Manual for Training of Extension Workers and Farmers on Alternatives to Methyl Bromide for Soil Fumigation

Cover photo
Training of trainers: soil solarization and biofumigation

Manual for Training of Extension Workers and Farmers on Alternatives to Methyl Bromide for Soil Fumigation

Prepared by
R. Braga
R. Labrada
L. Fornasari
and
N. Fratini

Contacts:

Dr. Ricardo Labrada, Weed Officer
Food and Agriculturen Organization of the United Nations - Plant Protection Service
Via delle Terme di Caracalla
00100 Rome, ITALY
Tel. +39-0657054079
Fax. +39-0657056347
E-mail: Ricardo.Labrada@FAO.org
Website: http://www.fao.org/WAICENT/FAOINFO/AGRICULT/AGP/AGPP/IPM/Weeds/Default.htm
Website: http://www.fao.org/WAICENT/FAOINFO/AGRICULT/AGP/AGPP/IPM/Web_Brom/Default.htm

Mr. Rajendra Shende, Chief
Energy and OzonAction Unit
Division of Technology, Industry and Economics
United Nations Environment Programme
Tour Mirabeau
39-43 quai André Citroen
75739 Paris Cedex 15, FRANCE
Tel. +33 1 44 37 1450
Fax. +33 1 44 37 1474
E-mail: ozonaction@unep.fr
Website: http://www.uneptie.org/ozonaction.html

This document is available on the FAO website at:
http://www.fao.org/WAICENT/FAOINFO/AGRICULT/AGP/agpp/IPM/Web_Brom/Default/htm and on the UNEP OzonAction website at: http://www.uneptie.org/ozonaction.html

CONTENTS

PREFACE

Methyl bromide is a broad-spectrum fumigant used worldwide for the control of soil-borne pests. When used as a soil fumigant, methyl bromide gas is usually applied to the soil before the crop is planted and the soil is then covered with plastic tarps. The treatment effectively kills various soil organisms, but once the tarps are removed, part of the gas will eventually enter the atmosphere.

The presence of bromine in the atmosphere is fatal due to its strong ozone-depleting action. For this reason methyl bromide use will be reduced and phased out completely by the end of the year 2015. Moreover, there is increasing resistance to acceptance of commodities produced using methyl bromide on the part of consumers. Therefore, it is essential to find appropriate alternatives that can be used effectively for the control of soil-borne pests. This approach should aim to make farmers aware of the need to discontinue the use of methyl bromide and to educate them in the application of newly developed alternatives.

The Integrated Pest Management (IPM) approach is the key to developing a comprehensive training programme for farmers on new alternatives. The basis of this approach is the training of extension workers and other agents who work closely with farmers.

Experience has shown that the majority of farmers are not persuaded to apply new innovative techniques by simple field demonstrations. This approach is a waste of time and money in many areas where it is implemented. Therefore, the second step in the IPM approach should be the training of farmers by building on so-called “Farmer Field Schools” where farmers learn to apply, adapt and improve the new control technologies.

This manual aims to provide guidance to extension workers in matters related to the setting up and conduct of Training of Trainers courses, as well as Farmer Field Schools, on alternative technologies to replace the use of methyl bromide as a soil fumigant. It provides a framework, relevant information and tools to build on these activities according to specific needs.

It is important to point out that, although FAO has vast experience in IPM projects in many developing regions of the world (including the setting-up of Farmer Field Schools), no experience specifically related to methyl bromide yet exists. In time, this manual will doubtless have to be revised and enriched with new elements and experience from countries where Farmer Field Schools have been developed for phasing out methyl bromide soil treatment.

The manual was prepared by a group of specialists familiar with Training of Trainers and Farmer Field Schools. It is aimed at extension officers and development agents who are

responsible for assisting those farmers who at present use methyl bromide as a soil fumigant.

We thank INIAP (Instituto Nacional Autónomo de Investigaciones Agropecuarias - Ecuador) and CIP (Centro Internacional de la Papa - Perú) for their courtesy to allow the use of the drawings reproduced (modified) in this publication.

This publication was prepared by the Food and Agriculture Organization of the United Nations (FAO) and sponsored by the United Nations Environment Programme – Division of Technology, Industry and Economics (UNEP-DTIE), as part of its OzonAction Programme under Montreal Protocol's Multilateral Fund.

Raimundo Braga EMBRAPA, Fortaleza (BRA)
Ricardo Labrada FAO, Rome (I)
Luca Fornasari Montpellier (F)
Nora Fratini Rome (I)

List of Acronyms

I. INTRODUCTION

Methyl bromide, or bromomethane (MeBr), is a highly effective fumigant used to control soil-borne pests in several crops worldwide. One of its main uses is for soil fumigation of seedbeds of tomatoes, peppers, eggplants, tobacco, strawberries, ornamentals and other crops. It is estimated that more than 80% of the global consumption of MeBr is for soil fumigation.

MeBr has been defined scientifically as a chemical that depletes the earth's ozone layer. Its ozone-depletion potential (ODP) is 0.4, i.e. greater than the admissible threshold of 0.2. Bromine released from applied MeBr is considered to be 40 times more efficient than chlorine in breaking down ozone, on a per atom basis.

All this information has led to a planned phase-out process in developed and developing countries, under the Montreal Protocol on substances that deplete the ozone layer. The complete phase-out of MeBr in developed countries is foreseen by 2005, while in developing countries a reduction should take place during the 2000s with the process completed by the end of 2015.

The phase-out implies that countries should develop viable alternatives to replace the present use of MeBr. These alternatives should be technically effective in controlling soil-borne pests, environmentally safe, easy to use and economically feasible for farmers. In many cases, it is unlikely that a single control alternative will be available to replace MeBr. It would probably be necessary to combine two, or more, control measures in order to achieve results as technically effective as MeBr.

Adoption of Integrated Pest Management (IPM) is also part of the solution. No new "magic potions" will be available for soil pest control, and regular assessment of pest organisms in soil will be required to make adequate pest control decisions.

IPM is a decision-making process that considers all possible control measures, such as cultural, mechanical, biological and chemical ones, selecting a control method to suit each individual situation. Where chemical control is indicated, specific pest populations are targeted for treatment at the time when they are most vulnerable rather than simply carrying out a general pesticide application. Through the use of appropriate control methods and their proper application, IPM can result in a reduction in the use of pesticides, including the fumigant MeBr.

Thus, the IPM process begins with the farmer (who takes the decisions in the field) and not the pest. In order to take effective decisions, farmers need to understand the agro-ecosystem, how different components in the field interact, and how their decisions affect the balance. Agricultural researchers need to understand local needs and provide farmers with a wide range of options that they can adapt and apply to their own individual situation. Agricultural extension and/or plant protection services should help facilitate this process, so that researchers understand the needs of farmers and the farmers themselves are able to adapt the available technologies.

Training of Trainers (TOT) and Farmer Field Schools (FFS) are two core activities of the IPM training and extension process. The former is an effective way to help bring extension workers up to date on newly developed MeBr alternatives and on IPM in general. The knowledge gained will enable them to organize Farmer Field Schools for the farmers in their area.

