fao economic and social development paper 28

assessment and collection of data on pre-harvest foodgrain losses due to pests and diseases

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 1983

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M-77

ISBN 92-5-101314-4

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FOREWORD

The manual is intended to serve as a guide to the statistical methodology for assessing and collecting data on pre-harvest foodgrain losses due to pests and diseases. It should be useful to those developing countries which plan to launch foodgrain losses reduction programmes but find themselves seriously handicapped because of lack of basic data. The manual will go a long way in assisting those who will be charged with the responsibility of planning and implementing surveys for estimating pre-harvest foodgrain losses due to pests and diseases.

The manual, at the request of the FAO, was prepared by the Indian Agricultural Statistics Research Institute under the technical guidance of Dr. D. Singh, Director and Mr. R.K. Khosla, Senior Scientist. This Institute has a long tradition of developing and testing statistical methodologies as applied to agricultural research and development. A number of its senior officers have served FAO in several projects for the improvement of agricultural statistics in the developing countries. It should, however, be borne in mind that the methodologies suggested in this manual are offered only by way of guidelines which need further study and adaptation to suit the conditions prevailing in specific countries. The issuance of the manual in its present form should be considered as an invitation to the countries to communicate to the FAO their own experiences in this field, particularly taking into account the methodologies suggested therein. The initiation of such dialogue will indeed be very helpful for effecting further improvements in the techniques and methods which could be incorporated in subsequent editions of this manual.

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1. INTRODUCTION

1.1 It is well-known that pests and diseases cause appreciable crop losses all over the world. However, reliable and objective estimates of such losses are hardly available in any of the countries. Only guess estimates are available, their credibility depending upon the agency making the estimates.

1.2 All our efforts to produce more foodgrains by using costly inputs go to waste if such losses are not controlled in time. Economic and effective control measures can be planned on a sound footing only if reliable estimates of crop losses due to pests and diseases are made available. Such reliable estimates of crop losses have become very important with the increasing use of fertilizers, manures and pesticides, introduction of high yielding varieties, adoption of better irrigation facilities and cultural practices, etc. For the planners, policy makers, administrators and other experts engaged in improving the crop yield, estimates are not only important but are rather a pre-requisite for discharging their respective duties with optimum efficiency. The scientists would also be guided by these findings in carrying out improvements in the crop production and protection programmes.

1.3 The problem is of much relevance to the developing countries where the production of foodgrains per head is much less as seen in Table 1 below:

Table 1 - Population and production of cereals in different regions 1/
(Average of 3 years - 1974-76)

Region	Total annual Production of cereals (million tons)	Population (millions)	Annual production of cereals per head (kilograms)
Developed countries	470	757	621
North America	274	236	1 161
West Europe	149	364	409
Oceania	18	17	1 059
Developing countries	414	1 958	211
Africa	45	319	140
Latin America	82	324	253
Near East	52	195	266
Far East	235	1 116	210

1/ FAO Yearbooks on Production.

1.4 The availability of reliable information on crop losses is, therefore, of great importance in developing countries, where, mainly due to lack of effective plant protection measures, the crop losses at pre-harvest stage in the cultivators' fields are substantial and affect their economy adversely. Moreover, the average yields of crops in the developing countries are much lower than those obtained in the developed countries. The crop loss due to incidence of pests and diseases at the pre-harvest stage is one of the major causes of lower yield in less developed countries.

1.5 The crop losses in the developing countries which run to billions of dollars affect adversely their economic and nutritional standards. The condition is all the more critical considering the fact that all the efforts made by these countries in producing more food-grains are vitiated by substantive pre-harvest crop losses due to pests and diseases.

1.6 The necessity of estimating reliable crop losses has been felt for some time. In 1967 the FAO convened a symposium on crop losses to emphasize the need for the development and us of experimental methods to estimate crop losses quantitatively. Consequently a manual of "Crop Loss Assessment Methods" was prepared by Dr. L. Chiarappa. Again in 1977 a workshop on "Assessment of Crop Losses due to Pests and Diseases" was organized by UN/FAO/ICAR at Bangalore (India) where important work on the subject completed during the last decade was presented. Particularly the studies made by the Indian Agricultural Statistics Research Institute regarding the development of statistical methodology for assessment of crop losses was much appreciated.

1.8 To achieve the above objective it would be desirable to study the work done by variou researchers and institutions in this field so that the problems concerning pre-harvest losse of foodgrains due to pests and diseases could be examined and identified and suitably studied to develop appropriate statistical methodology, keeping in view the conditions prevailing in developing countries. In this regard, various experts and organizations were contacted through correspondence. An attempt has been made to review all the publishec literature on the relevant subject, not only relating to the food crops but other crops alsc The review cannot be claimed to be very exhaustive as the material reviewed was selected out of the material received.

1.9 It was noticed that uniform concepts, definitions and measurement techniques have not been adhered to in different studies. It was, therefore, felt necessary to devote one chapter to this subject so that all the organizations could follow uniform concepts, definitions and measurement techniques to obtain comparable and reliable data over larger space and time.

1.10 Since the statistical methodology involved in the estimation of crop losses is not as simple as in the case of other studies like estimation of yield or area under crops, it has been dealt with in more detail in one chapter. The layout plan and execution of surveys for estimating the incidence of pests and diseases and consequent foodgrain losses with special reference to developing countries and the possibility of integration of such surveys with current agricultural surveys, being conducted in those countries, have also been discussed in this chapter.

1.11 Case studies, indicating the details of the statistical methodology used, etc., have been dealt with separately in the manual. The specimen forms for collecting and reporting of data, measurement techniques for incidence of pests and diseases and details of statistical procedures for analysis of data on pests and diseases and estimation of crop losses will be given in the Appendices.

2. CONCEPTS, DEFINITIONS AND RECORDING OF OBSERVATIONS

2.1 For evolving a suitable methodology for the estimation of crop losses due to incidence of pests and diseases of the crop and its relationship with the yield, it is necessary to understand the concepts and definition of incidence/infestation of pests and diseases, yields and losses. Clear concepts would help the research workers to compare the results obtained in various countries without any ambiguity. Such common and acceptable concepts and definitions may also help in increasing the reliability of data. On the basis of the concepts and definitions developed by various research workers in the course of their work, a common framework can be prepared for use by workers in the future. These are discussed in subsequent paragraphs.

Pests and Diseases

Degree of prevalence of pests and diseases

2.2 In the investigation for the assessment of crop losses due to pests and diseases, the first task to be undertaken should be to estimate the extent of prevalence of pests and diseases, i.e., what percentage of area is infected by pests and diseases. A degree of prevalence of 70 per cent means that 30 per cent of the area is free from the incidence of pests and diseases. The main study may now be confined to the 70 per cent affected area. This may be done by subjective or objective, or both, methods by adopting an appropriate sampling and measurement technique.

Intensity of disease incidence or pest infestation

2.3 The next step would be to know the intensity of disease incidence or pest infestation in the demarcated area, as defined above. This may be defined as the percentage of plants infected by disease or pest as determined from the sampling unit area in the field. This should be measured by objective methods.

Severity of disease incidence or pest infestation

2.4 Once the degree of prevalence and intensity of pests and diseases is known, one would like to know how severe the incidence or pest infestation is. This can be determined by measuring the severity of incidence due to different diseases. Such methods do not exist for measuring the severity of infestation of the pests. However, the severity of pest infestation can be measured by counting the number of eggs, larvae, pupae or flying insects, or by determining the percentage of infested leaf, if feasible.

Yield

2.5 This may be defined as a measure of produce obtained from a crop (group of plants).

Attainable yield

2.6 This may be defined as the resulting high yield of high quality when a crop is grown under optimal conditions, fully using the available modern technology, for example on experimental plots.

Economic yield

2.7 The attainable yield is the yield obtained by using the best available production technology without consideration of economics, but when economics is taken into consideration for obtaining a higher yield, it may be referred to as economic yield. This is the situation when the income in return is more than or at least equal to the cost of improved inputs, cultural practices, etc., used for producing that yield. Hence the economic yield may be equal to or less than the attainable yield.

Actual yield

2.8 This is obtained when crops are grown under farm conditions. The actual yield would obviously be less than the attainable yield. In developed countries the difference between these yields may be negligible, but in the developing countries the actual yield is far less than the attainable yield. FAO's main concern is to reduce this gap by raising the level of actual yield.

Losses

2.9 Losses of crop have been defined in various terms by research workers. Losses of foodgrains can occur during the pre-harvest, at-harvest and post-harvest stages but the discussion in this manual will be confined to the pre-harvest losses of foodgrains due to pests and diseases.

Crop loss

2.10 In simple terms this is a measure of reduction in either the quantity and/or quality of yield. It may be taken as the difference between actual yield and attainable yield.

Economic loss

2.11 This is the difference between actual yield and economic yield.

Potential loss

2.12 The difference between attainable yield and economic yield may be termed as potential loss.

Avoidable loss

2.13 This is the difference between the yields obtained from 'protected' and 'unprotected' fields. The plant protection schedule adopted in protected fields may vary from crop to crop depending on the occurrence of different pests and diseases.

Recording of Observations

2.15 During the growth period, periodical observations, measuring the intensity and severity of the incidence/infestation due to pests and diseases, are recorded. Finally the crop yield is recorded at the harvest. Since the crop grown in the cultivator's field is exposed to various pests and diseases, the observations on the incidence of all the pests and diseases should be recorded simultaneously. Observations on other factors, such as variety, soil type, irrigation, manuring, topography, cultural practices, climatic variations, variations due to geographical location, etc., should also be made so as to classify the effect of pests and diseases. The observations on these factors would make it possible to present the results in the contingency tables for undertaking a deeper analysis to locate the causes of incidence of pests and diseases.

2.16 Various researchers have measured the intensity of the incidence/infestation due to pests and diseases. The intensity of the incidence/infestation of pests and diseases is usually measured by taking the ratio of the infected plants to the total number of plants in the selected plot of the field at various stages of the growth period.

2.17 The severity of the diseases during the growth period is usually measured by assigning the score of disease infection on the leaves with the help of the standardized score charts, prepared by the plant pathologists. The number of grades of such score charts may vary from disease to disease for different crops. Usually it indicates the percentage infected area of the leaves. Near or at the harvest time, the severity of disease incidence may result in neck or ear infection of the plants.

2.18 The entomologists have developed various techniques for measuring the severity of pest infestation. The severity may be known by the infested portion of the leaves or it may be the number of eggs, larvae, pupae or flying insects, caught with the help of a standard net of about 30 cm diameter.

2.19 The yield of the crop in the selected plot is also recorded as this is the indicator of the result of the various inputs and other factors apart from incidence of pests and diseases. With the relationship of severity of incidence or infestation of pests and diseases and the resultant yield determined by taking into account the effect of other factors, the crop losses due to pests and diseases are determined.

2.20 Since much work on the concepts, definitions and recording of observations has already been done by subject specialists at experimental stations, it can easily be applied in the case of studies in the cultivators' fields with necessary modifications.

3. STATISTICAL METHODOLOGY

Methodology in vogue

3.1 Several methods, which are usually adopted at experimental stations, may be used to estimate crop losses. Such techniques can be categorized broadly as follows:

Mechanical

3.2 The crop is grown under controlled conditions, or in an enclosure of wire-gauze or cotton gauze, so as to keep disease/pest away and the yield of the crop under such conditions is compared with that obtained from infected/infested crop grown under similar conditions to estimate the degree of loss due to disease(s) or pest(s).

Chemical

3.3 Under this technique the crop is protection from pest(s) or disease(s) by using chemical plant protection measures. The yield of such a crop is compared with that of the crop grown under similar conditions and which is exposed to natural infection/infestation for estimation of the degree of loss in yield. The loss in yield which can be avoided by application of chemicals and by controlling the incidence of pests and diseases, has been defined as 'avoidable loss'.

Comparison of the yield in different fields having different degrees of incidence of pests or diseases

3.4 In this technique the yield per unit area in different fields having different degrees of incidence of pests or diseases and other factors which may affect the yield is recorded and the relation between the yield of the crop and the intensity or severity of disease or pest infestation is worked out to estimate the loss in yield.

3.5 This method can be adopted for the estimation of crop losses due to different pests and diseases on larger areas in cultivators' fields, after selecting these at random. The estimation of incidence of pests and diseases can be made after using standardized measurement techniques and the methodology can be used for finding the crop loss due to each of the pests and diseases separately and also the total loss due to all pests and diseases simultaneously by relating such incidences to the yield.

Comparison of the average yield of individual plants free from pest/disease incidence with those of the infected/infested plants

3.6 In this process, individual plants from the same field are examined for the degree of incidence and their individual yields are determined. Thereafter the average yield of the healthy plants is compared with that of plants showing different degrees of incidence for the estimation of the loss. Correlation between the yield and degree of incidence on individual plants is also sometimes worked out.

3.7 There might be a compensatory effect in the yield obtained from the plants which are free from pests/diseases, so the difference in yield between infested/infected plants and such plants may not give a true picture of crop loss due to pests/diseases. Moreover, this method is very time consuming and hence not practicable on a large scale in cultivators' fields.

The average amount of damage caused by an individual insect

3.8 The information is collected through primary studies on the biology of each species of insects. Details are also worked out regarding the amount of damage caused up to various stages or ages of the insect, the exact nature and amount of loss caused, etc. This technique is feasible only at a research station and it is very difficult to adopt it in a larger area because it is very time consuming.

Biological

3.9 The pests are controlled by introducing predators or parasites in the field and the yield of crop from such fields is compared with that of a crop where no such control measures are taken. Attempts have also been made to use disease-producing organisms in the control of insect pests. Investigations have also been carried out using artificial innoculation. This method is confined to small area research and is not practicable in the cultivators' fields covering large areas. Methods for estimation of crop losses were modified at the

Indian Agricultural Statistics Research Institute and used for estimation of losses in yield of paddy, wheat and maize crops.

Techniques for Measuring the Incidence of Pests and Diseases

3.10 One of the important factors for estimation of crop losses is the standardized technique for measuring the incidence of pests and diseases during the growth period as well as at harvest time. The standardized measurement techniques increase the objective procedures to be followed by the field investigators for taking and recording observations without any error. In other words, the observations recorded by different investigators utilizing the standardized measurement technique are the same, and if there are differences they may not be statistically significant. From the statistical point of view this aspect is very important. In the absence of such measurement techniques, the observations may be faulty and their statistical interpretations may be difficult. The method should be simple so that its adoption is easy for collection of reliable data on crop losses.

Sampling Design for Collection of Data

3.11 It is not possible to survey the whole of the affected area even for subjective type (estimation, etc.) study especially for such time consuming and complicated studies. One is, therefore, forced to adopt a sampling procedure. There are various sampling procedures such as simple random sampling, systematic sampling, successive sampling, stratified random sampling, double sampling, cluster sampling or multi-stage sampling, etc., which can be recommended depending upon the situation and type of data to be collected. The researcher has to choose a sampling technique which is suitable for the study he wants to make.

Optimum Plot Size

3.12 The investigator would be interested to know the optimum plot size where the incidence of pests and diseases is measured and recorded. The plant pathologists and entomologists can work out the optimum plot size and standardized measurement techniques at the research stations with the help of the statisticians without any difficulty. Much of the work has been done for certain pests and diseases for some crops and much work has still to be done for many other crops. For example, methods have been developed for measuring the severity of diseases in various crops.

Role of Field Experiments in Assessment of Crop Losses

3.13 Experiments in the fields are conducted by adopting, in general, randomized block designs or split-plot designs. Since these experiments are very time consuming and costly, various aspects are studied simultaneously. The experiments are conducted with various objectives such as finding out the efficacy of insecticides, fungicides, nematicides, rodenticides, pests and disease-resistant varieties or their relationship with the yield or the economic/injury thresholds, etc. The research conducted under controlled conditions in glasshouses/laboratories on the various topics referred to above can be tested and improved upon by conducting experiments in the cultivators' fields before final recommendations are made.

Suggested Methodology

3.14 In general, various researchers have dealt with the incidence or infestation of either single disease/pest or an index of diseases/pests, reducing the problem to a single variable, thus making the problem easy. The results of the study of crop loss due to a single pest or disease under controlled conditions in the laboratory/research station may not be applicable to the conditions of the cultivators. Since the pests and diseases occur simultaneously in the field crop, a multi-character approach, i.e., taking into account the incidence of all the pests and diseases, should be adopted as has been done by research workers at the Indian Agricultural Statistics Research Institute. The crop losses based on such studies may give a better picture instead of crop losses, worked out by several workers, on the basis of a single pest or disease and sometimes it may give, by adding losses worked out on the basis of individual pests and diseases separately, more than 100 per cent crop loss which is not consistent. Since there are several other factors, besides incidence of pests and diseases which affect the yield, an in-depth study which can remove the effect of the factors other than incidence of pests and diseases would be preferable. To simplify such complicated studies the following suggestions are made:

a) Such complicated surveys must be conducted jointly by a team of specialists, viz. entomologists, plant pathologists, statisticians, etc., so that objective and reliable data are obtained and results are interpreted scientifically.

b) Since the recording of observations for the estimation of incidence of pests and diseases and crop losses is very time consuming and costly, the study for estimating pre-harvest crop losses over a large area had to be carried out on a sampling basis.

c) The sampling design and other statistical methods should be as simple as possible so as to leave maximum time for taking and recording periodical observations on the incidence of pests and diseases.

d) Stratification and various stages of sampling units should be clearly defined, so that even non-statisticians may understand easily.

e) To meet the statistical requirements, only standardized measurement techniques, developed by the plant pathologists and entomologists, should be used to make the observational errors 'nil' or 'negligible'.

f) The schedules for the survey should be simple and clear and columns for coding be provided along the side of observations so that the data could be computerized later on.

g) Instructions to the field staff should be prepared in detail, indicating the selection of units, use of plant protection measures and how to record each and every observation.

h) The field staff having experience in taking and recording of observations with respect to entomology or plant pathology, should be appointed and thoroughly trained in the selection of sampling units at different stages and in the use of measurement techniques before starting the survey in each crop season.

i) The field survey work should be supervised frequently by the specialists, viz. entomologists, plant pathologists, statisticians, etc., and their difficulties should be removed on the spot.

j) Such studies should be carried out for a number of years so as to obtain sound statistical models for predicting the crop losses at pre-harvest stages in the subsequent years, besides gestting the estimates of losses for the years under study.

k) The indication of endemic areas and outbreaks of pests and diseases in epidemic forms can also be made on the maps of the areas covered if the studies are made for a number of years consecutively.

l) The avoidable loss, by taking pairs of protected and unprotected fields, should also be determined simultaneously so as to assess the efficacy of plant protection schedules.

m) Coding for computerizing the data should be done by the field staff, if possible, for obtaining quick results.

Planning and Execution of Surveys for Estimating the Incidence of Pests and Diseases and Consequent Foodgrain Losses with Special Reference to Developing Countries

3.15 The problem of assessment of pre-harvest foodgrain losses due to pests and diseases, which depends to a large extent on correctly estimating the incidence of pests and diseases and its relationship with the yield, should be viewed in its proper perspective. It should be borne in mind that the purpose of the assessment of losses due to pests and diseases is to examine the seriousness of the problem and developments for reducing such losses expeditiously and economically. It is necessary to identify the major pests and diseases and endemic areas in a country so as to adopt preventive and/or curative measures in plant protection programmes. The objective of studying a suitable statistical methodology for the assessment of pre-harvest foodgrain losses due to pests and diseases is, therefore, to provide methods giving reliable and objective estimates so that effective and economical plant protection programmes would be formulated in the developing countries.

3.16 For assessing the pre-harvest losses due to pests and diseases, it is necessary to demarcate the area and crops to be covered and also to utilize the prior knowledge of incidence/infestation of major pests and diseases, degree of prevalence, etc., if available. Next a suitable sampling procedure and measurement technique for different pests and diseases are to be adopted. Data required are to be clearly specified for different pests and diseases and suitable proformae drawn up for recording the periodical observations on them. The details of field organization are to be worked out, data collected, scrutinized and analysed to obtain estimates of crop losses due to different pests and diseases singly and collectively. The standard errors should also be worked out to judge the reliability of the information thus obtained. The components of variance should also be worked out to obtain a suitable sample size at different stages for a given degree of precision for future surveys.

3.17 All these points, viz. organization of the surveys, sampling design, recording of observations on different pests and diseases on major crops like paddy, wheat, maize and jowar, equipment required by the field staff, and statistical analysis for estimating the incidence of pests and diseases, and assessment of crop losses with special reference to developing countries are suggested below in brief.

Organization of the surveys

3.18 In such multi-disciplinary surveys a team of statisticians, entomologists, plant pathologists and an expert in plant protection measures should be formed under a project leader having basic knowledge of these subjects. All these experts should have sufficient field experience. The field staff should be preferably from the disciplines of entomology/plant pathology/plant protection. There should be field officers, supervisors and field assistants. The strength of various categories of field staff would depend on the area covered under the surveys, keeping in view the workload they can handle in the allotted area and in a given time. The field staff should be thoroughly trained by the experts of the team with respect to the aspects of statistics, entomology, plant pathology and plant protection. For selection of sampling units, recording of the observations and spraying schedule, there should be a team of two field assistants in each stratum or unit of area so fixed.

Sampling design

3.19 As mentioned earlier, the sampling design for such complicated surveys should be as simple as possible so as to spare maximum time for the field staff to record the periodical observations and thus increase the reliability of the data collected. Stratified multi-stage random sampling technique should be adopted. The country or the region under coverage may be divided into a number of strata, keeping in view the homogeneity of the area in respect of soil type, climate, irrigation, cropping pattern, accessibility and other administrative and field survey conveniences, etc. Within each stratum, (l) number of first-stage units (say villages) growing the crop under survey may then be selected at random, (m) second-stage units (say fields within villages) are then selected within each selected first-stage unit and so on. These stages may be two, three or more till we reach the field level. Supposing fields are the second-stage units then (m) number of fields in each first-stage unit are taken. In each field we may select (n) number of plots of 1m x 1m size each in case of paddy and wheat crops, and 2m x 2m size each in the case of sorghum and maize crops. However, the sizes of the plots may differ from one country to another depending on the cultivation practices followed for such crops.

3.20 The various stages of sampling units and plot size have to be determined on the basis of conditions existing in the country. If a well defined concept of a village along with its boundary demarcated maps exists, the village may be an appropriate first-stage unit. The crop field or cultivator may be adopted as the second-stage unit. This implies that the list of crop fields exists or can easily be prepared. If the procurement of the list of crops is difficult it is advisable to adopt the cultivator as the second-stage of sampling unit as the list of cultivators can easily be prepared. If a cultivator is the second-stage unit, the crop field will be treated as the third-stage unit. The list of fields of the sampled cultivators can easily be prepared. The ultimate sampling unit will be a fixed size plot. The size of the plot may vary from crop to crop depending upon its nature and stand. For homogeneous crops like rice, wheat, etc., a plot the size of 1 x $1m^2$ may be satisfactory while this size may be doubled in the case of millet crops.

3.21 For the purpose of assessing the avoidable loss in yield, two or more additional fields may be selected where plant protection measures could be used to control pests and diseases. These two or more fields could be selected at random out of (m) fields, already selected in each first-stage unit as mentioned above, then two more fields similar to these fields in respect of crop variety, fertilizer and manure application, topography, soil type, irrigation, cultural practices, etc., may be selected. These two pairs of similar fields are found in each first-stage unit besides (m-2) extra fields. One field from each such pairs may be selected at random, in which the pests and diseases would be controlled by chemical plant protection measures as recommended by the team of experts and may be called 'protected field'. The other field of each pair may be exposed to natural infestation and referred to as 'unprotected field'.

3.22 In each of the (n) selected plots, 5 plants, 4 corner ones and a central one, may be selected for recording the detailed observations in case of measuring the severity of diseases and pests as it is not possible to observe all the plants in a plot for such purposes. The observations on the major pests and diseases may be recorded at an interval of about 4 weeks or a fortnight, beginning with the first observation taken 4-6 weeks after transplanting or sowing and ending with the last observation at the time of harvest. The plots in the fields may be fixed for recording the periodical observations for the whole of the season.

Responsibilities of field survey

3.23 The field survey work will be the responsibility of the Project Co-ordinator and the field staff will be under his administrative control. Planning of the survey, analysis of data and preparation of reports thereon will also be the responsibility of the Project Co-ordinator. The division of responsibilities in brief will be as follows:

3.24 The Project Co-ordinator will

i) depute officer(s) for imparting intensive training regarding statistical, entomological, plant pathological and plant protection aspects to the field staff before starting the field work in each season,

ii) select villages in their allotted area and allot random number list for selecting the fields and location of plots within fields,

iii) supply the field staff with booklets containing technical instructions for reference and forms for recording observations,

iv) depute officer(s) for inspecting field survey work from time to time,

v) clarify the points, relating to statistical, entomological and plant pathological and plant protection aspects, raised by the field staff through the field officer,

vi) scrutinize, tabulate, analyse and prepare a report on the data collected,

3.25 The Field Officer will

i) arrange for the training in consultation with the Project Co-ordinator and the officers in charge of statistics, entomology, mycology/plant pathology and plant protection,

ii) obtain clarifications relating to statistical, entomological, mycological and plant protection aspects from the respective experts,

iii) obtain from the Project Co-ordinator the list of sample villages and random number lists for selecting the fields and for locating the plots in the fields in each stratum,

iv) impart detailed training to field assistants and helpers regarding the carrying out of the survey, thoroughly explain how the data on various items in the forms are to be collected and recorded,

v) arrange for the supply of specified equipment and material to the field assistants and helpers well in time for conducting the field survey work,

vi) clarify the points raised by the field staff from time to time,

vii) supervise, with the assistance of supervisors the work of the field assistants and helpers and apprise the Project Co-ordinator with the report of his observations during the survey in each season,

viii) collect completed copies of forms and ensure that the forms are correctly filled in by the field staff before onward transmission to the Project Co-ordinator.

3.26 The Field Supervisor will

i) attend the training arranged by the Field Officer and acquaint himself with the measurement and sampling techniques thoroughly for the field survey work,

ii) supervise the field work and other day-to-day work as and when assigned to him by the Field Officer.

3.27 The Field Assistant will

i) attend the training arranged by the Field Officer and thoroughly learn the measurement and sampling techniques for carrying out the survey in his allotted taluk/tehsil/stratum,

ii) note the sample villages and random numbers for the selection of fields and location of plots in the field,

iii) collect required number of copies of forms and a copy of the Instructions from the Field Officer,

iv) obtain different items of equipment and material, for conducting the survey, from the Field Officer,

v) contact immediately after the training, the patwari/village herdsman of each of the sample villages allotted to him and complete the selection of fields within each selected village with the help of the village map and other village data readily available,

vi) contact the cultivators of the respective selected fields, explain to them the purpose of the survey, obtain general information and fix the dates for recording the periodical observations and for taking the plant protection measures in the 'protected fields',

vii) send the completed form (in duplicate) for each selected village to the Field Officer as soon as the selection of fields is over and retain form IA with him for reference till the harvest,

viii) record the observations periodically in time,

ix) see that the plant protection measures are taken in time in the 'protected fields',

x) take the observations in the 'protected fields' before the plant protection measures are taken therein if the dates of recording the observations and taking the plant protection measures coincide,

xi) dispatch the completed forms immediately after completion of work to the Field Officer,

3.28 The Helper will

i) attend the training arranged by the Field Officer and acquaint himself thoroughly with the plant protection schedule and the precautionary measures to be taken,

ii) also assist the Field Assistant in such work as location and marking of the plots, etc., whenever free.

