be carried out by geneticists to evolve new varieties of plants

8.1 Studies to evolve such varieties which not only give higher yields of grains but also produce larger amounts of roots which may eventually contribute to the formation of soil humus.

8.2 Studies to evolve such varieties which may utilize very efficiently available nitrogen from soil organic matter and fertilizers.

8.3 Studies to evolve such varieties of cereals which may have the ability for biological fixation of nitrogen.

Extension

The central theme of all extension work should be that during the next two decades there will be shortage of fertilizers. Therefore there is no alternative for the farmers but to adopt the new strategy of use of organic materials as fertilizers on a large scale. The following steps should be taken to propagate the use of organic materials as fertilizers in the different parts of the world:

1. Biogas Plants: Steps should be taken to propagate the use of 'Biogas Plants' for the preparation of gas as well as manures from the animal manures, night soil and industrial waste in the villages. If necessary, the social structure required for this purpose may be established in the villages.

2. Composting

Steps should be taken to popularize the simple techniques of compostingamongst the farmers.

3. Training of extension workers and farmers

It is desirable that training programmes for extension workers for the efficient use of organic materials as fertilizers should be organized at agricultural schools, colleges and universities with the cooperation of appropriate government agencies. Furthermore, special training schools should be opened for the farmers (along with model farms if possible) to teach them the new methodology of efficient use of organic materials as fertilizers. Subsequently the extension workers should keep in touch with these farmers.

In addition, suitable steps should be taken for female education in rural areas on the use of organic materials as fertilizers as they can play very significant roles in conserving animal manure for manuring purposes.

4. Publications

FAO, international agencies, the departments concerned with the extension work in the different countries should publish leaflets, farm bulletins and popular books (written in a popular language for the layman) on organic materials as fertilizers. Furthermore, agricultural correspondents and science writers may be requested to publish popular articles on soil organic matter and organic manures in the language or languages of the country.

5. Use of radio, television and audio visual aids for extension work

Radio and TV should be extensively used for propagating the new technology of use of organic manures as fertilizers on a large scale. Furthermore, it may be mentioned that in the developing countries the majority of farmers are still semi-literate or illiterate. Therefore suitable steps should be taken for utilizing audio visual aids to popularize the use of organic materials as fertilizers amongst them.

Education

In order to utilize organic materials as fertilizers on a large scale during the next 10 to 20 years, it is essential to give utmost importance to manpower planning including in-service training of the research workers. For this purpose, there should be radical changes in education in this field. In this connection I think the following steps are essential:

1. Graduate and post graduate courses

Currently, in a number of agricultural colleges and universities of the developing countries, soil organic matter is taught as a part of soil chemistry graduate or post graduate courses. It is desirable that soil organic matter should be taught in agricultural colleges and universities under the following two courses: (i) chemistry of soil organic matter; and (ii) organic manures. A committee of experts appointed by FAO may prepare the detailed syllabi of these courses.

2. Ph.D. training

In order to obtain proper background for soil organic matter research, education and extension, the Ph.D. scholar would be well advised to complete the following courses (in addition to the courses on chemistry of soil matter and organic manure): (a) organic chemistry (elementary as well as advanced courses); (b) physical chemistry (elementary as well as advanced courses); (c) soil microbiology; (d) elements of soil science; (e) a course in agronomy; (f) modern instrumental methods of analysis and (g) radio tracer techniques.

Furthermore, he should work for his doctorate degree preferably on a problem of soil organic matter which has some relevance to the economy of the developing countries.

3. Establishment of 'centres of excellence' for soil organic matter research

The 'centres of excellence' for soil organic matter research should be established around the highly distinguished research workers in this field or the agricultural universities in the developing countries. In addition to research work these centres may also be used for the training of extension workers, leading farmers and in-service training of the members of the staff of agricultural colleges and universities.

4. International training courses on soil organic matter

It is desirable that FAO should organize international training courses on the following two topics so that the right type of manpower is created in this field: (a) the chemistry of soil organic matter (including modern methods of characterization of soil organic matter) and (b) organic manures. Subsequently, the trainees of these courses may organize similar courses in their countries on a national scale.

Publications

It need hardly be emphasized that in order to be able to do good quality research work, the research scientist must know the latest developments in his field. Unfortunately, in the developing countries due to poor financial conditions of the majority of research workers and due to the lack of proper library facilities, it is very difficult for a research worker to keep himself informed about the latest researches in his field. Therefore, in order to promote research work on organic materials as fertilizer, FAO should take the following steps in this direction:

1. Compilation of lists of publications on soil organic matter and organic manures

Steps should be taken by FAO for the preparation of detailed and up-to-date lists of publications as monographs, books, review articles and important papers on soil organic matter and organic manures. These lists should be provided by FAO to all the research workers in the field of soil organic matter research. FAO should also consider the possibility of providing a set of these publications to the libraries of the leading centres of research on soil organic matter and organic manures.