Farmer Field Schools are based on ecological principles, participatory training and non-formal educational methods. This model emphasizes learning through experience and dealing with real field problems. Training according to such principles implies facilitation of the learning process rather than instruction. In addition, FFSs give farmers the opportunity to experiment, sharpen their observation and research skills and take the initiative, adapting the alternatives to local conditions. In fact, one of the most important lessons learnt in the past by extension services has been that generalized recommendations to farmers from extension and research need to be carefully examined, tested and adapted by farmers themselves, according to the specific local conditions in their area. FFSs enable this process by enhancing the existing knowledge and skills that the farmers have gained through years of experience.

FAO's experience on pest management in various countries in Southeast Asia, Africa and Latin America has demonstrated that the training process is vital for the adoption of new pest control methods by farmers. This training should not be merely a field demonstration, or the organization of isolated field days. Usually farmers are eager to adopt alternative control technologies that they themselves have tested and improved.

This manual sets out the steps required for conducting comprehensive training on new alternatives to replace MeBr. It is the first edition, and we feel sure that the elements given here will be enriched and improved upon by future field experience in methyl bromide phase-out in different countries.

II. TRAINING OF TRAINERS

Training of trainers (TOT) is the prerequisite for an effective implementation of technical solutions in the field and an important step for their dissemination. The TOT, which is developed following a specific curriculum, consists of basic crop management skills and non-formal educational principles, as well as field practices such as agro-ecosystem analysis and testing of new alternatives in the field.

FAO/18351/P. Cenini

Training Of Trainers in a classroom

1. Preparatory workshop

A starting point for the training process is the identification of MeBr uses / applications and alternatives available in the country, or region in question. This information is essential when preparing the curriculum for the training. It is important to bear in mind that trainers should come to farmers with concrete proposals of alternatives, which farmers will later adapt to the local conditions.

The workshop, which normally lasts one or two days, should also identify the main elements of IPM to be applied during the training. These could be methods for regular assessment of pest organisms and other relevant procedures.

Participants in the workshop should be agricultural technicians from national institutions as well as from Non-Governmental Organizations, extension workers, agricultural associations and enterprises.

The main objectives of the workshop are to:

- raise awareness on the MeBr issue;
- inform interested parties and local institutions of the overall training process on MeBr alternatives;
- identify major soil-borne pest problems in crops currently treated with MeBr, and the IPM elements to be used;
- identify available alternatives and discuss their feasibility;
- based on the above information, prepare the curriculum for TOT; and
- identify the participants, i.e. agricultural technicians and extension workers, for the TOT.

2. Training of Trainers

Once the alternatives and IPM elements have been identified and the curriculum prepared, the TOT will follow.

The main participants in the training are agricultural extensionists, plant protection workers and other agricultural technicians. In some cases, they may have very little knowledge of IPM and MeBr alternatives.

During the training participants are acquainted with the new alternatives, methods to assess soil-borne pests, aspects related to farm production and the agro-ecosystem, with emphasis on IPM. The focus will be on hands-on activities in the field and facilitation skills based on non-formal adult education.

Usually the main facilitator is a specialist in MeBr alternatives and IPM. Trainers should have knowledge and experience of the organization and running of Farmer Field Schools (FFS).

The TOT is normally delivered throughout the crop season in order to follow through and observe the results of the experiments. However, in some circumstances this training may be shortened if extension workers already have sufficient knowledge and experience of IPM. One possibility could be to organize an initial short TOT with complementary field days later. In this way, the technicians will have time to assimilate all the new elements related to IPM and MeBr alternatives. The TOT may also be conducted in parallel with an FFS.

The main objectives are to:

- provide information and raise awareness on the environmental problems posed by and consumer resistance to MeBr;
- impart new MeBr alternatives and IPM elements;
- assist trainers in improving their skills to select and adapt the most feasible alternatives to local conditions; and
- improve training skills and learn how to set up Farmer Field Schools to facilitate improved decision-making by farmers.

The activities of the TOT are various and will depend on the duration of the training and the problems to be solved. Using a participatory approach to curriculum development (as suggested in the “Tool kit” sponsored by the Global IPM Facility at FAO, see also the guidelines modified in Chapter V), these may be:

- Field experiments
- Concept-specific learning activities
- Agro-ecosystem analysis

<u>2.1. Basic field experiments</u> take the place of demonstration plots, which were widely used in the past. Field experiments place more control of the learning process in the hands of farmers. The experiments promote a scientific approach to problem solving, including analysis and conclusion. Demonstration plots may have a role to play in some situations, but in general are less participatory and do not instil the same level of scientific approach in farmers.

These experiments may be:

- crop management practice
- assessment of the crop growth
- assessment of soil-borne pests and other elements of the agro-ecosystem

Case studies and field visits may also be part of the TOT field training. During the training, the participants may need to visit farmers' fields, or research stations, to observe case studies, learn about techniques that are in progress, or gain knowledge from other experiences in order to solve problems such as a new pest, or pathogen, seedbed establishment, etc. Case studies enable the participants to learn about existing problems, or problems that have been solved successfully.

<u>2.2. Concept-specific learning activities</u> are one to two hour-long learning activities which teach a specific concept that complements the topic of the training. For example, "root structure and depth" might be an activity related to water management, "biological control" might be an activity of pest management. The activities are always hands-on for better learning and comprehension. Digging up and analyzing root

structure, or *Trichoderma* inoculation, would be good examples of the above methods. Concept-specific activities follow adult learning concepts and the learning cycle.

2.3. Agro-ecosystem analysis is a two-hour activity that integrates observations, participant experiences and decision-making into one activity. The process of Agro-ecosystem Analysis allows participants' experience and knowledge to be brought together with new ecological concepts. During this activity, farmers have an opportunity to explain and defend their decisions. The process increases the confidence and skill of farmers, as well as building group cohesion (see Chapter V).

3. Team building and group dynamics

Team building and group dynamics activities are important features of the training process. Specific exercises encourage interactions, which helps in developing leaders and promotes cooperation and good relationships. Through team building and group dynamics activities, decision-making skills and value re-orientation are enhanced and inculcated in the participants.

4. Evaluation

Evaluation is part of the learning process (see Chapter V). Pre- and post-training tests may be used as evaluation tools. The tests may consist of questions intended to demonstrate the trainees' level of knowledge related to MeBr phase-out as well as on alternative technologies for its replacement, IPM principles, and the FFS approach and model. Based on the results of the pre-training test, the TOT facilitator can establish an accurate strategy for the TOT activities. The questions asked at the beginning should also be asked at the end in order to assess the knowledge gained during the training. Basic questions/topics could be as follows:

1. Problems posed by MeBr and the average amount of MeBr used by farmers in the area;
2. Main soil-borne pest organisms (arthropods, diseases, nematodes and weeds) in the crops currently treated with MeBr and alternatives;
3. IPM principles and elements;
4. FFS approach and non-formal adult education theory;
5. Description of various feasible alternatives.

In the context of the training of trainers, there might be some activities that need to be organized once the main training is over. These activities should be implemented in order to refresh the knowledge acquired by trainers, or to keep them up to date with new elements. Since long-term TOTs are not advisable in the case of MeBr alternatives, there are other useful activities that can be carried out once the main training exercises are finished. One of these activities is the agro-ecosystem analysis (AESA).

III. FARMER FIELD SCHOOLS

The next step in the training process is the organization of a Farmer Field School (FFS), aimed at the training of farmers on new alternatives and IPM.