Recording of observations

3.29 In each plot, the total number of plants (clumps), the number of plants attacked by pests and diseases, the total number of tillers, and the number of attacked tillers will be counted at each periodical observation. Besides, the total number of ears, the number of attacked ears and yield will also be recorded at the time of harvest. The procedures for recording of observations of pests and diseases on paddy crop in detail and self-explanatory schedules and tye types of observations to be taken and schedules in case of wheat, maize and sorghum crop will be provided.

Equipment for field staff

3.30 The field staff should be provided with the following minimum equipment for carrying out the field survey work, besides other facilities obtained in the country or region concerned:

i) A measuring tape (50m long) for measuring the length and breadth of the field and location of plots within the field, etc.

ii) A wooden frame of 1m x 1m for fixing the plot in case of paddy and wheat crops.

iii) Eight bamboo sticks of about 1m each and two sticks of about 35cm each for fixing the 4 corners and centres of 2 plots in the field for indicating selected plots for the periodical observations to be recorded in a crop season.

iv) A steel measuring tape (small size) for measuring the height of plants. etc.

v) A lens for identifying the infection of leaf diseases at the early stage of crop growth.

vi) A score chart for measuring the severity of the diseases by assigning the grade by comparing the infected leaf with the score charts.

vii) A net of a about 30cm diameter for taking sweeps for catching the insects in the field.

viii) A cyanide glass bottle for killing and counting the flying insects, caught in the net by taking sweeps in the field.

ix) A hand-operated sprayer/duster and pesticides for taking plant protection measures in the 'protected field'.

x) Two empty tins (kerosene oil tin size of buckets or other utensils) for preparing the spray fluid.

xi) A string about 50m long and five tall, strong and straight bamboo pegs for marking the bigger plots at harvest, in case the surveys are clubbed for other crop estimation surveys.

xii) Hessian cloth 2m x 2m in size for threshing the harvested produce.

xiii) A set of balance and standard weights.

xiv) A copy of instructions regarding selection of sampling units, recording of observations, precautions in handling pesticides, care and maintenance of plant protection equipment, etc. (for reference) and copies of various schedules for recording the observations.

xv) Two strong water proof bags, one for keeping schedules and other small items, and another for keeping pesticidal material.

Statistical analysis

3.31 Estimation procedure of average incidence of pest/disease and its standard error is given below:

Let y_{ijk} be the measure of the incidence in the k-th plot of the j-th field in the i-th village of a stratum. The additive model for the incidence y_{ijk} is given as:

$$y_{ijk} = \mu + v_i + f_{ij} + e_{ijk} \quad (i = 1,\ldots l;\ j = 1, \ldots m_i;\ k = 1, \ldots n_{ij})$$

where (μ) is the general mean, (v_i) the effect of the j-th field in the i-th village and (e_{ijk}) the effect of the k-th plot in the j-th field of the i-th village. Assuming that (v_i), (f_{ij}) and (e_{ijk}) are uncorrelated and distributed with means 0 and variance (σ_v^2), (σ_f) and (σ^2) respectively, the analysis of variance is given as:

Analysis of Variance of Incidence

Source of variation	Degrees of freedom	M.S.	Expected M.S.
Between villages	$l - 1$	s_v^2	$\sigma^2 + \lambda_2\sigma_f^2 \quad \lambda_3\sigma_v^2$
Between fields (within villages)	$\sum_{i=1}^{l} (m_i - 1)$	s_f^2	$\sigma^2 + \lambda_1\sigma_f^2$
Between plots (within fields)	$\sum_{i=1}^{l} \sum_{j=1}^{m} (n_{ij} - 1)$	s^2	σ^2

where (1) is number of villages in a stratum, (m_i) is number of fields in the i-th village, and (n_{ij}) is number of plots in j-th field village.

$$\lambda_1 = \frac{1}{\sum_{i=1}^{l} (m_i - 1)} \left\{ n_{..} - \sum_{i=1}^{l} \left(\sum_{j=1}^{m_i} n_{ij}^2 / n_{i.} \right) \right\}$$

$$\lambda_2 = \frac{1}{l-1} \left\{ \sum_{i=1}^{l} \left(\sum_{j=1}^{m_i} n_{ij}^2 / n_{i.} \right) - \frac{\sum_{i=1}^{l} \sum_{j=1}^{m_i} n_{ij}^2}{n_{..}} \right\}$$

$$\lambda_3 = \frac{1}{l-1}\left(n_{..} - \frac{\sum_{i=1}^{l} n_{i.}^2}{n_{..}}\right)$$

where $(n_{i.})$ is number of plots in the i-th village and

$$n_{..} = \sum_{i=1}^{l} n_{i.}$$

The mean value worked out for a stratum is given as:

$$\bar{y} = \frac{\sum_{i=1}^{l} \sum_{j=1}^{m_i} \sum_{k=1}^{n_{ij}} y_{ijk}}{\sum_{i=1}^{l} \sum_{j=1}^{m_i} n_{ij}}$$

For calculating the variance of mean incidence, the analysis of variance might be carried out, as per above table to separate the variation between villages, fields and plots in fields. Since the number of selected units at different stages usually does not vary much, instead of the exact formula for the variance of the estimated mean, the approximate formula given below may be used.

$$v(\bar{y}) = \frac{\hat{\sigma}_v^2}{l} + \frac{\hat{\sigma}_f^2}{\bar{m}} + \frac{\hat{\sigma}^2}{\bar{m}\bar{n}}$$

where $(\bar{m})$ is the average number of fields sampled in a sample village, $(\bar{n})$ the average number of plots selected in a sample field, $\hat{\sigma}_v^2$, $\hat{\sigma}_f^2$ and $\hat{\sigma}^2$ are the estimated components of variance between villages, between fields and between plots respectively, and other notations are the same as above. As the sampling fraction is small at all stages the finite correction factors have been ignored. The average incidence over all the strata may be calculated by taking a weighted average of the strata estimates, the weights being proportional to the estimated area under the crop in different strata.

3.32 Relating the incidence/severity of pests and diseases with yield, the loss in yield is estimated. The crop loss is usually estimated by using regression analysis. The multiple regression equation of yield on the measure of incidence may be worked out between plots within fields by removing strata, village and field variation, and is written as:

$$y = \bar{y}_o + \Sigma\, b_i\, x_i$$

where y is the crop yield (dependent variable), $\bar{y}$ is the sample mean yield, x's denote the incidences due to pests and diseases (independent variables), $\bar{x}_i$ is the mean of the i-th type of incidence, b's are the partial regression coefficients of yield on the x's incidences and $\bar{y}_o = \bar{y} - \Sigma\, b_i\, \bar{x}_i$. The variance of the partial regression coefficients and $\bar{y}_o$ are obtained as:

$$\hat{v}\ (b_i) = s_e^2\ c_{ii}$$

and

$$\hat{v}\ (\bar{y}_o) = s_e^2\ \frac{1}{n} + \Sigma\ c_{ii}\ \bar{x}_i^2 + 2 \sum_{i<j} c_{ij} \bar{x}_i\ \bar{x}_j$$

where s_e^2 is the mean square deviation from regression, n is number of observations and c_{ij} is the i, j-th element of the inverse of sum of squares and sum of products matrix of the incidences. For obtaining the expected loss per unit of the incidence, the multiple regression equation given above has been converted to percentage yield simply by multiplying the equation by $100/\bar{y}_o$ and is given as:

$$y = 100 + \Sigma\ b_i'\ x_i$$

where $b_i' = \frac{b_i \times 100}{\bar{y}_o}$ and its variance is given as:

$$\hat{v}(b_i') = (b_i')^2\ \left\{ \frac{s_e^2\ c_{ii}}{b_i^2} + \frac{\hat{v}\ (\bar{y}_o)}{\bar{y}_o^2} \right\}$$

ignoring covariance terms.

The expected percentage loss in yield due to individual mean incidence x_i is given as:

$$\text{Loss} = \bar{x}_i\ \ b_i'$$

and approximate estimate of its variance can be given as:

$$\hat{v}\ (\bar{x}_i\ \ b_i') = \bar{x}_i^2\ \ \hat{v}(b'i) + b'^2_i\ \hat{v}(\bar{x}_i) = \hat{v}(b_i')\ \hat{v}(\bar{x}_i)$$

The percentage overall loss in yield due to the mean incidence of all the major pests and diseases is given as:

$$\text{Total loss} = \Sigma\ b_i'\ \bar{x}_i$$

and its variance can be given as:

$$\hat{v}\ (\Sigma\ b_i'\bar{x}_i) = \Sigma\ \bar{x}_i^2\ \hat{v}\ (b_i') + \Sigma\ b'^2 \hat{v}\ (\bar{x}_i) - \Sigma\ \hat{v}\ (b_i')\ \hat{v}\ (\bar{x}_i)$$

Assessment of avoidable loss in yield

3.33 The yield and its variance in 'protected' as well as 'unprotected' fields and the difference of yield in each stratum is estimated by the usual procedure. The avoidable loss in yield is worked out as follows. Suppose y and y'are the mean yields in kg/ha in the 'protected' and 'unprotected' fields, respectively, the percentage loss in yield is worked out as:

$$\text{Loss} = \frac{\bar{y} - \bar{y}'}{\bar{y}} \times 100$$

and its variance is given as:

$$\hat{v}\left(\frac{\bar{y}-\bar{y}'}{\bar{y}} \times 100\right) = \left(\frac{\bar{y}-\bar{y}'}{\bar{y}} \times 100\right)^2 \quad \frac{\hat{v}(\bar{y}-\bar{y}')}{(\bar{y}-\bar{y}')^2} + \frac{\hat{v}(\bar{y})}{(\bar{y})^2}$$

ignoring covariance terms.

where $\hat{v}(\bar{y})$ is the estimated variance of $\bar{y}$, $\hat{v}(\bar{y}')$ is the estimated variance of $\bar{y}'$ and $\hat{v}(\bar{y}-\bar{y}') = \hat{v}(\bar{y}) + \hat{v}(\bar{y}')$ ignoring covariance terms.

Integration of Surveys for the Estimation of the Incidence of Pests and Diseases with Current Agricultural Surveys

3.34 The surveys for studying the incidence of pests and diseases may sometimes be integrated with the current agricultural surveys especially in the developing countries which lack necessary resources. Necessary precaution may, however, be taken while integrating such surveys. The collection of data on incidence of pests and diseases may require frequent visits to the sample units, while other agricultural surveys may need only one or two visits to the sample units. Because of this peculiarity, the pests and diseases surveys become time consuming and costly. Further, the unit for recording the data may not always be the same. For example, in case of yield estimation surveys relatively bigger plots are taken, while for recording data on incidence of pests and diseases smaller plots are generally recommended. It should be possible to locate smaller plots within the larger plot earmarked for crop estimation surveys. The incidence of pests and diseases can be related to the yield by separately harvesting the crop of the smaller plot meant for recording the data on incidence of pests and diseases. Such integration of surveys would, no doubt, cost less but this saving should not be at the cost of less reliable data regarding the incidence of pests and diseases. In view of the importance of studying the incidence of pests and diseases, the survey relating to crop loss may be treated as the main survey while the crop estimation survey may be the secondary one. In view of the interdisciplinary approach for the crop loss surveys, it will be desirable to plan such surveys independently.

4. CASE STUDIES

4.1 The Indian Agricultural Statistics Research Institute carried out a pilot sample survey in District Cuttack, India, during the years 1959-1962 with the objective of evolving a suitable statistical technique for estimating the incidence of pests and diseases on rice crop and assessment of consequent loss in yield. To verify the suitability of the techniques developed in the Cuttack survey in different agro-climatic conditions, it was extended to the District of Thanjavur, Tamil Nadu, in 1962 and to West Godavari in Adhra Pradesh in 1963 on rice crop. The surveys were conducted for four years. A similar survey was conducted on wheat and maize in the District of Aligarh, Uttar Pradesh, for four years from 1963 to 1967.

Survey Design

4.2 Stratified multi-stage random sampling design was adopted. Since in India, a complete list of villages along with maps showing the village boundary and other details like cultivated area, crops grown, etc., is readily available, it was possible to adopt the stratified multi-stage random sampling design. Each district was divided into 9 or 10 zones by grouping adjacent thanas or blocks consisting of 80-100 villages and these zones constituted the strata. In each zone (stratum), six villages growing rice crops and in each sampled village, four fields growing rice were selected at random.

4.3 In Thanjavur and West Godavari two more fields, in addition to these four fields were selected where plant protection measures (Table 4) were used to control pests and diseases for the purpose of assessing the avoidable loss in yield. The procedure of selection of these two fields was as follows:

4.4 Two fields were selected at random out of four fields, already selected in each village as mentioned above, then two more fields similar to these two fields with respect to variety, manuring schedule, topography, soil type, cultural practices, etc., were selected. These two pairs of similar fields were found in each village besides two extra control (unprotected) fields. One field from each such pairs was selected at random, in which the pests and diseases were controlled by chemical plant protection measures and called 'protected field'. The other field of each pair was exposed to natural infestation and referred to as 'unprotected field'. In each selected field four plots of size one sq. metre each were marked at random. With certain pests and diseases,where it was not possible to observe all the plants in a plot, only 5 plants, 4 corner plants and one central plant in each plot were selected for recording prescribed data.

Measurement techniques

4.7 The total number of tillers and those infected by different pests and diseases were counted in each selected plot on each occasion. The ratio of the two was taken as an index of the incidence in pre-harvest counts. At harvest the percentage ears infected by different pests and diseases out of the total number of ears was taken as the measure of incidence.

Pests

4.8 (i) Stem-borer (Tryporyza incertulas): The larva bores the stem of the tiller and the infected tiller is a dead heart. The number of dead hearts is counted during the growth period. At harvest it gives rise to a white ear, so the number of white ears due to stem-borer is recorded. The ratios of the number of dead hearts and white ears to the total number of tillers and ears respectively are taken as measures of the damage to the crop due to stem-borer during the growth period and at harvest time respectively.

4.9 (ii) Gall-fly (Pachydiplosis oryzae): The larva punctures the stem making a gall, and the infected tillers are known as silver shoots. No ear is formed. The percentage of silver shoots due to gall-fly of the total number of tillers is the index of the infestation during the growth period of the crop, and at harvest the ratio of silver shoots to the total number of ears is the measure of damage.

Diseases

4.10 (i) Blas (pyricularia oryzae): The four corner plants and a central plant were taken from each plot and with the help of the standard score chart (Appendix V), supplied by the Central Rice Research Institute, Cuttack, the maximum infected leaf of each of the five plants selected was assigned a score corresponding to the grade of infection by these charts. The number of grades varied from 0 to 8 for blast and 0 to 9 for helminthosporiose. The severity of the diseases was measured by these scores during the growth period. At harvest, the percentage of ears infected with helminthosporiose and blast were taken into account. The yield of rice was also recorded at harvest time.

Statistical Analysis

4.11 The study can be divided into four major categories:

(i) Estimation of mean pest/disease incidence and standard errors

(ii) Relationship of the incidence of pests and diseases with yield, and the assessment of loss in yield

The methodology adopted with respect to (i) and (ii) above was more or less the same as that presented in Chapter 3.

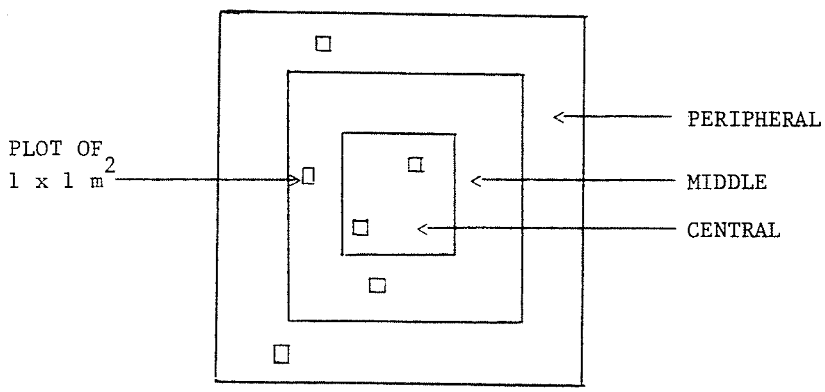
(iii) Association of the incidence of pests and diseases with agronomic and soil factors

4.12 The study was made to find the effect of agronomic and soil factors such as type of manuring, organic (compost, FYM, cow-dung, etc.), inorganic (nitrogen in different forms) at three levels, light, medium and heavy; method of sowing-transplanting and broadcast; topography low, medium and high land; and soil type, sandy, sandy loam, loam, clay loam and clay. In such studies the effect of strata on the incidence of pests and diseases was removed.

(iv) Work on appropriate sampling techniques

Efficiency of Sub-division of Fields

4.13 It is possible that the incidence of pests and diseases may vary from the border to the centre of the field. If so, it would be desirable to sub-divide the field and take plots from each sub-division for recording as shown in the figure. To investigate this, the observations described earlier were taken in six additional plots selected in each of the largest control fields in each selected village in only one stratum during each season. The six plots of 1 sq. metre each were located at random, two in each of the peripheral, middle and central portions of each field. The analysis was carried out for each pest and disease after transforming the data to normal variates.



Fixed Versus Variable Plots

4.14 Field observations were taken mainly for estimating the intensity or severity of incidence of pests and diseases at different stages of plant growth. The best procedure would have been to make a fresh selection of plots on each occasion. However, practical difficulties forced us to keep the plot fixed through the period of investigation in each season. To evaluate the loss of efficiency, due to using fixed plots, observations were taken on two fixed plots and on two plots located afresh on each occasion. The average incidence of each of the major pests and diseases during each season was worked out separately. They were analysed after suitable transformation to find out the difference in incidence in these two categories.

Number of Sampling Units to be Selected at Different Stages for a Pre-assigned Degree of Precision

4.15 As mentioned earlier, stratified multi-stage random sampling was used for the investigation. Village, field and plot were the primary, secondary and tertiary units of sampling respectively, with zones forming the strata. For investigating the suitable sample size at each stage, it is necessary to estimate the variation between the units at each stage. These estimates were calculated for the incidence of major pests and diseases and used in working out the number of sampling units required at different stages for a pre-assigned degree of precision using the formula given below

$$1 = \left(\hat{\sigma}_v^2 + \frac{\hat{\sigma}_f^2}{\bar{m}} + \frac{\hat{\sigma}^2}{\bar{m}\bar{n}}\right)\left(\frac{100}{\bar{x}p}\right)^2$$

where $(\hat{\sigma}_v^2)$, $(\hat{\sigma}_f^2)$, and $(\hat{\sigma}^2)$ are the estimated components of variance between villages, between fields and between plots respectively.

(1) is the number of villages in the sample in a district,

$(\bar{m})$ the average number of fields sampled in the village, and

$(\bar{n})$ the average number of plots randomly located in the field.

$(\bar{x})$ is the general sample mean of the incidence under study, and

(p) the percentage standard error of the mean.

4.16 In the formula given above which has been derived from the estimation of variance of the mean incidence, the values of $\bar{x}$ (mean incidence) and $\hat{\sigma}_v^2$, $\hat{\sigma}_f^2$ and $\hat{\sigma}^2$ (components of variance between villages, between fields and between plots respectively are treated to be fixed, whereas 1, $\bar{m}$ and $\bar{n}$ may change depending upon the different values of p. For example, we can work out the number of villages (1) for given value of p (1,2,3,4,5,...), $\bar{m}$ (1,2,3,4,...) and $\bar{n}$ (1,2,3,4,...) and prepare the following table for determining the sample size at various stages for the required degree of precision for the use of subsequent surveys.

Table 2 : Scheme for determining of sample size for given degree of precision

$\bar{m}$	$\bar{n}$ \ p	1 %	2 %	3 %	4 %	5 %	and so on
	1						
	2						
	3						
1	4						
	.						
	.						
	.						
	1						
	2						
	3						
2	4						
	.						
	.						
	.						
	1						
	2						
	3						
3	4						
	.						
	.						
	.						
	1						
	2						
	3						
4	4						
	.						
	.						
	.						
and so on							

Results

Estimation of losses in yield and mean incidence of pests and diseases

4.17 The multiple regression of yield on the incidence of major pests and diseases was worked out for varieties of different duration for each season in each district. Using multiple regression equations, the percentage losses due to major pests and diseases along with average incidences were calculated in each district, and are presented in Table 3.

4.18 The overall percentage losses due to the average incidence of all major pests and diseases in Cuttack were found to be 13.00, 7.13 and 11.38 for long duration varieties of the sarad crop, short duration varieties of dalua crop and medium duration varieties of dalua crop, respectively. The corresponding standard errors were 2.63, 6.32 and 5.72.

4.19 In Thanjavur, the overall percentage losses due to the average incidence of all major pests and diseases were 4.39, 3.25, 10.46 and 3.96 for short duration varieties of kurvai crop, medium duration varieties of kurvai crop and long duration varieties of samba and thaladi crops respectively, with corresponding standard errors of 1.03, 0.33, 1.65 and 4.15.

4.20 The average percentage losses due to the average incidence of all major pests and diseases in West Godavari, pooled over all the years, were 10.57 and 14.43 during kharif (long duration varieties) and rabi (medium duration varieties) respectively, with corresponding standard errors of 2.06 and 2.95.

Estimation of avoidable losses in yield

4.21 For estimating the avoidable loss in yield due to incidence of pests and diseases, two protected fields in each village in the sample were selected during the samba paddy season in Thanjavur and during the kharif and rabi seasons in West Godavari. Chemical plant protection measures as per schedules (Table 4), recommended by the Department of Agriculture of those States, were used in the protected fields. Such a study was not undertaken in Cuttack. The analysis of the yields of these protected fields and corresponding unprotected fields were carried out and the district-wise results are given in Table 5.

4.22 The avoidable loss in yield of paddy in Thanjavur district varied between 326 kg/ha and 552 kg/ha and the average avoidable loss in yield was 411 kg/ha with S.E. of 32 kg/ha. In the West Godavari, the loss was between 76 and 204 kg/ha in two seasons with S.Es of 27 kg/ha and 32 kg/ha. The low values of losses, particularly in Kharif season, reflect the inefficiency of the plant protection measures.

4.23 Taking into account the cost of pesticides used, and the cost of labour, the cost of spraying works out at Rs. 100/- and Rs. 67/- ha per season in Thanjavur and West Godavari respectively. Taking the price of paddy as Rs. 70/- per quintal, the expected net return, or the value of additional yield obtained less the cost of spraying, using recommended plant protection measures, worked out at Rs. 188/- ha with a S.E. of Rs. 22/- ha in the samba season in Thanjavur, and Rs. 76/- ha with S.E. of Rs. 22/- ha in the rabi season in West Godavari. So although the avoidable loss during kharif paddy in West Godavari was found to be significant, it did not prove economical, as the additional return did not cover the cost of the plant protection schedule used. The results did not indicate any consistent association between incidence of major pests and diseases and the agronomic and soil factors, such as soil texture, level of manuring and topography.

4.24 Investigations on the incidence of pests and diseases in various regions of the field, viz. peripheral, middle and central,did not indicate any difference among the incidences in different regions. This sub-division of fields into above-mentioned regions is not necessary for efficient sampling. The estimates of incidence of major pests and diseases based on plots fixed for all occasions of sampling in the crop season did not generally differ significantly from the estimates obtained with plots selected afresh at each occasion of sampling. Thus for the purpose of estimation of incidence of pests and diseases at different stages of plant growth, plots may be kept fixed for all occasions of sampling without much loss of efficiency.

4.25 In general, for major pests and diseases the component of variation among fields was found more than the component of variation among villages and component of variation among plots within fields. The results obtained indicate that at the district level it may be possible to estimate the incidence of major pests and diseases with standard error of not more than 10 per cent by selecting 100 villages, taking four fields in each selected village and four plots in each selected field.

Table 3 : Percentage loss in yield due to different pests and diseases

District	Pest/Disease	Crop season	Percentage loss	Standard error	Average incidence	S. E.
Cuttack (1959-62)	White ear due to Borers	*Sarad* (L.D.V.)	1.01	0.50	0.83	0.07
	Dead-hearts due to Stem-borers	*Dalua* (M.D.V.)	3.23	1.17	2.43	0.13
	Helminthosporiose infected ears	*Sarad* (L.D.V.)	12.89	2.63	1.42	0.05
	Infected areas due to Blast	*Dalua* (M.D.V.)	2.10	0.99	0.41	0.04
Thanjavur (1962-66)	White ears due to Borers	*Samba* (L.D.V.)	2.24	0.76	1.95	0.05
	Dead-hearts due to Stem-borer	*Samba* (L.D.V.)	1.51	0.73	1.73	0.08
	Ears damaged by rats	*Kuruvai* (S.D.V.)	2.91	0.84	1.90	0.16
	Ears damaged by rats	*Kuruvai* (M.D.V.)	1.38	0.29	1.90	0.16
	Ears damaged by rats	*Thaladi* (L.D.V.)	2.96	0.64	2.22	0.11
	Tillers cut by rats	*Kuruvai* (M.D.V.)	1.66	0.51	1.28	0.07
	Tillers cut by rats	*Samba* (L.D.V.)	1.63	0.31	1.23	0.08
	Infected ears due to Helminthosporiose	*Samba* (L.D.V.)	5.44	0.76	1.82	0.12
	Infected ears due to Helminthosporiose	Thaladi (L.D.V.)	2.48	0.74	2.11	0.14
West Godavari (1963-67)	White ears due to Borers	*Thaladi* (L.D.V.)	2.48	0.74	2.11	0.14
	White ears due to Borers	*Rabi* (M.D.V.)	5.15	1.57	4.99	0.18
	Infected ears due to Helminthosporiose	*Kharif* (L.D.V.)	2.99	0.08	13.49	0.34
	Infected ears due to Helminthosporiose	*Rabi* (M.D.V.)	6.67	1.97	15.66	0.59

Table 3 cont'd.

	Pest/Disease	Crop season	Percentage loss	Standard error	Average incidence	S. E.
	Infected ears due to Blast	Kharif (L.D.V.)	1.64	0.44	1.69	0.08
	Infected ears due to Blast)	Rabi (M.D.V.)	2.40	0.94	2.23	0.13

N.B.: S.D.V. indicates short-duration varieties (< 100 days)
M.D.V. indicates medium-duration varieties (100-130 days)
L.D.V. indicates long-duration varieties (> 130 days)

Table 4 : Spraying schedule adopted in protected fields

Treatment number	Stage of the crop	Pesticide
A. Samba paddy season in District Thanjavur (Tamid Nadu)		
First	Nursery	B.H.C. 50 per cent wettable power at 0.1 per cent (13.45 kg/ha) plus Fytolan at 0.125 per cent (2.41 kg/ha)
Second	A month after transplanting	Parathion (Folidol) at 0.025 per cent (0.454 kg/ha) plus Fytolan at 0.125 per cent (2.241 kg/ha)
Third	Shot blade	- do -
Rabi and Kharif paddy seasons in District West Godavari (Andhra Pradesh)		
First	During 3-4 weeks after transplanting	At 700 c.c. of Endrin per hectare mixed in 450 litres of water
Second	18-5 before the emergence of ears	700 c.c. of Endrin plus 3.6 kg of wettable copper fungicide per hectare (700 c.c. of Endrin to be mixed in 450 litres of water and 1 kg of copper fungicide to be mixed in 270 litres of water)

Table 5 : Average yield of paddy in 'unprotected' and 'protected' fields (kg/ha)

District	Season	Year	Unprotected fields(A)		Protected fields(B)		B - A	
			Mean	S.E.	Mean	S.E.	Mean	S.E.
Thanjavur	Samba	1962-63	2777	91	3168	82	391	62
		1963-64	2581	82	2955	67	374	68
		1964-65	2833	95	3385	108	552	69
		1965-66	2571	85	2897	85	326	56
		* Wtd.Av.	2686	44	3097	43	411	32
W.Godavari	Kharif	1963-64	2793	86	2892	88	99	91
		1964-65	2893	87	3035	88	142	37
		1965-66	3273	128	3258	133	-15	47
		1966-67	2835	105	2930	108	95	37
		* Wtd.Av.	2964	53	3040	55	76	27
W.Godavari	Rabi	1963-64	2316	103	2560	87	244	72
		1964-65	2882	144	3101	120	219	63
		1965-66	2422	195	2579	224	157	50
		1966-67	3095	105	3301	89	206	72
		* Wtd.Av.	2683	74	2886	76	204	32

* Weights are the number of pairs of fields.