2. Publication of a book entitled 'Soil Organic Matter: Its Nature and its Role in Soil Fertility in Tropical and Sub-Tropical Climatic Conditions'

Currently it is very difficult to find the relevant information on the composition of soil organic matter formed under tropical and sub-tropical climatic conditions, as well as its role in soil fertility in that part of the world. Therefore FAO may consider the possibility of arranging the publication of the book entitled 'Soil Organic Matter: Its Nature and Its Role in Soil Fertility in Tropical and Sub-Tropical Climatic Conditions' written by an eminent research worker in this field.

3. Annual review on soil organic matter and organic manures research

Steps should be taken for the publication of an "Annual Review" on soil organic matter and organic manures research.

International Co-operation

It need hardly be emphasized that the efforts of the scientists working in the field of soil organic matter and organic manure will be more fruitful for extensive use of organic materials as fertilizers during the next 10 to 20 years if they organize their activities jointly on an international scale. Therefore the following steps may be taken for international co-operation in the field of soil organic matter and organic manures research, education and extension.

1. Establishment of the International Research Institute for Soil Organic Matter Research

Steps should be taken for the establishment of the International Research Institute for Soil Organic Matter Research (with regional research centres for different climatic areas) with the financial assistance of FAO and other international agencies. Initially, until this research institute is established the research and training work on soil organic matter may be carried out at a centre such as the Institut für Biochemie des Bodens, Braunschweig, Fed. Rep. of Germany, with the financial assistance of FAO and other international agencies.

2. International training courses

The international training courses should be organized on the following two topics, especially for the benefit of research workers of the developing countries: (a) the chemistry of soil organic matter; and (b) organic manures.

3. Research projects

UNDP, FAO and other international agencies should sanction research projects on the topic suggested under 'Short Term Research' and 'Long Term Research' with multi-disciplinary approach at the various centres of research on soil organic matter, especially in the developing countries.

4. Short term consultants

FAO should provide the services of short term consultants (for 3 to 6 months) to the developing countries who are keen to initiate and develop their programmes for the Use of Organic Materials as Fertilizers.

5. Cooperation between one developing country and another developed country

UNDP, FAO and other international agencies should finance research projects on soil organic matter and organic manures for cooperation between one institute of a developing country and another institute of a developed country.

Summary of discussion

The wide ranging programme of research and new facilities proposed were welcomed. There were comments as to whether it might not be equally effective to intensify existing facilities and international cooperation.

On training, there were comments to the effect that students who had been trained in developed countries often found difficulty in adapting knowledge gained to conditions in their home country and in obtaining funds to pursue research and to travel even within their own country to cooperate with colleagues working on allied projects.

Another problem discussed was how to obtain and organize facilities for transmitting the results of research through to the farmer. The role of FAO in this respect through back-stopping projects in 16 countries was noted, as also the role of the FAO Fertilizer Programme with a task force of 40 experts in the field. It was hoped too that this Expert Consultation would play a major role in the overall programme for research and development in the use of organic fertilizers in the developing countries.

PROGRAMME

Monday, 2 December

9.30 a.m. Opening

I. Introduction

1. Use of organic materials as fertilizers in developing countries
   A. Singh

II. Specific effects of soil organic matter on the potential of soil productivity

1. Biochemistry of soil organic matter
   W. Flaig
2. Proposal for the characteristics of soil organic matter as an approach to the understanding of its dynamics
   H. Söchtig
   J. Salfeld

III. Characteristics, processing and use of organic materials

1. Organic manure: Collection, storage, processing, transport and application
   T.M. McCalla
2. A method for conservation of cattle manure
   M.M. Musa
3. Mulching for improved soil fertility and crop production
   A. Ayanaba and B.N. Okigbo

Tuesday, 3 December

(Continuation III)

4. Compost
   Use of compost in Korea
   J.F. Parr
5. Chemical and biochemical considerations for maximising the efficiency of fertiliser nitrogen
   J.F. Parr
6. Use of peat in horticulture
   V. Puustjärvi
7. Problems of improving soil fertility by green manuring in tropical farming systems
   Akinola A. Agboola
8. Biological source of nitrogen in natural ecosystems and crop production
   T. Yoshida

Tuesday, 3 December (Continued)

9. Experiences in biological nitrogen fixation in South America
C. Batthyany

10. Nitrogen fixation by some legumes in the Sudan Gezira
M.M. Musa

Wednesday, 4 December

(Continuation III)

11. Survey of city refuse composting
D. Stickelberger

12. Principle problems of the use of city wastes for crop production and soil conservation
C. Tietjen

13. Chemical and biological considerations for land application of agricultural and municipal wastes
J.F. Parr

IV. Experiences and new developments

1. The use of organic fertilizers in Japan
T. Egawa

2. The use of organic fertilizers in India
Ministry of Agriculture, New Delhi

3. The use of organic fertilizers in Brazil
C.A. Burnett

Thursday, 5 December

V. Soil management and organic fertilizers

1. Organic matter and biochemical properties of soil in the dry tropical zone of West Africa
C. Charreau

2. Interrelations between organic and mineral fertilizers in the tropical rain forests of Western Nigeria
Akinola A. Agboola