The conventional approach to farmer training, until recently, has been the organization of field days where farmers were given demonstrations of new technologies. The problem with this type of training is that farmers are passive participants; they listen to the advice given by extension workers, or agents, of agrochemical companies, but do not participate in the process of adaptation of the technology. The result is that farmers continue to use the traditional methods and are not encouraged to try out new technologies.

FFSs provide farmers with the opportunity to test the alternatives and to improve upon them by introducing new elements. A field plot shared by several farmers is used to test the alternatives. The main result of this training is that the farmers adopt the new alternatives voluntarily and implement them in their field plots.

The trainer who guides and facilitates the FFS should be an extension worker, plant protectionist, or other technician previously trained in a TOT, while the participants

FAO/19881

Farmers establishing nurseries in a Farmer Field School are growers organized into existing groups, or selected by the trainer in close consultation with the community leader.

The FFS is usually a medium-term exercise, which may last the whole cycle of the crop. When MeBr is applied to soil for producing seedlings to be transplanted, the duration of the FFS should be the seedling-production cycle.

An FFS normally involves three main phases: planning, implementation and evaluation.

1. Planning

Planning of an FFS involves the preparation of the training and should take into account the different aspects of the farming community to be trained. These elements can be:

Assessment of MeBr use and consumption, which should serve as a starting point for the analysis. The main data to be collected should be:

a. The number of farmers currently using MeBr as a soil fumigant, crops and application rates. The table below illustrates the initial data required.

Crops Using MeBr	Farmers	Seedbed Area (ha)	Methyl Bromide Consumption (kg)
Green pepper	30	0.2	160
Melons	100	0.5	400
Tomatoes	200	1.0	800

b. Methods of application of MeBr: It is important to know whether only farmers apply the fumigant, or whether they pay for the services of a fumigation company.

Socio-economic status of farmers: The educational level of farmers and their economic status

- Farmers' awareness and knowledge:
  a. Awareness about environmental problems posed by and consumer resistance to MeBr and the need to replace its use.
  b. Awareness and knowledge about the development of new alternatives, their effectiveness, etc.

There are other steps in the preparation of FFSs, such as identification of the community leader(s), identification of farmers to be trained and alternatives to be taught.

- The identification of the community leader(s) is vital to facilitate the involvement, interest and participation of growers. Interaction with the leader helps to identify and organize the growers, to establish and conduct the FFS and to carry out the follow-up actions.

- The identification of farmers to be trained takes place at a meeting led by the facilitator with the leader and the growers. At this meeting the FFS process is also explained in detail to prospective participants.

- Alternatives to be taught
  The trainer, or facilitator, who is already familiar with the treated crops and major pests, should be able to select the most promising alternatives for farmers to test during the FFS. The trainer should obviously have prior knowledge of the alternatives already studied and validated in the country.

- Another early step in the organization of FFSs is the establishment of a farmers' group. Usually, the group consists of 25 to 30 growers with common interests, e.g. growing the same crop and facing the same pest problems. The size of the group depends on the number of farmers who can comfortably work together with one facilitator. The participants are divided into groups of five to six people so that all members of the farming community can better participate in field observations, analysis, discussions and presentations.

- The duration of the FFS should in general be the length of the crop-cycle. An FFS may extend beyond one season if necessary, but can rarely be effective if shorter than the cycle of the crop. This depends on the crop and problems dealt with in the FFS.

- The schedule of the training is based on crop phenology, e.g. seedling issues are dealt with during the seedling stage. Lessons, or exercises, are usually four to five hours long and are held on a weekly basis.

- The FFS activities take place mainly in the field plot. However, it is important to have a shaded area close to the field plot to meet for discussions and other activities.

2. Implementation

For FFS implementation, farmers will:

1. Select a common site, which is normally situated in the community where the growers live. Its size will depend on the crop and its phase. Seedbeds may require a smaller area than planted crops.
   Some villages have communal lands that can be used free of charge, others may request inputs, or compensation in case of lower yields in experiments, etc. It is important to bear in mind that this land has to be maintained by the group of farmers.

2. Select the crop on which the exercises will be carried out. Obviously crops commonly treated with MeBr should be selected.

3. Implement the alternative. The technologies to be tested by farmers should be selected previously by the trainer and discussed with farmers. Once the alternatives are chosen, farmers will be responsible for setting up the activities in the field, examining and making decisions on how to apply the technique proposed.

   A comparison should be made between the alternative treatments being tested and conventional treatment with MeBr. The trainer should warn the farmers that in some cases MeBr treatment may be technically more effective, but since its phase-out is imminent, effective alternatives need to be found.

   Acceptance of the alternatives will depend on the success of their implementation and adaptation to local needs, so evaluating positive results from alternatives is a key element for making decisions.

   Other field activities and exercises necessary to cover other IPM issues may require longer periods than those needed for learning the new alternatives.

   Through these activities, farmers should be able to monitor pests and beneficial organisms and to know their life cycle. If the exercises proposed are adapted to the local conditions, they can provide practical experience on the inter-relationships existing among the components of a specific agro-ecosystem.

   Trials and exercises should also provide a good understanding of the basic principles of IPM in order to apply them in growing areas. The main IPM principles that should always be observed are: (1) growing a healthy crop and the need for healthy soil; (2) conserving natural enemies and understanding the eco-system; and (3) carrying out regular field observation and monitoring of pest organisms.

3. Evaluation

The FFS, like the TOT, should include evaluation of participants both before the course and at the end. For this purpose, a test should be set to assess the level of participants' knowledge of MeBr phase-out and of the available alternative technologies.

The first test will contain more elements for the preparation of the FFS programme while the final test will show the level of understanding achieved by farmers during the training.

The tests should consist of some basic questions, such as:

- identification of soil arthropods, nematodes, disease symptoms and common weeds

FAO/18359/P.Cenini

Farmers being trained in a Farmer Field School evaluate field trials

- types of pesticides currently used for the control of soil-borne pests knowledge of MeBr problems
- possible, or real, new methods to control soil-borne pests
- other IPM techniques

The final evaluation is an opportunity for trained farmers to pass on information about the alternatives, adaptations and other details. Some time may be dedicated to this exercise during one particular day, and the farmers should be able to describe:

- the efficacy of new alternatives
- how to use them
- the difference between new alternatives and MeBr treatment, emphasizing possible technical and economic advantages
- the characteristics of major pests and crop losses caused
- IPM principles

After the FFS, extension workers, under the supervision of the TOT trainer, should follow up the application of the alternatives in the farmers' fields in order to ensure their adoption and continued use.

To ensure successful application, the follow-up should consist of visits to farms on a monthly basis to ensure the correct application of new alternatives and rectify possible shortcomings.

Trainers will also benefit from such visits. Farmers' experiences would provide useful feedback for future research and training activities on MeBr alternatives in the country.

The successful results achieved with new alternatives should be extended to other farmers who are still using MeBr. In many cases, experienced farmers may serve as facilitators of new FFSs.

IV. EXAMPLES OF EXERCISES FOR TOTs AND FFSs

1. Understanding the soil system

Since we are dealing with soil fumigation and / or soil treatment for pest control, understanding the soil system is a good subject to include in TOT and FFSs related to MeBr alternatives.

It is a difficult element for trainers and farmers to deal with because much of what takes place underground is not easily visible. As a consequence of these difficulties in observing interactions in the soil, greater emphasis needs to be placed on developing exercises to assist in understanding cause and effect relationships.