APPENDIX I

TECHNICAL INSTRUCTIONS TO THE FIELD STAFF (PADDY)

1. Definition of a field: For the purpose of this survey, a field will mean a distinct piece of land growing paddy, which is clearly demarcated on all its sides either by bunds or by patches growing other crops, or left uncultivated.

2. Fields in the sense defined above are, however, not always separately numbered or shown on the village map. The selection of fields will, therefore, be made in two stages by random sampling, (i) selection of the survey number (see 4.1) and (ii) selection of a field (as defined above in para. 1) within the selected survey number (see 4.5). The fields selected for the survey should be large enough to accommodate a rectangular plot of 10m x 5m and two plots of 1m x 1m each. These plots should not overlap.

3. In each selected field two plots of 1m x 1m each for recording observations on incidence of pests and diseases during the growth period as well as at harvest and yield at harvest, and one plot of 10m x 5m (in paired fields) are selected to record the yield of the crop at harvest.

4. Selection of Khastra Survey Numbers and Fields

4.1 Selection of survey numbers: For each selected village four random numbers will be assigned. Select the survey number whose serial number is equal to this random number, if the random number is less than the highest survey number for the village. If it is higher, divide it by the highest survey number to obtain a remainder and select the survey number corresponding to this remainder. If the remainder is zero, that is if a random number is exactly divisible by the highest survey number, select the highest survey number itself. Thus four survey numbers are selected.

4.2 If a survey number so selected does not have even one field growing paddy crop or if all the fields growing paddy crop in the survey number are too small to contain three plots as mentioned above, replace the survey number by the next higher survey number and so on. No survey number should be rejected for other reasons, such as good or bad crop. If in this process you come to the highest survey number itself, begin again from survey number 1.

If the above procedure leads to the same survey number for more than one case (e.g. common remainder) select it for one case and select the next higher survey number for the second (or subsequent) case. Such cases will be rare.

4.3 Illustrative example for selection of survey number:

Name of village	Chintalpudi
Highest survey number for the village	764
Random numbers assigned	1049, 0761, 4320 and 0051
Remainders on dividing random numbers by highest survey number	285, 761, 500 and 51

Suppose survey No. 285 is sown with paddy and is large enough to contain 2 plots of 1 sq. metre each and a rectangular plot 10m x 5 m, select this survey number, i.e. 285. If survey numbers 500 and 51 are paddy growing and can contain all three plots, then select these also.

But suppose survey No. 761 does not grow paddy and survey numbers 762 to 764 do not grow paddy either, then, as 764 is the highest survey number, begin with survey No. 1 and select the first survey number if it is paddy growing, otherwise proceed further till you get a paddy growing survey number. This procedure may be biased but the bias will be negligible.

Rejection of survey/sub-numbers should not be made for reasons such as poor growth of the crop, bad patches of soil, etc., or for reasons of personal inconvenience.

4.4 If a selected survey number (e.g., survey No. 285) consists of more than one sub-number, select the first sub-number, i.e. 285/1. If the first sub-number does not grow paddy, select the second sub-number 285/2 and so on.

4.5 Selection of a field within a survey/sub-number

If in a selected survey/sub-number the crop is grown on more than one field or patch-bunded or otherwise, select out of these the field nearest to the south-west corner of the survey/sub-number. If two crop-growing fields are equally distant from the south-west corner, select the southernmost one.

4.6 Selection of protected fields

Select two of the four fields at random and then select fields similar to each one of these two fields in the neighbourhood (not adjacent) in respect of variety, manuring, cultural practices, topography, etc. The distance between two similar fields should not be less than 30 metres. In one field of each pair, selected at random, plant protection measures, as per prescribed schedule given in Appendix II(a), to control the pests and diseases will be adopted and called 'protected or sprayed field' and numbered 1B/2B while the other field will be left to natural infestation and called 'unprotected or unsprayed field' and numbered 1A/2A. Thus there will be six fields, viz. two protected fields, two unprotected fields and two other fields numbered 3 and 4 called 'extra control' where the cultivator will follow his normal practice.

4.7 Fill in the particulars of selection and other details in consultation with the cultivators concerned on Form I and IA in triplicate. The reason for rejection of survey Nos. from 761 to 764 should be clearly stated on Form IA. Pass on copies of the completed Forms I and IA in duplicate to the Field Officer immediately and retain a copy of each form for his reference until harvest. The Field Officer will forward one copy of each form to the Project Coordinator at headquarters.

5. Random Location of Plots

5.1 The random position of the plots within the field is fixed by means of random distances (of the south-west corner of the plot) from the south-west corner of the field as below:

Beginning from the south-west corner of the field, which will be the starting point, measure the length and breadth of the field along its longer and shorter sides respectively. Deduct 1m from the length and 1m from the breadth for locating a 1m x 1m plot, and deduct 10m from the length and 5m from the breadth for selecting 10m x 5m plots, and thus obtain the reduced length and breadth to prevent the plot from going beyond the field boundaries when marked completely. Two random numbers will be assigned for each plot. These will generally be much longer than the length and breadth of the field. Therefore, divide the random numbers assigned for length and breadth respectively by the reduced length and breadth and obtain remainders. These two remainders will determine the south-west corner of the plot to be marked, indicating respectively its distance from the starting point of the field along its length and breadth.

In case the random number assigned is less than or equal to the reduced length or breadth corresponding to it, the random number itself will be treated as the remainder.

5.2 Illustrative example for the random location of a plot of 10m x 5m within a field

Suppose that in the example given in para. 4.3 above the length and breadth of the selected field, say survey No. 285/2, are 62m and 39m respectively, and the random numbers assigned to the Field Assistant for locating the plot are 242 and 175 respectively for the length and breadth:

Length minus 10 is 62 - 10 = 52
Breadth minus 5 is 39 - 5 = 34

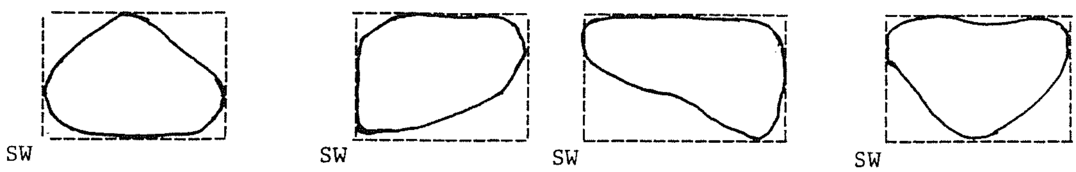
52/ 242 /4
208
34 (remainder for length)

34/ 175 /5
170
5 (remainder for breadth)

The pair of remainders 34, 5 indicate that the south-west corner of the plot to be marked will be at a distance of 34m from the starting point (south-west corner) of the field towards the length and 5m in a direction perpendicular to the length. The point reached by measuring these distances will be the south-west corner of the plot. The plot should be away from the starting point of the field. Its length should be parallel to the length of the field and its breadth perpendicular to its own length (App. I(a)).

5.3 Location of plots in an irregularly shaped field

If the selected field is irregular in shape, enclose the field by an outer rectangle of least possible dimensions. Measure the length and breath of the enclosing rectangle for the purpose of locating the south-west corner of the plot to be demarcated. The south-west corner of the rectangle may or may not coincide with the south-west corner of the field as may be seen from the diagram below:



The south-west corner of the plot should be fixed with reference to the south-west corner of the outer rectangle using numbers obtained with the help of random numbers as above.

6. Marking of the Plots

6.1 Marking of a 1m x 1m plot: Locate the south-west corner of the plot as described in para. 5.1 and fix a peg there. This will be the south-west corner of the plot. Fix the frame in such a way that the south-west corner is the south-west corner of the frame and one side of the frame is parallel to the length of the field. Fix pegs on the other three corners of the frame and one nearest to the central plant of the plot. The observations should be taken on the plants which lie within the frame and judged by the roots. In the case of plants on the boundary of the plot, include a plant within the plot if more than half its base lies within, and exclude it if more than half its base lies outside.

6.2 Marking of a 10m x 5m plot: This plot will be marked at the time of harvest. Locate the south-west corner of the plot as described in para. 5.1 and fix a straight peg there. This will be the first corner of the plot. Proceed from this point along the direction of the length of the field away from the starting point and fix a second peg at a distance of 10m. The line joining the first and the second corners will be the base line. Mark also the middle point (M) of the base line, by measuring 5m from the first corner.

Corners 3 and 4 will be marked by the triangular method in succession. To mark corner No. 3 let one man stand at corner No. 2 and another at point M. Let the former hold the measuring tape at its zero point and the latter at 12.07 m. A third man holding the tape stretched at 5m away from the starting point will automatically reach corner No. 3. Fix a peg at the point so reached. The same procedure repeated from corner No. 1 and the mid point of the base line (point M) will give corner No. 4. Fix a peg there. Check the distance between the third and fourth corners and see that it is 10m by making adjustments, if necessary, in the position of peg No. 4 only, but no other pegs.

The pegs should be tall, straight and firmly fixed in the ground. Tie a well-stretched string around the pegs and lower it gradually to ground level. Guided by the string position on the ground surface, clearly demarcate the plot for guidance during harvesting by including only plants which lie within the plot as judged by their roots. In the case of plants on the boundary of the plot, include a plant within the plot if more than half its base lies within, and exclude it if more than half its base lies outside.

6.3 For locating two plots of 1m x 1m and one plot of 10m x 5m, a set of three pairs of random numbers will be provided for each selected field; thus there will be six sets, each of three pairs of random numbers, for six fields in each selected village.

If the plot located by the above procedure does not lie within the field owing to irregular shape of the field, the pair of random numbers should be rejected and tried with a pair of random numbers allotted to the second field and so on, till you get the plot within the field.

6.4 Overlapping of plots: Suppose there is overlapping of the second plot (1m x 1m) with the first plot (1m x 1m) or of the third plot (10m x 5m) with the first or second plot, then reject the pair of random numbers and try with a pair of random numbers allotted to the second field and so on until you get non-overlapping plots within the field.

Stratification and Selection of Villages

1. The region to be covered under the survey will be divided into homogeneous strata largely based on geographical contiguity and as far as possible based on homogeneity in respect of climate, soil, cropping pattern, variety, etc. Within each stratum the survey will be carried out variety-wise.

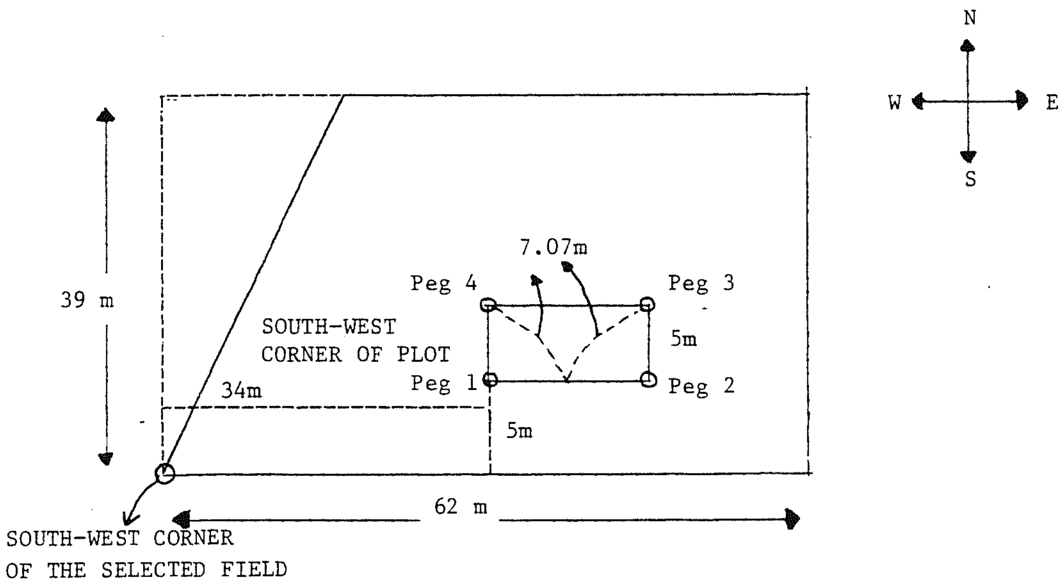
2. An alphabetical list of villages growing paddy will be prepared for the selection of villages (say six in each stratum) by simple random sampling method. The method of selection of villages in a stratum is explained in the following example.

3. Suppose that in a stratum 40 villages grow the selected variety of paddy. Make a list of the villages after arranging them in alphabetical order and serially number them. Since the total number of villages in the stratum is 40, use two-digit random number tables for the selection of villages. Divide the highest two-digit number, viz., 99 by 40 (40 being the number of villages in the stratum) and the remainder obtained is 19. Therefore, while using the two-digit random number tables for random selection of villages in the stratum, 19 consecutive numbers beginning from 99 arranged in a descending order (all the numbers from 81 to 99) will be excluded. In addition, if 00 occurs as the random number it will also be rejected. If any number between 01 and 40 occurs as the random number, then the village with the serial number equal to the random number will be selected. However, if a number between 41 and 80 occurs as random number, then the random number will be divided by 40 (40 being the number of villages in the stratum) and the remainder will indicate the serial number of the village to be selected. If the random number read is exactly divisible by 40, then the village with serial number 40 will be selected. Now refer to the two-digit random number table from the point where you stopped last. This can be known from the diary of random numbers which you are maintaining by referring to the last entry made in the diary for column number and row number. Read out the number column-wise beginning from the number following the number already used in that column. Suppose the numbers read are 86, 83, 80, 68, 40, 99, 24, 06, 81, 99, 91, 03, 27, 51, 48, 05, etc. The first two numbers in this series, viz., 86 and 83, will be rejected as they are greater than 80. The third number in the series is 80. Since it is the exact multiple of 40 (40 being the number of villages in the stratum), the village with serial number 40 will be selected. Divide the fourth number in the series by 40 and find out the remainder. The remainder obtained is 28 and hence the village with serial number 28 will be selected. The fifth number in the series happens to be 40 which is also the exact multiple of 40 (the number of villages in the stratum). But since the village with serial number 40 has already been selected, we reject randum number 40. The sixth number in the series, viz. 99 is also rejected (being greater than 80). The next number is 38. Hence the village with serial number 38 is selected. The eighth number in the series, viz., 96, will be rejected. The succeeding number is 24. Hence the village with serial number 24 will be selected. The next number in the series is 06 and hence the village with serial number 6 will be selected. The next three numbers in the series, viz., 81, 99 and 91, will be rejected, each number being greater than 80. The subsequent number is 03 and hence the village with serial number 3 will be selected. Thus the six villages randomly selected for the survey in the stratum are those with serial numbers 40, 28, 38, 24, 06 and 03. If for some reason any of the selected villages is found to be unsuitable from the point of view of the objective of the survey, reject the village and substitute it by another village again following the procedure given above. If a village is rejected record the reasons for doing so. The same procedure will be followed for the selection of villages in other strata also.

APPENDIX I (a)

ILLUSTRATION

RANDOM LOCATION AND MARKING OF PLOT (10m x 10m) RANDOM NUMBERS ASSIGNED FOR LOCATION OF THE PLOT ARE 242 (FOR LENGTH) AND 175 (FOR BREADTH)



1. Length of selected field = 62 metres (L). Breadth of selected field = 39 metres (B)

2. L-10 = 62-10 = 52; B-5 = 39-5 = 34.

3. Dividing the random number 242 by 52, and 175 by 34, the remainder are 34 for length and 5 for breadth.

4. Starting from the south-west corner of the field, go a distance of 34 metres along the length and then go a distance of 5 metres in a perpendicular direction, into the field. The point so reached is the south-west corner of the plot.

APPENDIX II

OBSERVATIONS ON PESTS, DISEASES AND CONTROL MEASURES (PADDY)

1. Observations on Pests

1.1 Stem-borer (Tryporyza incertulas): Count the number of dead-hearts in each plot. A dead-heart is a borer-attacked tiller where the central shoot withers and dries. The dead-heart will come off easily when pulled and broken and will show signs of damage by the larvae.

At harvest, count the number of white ears due to borers in the plot. A white ear is a panicle where all the spikelets are chaffy. Generally a hole will be present at or above the second node of the clump from the top. The white ear will come off easily when pulled and broken and will show signs of damage by the larvae. Ears partially damaged by borers will also be counted.

1.2 Gall-fly (Pachydiplosis oryzae): Count the number of silver-shoots in the plot. A silver-shoot is a long tubular outgrowth in the place of the normal central shoot in a tiller.

1.3 Gundhi bug (Leptocorisa acuta): Count the number of tillers/ears damaged by the gundhi bug. The bugs are greenish yellow with long legs and with a characteristic odour. The adults and numphs suck juice from the ears and thereby empty them.

Record the number of adults per sweep using the method given below:

A sweep will consist of a half circle or 180° swing with the hoop of an insect net with a diameter of 30 cm held in a verticle plane. The handle of the net should be about 1 metre in length. After each sweep, the insects may be killed by transferring them into the cyanide bottle provided for this purpose. The number of insects may be counted before taking the next sweep. Five sweeps, one each on the four sides and one in the centre, will be taken in each selected field.

1.4 Mealy bug (Ripersia oryzae): Count the number of dead tillers due to mealy bug infestation. Infestation is localized in patches and the plants appear stunted and scorched. In case of severe infestation ears are not formed. The bugs are found in colonies between the stem and the leaf sheaths. When a leaf sheath is drawn, numerous bugs, covered by white mealy powder are seen.

1.5 Swarming caterpillar (Spodoptera mauritia): Count the number of larvae for the selected clumps in each plot. A full grown swarming caterpillar is smooth and dark green in colour with light white or dull longitudinal dorsal stripes. Caterpillars nibble at the leaves.

1.6 Leaf roller (Cnaphalocrocis medinalis): Count the number of damaged tillers and the number of leaves rolled by leaf-roller in each plot. Count also the number of larvae for the selected clumps in each plot. The larva scrapes the green tissue off the leaves and remains inside the folded margins of the leaf blades where it pupates.

1.7 Jassids (Nephotettix tettigonially spectra): The sweeps made for gundhi bug will also be utilized for these insects. After separation, count the number of insects in the glass tube provided to you. Jassids are small wedge-shaped insects with rounded heads. They may be green or green with black markings, or dusky brown or pale white in colour.

1.8 Hispa (Hispa armigera): The sweeps stated above will also be utilized for this pest. Count the number of adults per sweep. Hispa is a small bluish-black beetle with numerous short spines all over the body.

1.9 Grasshopper (Neiroglyphus oxya velose): Sweeps will be used for this pest also. Count the number of adults per sweep. The adults are sturdy fliers.

1.10 Fulgorid (Nilaparvata sordescens), Tryporyza moths and Spedoptera moths: Sweeps will be utilized for these pests also. Count the number of adults per sweep separately.

1.11 Case-worm (Nymphula depunctalis): Count the number of damaged tillers and number of tubular cases of case-worm in each plot. The greenish caterpillars cut the leaves of the plants and make tubular cases and feed on the green matter of the leaves.

1.12 Rats: Count the number of tillers/ears damaged by rats in each plot.

1.13 Other pests: Record observations on other pests, if any.

2. Observations on Diseases

2.1 Blast (Pyricularia oryzae)

Symptoms: All the parts of the plant above the ground show symptoms of this disease. On the leaves broad spindle-shaped spots with a pale ashy centre and brownish red margin are seen. In severe leaf infection, several such spots join together and the whole leaf blade is destroyed. The nodes are blackened. When the main node from where the ear emerges is blackened or becomes dark brown, the symptom is called "neck infection". The heads and parts of the head may break over at the neck or at the branching, causing loss in yield. The ears with neck infection are mostly chaffy.

Count the number of tillers showing nodal infection, neck infection, ear infection, leaf infection and the number of leaves infected by blast separately in each plot. To measure the severity of the disease, take two plants, one at the south-west corner and the other at the centre from each of the two selected lm x lm plots and select one maximum infected leaf with this disease from each of the two plants and score the leaves by comparing them with the chart provided to you for the purpose. There are 8 grades marked 1 to 8 for scoring leaf infection due to the disease (Appendix V).

At harvest, count the number of neck-infested ears and infected ears in each selected plot.

2.2 Helminthosporiose (Helminthosporium oryzae)

Symptoms: This disease infects the leaf, sheath, nodes and grains. On the leaves small, oval to circular, irregularly shaped brown spots of about 2.5 mm diameter appear with a distinct darker central zone. Larger spots up to 10 mm x 7-8 mm have also been seen, but rarely. Under severe infection, nodal infection as well as neck infection as described for blast may also appear. The grains are severely spotted and appear shrivelled or chaffy.

Count the number of tillers showing leaf infection and the number of leaves infected by Helminthosporiose and ear infection in each plot. For measuring severity, observations on leaf infection should be taken from the maximum infected leaf due to this disease from each of the two selected plants, as in the case of blast. In case the selected leaf for blast also happens to have maximum infection due to Helminthosporiose, score independently for each disease on the same leaf. There are 9 grades marked 1-9 for scoring the infected leaves (Appendix V).

At harvest, count the number of ears infected by Helminthosporiose in each plot.

2.3 Bacterial blight

Symptoms: Linear stripes develop between the veins of the leaf blade and sheath. The stripes are water-soaked, light brown or bleached, with exudate on the surface. The disease causes brown to black discolouration of the grains.

Count the number of tillers showing bacterial leaf blight infection and the number of leaves infected by bacterial leaf-blight in each plot. To measure the severity of the disease, give the score by comparing the maximum infected leaf from each of the selected plants in each plot, as in the case of blast and Helminthosporiose, with the score chart provided to you.

2.4 Stem-rot (Sclerotium oryzae)

Symptoms: The sclerotia which are black, round and the size of a mustard grain, germinate at water level and enter the outer leaf sheath, causing browning at the point of penetration and yellowing of the corresponding leaf. The brownish patch increases in both ways up and down, turns black as the infection advances and the leaf sheat begins to rot.

Many black sclerotia and sometimes greyish mysalia are seen in the hollow of the clump or stem when cut open. The stem lodges and breaks off, hence it is called stem rot. The ears of the affected plants are mostly chaffy.

Count the number of dead tillers due to stem-rot in each of the selected plants in a plot and for observations on yellowing of leaves, note the severity of yellowing of the central and peripheral leaves in each selected plant by grading them as (i) light, (ii) medium and (iii) severe.

At harvest, count the number of chaffy ears due to stem-rot in each plot.

2.5 Root-rot Complex

Symptoms: The root system of the affected plant becomes highly weakened under certain unfavourable conditions. The rootlets become thin and start rotting giving off a foul smalI. Owing to root rotting, the aerial parts of the plant show yellowing, especially of the leaves, which may be brown or brownish red in some cases. Leaf-spot diseases like Helminthosporiose, cercospora, etc. develop in abundance on such plants. The growth of the plants is stunted with only a few tillers. Ear emergence is not complete and they also become stunted or twisted and are mostly chaffy. Observations on yellowing of leaves should be taken on the selected plants and yellowing of central and peripheral leaves noted and graded as (i) light, (ii) medium and (iii) severe in the case of stem-rot. Besides this, record the degree of stunting in each of the selected plants as (i) light, (ii) medium and (iii) severe.

2.6 Food rot (Fusarium moniliforme)

Symptoms: In the seed beds the infected seedlings become pale, thin, lanky and subsequently dry up and die. In the mature crop, the affected plants are much taller, with thin and lanky tillers and these tend to come to the shot blade stage earlier than the rest of the crop. The pink boom of the fungus may be seen on the nodes or on the sheaths.

Count the number of abnormally tall, lanky shoots or tillers in each plot.

2.7 False-smut (Ustilaginoidea virens)

Symptoms: The ovaries of a few individual grains are transformed into large, velvety green masses, only a few grains in each ear are usually affected.

Count the number of false smut-infected tillers/ears in each plot.

2.8 Bunt (Neovossia horrida)

Symptoms: This disease affects individual grains containing a black powdery mass of spores with or without slight development of kernels.

Count the number of bunt-infected tillers/ears in each plot.

2.9 Stack-burn (Trichoconis padwickii)

Symptoms: The leaf spots caused by this disease are large, round to oval, 3 to 9 mm in diameter with a dark brown margin and a dull grey centre.

Count the number of tillers showing leaf infection and number of leaves infected with stack-burn in each plot.

2.10 Other diseases: Record observations on other diseases, if any.

3. Plant Protection Measures in Protected Fields

3.1 Plant protection measures are to be taken for controlling the pests and diseases in the protected fields as per schedule given at the end of this Appendix.

3.2 Preparation of spray material

3.2.1 The spray fluid given below is meant for an area of 1/10th of a hectare assuming that a hand-operated sprayer will be used for the purpose. The spray fluid for fields in different areas should be prepared accordingly.

3.2.2 Seed treatment. Mix 100 mg (0.1 gm) of streptocycline and 2 grm of wettable 1% organi-mercurial compound in 3.6 litres of water. This pesticidal material is sufficient for treating 2.5 to 3 kg of seed required for 1/10th of a hectare.

3.2.3 Nursery (1/100th of a hectare). For the first spraying mix 3 cc of 50% Parathion or 7.2 cc of 20% Endrin E.C. or 14.4 grm each of 50% DDT and 50% BHC (wettable powder) in 0.6 litre of water. For the second spraying, use the same fluid as for the first spraying with the addition of 40 mg of streptocycline.

3.2.4 Field (1/10th of a hectare)

For the first spraying, mix 37.5 cc of 50% Parathion or 90 cc of 20% Endrin E.C. or 225 grm each of 50% DDT and 50% BHC (wettable powder) in 6 litres of water.

For the second spraying, prepare the spraying, prepare the spray mixture in the same way as for the first one and add 500 mg streptocycline. For the third spraying mix 45 cc of 50% Parathion or 108 cc of 20% Endrin E.C. or 270 grm each of 50% DDT and 50% BHC) wettable powder) in 6 litres of water. Add 60 mg of streptocycline also in the mixture.

For the fourth spraying mix 60 cc of 50% Parathion or 144 cc of 20% Endrin E.C. or 360 grm each of 50% DDT and 50% copper fungicide in 6 litres of water. Add 800 mg of streptocycline also in the mixture.

3.3 When to apply pesticides

The pesticides are to be applied at the time specified in the plant protection schedule, but the spraying should not be done during rains because the pesticides might be washed off. The spray should thoroughly cover the plant surfaces. If rain follows the spraying, repeated applications would be necessary. If rains come six to eight hours after the application of the spray, repeated spraying may not be necessary. However, if pests and diseases are not controlled because of rains following the use of pesticides, a repeated application of pesticides would be necessary.