VI. Economics

1. Economic aspects of the use of organic materials as fertilizers
A. Duncan

Thursday, 5 December (continued)

VII. Recommendations and guidelines

1. Proposals for short term research, long term research, extension, education and international cooperation in organic fertilizers
   B.R. Nagar

2. Discussion on recommendations; guidelines for follow-up action

Friday, 6 December

(Continuation VII, 2)

Discussion on recommendations and guidelines for follow-up action

Closing Session

LIST OF PARTICIPANTS

SIDA: C.B. Lostelius
Permanent Representative of SIDA to FAO and WFP

Dr. Akinola A. Agboola
Senior Lecturer (Soil Fertility)
Department of Agronomy
University of Ibadan
Ibadan, Nigeria

Dr. A. Ayanaba
Microbiologist
IITA
P.M.B. 5320
Ibadan, Nigeria

Dr. G. Batthyany
Chief
Laboratorio de Microbiologia de Suelos y Control de Inoculantes
Ministerio de Ganaderia y Agricultura
Plan Agropecuario
Ciudadela 1477
Montevideo, Uruguay

Dr. F.J. Bergersen
C.S.I.R.O.
Canberra, Australia

Dr. C.A. Burnett
DICOF (Fertilizer Unit)
Ministry of Agriculture
Brasilia, D.F., Brazil

Dr. C. Charreau
Research Engineer
IRAT
110 Rue de l'Université
75340 Paris, France

Mr. A. Duncan
The Lodge
Grazelay Court Farm, Grazelay
Reading, U.K.

Dr. T. Egawa
Director-General
National Institute of Agricultural Sciences
Tokyo, Japan

Dr. W. Flaig (Chairman)
Prof., Director
Institut für Biochemie des Bodens
3300 Braunschweig
Bundesallee 50
Germany, Federal Republic of

Dr. T.M. McCalla
Agronomy Department
University of Nebraska
Lincoln, Nebraska 68503, USA

Dr. M.M. Musa
Soil Microbiologist
Soil Science Section
Agricultural Research Corporation
Gezira Research Station
Wad Medani, Sudan

Dr. B.R. Nagar
Professor
Indian Agricultural Research Institute
New Delhi, India

Dr. J.F. Parr
Research Leader and Technical Adviser
USDA
P.O. Drawer U
University Station
Baton Rouge, Louisiana 70803, U.S.A.

Dr. V. Puustjärvi
Professor
Peat Research Institute
04300 Hyrlya, Finland

Dr. A. Singh
Assistant Director-General
Indian Council of Agricultural Research
New Delhi, India

Dr. H. Söchtig
Professor
Institut für Biochemie des Bodens
3300 Braunschweig
Bundesallee 50
Germany, Federal Republic of

Dr. D. Stickelberger
Deputy Manager
WHO International Reference Centre
Ueberlandstrasse 133
CH-8600 Duebendorf
Switzerland

Dr. C. Tietjen
Institut für Pflanzenbau und Saatgutforschung
3300 Braunschweig
Bundesallee 50
Germany, Federal Republic of

Dr. T. Yoshida
International Rice Research Institute
P.O. Box 583
Manila
Philippines

UNEP

Dr. R.J. Olembo
Senior Programme Officer
UNEP
Nairobi, Kenya

FAO

Agriculture Department

D.F.R. Bommer, Assistant Director-General

Land and Water Development Division

R. Tudal
Chief, Soil Resources Development and Conservation Service

F.W. Hauck
Senior Officer (Soil Development and Conservation)
Soil Resources Development and Conservation Service

H. Braun
Technical Officer (Soil Fertility)
Soil Resources Development and Conservation Service

H. Matsuo
Technical Officer (Fertilizer Use, Training and Research)
Soil Resources Development and Conservation Service

H. Mathieu
Manager, The Fertilizer Programme

L. Kadry
Land and Water Officer for Environmental Studies

H.A.E. Graetz
Consultant, Soil Resources Development and Conservation Service

I. Constantinesco
Editorial Secretary

Office of Assistant Director-General, Agriculture Department

A.M. Kesseba
Deputy Co-ordinator
International Fertilizer Supply Scheme

P.J. Mahler
Senior Officer, Environment Programme Coordinating Unit

F. Mouttapa
Environment Programme Officer

Plant Production and Protection Division

F. Riveros
Tropical Pasture Improvement

Agricultural Services Division

W. Barreveld
Agricultural Industries Officer (By-products Utilization)

Secretaries

Miss K. Duffy
Miss A. Schmidt Zaringer