This single group activity is a key one in understanding soil pests. To begin with, participants are asked to list major elements associated with the soil system. They then carry out an exploratory exercise in which they identify the main elements associated with the soil system, following which they are asked to draw a simple diagram containing five to six of the most important factors and their interrelationship. The facilitator uses one of the diagrams, or provides a synthesis of all of them, and draws key conclusions.

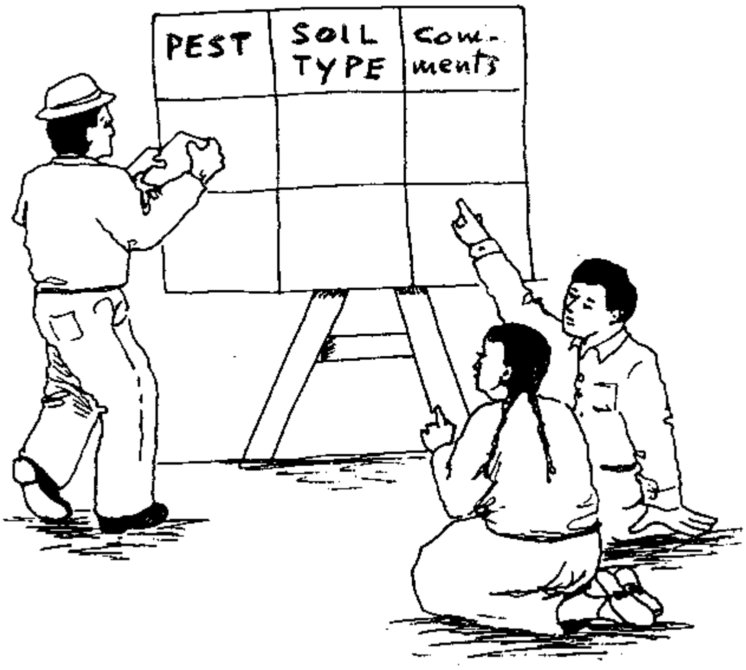
In the case of FFSs, the trainer should give explanatory lessons about the soil system and soil-borne pests, which may require more time than is the case of TOT.

The main goal is that trainers, or farmers, should be able to list main factors, living organisms and characteristics associated with a soil system. The exercise may last two to three hours and office materials are required, such as paper, pens, adhesive tape, etc.

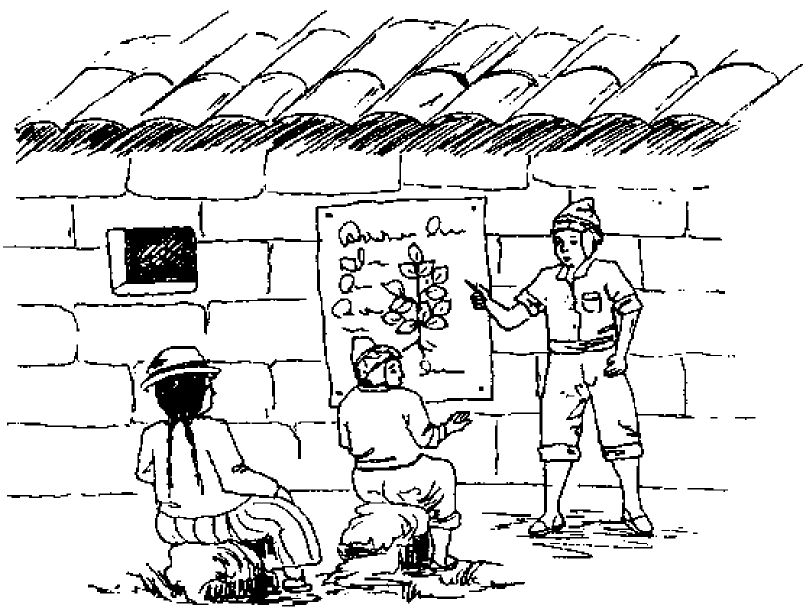
The detailed procedure is as follows:

1. Ask the trainees to list the main elements associated with the soil system. This should include soil characteristics (texture, structure, pH, moisture and others) and existing organisms (arthropods, seeds, roots, micro-organisms). The trainer should always help them to organize the list.

2. The trainees are requested to divide into small groups and each group draws up a list containing two columns showing the existing organisms and soil characteristics. Once the groups have finished this work, they will be asked to present their results in a summary diagram. Presentation of the results will enable the participants to discuss the issue in detail.



3. Following the discussion, the trainer should point out major conclusions and stress some difficulties in the assessment of soil-borne pests in the field. Some theoretical concepts should also be given by the trainer.



The main questions to be emphasized in this exercise should be:

- Arthropod and nematode survival in soil

- Seed viability and germination
- The soil factors that can be manipulated by growers
- The factor that has the greatest incidence and relationship with others

2. Assessing soil-borne arthropods (an exercise for FFS)

This exercise aims at listing and describing the characteristics of the main arthropods in soil, particularly insects, found in soil samples taken (a) before the preparation of the seedbed for the application of the new alternative and (b) 30 days after the application.

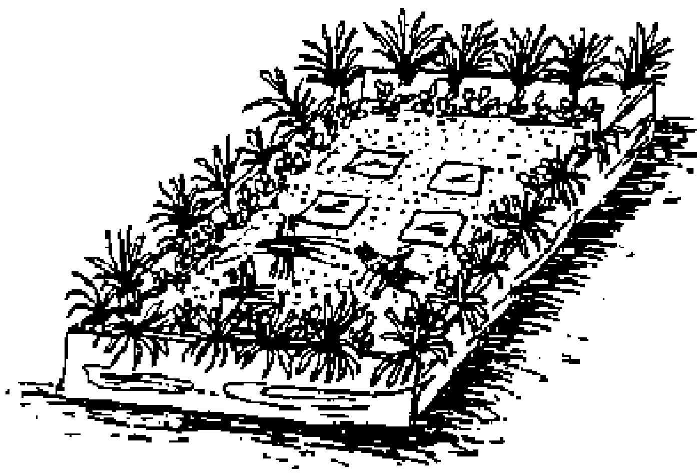
The main goal of this exercise is to list and recognize the main characteristics of existing insects in soil. Normally this activity takes around four hours (x 2) and requires only office materials, hand lens, vials and alcohol. Drawings of beneficial and pest insects may be useful to describe and identify organisms.