The spraying solution should reach the plant surface in a fine mist form. The sprays should be prepared in clear water. Certain pesticides are difficult to mix with hard and alkaline waters.

3.4 Care and maintenance of plant protection equipment

The following suggestions would be helpful in the proper maintenance and up-keep of the plant protection equipment:

i) Wash the sprayers thoroughly with clean water after use.

ii) Likewise, clean the hoses, nozzles and strainers.

iii) Overhaul the equipment quite often. Grease and oil the moving parts.

iv) Do not bend rubber hoses at angles when in use. Remove and keep them rolled when not in use.

v) Check valves and remove worn-out ones and replace them with new valves.

vi) Do not throw the nozzles of sprayers on the bare ground. Keep the parts, etc. while repairing, on a cloth or tarpaulin.

vii) Always keep a sufficient stock of spare parts and a tool kit.

viii) Strain the spray liquid and shift the dust to avoid clogging of the nozzles and the delivery tubes.

ix) Do not leave the plant protection equipment in the open when not in use. If the equipment is not required for a month or more, the different parts should be dismantled and stored safely.

x) Take all care while shifting and transporting the equipment from one place to another.

xi) Do not repair or handle the equipment unless you know the job well.

3.5 Precautions in handling and using pesticides

Since pesticides are poisonous, they can also be toxic to animals. Some are more toxic than others. It is necessary to take all possible precautions in handling, storing and using pesticides.

Personal care and awareness of responsibility are necessary to avoid harm to human beings, animals and property, directly or indirectly.

The following general precautions may be taken in handling and using pesticides.

i) Always read the label carefully and follow the manufacturer's instructions.

ii) Keep pesticides in labelled containers only.

iii) Keep pesticides under lock and key in a safe place and out of reach of children, irresponsible persons and pets.

iv) Never store pesticides near food stuffs or medicines.

v) Do not use empty containers of dangerous pesticides for any other purpose than for storing pesticides. Empty containers which are of no use should be properly disposed of.

vi) Use protective clothing and other devices while handling dangerous pesticides.

vii) Do not tear open the pesticide bags but cut them with a knife.

viii) Prepare spray fluid from concentrated and dangerous pesticides in deep bottomed vessels with the help of long-handled mixers. This is to protect the operator from splashes of the pesticides and to make it easy for him to stir in a standing position.

ix) Wash hands thoroughly with soap and water every time:

a) when the sprayer is filled with pesticides,
b) before eating, drinking or smoking, and
c) at the end of the day's work.

x) Carefully dispose of the water or any other liquid used in the washing of equipment. Scatter it over barren land or throw it in a deep pit.

xi) Do not blow, suck or apply mouth to any sprinkler, nozzle or other spraying equipment.

xii) Use separate working clothes; they should be washed and changed as frequently as possible.

xiii) Do not allow the operator to work for more than eight hours a day. Operators engaged in the handling of dangerous pesticides should be checked periodically by a physician.

xiv) Do not keep your food and drinking water near the pesticides and in the area of operation.

xv) All precautions prescribed by the manufacturer and the transport authorities should be observed in the transportation of pesticides by rail or road.

xvi) If symptoms of illness occur during or shortly after spraying or dusting, the patient should immediately be sent to the nearest hospital or a physician should be called on the spot to attend to the patient.

4. Harvesting the Crop

4.1 The crop outside the plot should not be harvested until the crop within has been removed to the threshing ground, etc. This will enable you to check whether the harvesting by the labourers has been confined to the plot as demarcated by you.

4.2 Complete the harvesting preferably before noon. Spread the harvested produce (without leaving any plant or ear in the plot) to dry on a piece of cloth for a while before threshing. The produce should then be threshed by beating with a wooden rod or by trampling under food on a hessian cloth and winnowed with soopa. Weigh the cleaned produce carefully and accurately to the nearest gramme.

4.3 The Field Assistant should personally attend to the operations of threshing and weighing in all cases. This should normally be completed on the day of harvesting itself, unless the harvested produce is so moist that the grain cannot be separated from the ears, in which case the produce may be allowed to dry for a day or two under the personal care of the Field Assistant before threshing.

4.4 Take care to ensure that there is no loss of grain at the various stages, viz., harvesting, carrying to the threshing floor, threshing, winnowing, cleaning and weighing. Particular care should be taken to ensure that all grain is separated from the ears and that the grain so separated is free from dust.

4.5 Record the weight of the harvested produce as on harvesting day and other particulars in Form III and forward it in duplicate to the Field Officer. One copy of Form III should be dispatched by the Field Officer to the Project Co-ordinator at headquarters, and the other retained in his office for record and reference.

5. Driage Assessment

5.1 The driage experiments will be conducted on the produce harvested from the 10m x 5m plots in field Nos. 1A, 1B, 2A and 2B of the first village assigned to the Field Assistant.

5.2 The object of the driage assessment is to obtain the weight of the yield in terms of dried grain.

5.3 Immediately after the weighment on harvesting day, store the grains from the plot in a bag. Seal the bag and label it accurately with the survey number and sub-numbers, if any, field number, date of harvesting and name of cultivator corresponding to it. Carry it to the office and keep it for at least two weeks until the produce is thoroughly dry. Exposure to the sun should be given whenever possible.

5.4 When the produce is completely dry, weigh it to the nearest grm and record the weight on Form III-A.

5.5 Dry weight should be recorded only when the weight of the produce becomes constant. For this purpose, after a period of about 10 days the weight should be taken at an interval of two days until two consecutive weights are identical.

5.6 There should be no loss of produce during the period of driage or exposure to sun.

5.7 Return the produce to the cultivator as soon as the assessment has been made.

6. Despatch of Forms

6.1 Form I gives general information and other particulars about the selected fields in each selected village and Form I-A indicates the details of the selection of fields and the location of plots therein for experiments. A separate form will be used for experiments in each selected village. The Field Assistant will fill in Form I in duplicate and despatch both copies to the Field Officer sufficiently in advance of recording the observations. The Field Officer will scrutinize the forms, inform the Field Assistant about discrepancies, if any, and rectify the discrepancies. The Field Officer will then forward one copy of Form I to the Project Co-ordinator at headquarters and retain the other copy in his office for record and reference. Before despatching Form I to the Field Officer, the Field Assistant should take care to enter the relevant particulars on Form II. Form I-A will be retained by the Field Assistant until the harvest is over and he will send it in duplicate to the Field Officer along with Forms III and III-A.

6.2 Form II gives the details of observations during the growth period. The first observation in the case of transplanted paddy will be taken about four weeks after transplanting and thereafter the observations will be taken at an interval of about four weeks up to and including harvest. Form II should be prepared in duplicate immediately after taking each observation and despatched to the Field Officer after all the observations during the growth period have been made and recorded. The Field Officer will scrutinize the forms, inform the Field Assistance of discrepancies, if any, and rectify the discrepancies. The Field Officer will then forward one copy of Form II to the Project Co-ordinator at headquarters, and retain the other copy in his office for record and reference. Before dispatching Form III to the Field Officer, the Field Assistant should note the results of weighment as on the date of harvesting and other necessary details on Form III-A.

6.3 Form III-A is meant for recording the result of the driage assessment. The Field Assistant will prepare Form III-A in duplicate and despatch it to the Field Officer immediately after the driage assessment is completed. This form will also be scrutinized by the Field Officer before forwarding one copy to the Project Co-ordinator at headquarters, the other copy will be retained in his office for record and reference.

6.4 The Field Assistant should remember to take Forms I and I-A with him when he visits the village for the selection of survey numbers and fields, location of plots therein and for obtaining general information and other particulars about the selected fields, Form II when he visits the selected fields to make periodical observations, and Forms III and III-A at the time of harvest.

N.B. Recording of observations on the incidence of pests and plant protection measures, etc., are likely to be modified in view of different areas, crops, pests and diseases, in consultation with the subject specialists concerned.

Sample Survey to Estimate the Incidence of Pests and Diseases on Paddy during 19

FORM I

A. General Information

		Code*			Code*
1. Region			8. (i) Total area of the village in hectares		
2. State			(ii) Cultivated area of the village in hectares		
3. Sub-region			9. Area under paddy in the village (last year figure in hectares) — I Crop		
			II Crop		
			III Crop		
4. District			10. (i) Total Khasra/Survey numbers in the village		
5. Taluk/ Tehsil			(ii) Highest Khasra/Survey numbers in the village		
6. Village					
7. Crop season					

B. Description of the Field

			Field Numbers											
			1A		1B		2A		2B		3		4	
11. Name of the cultivator				Code*		Code*		Code*		Code*		Code*		Code*
12. Khasra/Survey No. and Sub. No. (if any)														
13. Name of the immediately previous crop (if any)														
14. Manuring of immediately previous crop (if any)	(a) Organic	Kind												
		Amount in kg/ha												
	(b) Inorganic	Kind												
		Amount in kg/ha												
	(c) Other	Kind												
		Amount in kg/ha												
15. Nature of soil	i) Texture (sandy, sandy-loam, loamy, clayey and clayey loam													
	ii) Colour													
	iii) Drainage													
16. Source of irrigation if irrigated (canal, tank, well, stream and rivulet, others)														
17. Topography (low, medium and high)														

C. Sowing Operations on the Field

			Field Numbers					
			1A	1B	2A	2B	3	4
			Co*de	Co*de	Co*de	Co*de	Co*de	Co*de
18. Preparatory tillage	Number only	i) Ploughing						
		ii) Harrowing						
		iii) Pudling						
19. Basal manuring	(a) Organic manure	i) Kind						
		Amount in kg/ha						
		Time (week No. of the year)						
		ii) Kind						
		Amount in kg/ha						
		Time (week No. of the year)						
	(b) Inorganic manure	i) Kind						
		Amount in kg/ha						
		Time (week No. of the year)						
		ii) Kind						
		Amount in kg/ha						
		Time (week No. of the year)						
20. Variety		i) Name						
		ii) Duration in days						
		iii) Source of seed						

		Field Numbers											
		1A		1B		2A		2B		3		4	
			Co* de		Co* de		Co* de		Co* de		Co* de		Co* de
21. i) Sowing or transplanting													
ii) Date (week No. of year)													
22. In case of sowing	i) Method (broadcasting, drilling, others)												
	ii) Seed rate in kg/ha												
23. In case of trans-planting	a) No.of seedlings per hole												
	b) Age of seedlings												
	c) Spacing in cm												
	i) Between lines												
	ii) Within lines												

N.B. * Entry not to be made by the Field Assistant in Column 'Code'

Signature of the Field Assistant Dated....................

Name of the Field Assistant (in block letters)

Name of the Helper (in block letters)

Date of Inspection	I	II
Name(s) and Designation(s) of the Inspection Officers(s)		
Signature(s) of the Inspection Officer(s)		

Sample Survey to Estimate the Incidence of Pests and Diseases on Paddy 19

FORM - I A

(Selection of Fields and Plots therein)

A. General Information

		Code*				Code*
1. Region			8. i) Total area of the village in hectares			
2. State			ii) Cultivated area of the village in hectares			
3. Sub-region						
4. District						
5. Taluk/Tehsil			9. Area under paddy in the village (last year figure) in hectares	I Crop		
6. Village				II Crop		
7. Crop season				III Crop		
			10. i) Total Khasra/ Survey number in the village			
			ii) Highest Khasra/ Survey number in the village			

B. Selection of Field

	1	2	3	4
1. i) Random Nos. for selection of four Khasra/Survey Nos.				
ii) Remainders after division of random No. by highest survey No.				
iii) Rejected survey Nos. with reasons(if any)				
2. i) No. of sub-divisions in the selected survey No.				
ii) Rejected sub-division No. with reasons (if any)				
iii) Sub-division No. of the field selected finally				

B. Selection of Field (cont.)

3. Khasra/Survey No. and Sub. No. (if any) of fields selected finally				
4. Random Nos. for selecting the two fields out of four selected fields for the purpose of selecting the 'protected fields'				
5. Khasra/Survey No. and Sub. No. (if any) of two fields selected out of the four fields selected vide Item No. 3 above				
6. Khasra/Survey No. and Sub. No. (if any) of the two fields, similar in respect of variety, manuring, cultural practices, topography, soil type, etc., to fields selected vide item 5. above				
7. Random nos. for selecting 'protected fields' 1B and 2B from the pair of similar fields selected vide item nos. 5 & 6 above				
8. Khasra/survey no. and sub no. (if any) of two selected 'Protected fields' numbering 1B and 2B corresponding to 'Unprotected fields' 1A and 2A respectively				

	1A	1B	2A	2B	3	4
9. Khasra/Survey No. and sub no. (if any) of six ultimately selected fields for the survey						
10. Area of the fields in hectares (up to 2 decimal places)						
11. (i) Length (L) of the field in metres (ii) Breadth (B) of the field in m.						
(iii) Length of the field in m. minus 1m.						
(iv) Breadth of field in m. minus 1 m.						

C. Selection of two plots of 1 sq. metre each within each field

	1A		1B		2A		2B		3		4	
	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2
12. (i) Random no. for location of plots (L) (B)												
(ii) Remainders after dividing R. nos by L-1/B-1 (L) (B)												
(iii) Random nos. rejected (if any) with reasons for rejection (L) (B)												
(iv) Random nos. selected finally for location of the plot (L) (B)												
(v) Selected length and breadth in metres for locating the S.W. corner of the plot (L) (B)												

D. Selection of the plot of 10m x 5m each in field No. 1A, 1B, 2A and 2B only.

		1A	1B	2A	2B
13. (i) Length of the field in metres minus 10m and breadth of the field in m. minus 5m.	L-10				
	B-5				
(ii) Random numbers for location of plots	L B				
(iii) Remainder after dividing R. nos. by 1-10/B-5	L B				
(iv) Random Nos.rejected (if any) with reasons for rejection	L B				
(v) Random nos. selected finally for location of the plots	L B				
(vi) Selected length and breadth in metres for locating the South-West corner of the plot	L				
	B				

E. Sketch of each of six fields indicating the dimensions and location of plots therein

Field No. 1 A	Field No. 1 B
Field No. 2 A	Field No. 2 B
Field No. 3	Field No. 4

N.B. + To be supplied by Headquarters
* Entry not to be made by the Field Assistant in the column 'code'
P Indicates plot

Signature of the Field Assistant	Date	
Name of the Field Assistant (in block letters)		
Name of the Field Maistry (Helper) (in block letters)	I	II
Date of Inspection		
Name(s) and Designation(s) of the Inspection Officer(s)		
Signature of the Inspection Officer(s)		

Sample Survey to Estimate the Incidence of Pests and Diseases on Paddy during 19..

FORM - II

(Monthly Report for the Selected Field)

A. General Information

	Code *		Code *
1. Region		6. Village	
2. State		7. Crop	
3. Sub-region		8. Khasra/Survey No. and Sub.No. (if any)	
4. District		9. Field Number	
5. Taluk/Tehsil		10. Whether sprayed/ unsprayed or extra control	

B. Field Operations

			I Obs.	II Obs.	III Obs.	IV Obs.	Code *
1.	Date of recording the observation						
2.	(i) Weather condition (dry, rainy, fair, bright, cloudy, cold, frost) since last season						
	(ii) Rainfall in cm since last season						
3.	Condition of crop (bad, fair, good, very good)						
4.	Irrigation so far	(i) Source (canal, tank well, stream and rivulet, others					
		(ii) No. of irrigations					
5.	Cultural practices so far (interculture, weeding, etc.)	(i) Interculture					
		(ii) Weeding					
		(iii) Other (specify)					

			I Obs.	II Obs.	III Obs.	IV Obs.	Code *
6. Details of manuring since last visit	(i) Inorganic (specify)						
	A ount in kg/ha						
	Time (week No. of the year)						
	(ii) Other (specify)						
	Amount in kg/ha						
	Time (week No. of the year)						
7. Any factor affected the crop since last visit							
8. In case of transplanted paddy visual observations of the incidence of pests and diseases in the nursery for the first month only. Mention the Name and Intensity (nil, light, medium, severe)	(i) Name	(a) Pests					
	Intensity						
	(ii) Name						
	Intensity						
	(i) Name	(b) Diseases					
	Intensity						
	(ii) Name						
	Intensity						
9. Details of control measures taken since last visit (including nursery) in the case of transplanted paddy.	Kind	(a) Insecticides					
	Quantity/ha						
	Time (week No. of the year)						
	Kind	(b) Fungicides					
	Quantity/ha						
	Time (week No. of the year)						
	Kind	(c) Other					
	Quantity/ha						
	Time (week No. of the year)						

* N.B. Entry not to be made by the Field Assistant in the Column 'Code'

		I Obs.		II Obs.		III Obs.		IV Obs.	
		P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2
1. Total No. of clumps									
2. No. of clumps attacked by pests or diseases									
3. Total No. of tillers									
4. No. of tillers of attacked clumps									
5. No. of attacked tillers									
6. No. of silver shoots (Gallfly)	Code *								
7. No. of dead-hearts (stem-borer)									
8. No. of damaged tillers by gundhibug									
9. (a) No. of damaged tillers by case-worm									
(b) No. of tubular cases by case-worm									
10.(a) No. of damaged tillers by leaf roller									
(b) No. of leaves rolled by leaf roller									
11. No. of elongated Central Shoots (Foot Root)									
12. No. of False Smut-infected tillers									
13. No. of bunt-infected tillers									
14.(a) No. of tillers showing nodal infection by blast									
(b) No. of tillers showing neck infection by blast									

	Code*	I Obs.		II Obs.		III Obs.		IV Obs.	
		P_1	P_2	P_1	P_2	P_1	P_2	P_1	P_2
14. (c) No. of tillers showing ear-head infection by blast									
(d) No. of tillers showing leaf infection by blast									
(e) No. of leaves infected by blast									
15. (a) No. of tillers showing leaf infection by helminthosporiose									
(b) No. of leaves infected by helminthosporiose									
(c) No. of tillers showing ear infection by helminthosporiose									
16. (a) No. of tillers showing bacterial leaf-blight infection									
(b) No. of leaves infected by bacterial leaf-blight									
17. (a) No. of tillers showing leaf-infection by stack-burn									
(b) No. of leaves infected by stack-burn									
18. No. of tillers cut by rats									
19. No. of dead tillers due to Mealy-bug infestation									
20. Other infected tillers									

N.B. * Entry not to be made by the Field Assistant in the Column 'Code'.
P Indicates Plot.

FORM II - (Cont'd)

C. Observations on Pests and Diseases

	I Obs.				II Obs.				III Obs.				IV Obs.			
	P1.1		P1.2		P1.1		P1.2		P1.1		P1.2		P1.1		P1.2	
	C1*	C2**	C1*	C2**	C1*	C2**	C1*	C2**	C1*	C2**	C1*	C2**	C1*	C2**	C 1*	C2**
21. Details of observations on two selected clumps in each plot during different observations.																
(i) No. of tillers																
(ii) Height of the clump in cm.																
(iii) No. of stemborer egg masses																
(iv) No. of larval population																
a. Swarming caterpillar																
b. Leaf-roller																
c. Others																
(v) No. of dead tillers due to stem rot.																
(vi) Scores for:																
a. Helminthosporiose																
b. Blast																
c. Bacterial leaf blight																
(vii) Intensity of:*** (nil, light, medium, severe)																
a. Yellowing/reddening																
1. Central leaves																
2. Peripheral leaves																
b. Stunting																
1. Central leaves																
2. Peripheral leaves																

N.B. * South West Corner Clump

** Central clump

*** Intensity should be given in digits as 0, 1 and 3 indicating nil, light, medium and severe respectively.

FORM II (Cont'd)

C. Observations on Pests and Diseases (Cont.)

	Code+	Counts from five sweeps in a field during different observations																			
		I Obs.					II Obs.					III Obs.					IV Obs.				
		No. of sweep					No. of sweep					No. of sweep					No. of sweep				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
22. Jassids																					
23. Hispa																					
24. Grass hopper																					
25. Fulgorid																					
26. Schonobius moths																					
27. Spodoptera moths																					
28. Gundhi bug																					
29. i. Spodoptera caterpillars																					
ii. Other caterpillars																					
30. Others																					

\+ Entry not to be made by the Field Assistant in the column 'Code'.

N.B. Sw. 1 - Sweep 1 taken in the middle of the Southern side of the field.
Sw. 2 - Sweep 2 taken in the middle of the Western side of the field.
Sw. 3 - Sweep 3 taken in the middle of the Northern side of the field.
Sw. 4 - Sweep 4 taken in the middle of the Eastern side of the field.
Sw. 5 - Sweep 5 taken in the middle of the Central side of the field.

Signature of the Field Asst. ______ Date ______ Name of the Field Asst.(in block letters) ______

Name of the Field Maistry (helper) (in block letters) : ______

Name (s) and designation(s) of the Inspection Officer(s) : ______

SAMPLE SURVEY TO ESTIMATE THE INCIDENCE OF PESTS AND DISEASES
PADDY DURING 19..

FORM III
(Information at the time of harvest

	Code+
District:	
Crop season	

A. GENERAL INFORMATION

		Code+
1. State/ Region/ Sub-Region		
2. Taluk/Firka/Tehsil		
3. Village		
4. i) Field No. ii) Whether sprayed 'Protected'/ Unsprayed 'Unprotected'		
5. i) Khasra/Survey No. ii) Sub. No., if any		
6. Date of flowering		
7. Date of harvest		
8. Yield of 10m x 5m plot in Kgs. and gm - paddy (wet/dry)		

B. OBSERVATIONS ON PLOTS	Plot Number		
	1	2	
1. Total no. of clumps			
2. No. of clumps attacked by pests and diseases			
3. (a) Total no. of tillers (b) No. of tillers of attacked clumps (c) No. of attacked tillers			
4. Total no. of ears			
5. No. of ears of attacked clumps			
6. No. of attacked ears			
7. No. of white ears due to borers			
8. No. of partially borer attacked ears			
9. No. of ears damaged by gundhi bug			
10. No. of ears damaged by rats			
11. (i) No. of neckinfected ears due to blast (ii) No. of infected ears by blast			
12. No. of chaffy ears due to stem rot			

B. Observations on plots (Cont.)

	Plot Number 1	2	Code +
13. No. of white ears due to other causes			
14. No. of false smut-infected ears			
15. No. of bunt-infected ears			
16. No. of infected ears by helminthosporiose			
17. No. of infected ears by bacterial leaf-blight			
18. Infected ears by other pests			
19. Infected ears by other diseases			
20. Yield of the plot in grm: Paddy (wet/dry) Straw			
21. Weight per plot in grm* Grain Chaff			

Signature of the Field Asst. : ______________________ Date: ________________

Name of the Field Asst. (in block letters) : ---------------------------------

Name of the helper (in block letters): ______________________

Date of Inspection: :__________________

Name(s) & Designation(s) of the Inspection Officer(s) : ________________

Signature(s) of the Inspection Officer(s) : ______________________

+Entry not to be made by the Field Assistant in the column 'Code'

*Rounded to nearest gram .

Sample Survey to Estimate the Incidence of Pests and Diseases on Paddy during 19 ..

FORM III A

(Information at the time of driage assessment on the yield of plot size 10m x 5m in field No. 1A, 1B, 2A and 2B of the first village assigned to Field Assistant)

	Code+		Code +
1. Region		5. Taluk/Tehsil	
2. State		6. Village	
3. Sub-region		7. Crop season	
4. District			

	Field No.			
	1A Code+	1B Code+	2A Code+	2B Code+
8. Name of cultivator				
9. Survey/Khasra No. and Sub No. (if any)				
10. Date of harvesting				
11. Weight of paddy in Kg. and Gm on day of harvesting				
12. Reweighment:				
(i) After 10 days of harvesting				
(a) Date				
(b) Weight in Kg. and gm				
(ii) After 2 days of first reweighment				
(a) Date				
(b) Weight in Kg. and gm				
(iii) After 2 days of second reweighment				
(a) Date				
(b) Weight in Kg. and gm				
(iv) After 2 days of third reweignment				
(a) Date				
(b) Weight in Kg. and gr				

Signature of Field Asst.: ____________________ Date: ____________

Name of the Field Asst. (in block letters): ____________________

Name of the Helper (in block letters) . ____________________

Date of Inspection : ____________________

Name(s) and designation(s) of the Inspection Officer(s) : ____________________

Signature(s) of the Inspection Officer(s): ____________________

+ Entry not to be made by the Field Asst.

* Reweighment should be discontinued as soon as two consecutive weights are identical and in case even (iii) and (iv) reweighments are not identical, the observations should be continued at an interval of 2 days until two consecutive weights are identical.

APPENDIX II (a)

PLANT PROTECTION SCHEDULE [1/] FOR THE CONTROL OF PESTS AND DISEASES OF PADDY IN PROTECTED FIELDS

Seed Treatment

The seed (if not already disinfected) should be treated a day before sowing with chemical. Mix 0.5 gm of streptocycline and 10 gm of wettable 1 percent organo-mercurial compound in one kerosene tin full of water (18 litres). Two such tins of the solution will be sufficient to reat 25 to 30 kg of seed for one hectare. Dip the seed in this mixture and stir well with a wooden stick. Remove the floating seeds. Leave the rest in the mixture for 8 to 12 hours and dry in the shade before sowing.

Treatment in the Nursery

Spray the nursery twice, 15 days after sowing and a day or two before transplanting with the following mixture. First spraying: Mix 15 cc (3 tea-spoonfuls) of 50 percent Parathion or 36 cc (7 tea-spoonfuls) of 20 percent Endrin (emulsifiable concentrate - E.C.) or 72 gm each of 50 percent DDT and 50 percent BHC (wettable powder) in one kerosene tin full of water. Spray the seedlings with the mixture with 20 kerosene tinfuls per hectare. Second spraying: Prepare the same insecticide as stated above in one kerosene tin full of water and add to it 0.2 gm of streptocycline. Use 20 ** kerosene tinfuls of the mixture on every hectare of the nursery area.

Treatment in the Field

Spray the crop four times - 15, 30, 45 and 60 days (at the shot-blade stage) after transplanting as given below:

First spraying: Mix 15 cc (3 tea-spoonfuls) of 50 percent Parathion or 36 cc (7 tea-spoonfuls) of 50 percent Endrin E.C. or 90 gm each of 50 percent DDT and 50 percent BHC (wettable powder) in one kerosene tinful of water. Spray 25 ** tinfuls of this mixture on every hectare of the crop.

Second spraying: Prepare the spray mixture in the same way as for the first one and add 0.2 gm of streptocycline to every tinful of the mixture. Spray 25 ** kerosene tinfuls of the mixture per hectare.

Third spraying: Prepare the spray mixture in the same way as for the second spraying. But this time use 30 ** kerosene tinfuls of the spray mixture per hectare.

Fourth spraying: Mix 15 cc (3 tea-spoonfuls) of 50 percent Parathion or 36 cc (7 tea-spoonfuls) of 20 percent Endrin E.C. or 90 gm each of 50 percent DDT and 50 percent copper fungicide. Spray 40** kerosene tinfuls of the mixture per hectare.

1/ It is only a specimen and is likely to vary from country to country on the basis of the occurrance of the pests and diseases there and may be modified accordingly in consultation with the concerned subject specialists.

** This is the quantity of spray fluid required for one hectare with large volume high pressure spraying equipment. If low equipment is to be employed, use 60 litres of corresponding higher concentration spray fluid per hectare.