The procedure is as follows:

a. Since the subject will probably be new to growers, it starts with a discussion and questions asked by the facilitator. The main elements to point out are:

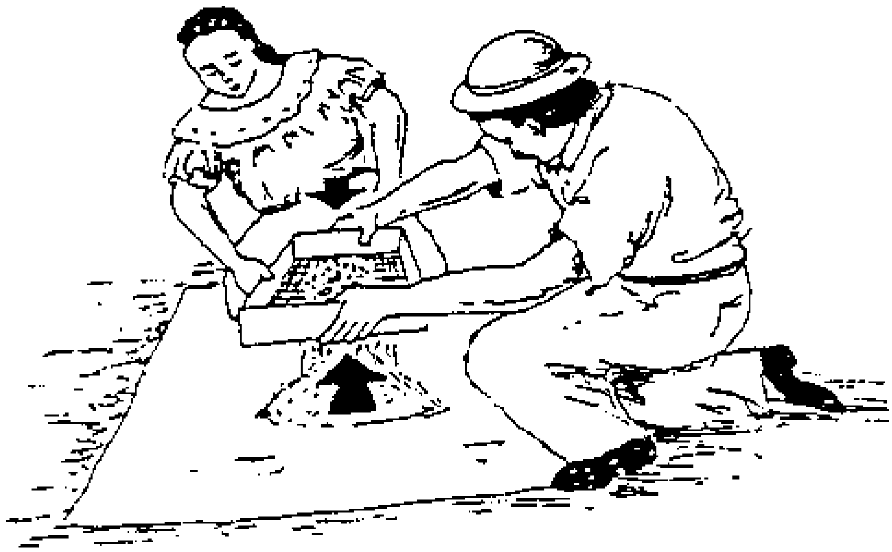
   - Types of arthropods (insects) living in the soil
   - Methods to assess their population
   - Methods for their collection
   - Damage caused to crops
   - Methods for their control

b. Before the application of the new alternative, each small group of growers will use a frame (30 cm x 30 cm) which is laid down at various spots in the plot for



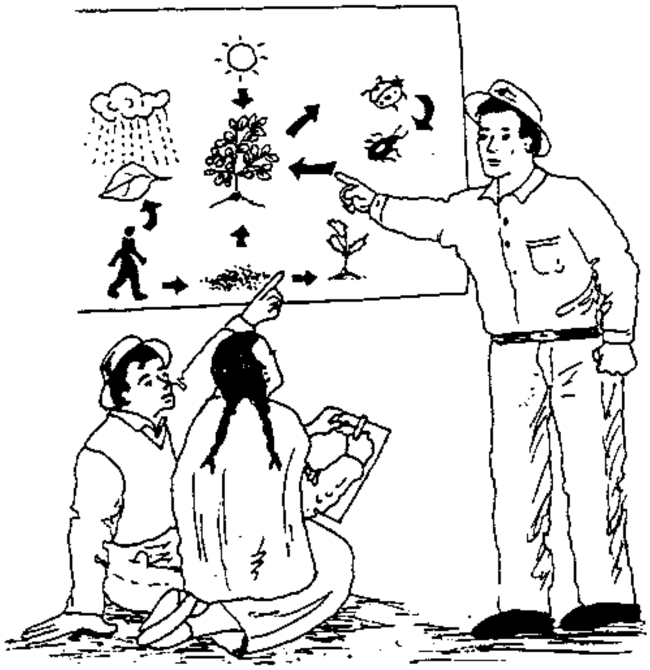
collecting soil samples at a depth of 30 cm. The samples are taken in plastic bags to a shaded area for further examination.

c. The soil is then screened using sieves to separate soil fractions and collect any organisms present, which are put in vials for identification and drawing.



d. The growers will make a drawing of all organisms found in the soil samples.

e. Discussion should take place in order to define the type of insects found, either beneficial ones, or pests, and the ways to control the latter.



f. Thirty days after the application of the alternative, the growers and facilitator will repeat the same procedure and will compare the insects collected before and after the application of the alternative. Discussion on the efficiency of the alternative in controlling soil arthropods should follow.

The main questions and points to emphasize in this exercise are:

- General explanation of the alternatives used for controlling soil-borne pests
- The method for sampling soil insects
- The efficiency of the alternative in controlling insects in soil and ways to improve it

3. <u>Assessment of weed stand (an exercise for FFS)</u>

The idea of this exercise is to train farmers in methods to assess weed populations in the field and to describe the characteristics of the major species found. Such assessment will also be useful to determine the effectiveness of the alternative in weed control.

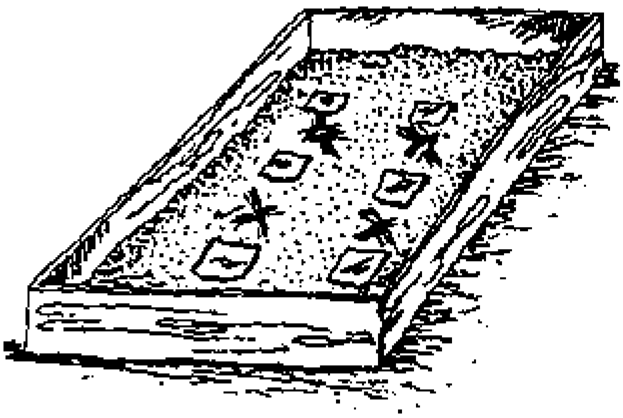
This exercise, which may last up to four hours, will require a wooden frame, plastic bags and office materials. Also in this case, illustrations of weeds may be useful to describe and identify them.

The exercise starts with a brief introduction by the trainer about the losses caused by weeds and the importance of their control. Immediately after this, the trainer will ask various questions, such as:

- Types of weeds common in the fields
- Methods to assess weed stand
- Damage caused to crops
- Feasible ways for weed control

The best way to assess weed control is to carry out a comparison between weed density in the area treated with the new alternative and an untreated area.

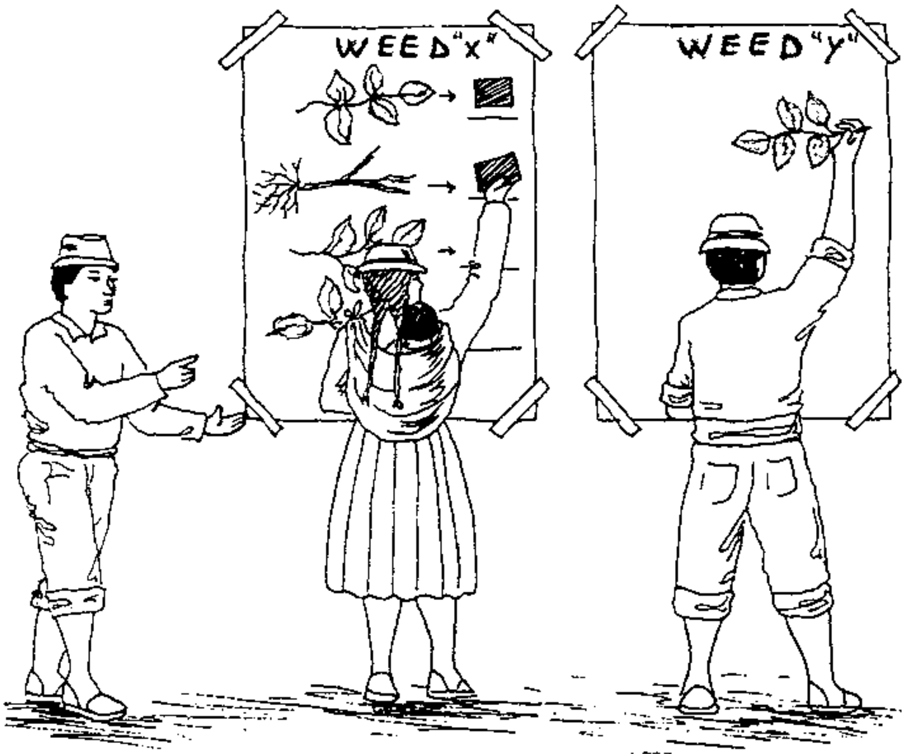
A month after the application of the new alternative the groups of farmers will place a frame (50 cm x 50 cm) diagonally in three or four different spots in the field. The farmers will identify the weed species present and count the individuals of each species inside the frame. The whole weedmass contained within the frame should be



collected in plastic bags for weighing in a shaded place.

Once the number of each species and the whole biomass have been recorded, the trainer should ask the farmers about the results obtained in the treated and untreated areas in order to evaluate the efficacy of the treatment.

After this first task, the trainer may ask farmers to describe some of the characteristics of the major weeds found in the field. The trainer should be able to identify the species found and to explain the differences between annual and perennial species, reproductive processes, etc.



Farmers should also discuss which species are not well controlled by the new alternative and suggest complementary methods to control them. Farmers should draw the main weed species and give a brief description of the plants, including their mode of reproduction.

The main questions to be stressed during the discussion should be:

- Characteristics of weeds, reproductive processes and losses caused
- Methods for measuring weed population densities
- Information about the effectiveness of the alternatives used for weed control
- Methods currently used for weed control

V. Participatory curriculum development

1. General

A participatory approach is recommended for the development of the plan of the training, in order to use successful models, but based on participants' own ideas, results and "Best Practices". For this purpose, the following guidelines (modified from the "Tool kit" sponsored by the Global IPM Facility at FAO) are provided. They include the learning activities mentioned in Chapter II:

- Field experiments
- Concept-specific learning activities
- Agro-Ecosystem analysis

2. Guidelines

It is a very simple process. It is just a matter of following the steps and instructions reported below.

Facilitation methods

- Divide the whole group into small groups of 5 persons per small group. The small groups will work together on a regular basis.
- Begin each day with body stretching. Include ice-breakers, energizers and group building activities in the programme - especially after lunch and when participants are tired.
- Participants should present their materials from the small group in a rotation so that all persons in the group have an opportunity to present.
- The whole group should discuss the day's progress, "good points" and "points to be improved" at the end of each day.

Section 1: Adult Education Theory and Practice (2 days)

- Read topic # 1 on Adult Learning Process then go through the exercises in small groups. Present the results of each small group to the whole group.
- Read topic # 2 on Farmer Field Schools. How are the community study groups different than traditional demonstration plots? How do study groups use adult learning concepts more effectively than demonstration plots? Why do adults need an opportunity to "convince themselves"?
- Discuss your experiences with facilitation in topic # 3.
- Carry out activity # 4 (What is this?) in a natural setting, possibly a field situation, where plants, insects, diseases, etc. are available.
- Discuss topic # 5, the Self-Evaluation Matrix for Facilitators. Do you always follow the "Best Practices" for facilitation?

Section 2: Field Experiments (1-3 days)

- Topic # 6. Discuss how experiments could be improved first based on your experience. Discuss why an experiment is not "research", but a learning activity. Discuss why an experiment run by participants is better than a demonstration plot in which participants are more passive observers.
- Make a list of critical concepts from the "Best Practices" that can be illustrated through field experiments (e.g. cultural practices, varieties, local needs for pest management, etc.).
- Use this list to design at least 2 field experiments per focus crop in small groups. Note: A community study group can usually only maintain 2 or 3 experiments in a season.
- Each group should share their experiment with the whole group.
- The whole group should then prepare a final draft of 2 to 3 studies per focus crop for the community study groups.

Section 3: Concept Specific Learning Activities (2-3 days)

- Divide the activities described in Chapter II across small groups. Each small group should do at least 2 of the activities, discuss the activity, and prepare a presentation for the whole group on the activity. [Even better if all groups do all activities - if time is sufficient!]
- Discuss for each crop, and within "Best Practices" the specific concepts that should be studied by farmers to better understand how to implement these practices. Make a list by writing the topics on a large sheet of paper. Some concepts will be similar and can be combined. Some concepts will be to complex and need to be broken into sub-concepts. Finalize the list.
- Now, each small group should prepare 2 activities and test them by carrying them out. The exercises will be presented to the other groups for comments and revision.
- Compile the activities for the whole group.

Section 4: Agro-Ecosystem Analysis (2-3 days)

- Do activity # 8 on defining "an ecosystem". What are good words in local languages to describe the concept of an ecosystem? How are your traditional ideas of nature and environment connected to managing ecosystems? How are the "Best Practices" connected to ecosystem management?
- Conduct activity # 9. Remember that each small group should present its results and facilitators should assist by asking questions, inviting other farmers to ask questions and provide answers, or own experience, and provide inputs according to experience and knowledge.
- Improve the process in activity # 9 by preparing better guidelines on what to observe, discuss, and where to focus management decisions for each week of the focus crops. The group may decide to make a crop development chart that includes each critical crop stage (e.g. seed, seedling, early vegetative, etc.) and the appropriate "Best Practice" for the crop stage (e.g. management of soil, agronomy, pests and diseases, water, market, etc), including appropriate knowledge and information needed to make good decisions (see section 2 and 3 above).

3. Topics

- **Section 1: Adult Education Theory and Practice**

1. The Adult Learning Process

   Adult learning process differs from child learning, since it is influenced by previous experience and - to be effective - needs to be supported by evidence of practical results. Learning depends essentially on the trainee and the trainer can only stimulate him and facilitate the discovery and understanding of facts and situations. Discussion with trainers about informal teaching will help trainers to better understand the training process and the nature of the activities.

   Exercise: Discuss with participants about the way adults learn. Identify important conditions for adult learning. Ask participants to write their ideas before the discussion. Ask to write the most important thing participants learnt in their everyday life (not in school) and that affects their everyday life and ask to describe under which circumstances they learnt it (why they learnt it, how, who / what helped to learn).

2. Farmer Field Schools (FFS): A Group Extension Process Based on Adult Non-Formal Education Methods

   As previously discussed, this approach allows farmers to play an active role in the learning process. This kind of learning assumes that trainees already possess knowledge in the field and a rich experience, and also that they may have wrong ideas about agricultural practices and the way to solve agricultural problems. Therefore the facilitator has to guide them through this process. Usually the groups have around 25 participants.

3. Facilitation Skills

   The goal is to have the participants actively involved in the discussions, through the recognition of the importance of individiual participants and giving them a chance to speak, ask questions and aswering to them in a way they feel satisfied. All this is part of facilitation.

4. What is this?

   A good teaching method is to ask questions to participants to stimulate their own analysis and understanding. There are many ways to answer the question “What is this?”. Instead of saying the name of the organism, a better way to answer is to ask another question, such as “Where did you find it?”, or “Where ther many?”, in order to stimulate the learning process. After this exercise you should be able to give several answers to the question “What is this?” and none of them should be its name.