APPENDIX III

OBSERVATIONS ON PESTS AND DISEASES (OTHER CROPS)

A. Wheat

In each selected plot, the number of plants (clumps), and the number of plants damaged by termites, gujhia weevil, rats, etc., will be counted. The severity of infection in leaf diseases such as rusts will be scored by comparing the maximum infected leaf in each of the five selected plants, four corner plants and one central plant, of each plot with score charts. At the time of harvest the number of clumps (plants), the total number of ears, the number of infected ears by loose smut, earcockle, Karnal bunt, ears damaged by rats, etc., will be counted in each plot and also in the five selected plants individually. The ears of the five plants will be separately harvested and will be classified into (i) healthy ears, and (ii) ears attacked by pests and diseases. The ears of the single plants will be separately threshed and the weight of grains will be taken. The yield of grain will be recorded for each plot. The yield data will also be collected by sample crop-cutting experiments on a plot of size 10m x 5m in each field separately. The observations on the incidence of pests and diseases and yield will be taken and recorded in the 'protected' fields as well as in the 'unprotected' fields. The specimen proformae I-III for recording the observations on wheat crop are attached.

B. Maize

In each selected plot, the number of plants and the number of plants affected by stem-borer, grass-hopper, gujhia weevil, termite, rat, leaf roller, stalk-rot, leaf blight, etc., will be counted. The severity of infection with the leaf-blight disease will be scored by comparing the maximum infected leaf in each of the five selected plants, four corner plants and one central plant, of each plot with score charts. At the time of harvest the number of plants, the total number of cobs, the number of infected plants and cobs by stem-borer, rat, leaf blight, etc., will be counted in each plot and also in the five selected plants individually. The plants and cobs of the five plants will be separately harvested and will be classified into (i) healthy cobs and (ii) cobs attacked by pests and diseases. The cobs of the single plants will be separately thrashed and the weight of grains will be taken. The yield of grain will be recorded for each plot. The yield data will also be collected by sample crop-cutting experiments on a plot of size 10m x 10m in each field separately. The observations on the incidence of pests and diseases and yield will be taken and recorded in the 'protected' fields as well as in the 'unprotected' fields. The specimen proformae I-III for recording the observations on maize crop are attached.

C. Sorghum

In each selected plot the total number of plants and the number of plants damaged by stem-borer, red and other hairy caterpillars, grass-hoppers, rat, etc., will be counted. The severity of infection in leaf diseases such as rusts will be scored by comparing the maximum infected leaf in each of the five selected plants, four corner and one central, of each plot with score charts. At the time of harvest the number of plants, the total number of cobs, the number of plants and cobs infected by stem-borer, rat, smut, etc., will be counted in each plot and also in the five selected plants individually. The plants and cobs of the five plants will be separately harvested and will be classified into (i) healthy (ii) attacked by specified pests and diseases. The cobs of the single plants will be separately thrashed and the weight of the grains will be taken. The yield will be recorded for each plot. The yield data will also be collected by sample crop-cutting experiments on a bigger plot of size 10m x 10m in each selected field separately. The observations on the incidence of pests and diseases and yield will be taken and recorded in the 'protected' fields as well as in the 'unprotected' fields. The specimen proformae I-III for recording the observations on sorghum crop are attached.

N.B. The proformae for paddy, wheat, maize and sorghum are likely to be modified in the light of the pests and diseases prevalent in the region to be covered, in consultation with the subject specialists.

Sample Survey to Estimate the Incidence of Pests and
Diseases on Wheat Crop during 19..

Code+

District ________________
Crop Season ________________

FORM I
(General Information)

		Code+
1. Zone		
2. Taluk/Firka/Tehsil		
3. Village		
4. Area of the Village in hectares		
5. Area under wheat crop in the Village in hectares (latest figure)		
6. Total khasra/survey number growing wheat crop in the Village		
7. Name of the Field Assistant		

Items of information	Field Numbers											
	1A		1B		2A		2B		3		4	
8. Khasra/Survey No. & Sub.No. if any		Code+		Code+		Code+		Code+		Code+		Code+
9. Area (i) Hectares												
(ii) Length (mt)												
(iii) Breadth (mt)												
10. Name of the cultivator												
11. Previous crop												
12. Manuring of previous crop per hectare (i) Kind												
(ii) Amount in Kg												
13. Nature of soil (i) Texture*												
(ii) Colour												
14. Topography Low/Medium/High												
15. (i) Variety**												
(ii) Duration in days												
16. Preparatory tillage (i) Description												
(ii) Date												
17. Basal Manuring per (a) Kind												
(b) Amount in Kg												
(c) Time												
(d) Method of each manure applied												

	1A		1B		2A		2B		3		4	
		Code+		Code+		Code+		Code+		Code+		Code+
18. (i) Date of sowing												
(ii) Method of sowing												
(iii) Seed rate in kg/hectare												
19. Spacing in cm. if any (i) Between lines												
(ii) Within lines												

20. Sketch of each field indicating the dimensions and the location of the permanent plots

Field 1A	Field 1B
Field 2A	**Field 2B**
Field 3	**Field 4**

Date____________________ Signature of the Field Assistant

\+ Entry not to be made by the Field Assistant in the 'Code' column. 1B and 2B are the 'protected fields' corresponding to 'unprotected fields' 1A and 2A.

* In terms of clayey, clayey-loam, loamy, sandy-loam, sandy, etc.

** If the variety is local the word local should be written in brackets along with the name of the variety.

Sample Survey to Estimate the Incidence of Pests and Diseases on Wheat Crop during 19 ..

	Code+
District	
Crop Season	

FORM - II

(Periodical Report of the Date for a Field)

A. LOCATION

			Code+
1.	Zone		
2.	Taluk/Firka/Tehsil		
3.	Village		
4.	(i) Field No.		
	(ii) Whether sprayed 'protected'/unsprayed 'unprotected'		
5.	(i) Khasra/Survey No.		
	(ii) Sub No. if any		
6.	(i) Area of the field in hectares		
	(ii) Length (in metres)		
	(iii) Breadth (in metres)		

+ Entry not to be made by the Field Assistant in the column 'Code'

B. BASIC INFORMATION

			Code+
1.	Month		
2.	Weather condition		
3.	Condition of crop		
4.	Irrigation (a) Source		
	(b) No. of irrigations		
	(c) Rainfall in cm.		
5.	Cultural practices (i.e. interculture, weeding, etc.) (a) Name		
	(b) Number		

6. Manuring per hectare	Kind*	Code+	Amount in kg.	Code+	Time	Code+	Method	Code+

7. Control measures taken	Pesticide used or any other measure taken	Code+	Quantity	Code+	Date	Code+	Method	Code+

C. OBSERVATIONS ON PESTS AND DISEASES Item of Information	Code+	Plot No. 1**	2**	3**	4**
1. Pair of random numbers for selecting the Unit — Length					
Breadth					
2. Total no. of clumps (plants)					
3. No. of clumps (plants) infected by pests or diseases					
4. (i) Total no. of tillers					
(ii) No. of tillers of infected plants					
(iii) No. of infected tillers of infected plants by pests or diseases					
5. No. of tillers damaged by (i) Termites					
(ii) Gujhia weevil					
(iii) Rats					
6. No. of tillers damaged by other pests (specify)					
7. No. of tillers infected by (i) Ear-cockle					
(ii) Loose smut					
(iii) Karnal bunt					
(iv) Golden ear rot					
(v) Other diseases (specify)					
8. Score for the rust for the whole unit					

+ Entry not to be made by the Field Assistant in the 'Code' column

* Components in percentages of fertilizers should be given if patent name is given.

**Fixed for the whole season.

D. OBSERVATIONS OF THE FIVE SELECTED CLUMPS

Plot No.1*			1	2	3	4	5+
1. Height of the clump in cm.							
2. Scores for rust:	Yellow						
	Brown						
	Black						
3. Intensity of**	Central leaves	(yellowing/ reddening)					
	Peripheral leaves						
	Stunting						
Plot No.2*							
1. Height of the clump in cm.							
2. Scores for rust:	Yellow						
	Brown						
	Black						
3. Intensity of**	Central leaves	(yellowing/ reddening)					
	Peripheral leaves						
	Stunting						
Plot No.3							
1. Height of the clump in cm.							
2. Scores for rust:	Yellow						
	Brown						
	Black						
3. Intensity of**	Central leaves	(yellowing/ reddening)					
	Peripheral leaves						
	Stunting						
Plot No.4							
1. Height of the clump in cm.							
2. Scores for rust:	Yellow						
	Brown						
	Black						
3. Intensity of**	Central leaves	(yellowing/ reddening)					
	Peripheral leaves						
	Stunting						

* Fixed for the whole season

+ Central

** In terms of light/medium/severe

Date__________________

Signature of the Field Assistant

Sample Survey to Estimate the Incidence of Pests and Diseases on Wheat Crop during 19..

		Code+
District		
Crop Season		

FORM - III

(Information at the time of Harvest)

A. BASIC INFORMATION

	Code+
1. Zone	
2. Taluk/Firka/Tehsil	
3. Village	
4. (a) Field no.	
(b) Whether sprayed 'protected'/unsprayed 'unprotected'	
5. (a) Khasra/Survey No.	
(b) Sub. no. if any	
6. Date of flowering	
7. Date of harvest	
8. Name of the Field Assistant	

B. OBSERVATIONS ON PLOTS

	Plot No.					
		1*	2*	3	4	
	Code+					
1. Total no. of clumps (plants)						
2. No. of clumps (plants) infected by pests and diseases						
3. (i) Total no. of ears						
(ii) No. of ears of infected clumps						
(iii) No. of infected ears of infected clumps						
4. No. of clumps damaged by termites						
5. No. of ears damaged by rats						
6. No. of ears damaged by other pests (specify)						
7. No. of infected ears by (i) Loose smut						
(ii) Ear-cockle						
(iii) Karnal bunt						
(iv) Rust						
8. No. of golden ears						

		Plot No. 1*	2*	3	4
9. No. of ears damaged by other diseases (specify)	Code+				
10. Yield in gm of plot of 1 sq.m.(excluding 5 selected clumps), grain (wet/dry)**					
11. Yield of 10m x 5m plot in Kg/gm grain (wet/dry)**					

C. OBSERVATIONS ON THE EARS OF FIVE SELECTED CLUMPS

Plot No.	Code +	Total No. of ears	Healthy ears				Attacked ears								
			No.	Weight of grain (in gm)	Weight of chaff (in gm)	Weight of 1000 grains (in gm)	Name of pest/ disease	Code +	No.	Weight of grain (in gm)		Weight of chaff (in gm)	Weight of 1000 grains (in gm)	
										Healthy	Attacked		Healthy	Attacked
1*														
2*														
3														
4														

N.B. : + Entry not to be made by the Field Assistant in the Column 'Code'
* Fixed for the whole season
** Rounded to nearest gm.

Date: ______________ Signature of FIeld Asst.: ______________

PILOT SAMPLE SURVEY TO ESTIMATE THE INCIDENCE OF PESTS AND DISEASES ON MAIZE CROP DURING 19..

District ___________ Code+ _________

Crop season ______________

FORM - I

(General Information)

	Code +
1. Zone	
2. Taluk/Firka/Tehsil	
3. Village	
4. Area of the village in hectares	
5. Area under maize crop in the village in hectares (latest figure)	
6. Total Khasra/Survey Number growing maize crop in the village	
7. Name of the Field Assistant	

Item of information	Field Number											
	IA		IB		2A		2B		3		4	
		Code+		Code+		Code+		Code+		Code+		Code+
8. Khasra/Survey No. and Sub No. if any												
9. Area: i. Hectares												
ii. Length (mt)												
iii. Breadth(mt)												
10. Name of the cultivator												
11. Previous crop												
12. Manuring of previous crop per ha. i. Kind ii. Amount in Kg.												

+ Entry not to be made by the Field Assistant in the column 'code'; IB and "B are the 'Protected Fields' corresponding to 'Unprotected FIelds IA and 2A.

	IA		IB		2A		2B		3		4	
		Code+		Code+		Code+		Code+		Code+		Code+
13. Nature of soil: i. texture ** ii. colour												
14. Topography: Low/medium/high												
15. i. variety * ii. duration in days												
16. Preparatory tillage: i. description ii. date												
17. Basal manuring per hectare i. kind ii. amount in Kg. iii. time iv. method of each manure applied												
18. i. Date of sowing ii. method of sowing iii. seed rate in Kg/ha.												
19. Spacing in cm. if any i. between lines ii. within lines												

\+ Entry not to be made by the Field Assistant in the column 'code'

** In terms of clayey, clayey-loam, loamy, sandy-loam, sandy, etc.

* If the variety is local the word local should be written in brackets along with the name of the variety.

20. SKETCH OF EACH FIELD INDICATING THE DIMENSIONS AND THE LOCATION OF THE PERMANENT PLOTS

Field IA	Field IB
Field 2A	Field 2B
Field 3	Field 4

Date: ______________ Signature of the Field Assistant: ____________

SAMPLE SURVEY TO ESTIMATE THE INCIDENCE OF PESTS AND DISEASES ON MAIZE CROP DURING 19..

Code+

District ------------------------

Crop Season ---------------------

FORM - II

(Periodical Report of the Data for a Field)

A. LOCATION

		Code+
1. Zone		
2. Taluk/Firka/Tehsil		
3. Village		
4. i. Field No. ii. Whether sprayed 'protected'/ Un-sprayed 'un-protected'		
5. i. Khasra/Survey No. ii. Sub No. if any		
6. i. Area of the Field in hectares ii. Length) (in metres) iii. Breadth)		

+Entry not to be made by the Field Assistant in the Column 'Code'.

B. BASIC INFORMATION

	Code+
1. Month	
2. Weather condition	
3. Condition of crop	
4. Irrigation i) Source ii) No. of irrigations iii) Rainfall in cm	
5. Cultural practices(i.e. inter-culture, weeding, etc.) i) Name ii) Number	
6. Manuring per hectare i) Kind * ii) Amount in Kg iii) Time iv) Method	
7. Control measures taken: i) Pesticide used or any other measure taken ii) Quantity iii) Rate iv) Method	

\+ Entry not to be made by Field Assistant in the Column 'code'

* Components in percentages of fertilizers should be given if patent name is given.

C. OBSERVATIONS ON PESTS AND DISEASES

Item of information	Plot No.				
	Code+	1*	2*	3	4
1. Pair of random numbers for selecting the Unit Length Breadth					
2. Total number of plants					
3. Number of plants infected by pests or diseases					
4. Number of plants damaged by: i. stem-borer ii. grass-hopper iii. gujhia weevil iv. termites v. rats vi. leaf-roller vii. hairy caterpillar viii. other pests (specify) ix. stalk-rot x. leaf-blight xi. downy mildew xii. Mosaic xiii. other diseases (specify)					

+ Entry not to be made by the Field Assistant in the column 'code'

* Fixed for the whole season

D. OBSERVATIONS OF THE FIVE SELECTED PLANTS

Selected plant No. :	1	2	3	4	5**
Plot No. 1+					
1. Height of the plant in cm					
2. Scores for leaf blight					
3. Intensity of yellowing/reddening* i. Central leaves ii. Peripheral leaves					
4. Stunting					
Plot No. 2+ 1. Height of the plant in cm					
2. Scores for leaf blight					
3. Intensity of yellowing/reddening* i. Central leaves ii. Peripheral leaves					
4. Stunting					
Plot No. 3 1. Height of the plant in cm					
2. Scores for leaf blight					
3. Intensity of yellowing/reddening* i. Central leaves ii. Peripheral leaves					
4. Stunting					
Plot No. 4 1. Height of the plant in cm					
2. Scores for leaf blight					
3. Intensity of yellowing/reddening* i. Central leaves ii. Peripheral leaves					
4. Stunting					

** Central   * In terms of light/medium/severe   + Fixed for the whole season

Date: ____________   Signature of field assistant: ______________

SAMPLE SURVEY TO ESTIMATE THE INCIDENCE OF PESTS AND DISEASES ON MAIZE CROP DURING 19 ..

		Code+
District		
Crop season		

FORM - III

(Information at the time of harvest)

A. BASIC INFORMATION

		Code+
1. Zone		
2. Taluk/Firka/Tehsil		
3. Village		
4. (a) Field No. (b) Whether sprayed 'Protected'/ Un-sprayed 'Unprotected'.		
5. (a) Khasra/Survey No.		
(b) Sub. No. if any		
6. Date of flowering		
7. Date of harvest		
8. Name of the Field Assistant		

+Entry not to be made by the Field Assistant in the column 'Code'.

B. OBSERVATIONS ON PLOTS

	Code+	Plot Nos. 1*	2 **	3	4
1. Total No. of plants					
2. Number of plants infected by pests or diseases					
3. No. of plants damaged by i. Rats ii. Stem-borer iii. Other (specify)					
4. No. of plants infected by: i. leaf blight ii. downy mildew iii. mosaic iv. stalk-rot v. common smut vi. head-smut vii. other diseases (specify)					
5. Total number of cobs i. No. of cobs infected by stem-borer ii. No. of cobs damaged by birds					
6. No. of cobs (excluding five selected clumps)					
7. Yield in gm** of plot of 4 sq.m (2m X 2m) (excl. five selected clumps) i. cobs (wet/dry) ii. Grains (wet/dry)					
8. Yield in Kg/gm of 10m x 10m plot i. Cob (wet/dry) ii. Grain (wet/dry)					

+ Entry not to be made by the Field Assistant in the column 'code'

* Fixed for the whole season

** Rounded to nearest gram

C. OBSERVATIONS ON THE COBS OF FIVE SELECTED PLANTS

Item of information	Code +	Plot No.			
		1*	2*	3	4
Total number of cobs					
1. Healthy cobs i. No. of cobs ii. Weight of grain in gm** iii. Weight of stalk in gm** iv. Weight of 1000 grains in gm v. Name of the pests/diseases					
2. Attacked cobs i. No. of cobs ii. Weight of grain in gm ** (a) healthy (b) attacked iii. Weight of stalk in gm ** iv. Weight of 1000 grains in gm (a) healthy (b) attacked					

+ Entry not to be made by the Field Assistant in the column 'code'
* Fixed for the whole season
**Weight of grain and stalk should be given to nearest milligram

Date : ____________________ Signature of Field Asst. ____________________

SAMPLE SURVEY TO ESTIMATE THE INCIDENCE OF PESTS AND DISEASES ON SORGHUM CROP DURING 19..

		Code+
District		
Crop Season		

FORM - I

(General Information)

		Code +
1. Zone		
2. Taluk/Firka/tehsil		
3. Village		
4. Area of the village in hectares		
5. Area under sorghum crop in the village in hectares (latest figure)		
6. Total khasra/survey numbers growing sorghum crop in the village		
7. Name of the Field Assistant		

Item of Information	Field Numbers											
	1A		1B		2A		2B		3		4	
		Code +		Code +		Code +		Code +		Code +		Code +
8. Khasra/Survey No. and Sub No if any												
9. Area : i) hectares ii) length (m) iii) breadth (m)												
10. Name of the cultivator												
11. Previous crop												
12. Manuring of previous crop per hectare i) kind ii) amount in Kg.												

+Entry not to be made by the Field Assistant in the column 'Code'.

1B and 2B are the 'Protected Fields' corresponding to 'Unprotected Fields' 1A and 2A.

	1A		1B		2A		2B		3		4	
		Code +		Code +		Code +		Code +		Code +		Code +
13. Nature of soil i) Texture * ii) Colour												
14. Topography: Low/medium/high												
15. i) variety ** ii) duration in days												
16. Preparatory tillage: i) description ii) date												
17. Basal manuring per hectare: i) kind ii) amount in Kg. iii) time iv) method of each manure applied												
18. i) date of sowing ii) method of sowing iii) seed rate in Kg/ha												
19. Spacing in cm, if any i) between lines ii) within lines												

+ Entry not to be made by the Field Assistant in the column 'code'

* In terms of clayey, clayey-loam, loamy, sandy-loam, sandy, etc.

**If the variety is local, the word local should be written in brackets along with the variety.

20. SKETCH OF EACH FIELD INDICATING THE DIMENSIONS AND THE LOCATION OF THE PERMANENT PLOTS

Field 1A	Field 1B
Field 2A	Field 2B
Field 3	Field 4

Date: ------------------ Signature of the Field Asst. ______________

SAMPLE SURVEY TO ESTIMATE THE INCIDENCE OF PESTS AND DISEASES ON SORGHUM CROP DURING 19..

		Code+
District		
Crop season		

FORM - II

(Periodical Report of the Data for a Field)

A. LOCATION		Code+
1. Zone		
2. Taluk/Firka/Tehsil		
3. Village		
4. i) Field No. ii) Whether sprayed 'Protected'/ unsprayed 'Unprotected'		
5. i) Khasra/Survey No. ii) Sub. No., if any		
6. i) Area of the field in hectares ii) Length) in metres) iii) Breadth)		

+ Entry not to be made by the Field Assistant in the column 'code'.

B. BASIC INFORMATION

		Code +
1. Month		
2. Weather conditions		
3. Condition of crop		
4. Irrigation (a) Source (b) No. of irrigations (c) Rainfall in cm.		
5. Cultural practices (i.e. interculture, weeding, etc.) (a) Name (b) Number		
6. Manuring per hectare: (a) Kind * (b) Amount in Kg. (c) Time (d) Method		
7. Control measures taken: (a) Pesticide used or any other measure taken (b) Quantity (c) Rate (d) Method		

\+ Entry not to be made by Field Assistant in the column 'code'

* Components in percentages of fertilizers should be given if patent name is given.

C. OBSERVATIONS ON PESTS AND DISEASES

Item of information	Code*	Plot Number			
		1 +	2 +	3	4
1. Pair of random numbers for selecting the Unit — Length					
Breadth					
2. Total number of plants					
3. Number of plants infected by pests or diseases					
4. Number of plants damaged by:					
i. Stem-borer					
ii. Grass-hopper					
iii. Rats					
iv. Red and hairy caterpillars					
v. Other pests (specify)					
vi. Rust					
vii. Smut					
viii. Other diseases (specify)					

* Entry not to be made by the Field Assistant in the column 'Code'

\+ Fixed for the whole season

D. OBSERVATIONS ON THE FIVE SELECTED PLANTS

	Selected plant No. 1	2	3	4	5*
Plot No. 1**					
1. Height of the plant in cm					
2. Score for rust					
3. Intensity of yellowing/reddening:+ i) central leaves ii) peripheral leaves					
4. Stunting					
Plot No. 2**					
1. Height of the plant in cm					
2. Score for rust					
3. Intensity of yellowing/reddening:+ i) central leaves ii) peripheral leaves					
4. Stunting					
Plot No. 3					
1. Height of the plant in cm					
2. Score for rust					
3. Intensity of yellowing/reddening:+ i) central leaves ii) peripheral leaves					
4. Stunting					
Plot No. 4					
1. Height of the plant in cm					
2. Score for rust					
3. Intensity of yellowing/reddening:+ i) central leaves ii) peripheral leaves					
4. Stunting					

* Central
** Fixed for the whole season
\+ In terms of light/medium/severe

Date: -------- Signature of Field Asst.-----

SAMPLE SURVEY TO ESTIMATE THE INCIDENCE OF PESTS AND DISEASES ON SORGHUM CROP DURING 19 ..

		Code+
District		
Crop season		

FORM - III

(Information at the time of harvest)

A. BASIC INFORMATION		Code+
1. Zone		
2. Taluk/Firka/Tehsil		
3. Village		
4. (a) Field No. (b) Whether sprayed 'Protected'/ unsprayed 'Unprotected'		
5. (a) Khasra/Survey No. (b) Sub. No. if any		
6. Date of flowering		
7. Date of harvest		
8. Name of the Field Assistant		

+ Entry not to be made by the Field Assistant in the column 'code'.

B. OBSERVATIONS ON PLOTS

	Code +	Plot no.			
		1*	2*	3	4
1. Total number of plants					
2. Number of plants infected by pests or diseases					
3. i) Total number of ears ii) No. of ears of infected plants iii) No. of infected ears of infected plants					
4. No. of ears damaged by: i) Rats ii) Stem-borer iii) Ear bug iv) Other pests (specify) v) Smut vi) Other diseases (specify)					
5. Field in gm.** of plot of 4sq.m. (excl. five selected clumps) Grain (wet/dry)					
6. Yield in Kg/gm** of 10m x 10 m plot, Grain (wet/dry)					

+ Entry not to be made by the Field Assistant in the column 'code'.
* Fixed for the whole season
** Rounded to nearest gram.

C. OBSERVATIONS ON THE EARS OF FIVE SELECTED PLANTS

	Code+	Plot No. 1*	2*	3	4
1. Total number of ears					
2. Healthy ears					
i) Number					
ii) Weight of grain (in gm)					
iii) Weight of chaff (in gm)					
iv) Weight of 1000 grains (in gm)					
4. Attacked ears					
i) Name of pest/disease					
ii) Number					
iii) Weight of grain (in gm)					
vi) Weight of chaff (in gm)					
v) Weight of 1000 grains (in gm)					

+ Entry not to be made by the Field Assistant in the column 'Code'.

* Fixed for the whole season

Weight of grain and chaff should be given to nearest milligram.

Date: ________________ Signature of the Field Assistant ___________

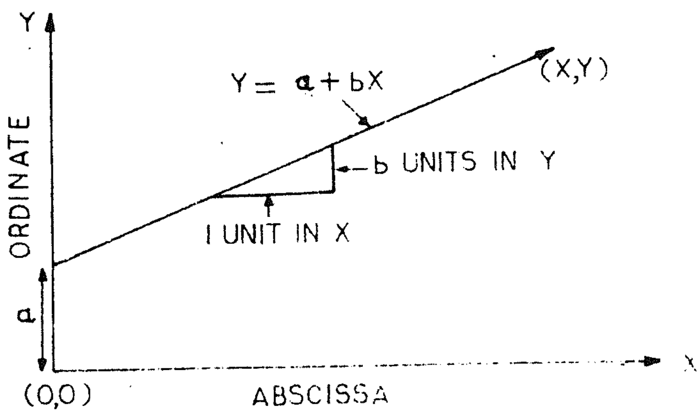
APPENDIX IV

Regression can be linear or curvi-linear. Further, it may be simple or multiple, that is involving one or more independent variables. Here we would deal with simple as well as multiple linear regressions which are commonly used in the crop-loss appraisal programme. These two systems of regressions are explained below in brief:

Simple Linear Regression

Regression means the dependence of one variable (Y) on another variable (X). In linear regression of (Y) on (X), (Y) values are obtained and determined from the corresponding values of (X). The linear regression line can be shown by the equation $Y = a + bX$, known as the regression equation, where (Y) is termed the dependent variable, (X) is called the independent variable, (b) is called the regression coefficient (measure of dependence of (Y) on (X)) and (a) is a constant.

Geometrically $Y = a + bX$ is an equation of a straight line which serves as a moving average of the (Y) values, where any point (X, Y) on this line has a (X) coordinate of abscissa and a (Y) coordinate of ordinate, (a) is the point where the line crosses the (Y) axis, i.e., it is the (Y) intercept and (b) is the slope of the line. In the equation a unit change in (X) results in a change of (b) units in (Y), or the increase or decrease in (Y) for change of one unit in (X). These are indicated in the following diagram.



In the mathematical model of linear regression of (Y) on (X) the following assumptions are made:

(i) For each selected (X) there is a normal distribution of (Y) from which the sample value of (Y) is drawn at random. Since the values of (X) determine which populations of (Y)'s are samples, the (X)'s must be measured without errors.