   Exercise: Go to a field crop and stimulate participants to ask questions about that specific ecosystem (e.g. pests, soil type, beneficial organisms, water, etc.), such as: “What is this?” Write the answers to this question. The trainer should provide only technical information, answering something like : “It is a good question – where did you find it? What was it doing? Did you observe it in the past? What do you think?” – continue to ask questions. Try not to give the direct answer (!) - for instance saying “It is a pathogen attacking the plant. Usually it does not cause serious injury to the plant, unless climatic conditions are ...”. (duration: one hour)

5. Self-Evaluation Matrix for Facilitators

Facilitation Skills	Bad	Good	Best Practices
1. Preparation	Poor	Good	Accurate Preparation of All Topics
2. Study site / Field	Warm / Uncomfortable	Comfortable	Excellent Preparation (Signs, etc.)
3. Goal	Not Defined	Well Defined	Clearly Identified, but Illustrated with Various Tools / Examples
4. Time Frame	Not Defined	Well Defined	Discussed with Participants
5. Introduction	No	Provides Background	Rich in Information, but not Lengthy
6. Steps / Procedure	Unclear	Clear & Complete	Repeat / Provide Details for Complex Tasks
7. Go from one Group to Another	No	Yes – As Needed	General Discussion
8. Answer to Questions	Direct	Questions / Explains the Context, etc.	Varied & Involve the Group (“*Who can Answer?*”)
9. Time Management	Poor	Keeps on Track	Verifies, Adjusts, Stimulates, etc.
10. Ask questions	No	Yes	Stimulates Input from Participants, Analysis
11. Discussion	No	Yes	Stimulates Input from Participants, Analysis
12. Summary	No	Yes	Varied Style with Contribution from Participants
13. Who speaks?	Facilitator	Facilitator & Farmer	Mainly Participants
14. Continuous Evaluation	No	Yes	Varies Style – Questions, Diagrams, Repeats
15. General Evaluation	No	Yes	Varied: Informal, Tables & Figures, etc.
16. Organization of Next Meeting	No	Announced	Contact for Follow-up before Next Meeting
17. Enthusiasm / Motivation	Scarce	Yes	Stimulates Learning Process
18. Kindness	Scarce	Yes	Favors Communication & Learning Process

- **Section 2: Field Experiments**

6. Organize field experiments as described for FFS (Chapters III and IV)

- **Section 3: Concept Specific Learning Activities**

7. Conduct activities as suggested in Chapter II

- **Section 4: Agro-Ecosystem Analysis**

8. Introduction of the concept of Ecosystem

   It is important that participants are aware of the role and interrelationships existing among organisms and of the fragility of the whole system. There are different levels of functions in all ecosystems. The first level is represented by plants (producers), the second by herbivores (consumers), the third by animals feeding on the second level and the fourth by decomposers (e.g. bacteria and fungi). A given crop may represent an agro-ecosystem. This activity, which will require 1.5 – 2 hours, may be conducted during the FFS exercise. The participants will conduct field observations in groups, taking notes, for ten minutes and then will get together again to discuss their findings. Each group will explain its observations to all participants. A general discussion will follow, with the guidance provided by facilitators.

   Possible questions to foster the discusion:
   - Which / how many interrelationships did we find?
   - What would happen to the system, if we would eliminate one component (e.g. trees, water, sunlight, birds, phytophagous insects, spiders, weeds, plant pathogens, etc.)?
   - Which elements do we frequently alter in our fields?
   - Which should be the environmental components that would be affected by such changes?
   - How often do we think - or do we think at all – about these relationships when we decide to take actions in the field – for instance for crop protection practices?

9. Agro-Ecosystem Analysis: Making a Crop Management Decision

   Choose one crop of interest in the area considered as an example of ecosystem. The components of that ecosystem will be studied conducting weekly observations throughout the FFS activity. Participants will study the morphology of the plant, its agronomy, plant pests and the natural enemies of these pests. Agro-ecoystem analysis (AESA) is a way to place the factors considered into groups and in a context that allows to take decisions, considering various aspects. The old IPM approach was based on the Economic Threshold Level (ETL) to justify pest management decisions, but the rationale of that approach was limited, since it did not consider the other factors in the agro-ecosystem in agricultural production.

The training may be developed through the following steps:

a. If participants are familiar with AESA, ask them why they do the AESA.
b. If participants are not familiar with AESA, ask them what kind of information they need to take decisions on agricultural production.
c. Discuss which plants to consider and how to choose them.
d. Arthropods - Discuss the way to examine the arthropods on the crop, their

FAO/19702/G.Bizzarri

Farmers drawing what they have observed in the field during the Farmer Field School damage, mode of reproduction on the host, parts affected, etc. How to record that information? Collect specimens to make drawings of the organisms.

e. Diseases - Discuss the way to examine diseases on the crop, their symptoms, etc. How to record that information? How to represent it in drawings?
f. Plant morphology and plant stage – Is it useful to mention the plant stage (e.g. its height, number of leaves, etc.)? How to show this in a drawing?
g. General observations – What else is useful to mention (e.g. weeds, water, fertilizers, wheather conditions, etc.)? Is it usually a healthy crop, or not? How to show all this in the drawing?
h. Go to the field to conduct observations and collect data during a 30 minutes period.
i. Get together again (in the classroom, or in the shade) and make a drawing of the plant with the average number of leaves. Write the numer of leaves, average height, and all the information collected in the field (noted on paper), preferably using color pencils.
l. Make a drawing of the the pest organisms found, for instance placing them on a side of the plant, with an arrow showing where they were found. Write the number of individuals of each species that were found and calculate the total number. Write the local name of the species found, if known.
m. In the same way, add in the drawing the beneficial organisms found.
n. Note climatic conditions (e.g. sunny, cloudy, rainy, windy, etc.).
o. Note the cultural practices conducted during the previous week (fertilizers, spraying, watering, etc.).
p. Important observations and recommendations can be written at the bottom of the poster.
q. Each sub-group presents its poster to the entire group. The information shared should allow the group to judge the decisions taken for IPM and confirm, or modify them in the future. The posters should be kept for comparison during the AESA conducted the following week. A person in charge of taking IPM decisions should be identified.

The trainer will stimulate discussion with approapriate questions throughout the exercise, depending on the crop, situation, local conditions, etc.

VI. DESCRIPTION OF MAIN ALTERNATIVES

The alternative materials and methods presented are only a reference for extensionists working on the phase-out of MeBr.

Any new alternative may require additional development and adaptation to become an effective pest control tool. Some problems of pest control, or of application, may arise once the alternative is locally tested, and they should be identified and corrected for further improvement of the alternative.

Table 1 gives a list of the most common alternative technologies to the use of methyl bromide as a soil fumigant.

Table 1. Main available alternatives to the use of methyl bromide as a soil fumigant

1. NON-CHEMICAL ALTERNATIVES

1.1. Cultural practices

Crop rotation
Soil amendments and biofumigation
Soil-less cultivation systems
Resistant cultivars
Grafting

1.2. Physical control

Soil solarization
Steam
Hot water
Flooding

2. CHEMICAL ALTERNATIVES

Methyl isothiocyanate (MITC)
MITC generators
1,3-dichoropropene
Chloropicrin

1. NON-CHEMICAL ALTERNATIVES

1.1. Cultural practices

Crop rotation

For the purpose of controlling soil-borne pests, crop rotation consists in the planting of successive crops that are non-host, less suitable hosts, or trap crops for the target soilborne pests. Many rotations include fallow, which consists of taking the land out of production temporarily to reduce soil pathogen and other pest populations by removing the hosts, or substrates, for their development and exposing them to adverse environmental conditions. Crop rotation has been practised since ancient times and is still applied as part of a sustainable agricultural system for the control of many soil-borne pests on crops all over the world. The absence of a suitable host leads to a reduction in pest numbers and reduces the pathogen inoculum, but rarely eliminates pest, or disease problems.

Soil amendments

Adding materials to the soil reduces, or suppresses, some soil-borne pathogens by stimulating antagonistic micro-organisms, increasing resistance of host plants, providing extra nutrients, altering the pH, or by various other environmental effects.

Organic and inorganic amendments, such as compost of different types (by-products from agriculture, forestry and food industries, etc.), manure, inorganic amendments and crop residues, can all have the effect of controlling soil-borne pathogens in crops and may be easily applied in the vegetable and ornamental sectors.