(ii) The population of values of (Y) corresponding to a selected (X) has a mean (μ) that lies on the straight line $\mu = \alpha + \beta (X - \bar{X}) = \alpha + \beta x$, where ($\alpha$) and ($\beta$) are parameters and x the deviation from its mean.

(iii) In each population the standard deviation of (Y) (measure of dispersion) about its mean $\alpha + \beta x$ has the same value, often denoted by (σ), i.e., we assume that (ε)'s, deviations of (Y) values from the regression line are normally and independently distributed with a common variance and that regression is linear. In the model $Y = \alpha + \beta x + \varepsilon$, where ($\varepsilon$) is a normally distributed random variable $N(o, \sigma^2)$, (Y) is the sum of a random part, (ε) and a part fixed by x, i.e., $\alpha + \beta x$. The fixed part according to assumption (ii) above determines the means of the populations sampled, one mean for each (X). These means $\mu = \alpha + \beta x$, lie on the population regression line. The parameter (α) is the mean of the population that corresponds to $x = o$: thus, (α) specifies the height of the line when $x = \bar{X}$, β is the slope of the regression line, or the rate of change in (Y) for per unit increase in (X).

Method of Least Square

The choice of (Y), the mean of (Y) values and (b) to estimate the parameters (α) and (β) respectively is an application of a principle widely used in problems of statistical estimation and known as the Method of Least Square.

In the linear regression model $Y = \alpha + \beta x + \varepsilon$, the parameters α and β are estimated with the help of sample values by following the principle of least square. The principle lies in minimizing

$$\sum_{i}^{n} (Y - y)^2 \qquad \text{with respect to } \alpha \text{ and } \beta .$$

y is the observed value corresponding to the value of x. The method can be seen in any standard text book on statistical methods. The book by Snedecor and Cochran (1967) is recommended in this connection. The estimated values of α and β can be denoted as:

$$\hat{\alpha} = \bar{Y} - b\bar{x} , \quad \hat{\beta} = b$$

Analysis

Since the regression equation passes through the sample means it may be written as $Y - \bar{Y} = b\,(X - \bar{X})$ or $Y = \bar{Y} + bx$ where (Y) is the yield of the crop, (X) is measure of incidence of pest/disease, and (b) is the regression coefficient. This indicates that if there is a unit increase in pest/disease incidence there is a decrease of (Y) yield by (b) units. The table of analysis of variance is given below:

Source	d.f.	S.S.	M.S.
X(Regression)	1	$(\sum_1^n xy)^2 / \sum_1^n x^2$ {or $= R^2 \sum_1^n y^2$} (Reg. S.S.)	same as S.S.
Residual (deviation from regression)	n - 2	$\sum_1^n y^2 - \frac{(\sum_1^n xy)^2}{\sum_1^n x^2}$ {or = Total S.S. - Reg. S.S.}	$\frac{S.S.}{n-2}$ {or $= \hat{\sigma}^2$}
Total	n - 1	$\sum_1^n y^2 = \sum_1^n (Y - \bar{Y}^2)$ {Total S.S.}	$\frac{\sum_1^n y^2}{n-1}$

Note: (x) and (y) are the deviations from their respective means and n is the sample size

$$b \text{ (the sample regression coefficient)} = \frac{\sum_1^n xy}{\sum_1^n x^2}$$

and

$$\hat{V}(b) = \frac{\hat{\sigma}^2}{\sum_1^n x^2}$$

$$\hat{V}(Y) = \hat{\sigma}^2 \left\{ \frac{1}{n} + \frac{x^2}{\sum_1^n x^2} \right\}$$

$$R^2 = \frac{\left(\sum_1^n xy \right)^2}{\sum_1^n x^2 \sum_1^n y^2}$$

where (R^2) indicates variation in (Y) contributed by (X).

Multiple Linear Regression

Multiple regression means dependence of one variable (Y) on (X)'s independent variables. For given values of Xi's, the individual values of (Y) vary about the regression surface in a normal distribution with mean (o) and variance (σ^2). Hence the model is:

$$Y = \alpha + \sum_{i=1}^{k} \beta_i X_i + \varepsilon \qquad \varepsilon \Rightarrow \qquad N(o, \sigma^2) \quad .$$

With a sample of (n) values of ($Y, X_1, X_2, \ldots\ldots, X_k$),
the multiple linear regression equation becomes, as given below:

$$Y = a + b_1X_1 + b_2X_2 + \quad , \ldots\ldots , \quad + b_kX_k ,$$

b_i's are the partial regression coefficients of Y on X_i's estimated from the sample values by following the principle of least square.

If the value of X_1 increases by 1 unit, while the values of X_2 , X_3 , ... X_k remain unchanged, (Y) becomes

$$Y^{-} = a + b_1X_1 + b_1 + b_2X_2 + \quad , \ldots\ldots , \quad b_kX_k$$

$$= Y + b_1$$

Thus b_1 measures the change in Y when X_1 increases by 1 unit, while X_2 , X_3 , ...X_k remain unchanged. For this reason b_1 is called the partial regression coefficient of Y on X_1 and so on.

Analysis

Since the regression equation passes through the sample means, it may be written as:

$$Y = \overline{Y} + \sum_{i=1}^{k} b_i \left(X_i - \overline{X}_i \right)$$

The table of analysis of variance for the multiple regression based on n sets of observations may be written as follows:

Source	d.f.	S.S.	M.S.
X's (regression)	k	$b_1 \sum_1^n x_1 y + \dots + b_k \sum_1^n x_k y$	$\frac{S.S.}{k}$
Residual (deviation from regression)	$n - k - 1$	Total S.S. - Reg. S.S.	$\frac{\text{Total S.S.} - \text{Reg.S.S.}}{n-k-1}$ (or $= \hat{\sigma}^2$)
Total	$n - 1$	$\sum_1^n y^2 = \sum_1^n (Y - \bar{Y})^2$ (Total S.S.)	$\frac{\text{Total S.S.}}{n-1}$

Note: (x_i 's) and (Y) are the deviations from their respective means.

$$R = \sqrt{\frac{\sum_{i=1}^{k} b_i \left(\sum_1^n x_i y\right)}{\sum_1^n y^2}}$$

(multiple correlation coefficient)

$$b_1 = \sum_{i=1}^{k} C_{1i} \sum_1^n x_i y$$

$$b_2 = \sum_{i=1}^{k} C_{2i} \sum_1^n x_i y$$

and so on.

$$\hat{V}(b_i) = C_{ii}\hat{\sigma}^2$$

$$\text{Cov.} \quad (b_i b_j) = \hat{\sigma}^2 C_{ij}$$

and

$$\hat{V}(Y) = \hat{\sigma}^2 \left(\frac{1}{n} + \sum_{i=1}^{k} C_{ii} x_i^2 + \sum_{i<j}^{k} C_{ij} x_{ij} \right)$$

where (C_{ii}) and (C_{ij}) are the elements of the inverse matrix. (See Steel and Torrie (=960), pp.277-304 and Snedecor and Cochran (1967), pp.381-418).

Application in Crop Loss Appraisal Programmes

The relationship of yield to incidence for the assessment of crop loss is found by calculating the multiple regression equation of yield on the incidence of pests or diseases observed at different stages of the crop growth and at harvest. Since the standard measurement techniques of incidence are adopted, there may not be any observational error, hence the usual regression theory treating the independent variables as measured without error, is applicable. The yield (Y) is taken as the dependent variable and incidence (X_i) as the independent variable. Although there may be a large number of factors causing the crop loss, some may be relatively not so important and these may be ignored while fitting the regression functions. One may choose only those pests and diseases which cause significant crop losses. After the final selection of the independent variables the multiple regression may be written as:

$$Y = \bar{Y} + \sum_{i=1}^{k} b_i (X_i - \bar{X}_i)$$

or

$$Y = \bar{Y}_o + \sum_{i=1}^{k} b_i X_i$$

where $\bar{Y}_o = \bar{Y} - \sum_{i=1}^{k} b_i \bar{X}_i$. $\bar{Y}_o$ may be interpreted as the the yield when there is no incidence of pests and diseases, and relative to this the loss in yield is measured: $\bar{Y}$ is a general mean of yield and b_i's are the partial regression coefficients of yield on the incidences. With the help of b_i's the absolute crop loss in yield per unit increases in the incidences (X_i's) are measured. Hence the terms, ($b_i X_i$'s) measure the absolute loss in yield due to the various pests and diseases.

The equation in terms of percentages may be written as

$$Y = 100 + \sum_{i=1}^{k} b_i' X_i$$

where b_i''s are the percentage decreases in yield per unit increase in X_i's, and b_i''s multiplied by the observed X_i's give the percentage loss in yield due to X_i's. Thus the loss in yield due to individual pest or disease and the total loss in yield due to all the pests and diseases under the study both in absolute and percentage terms are shown as:

Loss in yield due to pest or disease $X_i = b_i x_i$

Percentage loss in yield due to pest or disease X_i $= \dfrac{b_i x_i}{\bar{Y}_o} \times 100$

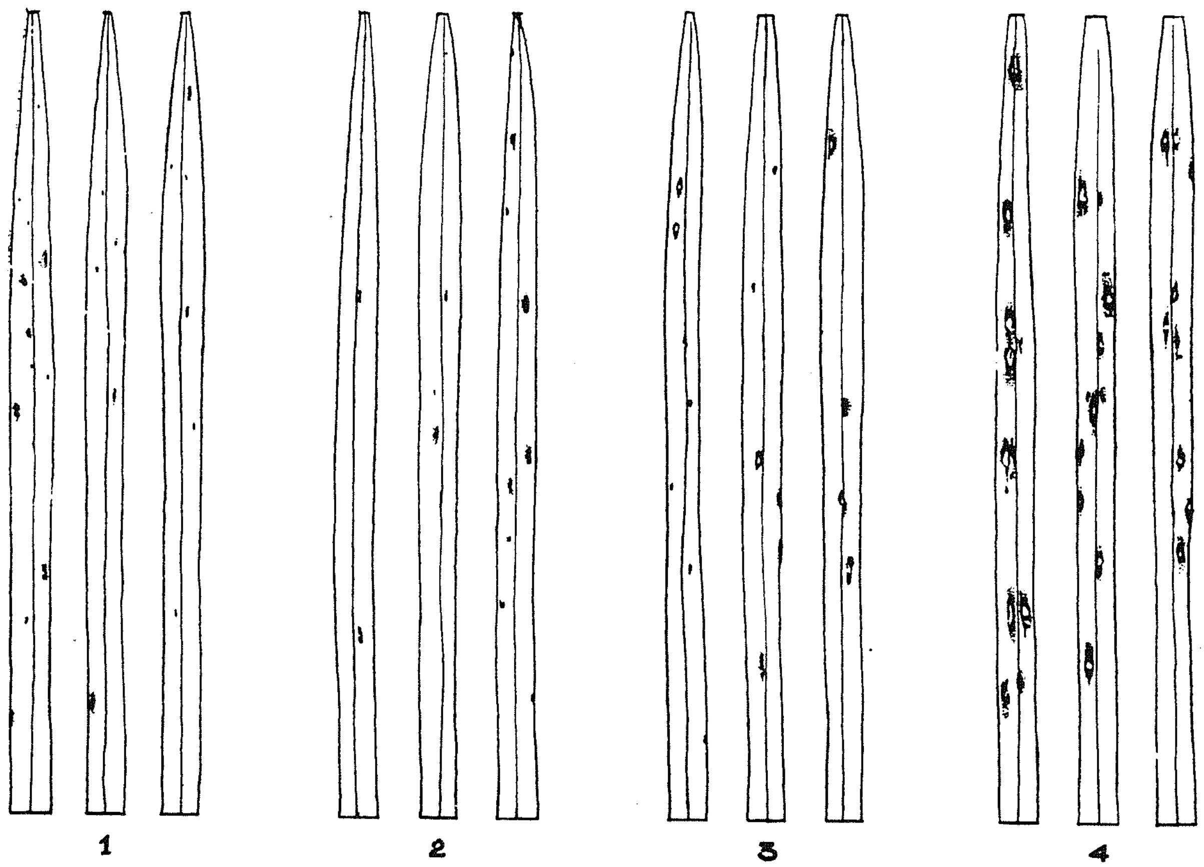
Total loss due to pests and diseases $= \sum_{i=1}^{k} b_i x_i$

Percentage loss due to pests and diseases $= \dfrac{\sum_{i=1}^{k} b_i x_i}{\bar{Y}_o} \times 100$

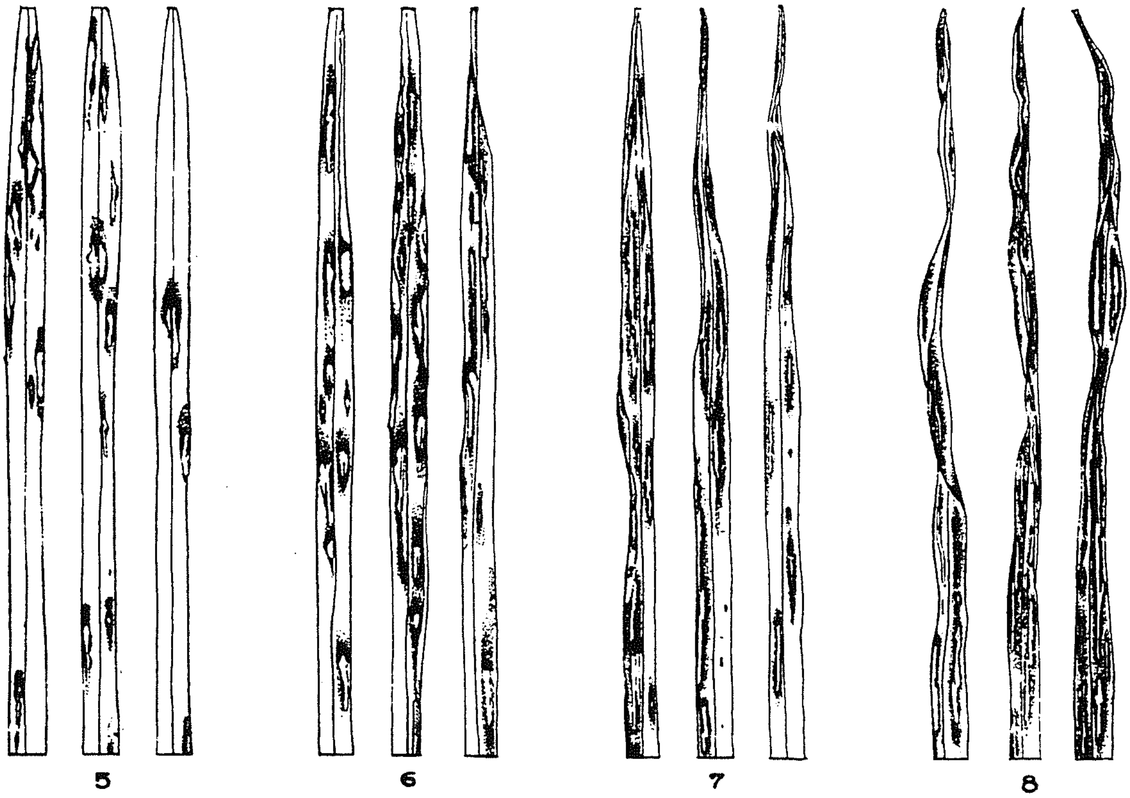
APPENDIX V

SCORE CHARTS

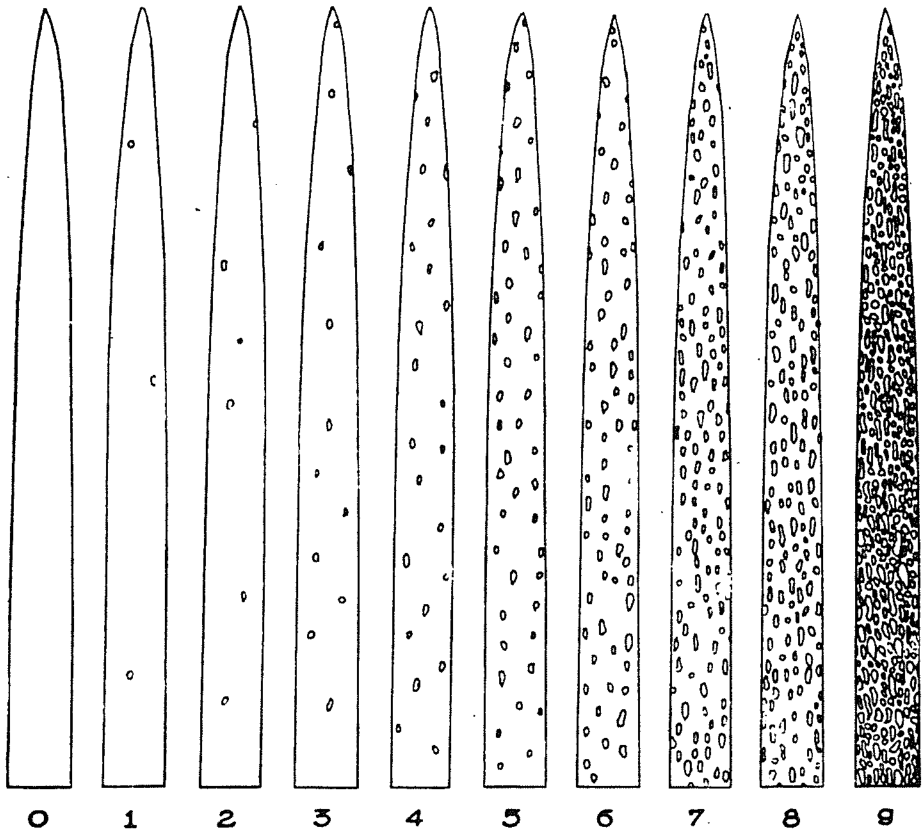
BLAST INFECTION GRADES - 1



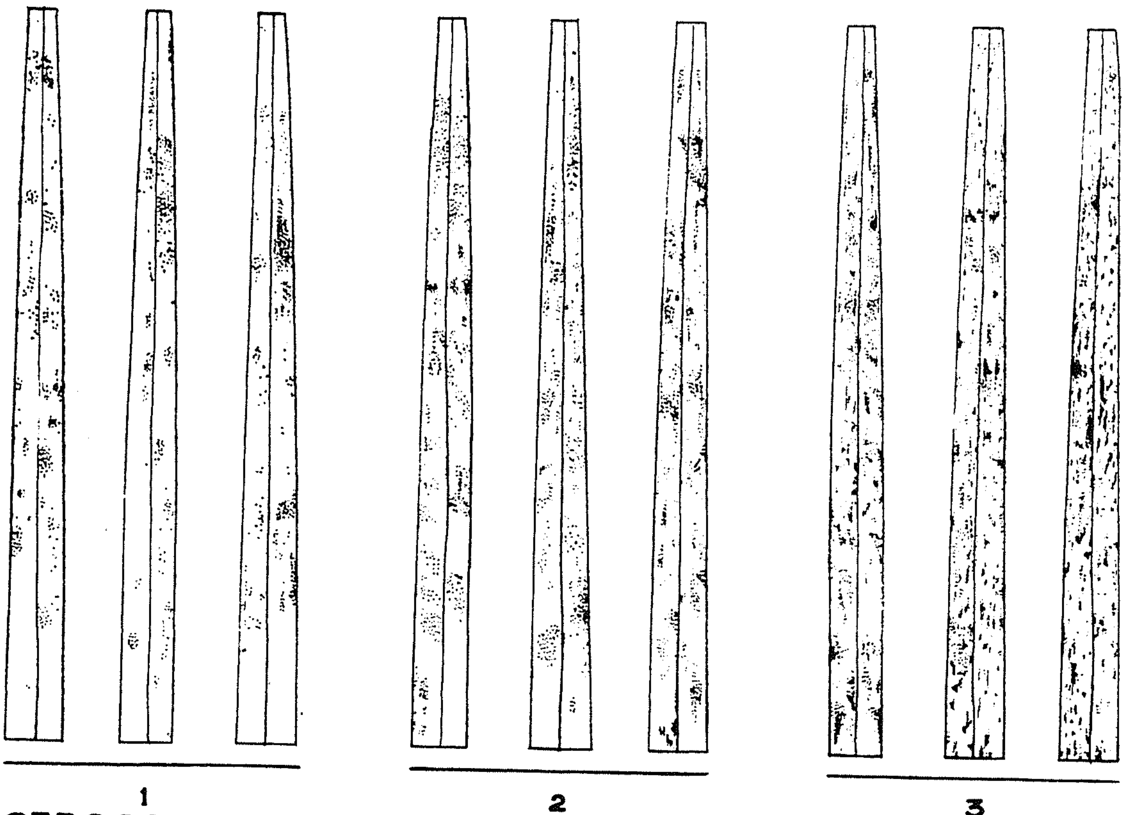
BLAST INFECTION GRADES - 2.



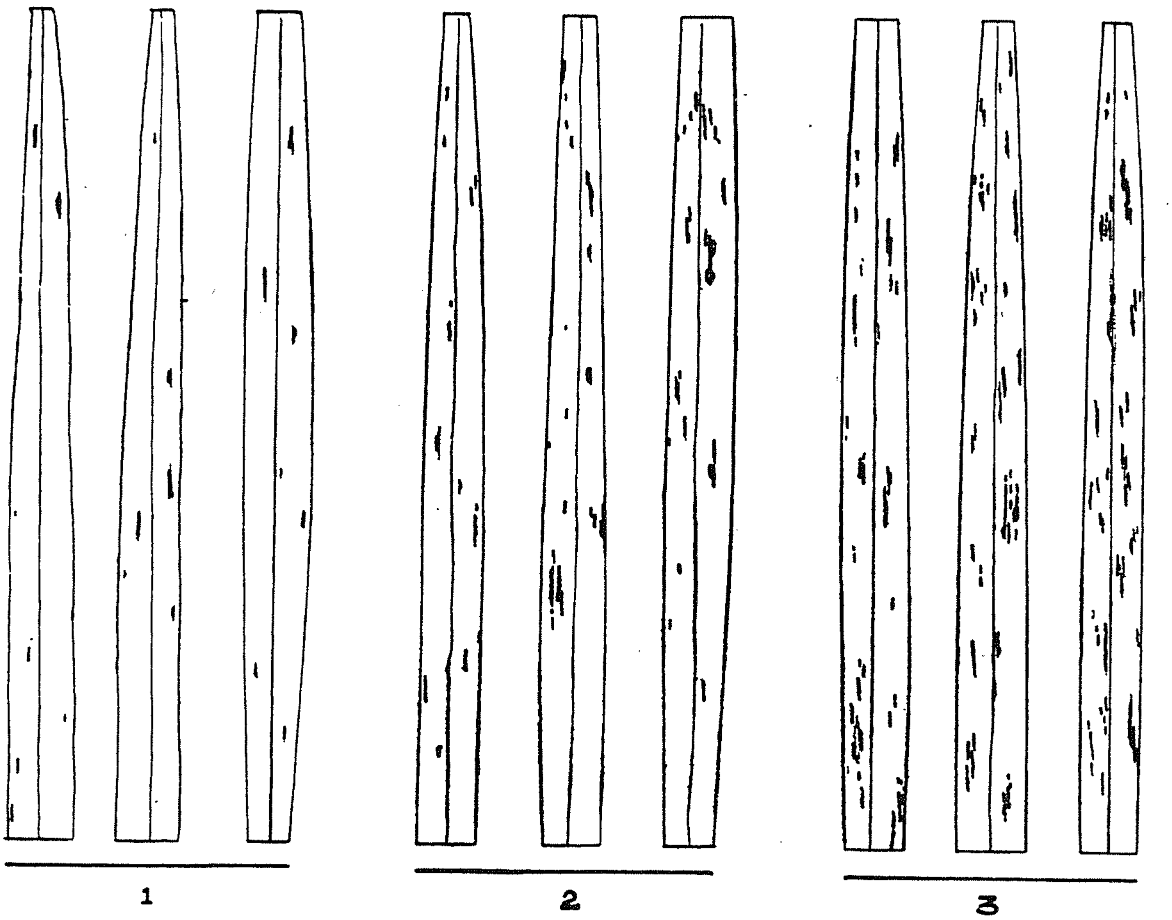
HELMINTHOSPORIUM LEAF-SPOT INFECTION GRADES



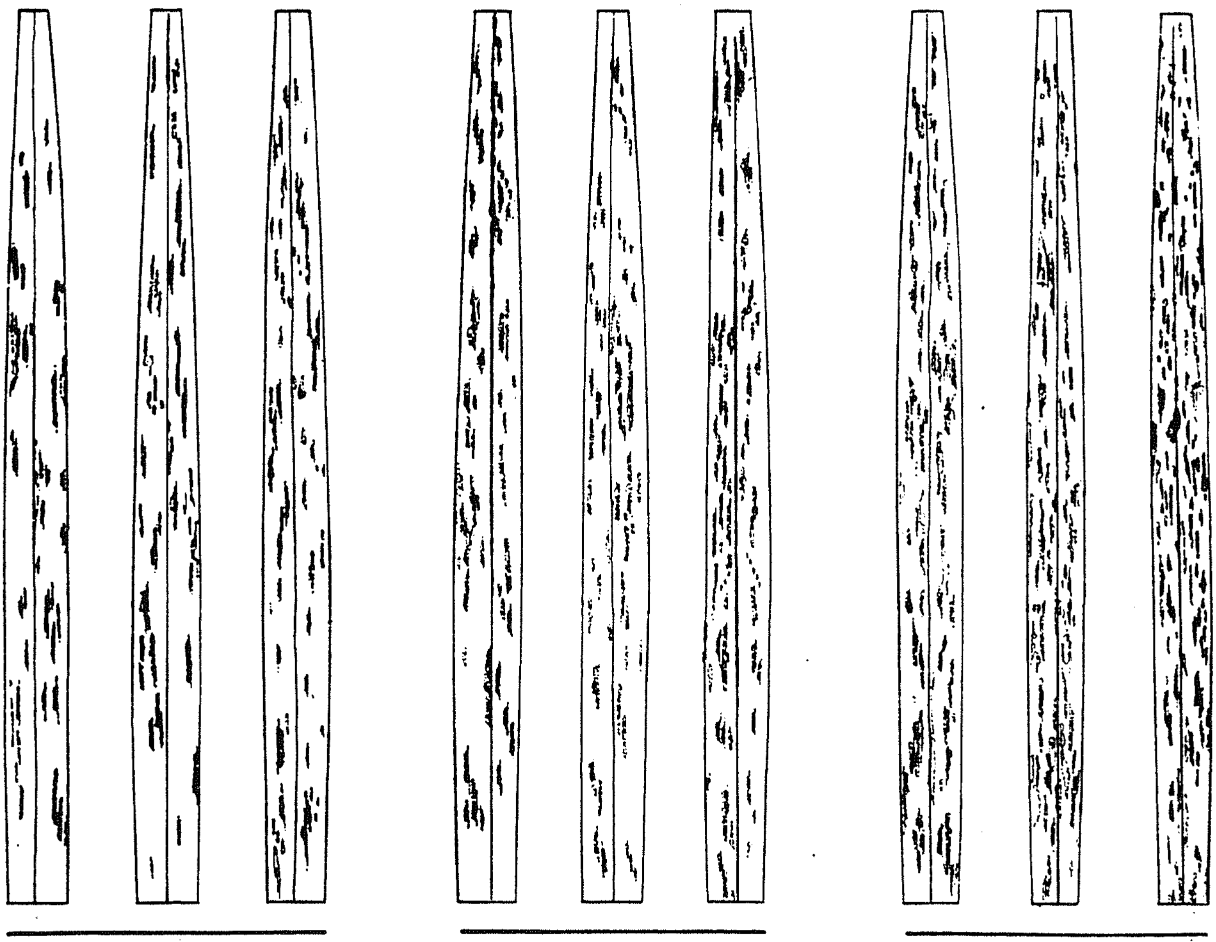
ENTYLOMA ORYZAE INFECTION GRADES



CERCOSPORA LEAF-SPOT INFECTION GRADES- 1



CERCOSPORA LEAF-SPOT INFECTION GRADES- 2.



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DIRECTOR, C.R.R.I.-1959.

APPENDIX VI

PILOT SURVEY TO ESTIMATE THE INCIDENCE OF PESTS AND DISEASES ON PADDY

District: ______________ Crop season: ____________

FORM I

(General Information)

		Code +
1. (a) Revenue Division (b) Zone No.		
2. Taluk/Block		
3. Village		
4. Area of the village in hectares		
5. Area under paddy in the village (latest figure available) in ha.		
6. Total Survey Number growing paddy in the village		
7. Name of the Field Assistant		

	Field No.					
	1A	1B	2A	2B	3	4
8. Survey and sub. no. if any						
9. Area (i) Hectares						
(ii) Length and breadth (in metres)						
10. Name of the cultivator/owner						

	Code+	Code+	Code+	Code+	Code+	Code+
11. Previous crop						
12. Manuring of previous crop per hectare						
i) kind						
ii) amount in kg.						
13. Nature of soil						
i) texture						
ii) colour						

	Field No.					
	1A Code+	1B Code+	2A Code+	2B Code+	3 Code+	4 Code+
14. Topography: low/medium/high						
15. Variety and duration in days						
16. Preparatory tillage						
i) Description						
17. Basal manuring per hectare (indicate serially) a) kind b) amoung in kg. c) time d) method for each manure applied						
18. i) Sowing or transplanting ii) Date						
19. In case of sowing i) method						
ii) seed rate in kg/hectare						
20 In case of transplanting, No. of seedlings per hole						
21. Spacing in cm						
i) Between lines ii) Within lines						

22. Sketch of each field indicating the dimensions and location of the permanent sampling units.

Field No. 1A	Field No. 1B
Field No. 2A	**Field No. 2B**
Field No. 3	**Field No. 4**

Date: ______________ Signature of Field Assistant __________

+ Entry not to be made by the Field Assistant in the column 'Code'

FORM II

(Monthly Report of the Data for a Field)

A. LOCATION	Code +
1. (a) Revenue Division (b) Zone No.	
2. Village	
3. Taluk/Blocks	
4. Field No.	
5. Survey No. and Sub. No. (if any)	
6. Area in hectares (i) Length)) in metres (ii) Breadth)	

B. BASIC INFORMATION	
1. Month	
2. Weather condition	
3. Condition of crop	
4. Irrigation (a) Source (b) No. of irrigations (c) Rainfall in cm.	
5. Cultural practices (i.e. interculture, weeding, etc.)	
6. Manuring per hectare (i) Kind (ii) Amount in kg. (iii) Time (iv) Method	
7. Control measures taken: (i) Pesticide used or any other measure taken (ii) Quantity (iii) Date (iv) Method	

B. BASIC INFORMATION (Cont.)	Code+
8. In case of transplanted paddy, visual observations on the incidence of pests and diseases in the nursery for the 1st month only, mention the name and intensity (nil, light, medium and severe) (i) Name (ii) Intensity	

C. OBSERVATIONS ON PESTS AND DISEASES

	Sampling Units. Nos. 1*	2*	3	4
1. Pair of random numbers for selecting the unit Length Breadth				
2. Total Number of clumps				
3. Total number of tillers				
4. Number of silver-shoots				
5. Number of dead-hearts				
6. Number of elongated central shoots				
7. Number of false-smut infected tillers				
8. Number of bunt-infected tillers				
9. (a) No. of tillers showing nodal infection by blast (b) No. of tillers showing neck-infection by blast				
10. (a) No. of tillers showing helminthos-poriose leaf infection (b) No. of tillers showing helminthos-poriose ears infection				
11. Number of tillers cut by rats				
12. No. of dead-tillers due to mealy bug infestation				

C. OBSERVATIONS ON PESTS AND DISEASES (Cont.)

	Counts from 5 sweeps				
	1st	2nd	3rd	4th	5th
13. Jasids					
14. Hispa					
15. Grass-hopper					
16. Fulgorid					
17. Schoenobius Moths					
18. Spodoptera Moths					

Sampling Unit Nos. 1*/2*/3/4	Selected clump numbers				
	1	2	3	4	5**
Number of tillers					
Height of the clump in cm					
No. of stem borer egg meases					
No. of larvel population:					
(a) Swarming caterpillar					
(b) Leaf roller					
(c) Others					
No. of dead tillers due to stem-rot					
Scores for: blast					
helminthosporiose					
Intensity of*** yellowing/ reddening:					
(a) Central leaves					
(b) Peripheral leaves					
Intensity of stunting					

Date: ________________ Signature of the Field Asst.: ________________

+Entry not to be made by the Field Assistant in the column 'Code'
*Sampling units fixed for the whole season

** Central
*** In terms of low/medium/severe

(Information at the time of harvest)

A. BASIC INFORMATION

	Code +
1. (i) Revenue Division	
(ii) Zone number	
2. Taluk/Block	
3. Village	
4. Field No.	
5. Survey No. and Sub-No. if any	
6. Date of flowering	
7. Date of harvest	
8. Name of the Field Assistant	

B. OBSERVATIONS ON SAMPLING UNITS

	1*	2*	3	4
1. Number of clumps				
2. Total number of ears				
3. (a) No. of white ears due to borers				
(b) No. of partially borer-attacked ears				
4. No. of neck-infected ears due to blast.				
5. No. of chaffy ears due to stem-rot				
6. No. of white ears due to other causes				
7. No. of ears damaged by rats				
8. No. of false smut infected ears				
9. No. of bunt-infected ears				
10. No. of infected ears by helminthosporiose				
11. Total yield of the unit in gm/sq.m.				
(a) grain **				
(b) straw ***				

\+ Code

* Fixed for the whole season

** Excluding the five selected clumps

*** Including the five selected clumps

C. OBSERVATIONS ON THE EARS OF FIVE SELECTED CLUMPS

	Sampling Unit No.			
	1*	2*	3	4
1. Total number of ears				
2. Healthy ears:				
(i) Number				
(ii) Weight of grain (gm)				
(iii) Weight of chaff (gm)				
(iv) Weight of 1000 grains (gm)				
3. Attacked ears:				
(i) Name of pest/disease				
(ii) Number				
(iii) Weight of grains (gm)				
(a) healthy				
(b) attacked				
(iv) Weight of chaff (gm)				
(v) Weight of 1000 grains (gm)				

Date: ______________________ Signature of Field Asst. ______________________

* Fixed for the whole season

APPENDIX VII

REVIEW OF WORK DONE

The estimates of degree of incidence of infestation of diseases and pests and the degree of severity and consequent quantitative crop losses are important pre-requisites for planning economic and efficient plant protection measures. Several research workers are engaged in working out the estimates of incidence of pests and diseases and consequent crop losses and their findings have been published in various journals. Since there are numerous publications on the subject all over the world, it is not possible to make an exhaustive review of all of them. As such the present review is confined to selective and more recent work done in this field out of the materials which were accessible to the authors. Emphasis is laid on the statistical methodologies adopted in such assessment. Crop-wise and year-wise review in brief has been presented below:

Rice

Abraham and Khosla (1965) made an attempt to reduce the number of variables and to form a single index of the level of incidence of pests and diseases on rice crop in the cultivators' fields. The technique of component analysis was used for this purpose. It was found that about 33 to 39 per cent of the total variation has been accounted for by the index in different years. Alternative indices based on (i) ranking methods, (ii) method suggested by Elston and (iii) standardized values were also worked out and compared with each other.

Padmanabhan (1965) observed that by and large, loss in yield with 1 per cent increase in neck infection was 0.4 per cent for a resistance variety and 0.98 per cent for susceptible one. The estimated loss of grain yield for a resistant variety was 4 per cent while in the case of a susceptible variety, it was as high as 75 per cent.

Abraham and Khosla (1967) presented the results obtained from a pilot sample survey carried out on rice crop in cultivators' fields in District Cuttack of Orissa (India) during 1959-62. Stratified multi-stage random sampling technique was adopted. About 11 to 17 per cent losses were estimated for different years. The maximum loss was due to helminthosporiose consistently in all the years. It was also found that for every 1 per cent increase in white earheads, the yield decreased by 0.6 per cent.

Abraham *et al* (1969) examined the use of successive sampling in pests and disease surveys on rice crop for obtaining better estimates of (i) the incidence in the second year of the survey, (ii) the change in their occurrence from one year to the next and (iii) the overall mean incidence over the two years. They discussed the relative efficiencies of various estimates based on matched sampling.

Sardana *et al* (1971) studied the sample size required at various stages of stratified multi-stage random sampling on the basis of the pilot sample surveys carried out in the districts in the paddy growing States of Orissa, Andhra Pradesh and Tamil Nadu in India. It was observed that at district level it might be possible to estimate the incidence of major pests and diseases with standard error not more than 10 per cent by drawing a sample of 100 villages, 4 fields per selected village and 2 plots of one square metre each per selected field.

Seth *et al* (1971) reported the results of the sample surveys conducted on rice crop in three districts, viz. Cuttack (1959-62), Thanjavur (1962-66) and W. Godavari (1963-67) in India. The percentage losses due to average incidence of all the major pests and diseases over all the years in Cuttack district were found to be 13.00, 7.13 and 11.38 for long duration varieties of *sarad* crop, short duration varieties of *dalua* crop and medium duration varieties of *dalua* crop respectively. The corresponding standard errors were 2.63, 6.32 and 5.72. The overall percentage losses due to average incidence of all the major pests and diseases in Thanjavur district were 4.39, 3.25, 10.46 and 3.96 for short duration varieties of *kuruvai* crop, medium duration varieties of *kuruvai* crop and long duration varieties of samba and thaladi crops respectively. The corresponding standard errors were 1.03, 0.33, 1.65 and 4.15. For the Godavari survey the average percentage losses due to incidence of all the major pests and diseases pooled over the years were 10.57 and 14.43 during kharif (long duration varieties) and rabi (medium duration varieties) seasons respectively with the corresponding standard errors of 2.06 and 2.95. The average avoidable loss over all the years during samba season in Thanjavur district was 411 ± 32kg. per hectare and the consequent losses in W. Godavari district were 76 ± 27kg. and 204 ± 32kg. per hectare during kharif and rabi seasons respectively. The major pests and diseases were stemborer (Trypoyza incertulas), gall fly (Pachydiplosis oryzae), helminthosporiose (Helminthosporium oryzae) and blast (Pyricularia oryzae).

Naik et al (1972) reported that 14 varieties of rice were rated for potential losses they might suffer from the attack of bacterial-streak disease caused by Xanthomonas translucens Dowson f.sp. oryzicala (Farn et al) Bradbury. 'PI 180061' and 'BC5' were found resistant, 'CR 42-38-173' intermediate, and other 11 susceptible. Of the susceptible varieties 'Padma', 'IET 400', 'IR8', 'Kalimooch', 'JR 285' and 'BC6' were tolerant. 'Cauvery', 'Java' and 'IR22' moderately susceptible and 'IR20' and 'Pura 2-21' highly susceptible.

Singh et al (1973) reported on the basis of sample surveys that the average avoidable loss in yield of paddy in samba season in Thanjavur district, kharif and rabi seasons in West Godavari district were 411 kg/ha., 76 kg/ha. and 204 kg/ha. respectively with corresponding standard errors of 32, 27 and 32 kg/ha. The estimates of average avoidable loss in yield of early and late maize in Aligarh district were found to be 193 ± 63 kg/ha. and 181 ± 48 kg/ha. respectively. Though the avoidable loss in yield of wheat in Aligarh district was estimated to be 185 kg/ha. but it was not statistically significant.

Chakrabarti (1974) reviewed the work regarding rice diseases, viz., blast (Pyricularia oryzae Cax) and helminthosporiose (Helminthosporium oryzae Bred de Hann), and the crop losses caused by those in India and other countries of the world up to 1972.

Roy (1974) reported that the average pre-harvest physical loss of aman rice caused by field rats in the agricultural farm of the Indian Statistical Institute in Giridih in South Bihar over the two years was about 7 per cent. He also suggested that further investigations were required as the problem was intricate, since the extent and cost of damage vary with the crop, the season and the tract. Moreover, the methods of recording have not been standardized making it difficult to compare results of different studies.

Ahmed and Singh (1975) studied disease development and yield loss due to bacterial leaf blight in 19 high-yielding varieties adopting a split-plot design. The extent of loss in yield due to this disease varied from 6.12 (Cr 44-35) per cent to 74.20 per cent ('Bala') in different varieties.

Chattopadhyay et al (1975) reported that percentage of infection on total grains were computed plant-wise for "fertile spotted", "sterile spotted" and "sterile spotless" as different categories of infection and yield were recorded for two cultivars, namely, susceptible 'Tilakachery' and moderately resistant 'Bhasamanik'. All the above three grain characters in general caused loss in yield in case of heavy infection. In 'Bhasamanik' only sterile spotless grains caused loss in yield thereby indicating that this cultivar is comparatively resistent to brown spot. Estimation of loss was made in each case, and a close parallelism between the extent of grain infection and loss in yield was noticed.

Krishnakumari (1975) dealt with the factors and problems that affect the implementation of rodent control measures. She also mentioned in her paper that the rat population in India was estimated at 2,400 to 5,000 millions. Recently 8 per cent loss during cultivation of rice grains was reported by the Pesticide Association of India (1975).

Upadhyay et al (1975) reported that the rice leaf-folder Cnaphalocrosis medinalis G. appeared in an epidemic form for the first time in Gujurat in 1971. A preliminary study on variety 'J-280' indicated an average infestation of 73 per cent of leaves which resulted in reduction in grain yield in high infestation over low infestation to the extent of 13.68 quintals per hectare and an economic loss of about Rs.1368/- per hectare. The observations from varietal resistance trials indicated that variety 'N-19' appeared to be highly resistant as compared with other varieties, viz., 'J-280', 'K-118', 'Jaya' and 'IR-8'.

Chakrabarti and Padmanabhan (1976) reported that the poor yield of rice specially during kharif season was mainly due to frequent out-break of disease and insect pests. Hence the importance of their control could not be overlooked. Till lately, plant protection measures were usually adopted after the outbreak of diseases or pests. The recent trend is based on strict disease surveillance and application of appropriate measures before the disease commences. Integrated approach to disease control is recommended. Growing of varieties with at least a moderate degree of resistance to more than one major disease or insect pests, adoption of suitable agronomic practices and introduction of surveillance would not only help crop protection, but also reduce the cost.Strict application of quarantine rules is also emphasized.

Chakrabarti (1977) reported that the outbreak of blast and helminthosporiose diseases of rice of severe degree occurred in endemic areas year after year whereas in other locations the occurrence was seasonal. The observations made were, however, generally not based on statistical experiments or surveys.

Joshi and Bhakta (1977) reported by conducting split-plot design experiment that in case of '117-1' and 'Gaur-100' not only the percentages of infection due to false smut were higher (19.5 and 9.5 respectively) as compared with six other varieties, but the percentages of yield losses were also higher (47.8 and 29.2 respectively). Yielding ability of 'IR-28', 'Ratna' and 'Masuri' were on par and better as compared with others in favourable conditions of infection.

Khosla (1977a) suggested three methods for the assessment of crop losses caused by pests and diseases (i) using the multiple regression study involving the actual incidences of major pests and diseases on rice as independent variables and yield as the dependent variable, (ii) forming an index based on the incidences of major pests and diseases on rice by component analysis technique, reducing to a linear regression of yield on an index thus formed and (iii) adopting chemical plant protection measures to control the incidence of pests and diseases in one of the paired selected fields. The formulae were simplified as far as possible and applied to the data of the pilot sample survey carried out in one of the paddy growing districts. The estimated percentage losses by the methods of regression study and index formation were 19.21 and 20.35 respectively, with standard errors of 9.58 and 5.36. The percentage of avoidable loss in yield by adopting plant protection measures was 4.68 with standard error of 1.17.

Khosla (1977b) presented the methodology for measurement and estimation of incidence of pests and diseases and assessment of crop losses by relating the incidences with the yield of rice crop in India.

Singh et al (1977) reported that the disease caused substantial decrease in the head rice recovery; the losses ranged from 50-76 per cent in different varieties. Grains from diseased crop were poor in water absorption, volume expansion and Kernal elongation values. This effect varied in different varieties depending on disease severity.

In the interim report on constraints to high yields on Asian rice farms issued by IRRI, Philippines (1977), the constraints due to incidence of pests and diseases have been dealt with by conducting factorial experiments in South-East countries, viz., Indonesia, Sri Lanka, Thailand, Philippines and Taiwan.

Some experiments adopting R.B.D. and split-plot designs have been conducted at Paddy Experimental Station, Ambasa Mudran (Tamil Nadu) during 1977-78 studying the efficiency of the various methods of application of insecticides for the control of pests and diseases of paddy. The results of these experiments are under publication.

De Datta et al (1978) prepared a handbook for an integrated experiment/survey on yield (rice) constraints methodology. Yield constraints due to the incidence of pests and diseases have also been dealt with by adopting factorial experiments and sample survey methodology.

Wheat

Rawat and Sahu (1969) reported that phorate 10 per cent and lindane 10 per cent applied below the seed and mixed with seed at 20 kg. per hectare were most effective in controlling the pest. Lindane mixed with seed gave the best control and highest yield, and was most economical.

Nema and Joshi (1971) reported that out of the five wheat varieties, viz., 'NP 884', 'NP 852', 'Lerma Rojo', 'Sonora 64' and 'S 227', 'Lerma Rojo' was highly susceptible to *Helminthosporium sativum*. P.K. and B.A. scale was devised to measure the disease intensity on the basis of the number and type of lesions. The reduction in grain weight was correlated to number of spots and disease intensity per unit area of flag leaf.

Slope and Etheridge (1971) reported that the yield of wheat and the incidence of take-all were measured in crops grown in six different 4-year sequences, repeated in 3 successive years. The first crop of winter wheat grown after oats or beans yielded (13-23 cwt/per acre or 1632-2887 kg/ha.) more than wheat after wheat or barley. Spring wheat after oats yielded (2-5 cwt/acre or 250-625 kg/ha.) more than spring wheat after wheat. The smaller yields of wheat after wheat or barley were caused mostly by the greater prevalence of take-all. The regression analysis indicates that each 1 per cent, increase in straws with take-all decreased yield of winter wheat by 0.6 per cent. Take-all was more prevalent in the second and third successive wheat crops after oats than in the fourth crop.

Kishen et al (1972) observed on the basis of a pilot sample survey undertaken in the Aligarh district of U.P. in 1963-67 that *gujia* weevil (*Tanymecus indicus* Fst.) and termites (*Microtermes abesi Holmgr.*) were the major pests of wheat (*Triticum aestivum* L:): The peak period of their infestation was the second fortnight from the date of sowing. *Gujia* weevil damaged 14.42 $\pm$ 0.65 per cent and termites 2.08 $\pm$ 0.43 per cent of the clumps. Brown rust (*Puccinia graminis tritici* (Pens.) Erikss & P. Henn) were the major diseases and their maximum incidence was in the 11th fortnight. The percentage infection of brown rust in the peak period was 14.57 $\pm$ 0.44 and of black rust 4.49 $\pm$ 0.25.

James and Shih (1973a) reported that the disease incidence and severity data for powdery mildew (*Erysiphe graminis* DC. Ex. Merat. f. sp. tritici Em. Marchal) and leaf rust (*Puccinia recondita* Rob.Ex Desm. f. sp. tritici Eriks.) of winter wheat (*Triticum aestivum* L.) were recorded during three surveys in Ontario in 1969 and 1970. An exponential equation was used to describe the relationship between the incidence (percentage of leaves infected) and severity (percentage of leaf area affected) for the two diseases on particular leaves. A linear regression was found to be adequate to estimate severity for incidence values of 65% or below. The relationship between incidence and severity for each of two diseases was consistent over a large geographical area, but differed for the 2 years.

Singh et al (1973) reported on the basis of sample surveys that the average avoidable loss in yield of paddy in *samba* season in Thanjavur district, *kharif* and *rabi* seasons in West Godavari district were 411 kg/ha., 76 kg/ha. and 204 kg./ha. respectively with corresponding standard errors of 32, 27 and 32 kg/ha. The estimates of average avoidable loss in yield of early and late maize in Aligarh district were found to be 193 $\pm$ 63 kg/ha. and 181 $\pm$ 48 kg/ha. respectively. Though the avoidable loss in yield of wheat in Aligarh district was estimated to be 185 kg/ha. it was not statistically significant.

Naik et al (1974) reported that there was a direct relationship between yield and leaf rust except in varieties 'Moti', 'HD 4530', 'EK 69', 'J-1-7', 'NP 200', 'HP 916', 'Hira' and 'K-68' and therefore these varieties were rated as tolerant.

Calpouzus et al (1976) described a comprehensive study of yield losses in spring wheat due to wheat stem rust disease, incited by Puccinia graminis Pers. f. sp. tritici Eriks. & E. Henn. The main objective of the study was to develop a model that would improve the accuracy of estimates of yield losses due to wheat stem rust.

King (1977a) estimated that the loss in yield of wheat due to particular diseases varied from almost zero caused by yellow rust in 1970 to 7.4 per cent caused by Septoria in 1972 in England and Wales. The survey was conducted during 1970-75 in about 300 farms selected at random.

Zende (1977a) reported reduction in wheat yield of the control plot by 41 per cent when compared with the best treatment.

Barley

Srivastava (1966) reported that the damage to barley crop caused by field rats at the tillering stage varied from 5.4 to 12.47 per cent. The percentage loss in yield was worked out to be 5.88.

Stern (1967) presented the results of the study made by conducting insecticidal experiments from 1958 to 1963 in Imperial Valley, California, on barley yellow-dwarf virus.

King (1972) estimated annual losses in yield of spring barley in England and Wales (1967-70) due to mildew to 7-11 per cent, with a mean over the four years to 9 per cent. Losses caused by leaf blotch infection were estimated to 1 per cent in 1967, 1968 and 1969 and nil in 1970. These results were based on the samples of 250-300 spring - sown barley crops including all opular cultivars, taken when the grain was milky ripe.

Jenkyn (1974) reported that the mildew decreased grain yield by decreasing ear number and grain size (but not grain number/ear), the damage depending on the earliness and severity of mildew. In 1971 when mildew was early and severe, ethirimol seed dressing at 0.22 kg. a.1/ha., which gave only early protection, increasing yield more than did ethirimol sprays applied to protect the flag leaf and ear. In 1972, sprays were better than seed dressings at this rate because mildew was less severe during the seedling stage.

Jenkyn and Bainbridge (1974) reported that in two experiments on 'Julia' and 'Zephyr' spring barley, evidence was obtained that the development of powdery mildew in sprayed plots depended very much on their proximity to unsprayed crop. Mildew incidence differed widely between plots because it was affected both by the spray treatment and distance from the surround. The regression coefficients of yield on mildew were significant. Although yields of twice sprayed plots were usually greater than those of once sprayed plots at each distance from the surround, their differences were not statistically significant.

Bainbridge and Jenkyn (1976) reported that in Lattin Square Design (L.S.D.) in 1973 and 1974, reinfection of sprayed barley by mildew (Erysiphe graminis f. sp. bordei) decreased by widely spacing the plots. In 1974, when yields differed between plots which were either contiguous or separated, the results suggested different times to spray for best yield increase.

King (1977) reported that the annual estimates of yield losses in barley crop caused by mildew varied from 5.7 to 13.0 per cent and 0.2 to 1.7 per cent by brown rust or leaf blotch during 1972-75 in England and Wales. Random sampling technique was adopted.

Jenkyn (1978) reported that in 1973, combinations of seed treatment and spray or two sprayed did not yield better than the best component treatment applied along or the most effective single spray of tridemorph applied on 1 June. In 1974, mildew developed usually early and yields increased by applying ethirimol to the seed plus a tridemorph spray or two tridemorph sprays. Sprays of captafol and tridemorph, applied as separate treatments, successively to the same plots on three occasions, gave the best yield in both years. Treatment affected ear number most and did have some effect on all components of yield. In 1974, there was a significant relationship between ear number and the variance of the number of grains per year.

Maize

Chatterji et al (1969) reported that the evaluation of losses caused by insect pests of maize with particular reference to the stem borers, by chemical protection of crop, was carried out at four different centres. It was observed that there was no significant difference between four applications of endrin and six applications of endrin with regard to the number of infected plants and the grain yield in most of the trails. Thus, the average avoidable loss (1965-66) as calculated by the difference in yields of plots treated with four applications of endrin and untreated plots, was found to vary from 24.3 to 36.3 per cent.

Singh et al (1971a) presented the results of a study made on maize (Zea mays L.) in Aligarh district in 1964-67 regarding the infestation of major pests and consequent losses in yield. The percentage of plants damaged by major pests, viz., stemborer (Chilo partellus Swinhoe), gujia weevil (Tanymecus indicus Faust) and leaf-roller (Marasmia trapezalis Guenee) were 11.38, 34.38 and 7.90, respectively for early maize during 1964-67 and were 14.73, 32.61 and 15.59 for late maize during 1964-66. The significant decrease in yield due to infestation of gujia weevil and leaf-roller in the early maize was 12 and 3 per cent respectively. The average avoidable loss in yield in the district was 1.93 and 1.81 q/ha. in the early and late maize respectively.

Chatterji et al (1972) reported that seven insecticides, viz., lindane and endosulfan (granules and emulsifiable concentrates), carbaryl (wettable powder and granules), trichlorphon (sprayable powder and granules), aldicarb, mephosfolan and carbofuran in granular formulation were evaluated for their efficiency against the maize stem-borer (Chilo zonellus). Mephosfolan and carbofuran showed significantly less damage than control. The yield of maize grains was also significantly more in the plots treated with mephosfolan and carbofuram granules. In addition to these two, treatment with endosulfan in emulsion and granular formulations also showed less infestation and increased yield by 16.4 per cent over control.

Sharma (1977) reported from the experiment conducted at Bajaura experimental farm (H.P.) in India by adopting split-plot design that the percentage reduction in yield of maize (Bassi local) by spraying dithane 2.78 were 29.1 and 63.4 during kharif season of 1975 and 1976 respectively.

Zende (1978) reported that Helminthosporium leaf blight caused a reduction of 42 per cent in the grain yield of maize.

Sorghum

Karve (1970) reported that shoot-fly caused a loss of 51.71 per cent in the grain yield of hybrid sorghum.

Rawat et al (1970) reported that all the untreated ears received a heavy attack of caterpillars, the average population per ear being 38. The maximum population recorded was of Cydia sp. and Ectomyelois sp. (30), followed by Eublemma sp. (6), Heliothis armigera Hb. (2), and Euproctis Limbata Wlk. (1). Treated ears were practically free from infestation. As there were no other ear-infesting pests, the losses in yield can only be attributed to the damage caused by these caterpillars. The grain yield of untreated ears was significantly less than that of treated ears - the average grain yield per treated ear was 37.37 g. and that of untreated ear 28.91 g. The estimated loss in grain yield thus amounted to 18.26 per cent, or 717 kg./ha. The highest yields (4,785 to 4,797 kg/ha.) were obtained with endosulfan dichlorvos and carbaryl, as compared to control (3,995 kg/ha.).

Mistry (1977) reported the the loss of yield in quintals per hectare during rabi and kharif seasons due to individual pests and all pests in combination were as follows:

Pest	Rabi Season	Kharif Season
Shoot-fly	5.98	1.59
Stem-borer	4.48	5.24
Mite	0.38	4.96
Ear-worm	0.62	0.66
Aphid	0.13	3.18
All pests controlled	-	-
Untreated control	13.51	10.60

Kai *et al* (1978) observed significant negative correlation between sorghum shoot-fly infestation (measured in terms of percentage dead hearts) and grain yield on the basis of field experiments conducted in randomized block design (1973 and 1974) and split-plot design (1975 and 1976). The relationship was found to be basically linear. Economic injury levels of shoot-fly infestation were estimated on the basis of cost of protection with two insecticides, viz., carbofuran seed treatment and disulfoton granules as soil application. The losses ranging from 13 to 20 per cent, and from 60 to 90 per cent were estimated at 20 and 90 per cent infestation levels respectively.

Soyabean

Gangrade *et al* (1967) reported that a significant reduction in weight of grains of 'Bragg' variety was noted at 10-larvae per metre row in all cases when the larvae of *D.obliqua* and *S.exiqua* consumed about 40 and 25 per cent leaf area respectively, whereas the larvae of *H. armigera* caused near complete loss of grain.

Singh and Gangrade (1974) reported that as a result of reduction in the photosynthetic activity due to the loss of chlorophyll from 85 per cent of the leaves, both pod number and grain weight were reduced, the reduction being 2.5 and 3 times in 'Bragg' and 2.7 and 4.5 times in 'Clarke 63', respectively. The loss in grain weight was observed to be 24.0 per cent in 'Bragg' and 11.8 per cent in 'Clarke 63'. No loss of carbohydrates, protein and oil contents of the grain was noted.

Gangrade and Singh (1975) reported that the cut-off height of the infested plants was negatively correlated with pod loss ($r = -0.755$), pod weight ($r = -0.900$), grain number ($r = -0.955$) and grain weight ($r = -0.625$) and a linear relationship was found between them.

Gangrade and Singh (1976a/b) further reported that the loss worked out to 2.33 q/ha. in 53 per cent plants, yielding significantly in an optimum plan population of 40000/ha. As a result of early infestation of plants, 75 per cent plants were dead before maturity. The late infestation of plants by the beetle did not cause any mortality but the weights of the pods and grains of healthy plants were 2.9 and 3.0 times more than those of attacked plants. The loss of pods and grains amounted to 84.4 kg. and 47.2 kg. per hectare at an average plant infestation of 8.7 per cent.

Bajra

Zende (1977b) reported that downy mildew of *bajra* reduced the grain yield of the susceptible variety 'HB-3' by 32.43 per cent.

Cereals (General)

Pradhan (1964) has reviewed the work done on crop losses due to pests in detail.

The Near East Commission on Agricultural Statistics in its Fourth Session held at Baghdad, Iraq, in September 1968, suggested some concepts and definitions relating to the estimation of damage to crops in the field or in storage due to pests and diseases. It was felt that much work could be done through cooperation between statisticians and plant protection specialists.

The Asia and Far East Commission on Agricultural Statistics in its Second Session held at New Delhi, India, in December 1968, aimed at bringing to the attention of the countries the importance of statistics of crop losses in planning greater food production. The assessment of pre-harvest and post-harvest losses were discussed and the difficulties encountered pointed out.

LeClerg and Church (1971) discussed the topic "Field Experiments on Crop Losses" and "The Place of Sample Survey in Crop Loss Estimation", respectively in FAO Manual on Crop Losses in detail.

The problem of estimation of crop loss was discussed in the Symposium convened by the FAO in 1967 and on the recommendations of this Symposium a Manual on "Crop Loss Assessment Methods" was prepared and edited by Chiarappa et al in 1971 which provides very useful information in this field.

James (1971) prepared a series of score charts for plant diseases on different crops which could be used for the measurement of severity of diseases during the growth period of the crops in future studies.

Singh et al (1971b) made a critical review of 28,932 field experiments conducted during 1948-64. It was mentioned that very few experiments were conducted on the control of pests and diseases and on weedicides.

Joshi and Singh (1972) presented a review of work done on major food and other crop losses due to pests, plant diseases and weeds in India during the period mainly from 1947 to 1965.

Judenko (1972) discussed the problems of the economic loss in crop yield and the economic threshold. He has also presented the results of economic loss in yield on the basis of an experiment on the control of fruit-fly on sweet corn with phorate by using the paired plant method. The percentage of economic loss was 25.6 and 51.3 in treated and untreated plots respectively.

Webster (1972) discussed the extent and type of crop losses due to diseases, economic principles, evaluation of the losses and economic aspects of disease control. The chapter also includes two tables on annual world crop losses due to insect pests, diseases and weeds.

James and Shih (1973b) reported that the data from uniformity trials on healthy and diseased wheat and oat crops showed that the coefficient of variation for yield decreased as plot size increased. The shape of the plot tended to square type. Infection with Septoria leaf blotch of oats and powderly mildew of wheat did not appear to affect yield variability. Plots longer than rod row size (where 5 metres of the centre row of 3 rows is harvested) are recommended to detect differences of 10 per cent in yield between two treatments.

King (1973) presented the losses in percentage due to mildew varying 6-14 (1967-73) and 2-5 (1970-73) in the yields of barley and wheat crops respectively in the UK. Stratified random sampling technique was adopted in selection of 300 farms.

Khosla et al (1973) reported that out of the 5,762 agricultural statistics experiments excluding purely varietal ones, conducted in India during 1965-70, 13.3 per cent were those connected with the use of insecticides and pesticides on various crops.

George (1974) gave results from experiments conducted in 130 sampled fields in 1972. He studied that aphid burdens on winter ears, stems and leaves at the levels encountered in these experiments had little effect before the grains started to fill, but once this happened, a product of aphid numbers and time came into operation and had a yield-reducing effect.

Golightly and Woodville (1974) estimated, on the basis of the trials conducted on wheat and barley in UK, losses of 7.2 and 10.3 cwt/acre (9 and 12.9 q/ha.) for the moderate (6-10) and heavy galling categories (more than 10) respectively. As the four categories (0, 1-5, 6-10 and ⩾ 10 galls/stem) were in equal proportion, the mean theoretical yield of 31.4 cwt/acre (39.4 q/ha.) indicated a yield loss of 4.5 cwt/acre (5.7 q/ha.) or 12.6 per cent on the potential yield.

James (1974) reviewed the recent advances in phase one involving the development of methods for assessing loss and presented a critical discussion of selected references which hopefully may serve as a guide for future research. Most of the recently published work on methodology of disease assessment concerns foliage diseases, particularly of cereals and potatoes, and the content of this review reflects this imbalance.

Kolbe (1974) established the relationship between aphid density and yield on the basis of numerous trials conducted from 1968 to 1972 in the Rhine valley (W. Germany). He observed that infestation of 20-30 aphids/ear could cause losses up to 10 per cent; these could go up to 30 per cent when the attack was prolonged and reached levels of 150 aphids/ear. On the basis of the results over 5 years, he indicated an increase of 10 per cent in the yield (at infestation level of 30 aphids/ear) to be due to a 10 per cent increase in number of grains/ear and a 4 per cent increase in 1000 grains weight. Higher yield increases were recorded when control measures were taken earlier.

Ennis et al (1975a) discussed the nature and extent of losses caused by pests. They have also discussed about the various methods, viz., preventive, genetic, biological control, cultural and physical, chemical control, etc., for avoiding these crop losses.

Ennis et al (1975b) discussed about the nature and extent of losses caused by various pests including plant diseases, nematodes, mites, insects, weeds and vertebrates, especially birds and rodents. Some specific examples are provided of some of the major pests attacking crops.

George (1975) established, on the basis of the results of a cooperative experiment, conducted jointly in the UK and other West European countries, the threshold in terms of cereal growth stage and aphid number per tiller at which spraying with an insecticide becomes economically justifiable. The technique of replicated paired plot was adopted.

Urs et al (1975) studied the eco-behaviour, species inter-relationship, territoriality, habitat preferences of the rodents released in the rattery. The amount of food consumed by a population of 22 rodents within 30 days in rattery conditions and the number of pellets and hair that could be collected continuously for five days as reported in this paper are indicative of the amount/degree of food loss, pollution (both quantitatively and qualitatively) occurring constantly in rural and urban habitats.

Rijsdijk and Zadoks (1976) presented the relation between damages due to leaf rust and stem rust on wheat and stripe rust on wheat and barley; and yield losses in percentage, using regression lines. The data were available from enquiry or literature in Europe. The epidemiology and forecasting of cereal rusts, studied by means of a computer simulator named EPISIM has also been referred to.

King (1977c) reported the loss in grain yield caused by spring barley mildew to have been worth about £35 million in 1976 £25 million in 1977. In winter wheat, mildew losses were about £7 million and £5-6 million in 1976 and 1977 respectively. Stratified random sampling technique was adopted.

Khosla (1977c) reviewed and discussed the various techniques adopted for the assessment of crop losses due to pests and diseases. The statistical methods adopted were also enumerated.

Khosla (1977d) explained the regression techniques, both simple and multiple, relating to the incidences of crop pests and diseases and yield in detail.

Khosla (1977e) reviewed and discussed the sampling techniques for assessment of crop losses. Some recommendations were also made for employing sample survey techniques.

Rijsdijk and Zadoks (1977) reported the data based on international enquiry and extracted from the literature. Data processing led to loss maps of Europe showing the mean annual loss due to each cereal pest and disease by means of isoloss curves and risk maps of Europe for selected pests and diseases showing the relative risk incurred by the cereal crop in each climate area as determined by the climate of that area, areas with equal risk separated by isorisk curves. New developments in detailed disease survey combined with a computer based warning system for some cereal diseases in Netherlands has also been indicated.

Smith (1977) recommended in his paper that, as part of the programme suggested by him, pilot and later detailed surveys of crop production and crop losses should be conducted.

Zadoks (1978) reviewed the concepts and definitions of yields, incidence and losses due to diseases. He has also dealt with the statistical aspects in brief.

Vegetables

Bindra and Jakhmola (1967) reported that the incidence of and losses caused by pod fly, plume moth, pulse beetle and other pests was studied for 11 varieties during 1964-65. Losses caused by pod fly varied from 6.09 to 10.31 per cent, that of plume moth from 1.96 to 4.82, pulse beetle from 0.02 to 0.82 and by other means from 1.41 to 3.92 per cent. The combined losses in yield by pod infesting insects was from 12.31 to 20.45 per cent.

Rawat et al (1969) compared the pod formation in plants treated twice at weekly intervals with a mixture of dimithoate 0.03 per cent and endrin 0.02 per cent in ratio 1:1 at the rate of 750 litres per hectare, to keep them free from thrips, a reduction of 36.0 per cent in pod formation was observed in the untreated plants as a result of infestation by blossom - thrips.

Srivastava et al (1969) investigated, by conducting nematocidal randomised block design experiments, that Nemagon at 6-7 litres per hectare was significantly superior reducing the nematode population to the extent of 95-98 per cent and giving the highest yield nearly 4 times to that in the control.

Philpoths and Wallen (1970) interpreted with the use of colour infra-red aerial photographs, taken in 1968, more than 218 hectares of white beans, representing 25 fields in the Hensall area of Ontario to measure the extent of blight. The data were analysed to estimate the types of losses, including that caused by blight, to the producer. The total loss per hectare including blight loss was about $52. The average loss because of blight was about $25 per hectare or almost half of the total loss.

James et al (1971) observed, by conducting R.B.D. experiments in eastern Canada in 1969-70, that the actual and the estimated losses in yield of potatoes caused by late blight were in poor agreement. However, the reasons for the divergence in results are discussed.

James et al (1972) developed a method for estimating the loss in tuber yield caused by late blight by using data from 11 experiments conducted during the period 1953-1970 in eastern Canada. A multiple regression equation was derived using the increase of disease during 9 weekly periods as the independent variables and yield loss as the dependent variable. The empirical equation could be used to estimate the yield loss associated with any given progress curve. The difference between estimated loss, computed from the equation, and actual loss, derived by weighing, was less than 5 per cent in nine cases out of 10.

Hide et al (1973) reported that 'King Edward' and 'Majestic' seed potatoes selected as 'clean', 'moderate' and 'severe' according to the extent of skin spot were planted in field experiments at Rothamsted between 1964 and 1968. Plants from severely infected seed tubers emerged more slowly, had full stems and yielded less (King Edward 20%, Majestic 13%). Seed infection also affected tuber size distribution; severely infected seed of 'King Edward' yielded almost 4 tons/acre (10 t/ha.) less of $1^1/4$ - $2^1/4$ in. (3.2-5.7 cm.) tubers and 'Majestic', 1 ton/acre (2.5 t/ha.) less of $1^1/4$ - $2^1/4$ in. (3.2-5.7 cm.) tubers and 2 tons/acre (5 t/ha.) less $2^1/4$ - $3^1/4$ in. (5.7-8.3 cm.) tubers. However, the total yield from diseased seed stocks was only slightly less ('King Edward' 0.6 ton/acre (1.5 t/ha.) and 'Majestic' 0.8 ton/acre (2 t/ha.) than the yields from the 'clean' tubers selected from them. Seed severely infected by Oospora pustulans often increased infection of the progeny tubers, and usually decreased their infection by Rhizoctonia solani and sometimes by Helminthosporium solani.

Another series of experiments compared 'King Edward' seed tubers classified according to the number of live eyes showing in March. Seed with one, two, three and more live eyes yielded equally. About half the tubers without live eyes in March eventually produced plants but late, with few stems and giving only half the yield of seed with three or more live eyes. Surprisingly, the progeny tubers from and without live eyes were least infected by O. pustular R. solani and H. solani. Progenies of 'King Edward' and 'Majestic' seed from a common source grown on seven widely separated farms were infected more in 1963 than in 1964, but in each year infection differed widely among farms.

Hide et al (1973b) reported that the crops from severely diseased seed yielded, on an average, 7% less than those from clean tubers ('King Edward' 6.8% less and 'Majestic' 0-20% less). Seed infection affected tuber size distribution, compared with clean seed. 'King Edward' seed yielded slightly more Chats ($1^1/2$ in., 3.8 cm.) and 1.5 ton/acre (3.8 ton/acre) less large tubers ($2^1/4$-$3^1/4$ in., (5.7-8.3 cm.)). The effects were similar with 'Majestic' although differences were smaller. However, total yields from diseased stocks (unselected) seldom differed significantly from the clean tubers selected from them. Crop from moderately and severely diseased seed had more Corticium on stems and black scurf on tubers and usually less Oospora pustulans than those from clean seed.

Hirst et al (1973) reported that the plots gapped (gaps between plants) randomly to varying degrees at emergence or flowering showed that the yields decreased by 0.332 ($\pm$.129%) and 0.833 ($\pm$0.994%) respectively, for every 1 per cent of plants removed. When up to 24 per cent of plants were removed the regression of percentage gaps on yield did not become significantly non-linear.

Griffith et al (1974) reported that the seed tubers of the varieties 'King Edward', 'Majestic' and 'Pentland Crown' selected as 'clean' (lesion free), moderately, or severely affected by gangrene lesions were planted in field experiments. On an average, severely affected seed yielded 20 per cent less than 'clean' seed. Seed infection also increased the proportion of tubers in smaller size grades; consequently crops from severely infected 'King Edward' seed averaged 1.4 ton/acre (3.5 t/ha.) less small ware and 2.5 ton/acre (6.3 t/ha.) less large ware than crops from clean seed. In 'Majestic', small ware increased (2.7 ton/acre (2.8 t/ha.)) and large ware decreased (4.4 ton/acre (11.0 t/ha.)). 'Pentland Crown' was similarly affected with increase in small ware (0.8 ton/acre (2.0 t/ha.)) and decrease in large ware (3.9 ton/acre (9.8 t/ha.)). In eight out of twelve experiments unselected diseased stocks yielded significantly less than 'clean' tubers.

Wallen (1974) recorded yield losses up to 50 per cent in pea plots innoculated with Ascochyta pinodes and Ascochyta pinodella. Six weeks after planting, reductions in stand of 24 per cent and 14 per cent, caused primarily by foot rot, were recorded for A. pinodella and A. pinodes, respectively. Severe leaf infection and defoliation resulted in reduction in the number and weight of pods of plants. Only a slight yield reduction occurred in plots innoculated with Ascochyta pisi.

Sakhi et al (1975) studied the effect of different fungicides on the incidence of powdery mildew in bottlegourd.

Wallen and Jackson (1975) described a model for the assessment of yield losses in field losses in field beans due to bacterial blight (Xanthosmonas phaseoli). The model uses a yield loss factor of 38 determined from the average yield loss in 2-year field plot trials, combined with results on the incidence of bacterial blight in commercial bean fields as determined by aerial infra-red photographic surveys conducted in 1968, 1970 and 1972 in

Ontario. Losses in the field bean crops in Ontario were as high as 1, 251, 913 kg. (46,000 bu) in 1970 and as low as 217,274 kg. (8,000 bu) in 1972.

James et al (1976) reported the results from the field experiments (R.B.D,) with potatoes infected with Phytopthora infestans, studying the relative importance of positive and negative interference (over-estimation and under-estimation of yield losses associated with fungicide treatments) in plots sprayed with Dithane M-45. At both Ottawa and Charlottetown, a negative interference was recorded in the sprayed plots when they were next to plots where the disease had been completely, or nearly completely controlled. At both locations the negative interference was greater than corresponding positive interference (9% and 22% respectively at Ottawa and 8% and 10% respectively at Charlottetown). An epidemic in some plots resulted in positive interference in fungicide sprayed plots in the same experiment despite the application of five protectant sprays. Negative interference occurred in sprayed plots adjacent to plots with no disease, and the magnitude of negative interference was greater than the positive interference. The representational errors between treatments due to interference were equal to or greater than the corresponding experimental errors.

Sohi and Sokhi (1976) studied that the yield in bottle-gourd increased mainly due to more fruits per plant in different treatments. The fruits were comparatively heavier in Bavistin and Benomyl treatments. In watermelon the yield was comparatively low in general.

Krishnaiah (1977) reported that the percentage of avoidable losses (differences in yield of protected and unprotected plots) were in the ranges of 40-56, 49-74, 16-46, 54-66, 44-54 and 20 in okra (leaf hopper - February to May), okra (fruit-borer - June to September), tomato (fruit-borer), egg plant (fruit-borer), cabbage (leaf-eating caterpillar and aphids) and pea (aphids) respectively.

Rawal (1977) observed a loss of 37.69 per cent in yield when the infection took place in one-week old crops as against 6-week old crops.

Wallen and Galway (1977) developed, by conducting randomized block design, similar disease progress curves from the results of disease assessments for bacterial blight (Xanthomonas phaseoli) on 'Sanilac', 'Seafarer' and 'Kentwood' field-bean cultivars in field plots over a 3-year period 1974-76. Although losses due to bacterial blight were substantial, mean 3-year losses were similar among the varieties ('Seafarer' 32%, 'Kentwood' 32.2% and 'Sanilac' 33.1%). Crop canopy development was influenced by the intensity of the disease, a hastening of maturity and senescence and early defoliation of infected plants. In 1975, when yield losses were greatest, differences in canopy development between control plots and infected plots were also the greatest.

Krishnaiah et al (1978) made an attempt to work out economic injury level for okra fruit-borer during fruiting stage. An easy, reliable and inexpensive pest sampling technique for effective use of economic injury level was accomplished by sequential sampling plan.

Manzer et al (1978) studied the effects of potato virus S and two strains of potato virus X on yields of 'Russet Burbank', 'Kennebec' and 'Vatahdin' cultivars in Maine by employing split-plot designs.

Sohi (1978) reported losses (a) in tomato due to buck eye rot ranging from 18 to 35 per cent, Septoria bycoperrici 20 per cent, bacterial wilt up to 90 per cent and leaf curl 29.8 to 92.3 per cent; (b) in potato due to late blight (20-40 per cent), early blight (20%), leaf curl (20-25%) and bacterial blight (30-70%) and (c) chillis and bell pepper due to fruit rot (33-34%) and powderly mildew (35.0%).

Fruits

Sohi and Sridhar (1973) reported that there was increase in yield of sprayed trees over unsprayed control ones. An additional yield of 42.15 kg/tree was obtained giving an additional income of Rs.42.15 per tree when sprayed with Dithane Z-78 (0.2%) at monthly intervals.

Oilseeds

Rawat and Deshpande (1970) studied that the pest *Laplygma exigua* reduced the plant height and yield significantly. The percentage reduction due to the pest in plant height and in the number and weight of capsules was 16.0, 46.6 and 44.3 respectively.

Vaishampayan *et al* (1969) observed that capsule-fly damaged on an average 37.5 per cent $\pm$ 6.20 capsules of safflower. The net loss in the yield of seeds was 26.13 per cent, taking into consideration the 30.33 per cent recovery of good marketable seeds from the damaged capsules.

Jakhmola *et al* (1973) reported that the early sown linseed crop was significantly less damaged than the late sown one. A significantly high yield of 1,027 kg./ha. was observed from the crop sown early. A negative correlation (γ = -0.991) was observed between the date of sowing and grain yield. The infestation by the pest was negatively correlated with grain yield (r = -0.973).

Karve *et al* (1977) reported that the aphids and *Acanthiophilus helianthi* caused a yield reduction of 32 and 35 per cent respectively. Leaf blight caused by *Alternaria carthamia* reduced the yield of safflower from 75 per cent to 85 per cent depending upon the variety and climatic conditions.

Narayanasamy and Ramiah (1977) reported the loss induced by the ring mosaic virus in groundnut ranging from 77.7 to 100 per cent in kernel weight depending on the age of plants at the time of infection. Since the plant susceptibility decreased with increase in age and the kernel weight increased with increase in age at infection, the linear relationship between these two factors was worked out.

Suryawanshi and Pawar (1977) reported that the treated plots showed negligible infestation due to *D.sonchi* but the untreated plots were heavily infested. The incidence of other pests was negligible. The total number of capsules and yield were significantly less in the untreated plots than treated ones. The percentage loss in yield of safflower due to aphids was 66.45% in untreated plots.

Singh (1978) reported that *tikka* disease, caused by *Cercospora* sp. reduced the pod yield of groundnut by about 25 per cent during summer planted crop, while in the monsoon crop this disease reduced the pod yield from 40 to 45 per cent, depending upon the variety.

Singh and Rawat (1978) reported that the cabbage web-worm infested 17.54 to 47.82 per cent (mean 27.65%) plants of mustard at pre-flowering stage and 10.00 to 30.50% (mean 17.50%) plants at flowering/podding stage. The number of larvae per plant ranged from 1 to 70 at pre-flowering stage and 1 to 40 at flowering/podding stage. The net loss of yield worked out to 5.67 q./ha. and 3.82 q/ha at pre-flowering and flowering/podding stage respectively

Cash Crops

Acharya *et al* (1957) studied the efficiency of systematic selection of canes in a field against random selection for estimation of borer incidence. The results indicated the superiority of systematic selection.

Sen and Chakrabarty (1964) estimated the loss in the tea crop due to pests and diseases in tea estates of north-east India on the basis of sample surveys. A stratified multi-stage sampling design was adopted, with partial replacement of sampling units in the successive years. For mature tea, the overall loss due to major pests and diseases during 1959 in Assam Valley was estimated to be about 1 quintal per hectare under actual conditions, using normal control measures. This was 5-6 per cent of the disease-free crop.

Sen *et al* (1966) described sampling techniques for estimating the degree of infestation of pests in tea estates, with particular reference to red spider mite in north-east India. Systematic sampling of bushes from a section of an estate has been shown to be at least as efficient as any alternative sampling scheme, for the same sample size. They discussed possible gain due to double sampling, using combination of eye estimation of incidence in a section with scoring of bushes for a sub-sample of sections.

Sen and Chakrabarty (1967) estimated loss in tea due to red spider mite with incidence index of 16.2 per cent as 139 ± 34, 141 ± 59 and 124 ± 49 kg./ha. by using the least square method and those developed by Wald and Bartlett respectively.

Tripathi and Bhattacharya (1968) estimated about 18% loss in fibre yield due to damage by Apion corchori in Corchorus capsularis jute (JRC 212).

Patel et al (1971) estimated the reduction in yield of tobacco due to the damage by the infestation of different number of larvae of leaf-eating caterpillar ranged from 326 kg./ha. to 702 kg./ha.

Tripathi and Sri Ram (1972) reported that the amount of loss in fibre yield by semi-looper varied from 22.47 per cent to 48.47 per cent in C.olitorius jute varieties JRO 632.

Crawford (1973) reported a table of estimates of losses in cotton production caused by various diseases in the cotton growing states.

Das and Singh (1974) reported that the extent of loss in fibre yield by yellow-mite varied from 38.3 per cent to 60.5 per cent depending on the protection provided in C. olitorius jute variety JRO 878.

Alexander (1975) studied the losses in sugarcane due to infection with mosaic and smut disease by conducting investigation in randomized block design.

Alexander and Rao (1976) reported that there was no significant difference in the weight and juice quality between mosaic infected and healthy canes in three varieties studied by them.

Alexander and Rao (1977) reported that the secondary spread of mosaic in canes was at random with maximum spread during June and July which also coincided with maximum vector population.

Sevacherian et al (1977) observed that a single areawise insecticide treatment of safflower fields at the critical stage before the Lygus began to disperse to other crops was sufficient on the west-side of the Sam Joaquin-Valley.

Others

Leath et al (1973) observed that forage yields from the benomyl-treated plots were significantly higher than yields from the untreated plots.

Jenkyn (1975) reported that benomyl sprays, applied monthly from September to January, increased the survival and dry-matter yield of red colour and decreased the number of opothecia of Sclerotinia trifoliorum. Two sprays increased dry matter yield in the harvest year, if applied between October and December but decreased yield in the second harvest year.

Jenkyn and Rawbinson (1977) observed that the fungicides, applied to powdery mildew (Brassica napus L. var. napobrassica Peterm) on swedes (Erysiphe cruciferarum Opiz ex L. Junell) increased root yield by up to 66, 57 and 45 per cent in 1974, 1975 and 1976 respectively. In 1975, early-sown swedes yielded more than late-sown swedes when sprayed to control mildew. Untreated swedes gave similar yields whether sown early or late. Early sowing also increased the incidence of virus diseases. Insecticide sprays decreased aphid numbers but had little effect on virus incidence; they significantly increased root yield when tested in 1975 but not in 1976

Jones et al (1977) reported that during the build up of rye-grass mosaic virus (RMV) infection, dry-matter yield was usually decreased in infected swards and the effect was confirmed when single vegetative regrowths of swards were investigated in detail. The primary cause of lower yields in RMV-infected swards appears to be because of a decrease in net canopy photosynthesis (max. decrease about 50%) and an associated increase in dark respiration (max. increase about 50%). A secondary effect of RMV infection is decrease in tillering (max. decrease about 30%) which results in a change in canopy structure and in particular a lower leaf area index. In this experiment lower light utilization by the swards is less important than the decrease in leaf photosynthesis efficiency in lowering yield.

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