Previous research has proved the high efficacy of solar heating (solarization) combined with some effective amendments such as cruciferous residues, manure, etc. When added to the soil, these amendments are exposed to microbial degradation, resulting in the production of biotoxic volatile compounds and alcohols, aldehydes and other volatile compounds that can stimulate germination of fungal propagules and increase microbial antagonistic activity in the soil. Microbial activity against pathogens in the soil can weaken propagules during solarization, or suppress their re-establishment in the soil after treatment. This has been proven effective for several soil-borne fungi (*Verticillium* spp., *Rhizoctonia solani, Pythium* spp., etc.), nematodes and many weeds. The control of *Pythium ultimum* and *Sclerotium rolfsii* in soil exposed to vapour has also been successfully demonstrated in Italy.

Biofumigation

Biofumigation is defined as the action of volatile substances produced in the biodegradation of organic matter for the control of soilborne pests. This technique increases its efficacy in due course when it forms part of an integrated crop management system. It has been found that, generally, almost any organic matter can act as a biofumigant, its effectiveness depending principally on the dose and the method of application.

In order to obtain the fermentation of the organic matter below the surface of the soil, the latter is irrigated to the field capacity and covered with plastic sheets. This fermentation generates volatile compounds which are lethal for many micro-organisms, including several nematodes, weeds and fungi. The technique can result in the selection of a specific beneficial micro-flora. The suppressive activity depends on thermal inactivation, release of volatile biotoxic compounds, such as ammonia, methyl-isothiocyanates and other sulphur compounds as well as compounds that stimulate saprophytic soil antagonists (aldehydes, alcohols, etc.), or allelopathic toxins.

Resistant varieties
Varieties which are resistant, or tolerant, to one, or a few, specific pathogens (and races) are already available for many crops. Resistant hybrids with multiple resistance to several pathogens exist and are currently used in vegetable production. In most cases, new varieties are developed through plant breeding techniques to address specific pest problems, but systematic genetic modification of germplasm by using new biotechnologies is becoming more frequent.

Grafting
Grafting consists of using resistant rootstocks for susceptible annual (e.g. tomato, eggplant) and perennial (e.g. fruit trees, citrus, grapes) crops to control soil-borne pathogens. Grafting of susceptible crops on resistant rootstocks is now possible for several crop species: tomato (hybrids resistant to *Verticillium* and *Fusarium* wilt and *Pyrenochaeta lycopersici),* cucumber *(Cucurbita vicifolia* as rootstock resistant to *Fusarium* wilt) and melon (*Benincasa cerifera* resistant to *Fusarium* wilt). Grafting on resistant rootstocks is extremely popular in the Far East.

Soil-less cultivation
Soil-less cultivation is rapidly expanding, although at a lower rate in comparison with Northern Europe, not only in order to bridge unusual production periods and circumstances, but also as an answer to the need to reduce the use of soil fumigants. Soil-less cultivation represents an interesting alternative to traditional agricultural systems for high value crops such as rose, carnation, gerbera, basil, lettuce, etc. The choice of the most suitable soil-less cultivation system for a given environment relies on technical, economic and phytopathological factors. Soil-less cultivation is increasingly adopted in the case of ornamental crops (rose, gerbera) and in some cases for strawberry. A total of approximately 100 ha is at present cultivated soil-less in Italy.

Floating trays ("float") system
An example of this technique is the so-called “float system” used in Brazil, consisting of growing seedlings in Styrofoam trays placed in a pool with water, under a plastic tunnel. The float system uses commercially prepared and sanitized media. The most commonly used media preparation contains fermented pine barks, expanded

vermiculite and perlite. Currently, in the state of Rio Grande do Sul, south of Brazil, 60 % of tobacco seedlings are produced with the float system. This system is also the most common in Santa Catarina, the second largest tobacco-producing state. One important advantage of this system is the fact that the production of tobacco seedlings requires 50 to 60 days until they reach a height of 15-20 cm. In the conventional seedbed, three months are necessary for seedlings to complete their development. The float production system produces tobacco seedlings for transplant that are of greater uniformity, with a much stronger root system and at reduced labour costs. This system is applicable to to the production of many vegetable seedlings as well.

1.2. Physical control

Steam

Steaming is the introduction of water vapour into the soil, under plastic mulches, to increase soil temperatures to levels lethal to soil-borne pests. Soil temperature and treatment duration determine whether complete elimination (sterilization: few minutes at 90-100°C), or only partial removal of soil micro-flora (pasteurization: air-vapour mixture, for 20-30 minutes at 70-80°C) occurs. Steaming at negative pressure is a promising energy-efficient and more rapid alternative.

Soil solarization

Solarization is a hydrothermal process, which utilizes solar radiation captured under plastic film mulch to heat soil (up to 50-55°C at a 5 cm depth and 40-42°C at a 20-25 cm depth) and disinfect it. Solarization has a complex mode of activity, can control a broad spectrum of soil-borne pathogens, weeds, insects and nematodes, and can be successfully combined with other control measures.

Solarization leads to a drastic reduction in inoculum density by thermal inactivation and induced suppressiveness (quantitative and qualitative shift in the micro-flora population, establishment of a new biological equilibrium); it also induces the phenomenon of increased growth response (IGR) affecting plant growth.

Hot water treatment

Tsukuba National Research Centre (Japan) developed this method. Water boiled at 95°C is poured over a field. The treatment kills several organisms, including pests, pathogens and weeds, and its effectiveness lasts up to three years in protected cultivation areas. It is necessary to improve the hot water-producing equipment, by reducing its size and decreasing its cost, in order to bring it within the means of farmers. This kind of treatment is not suitable for large areas.

Flooding

This is one of the most widely used methods in Japan in areas where eggplants, tomatoes, strawberries and cucumbers are cultivated. Soil-borne diseases and nematodes are controlled. This method appears to be one of the most promising ways to control soil pathogens in the future.

2. CHEMICAL ALTERNATIVES

Chemical products for soil disinfection may be for a broad spectrum of activity (fumigants), or for a specific spectrum of activity over particular pest organisms (fungicides and nematicides).

Fumigants are toxic substances that are applied to the soil as gas, dust, drenches, or granules, to control several soil-borne fungi, bacteria, nematodes, insects and weeds. Solid, or liquid fumigants, once incorporated into the soil, turn volatile so that they penetrate (fumigate) the soil throughout.

These chemicals are selected according to various characteristics, such as spectrum of activity; penetration capacity; waiting period between treatment and planting; availability and ease of use; reliability; suitability to different environmental conditions; cost; and environmental impact.

Chemical fungicides and nematicides are generally used for more specific pathogen control. Benomyl, tolclofos-methyl, prochloraz and iprodione are some of the fungicides commonly used in vegetable and ornamental crops. Fenamiphos is currently used as a nematicide.

Over the last few years, the number of pesticides registered for soil disinfection has drastically decreased due to the severe restrictions imposed on their use. Governments have become increasingly aware of the drawbacks of these chemicals in terms of impact on public health and the environment.

It must be pointed out that no single chemical alone provides an alternative to pre-plant uses of MeBr in terms of consistency and efficacy against target pests.

Methyl isothiocyanate (MITC) and its generators

Metham sodium is a liquid soil chemical that produces methyl isothiocyanate. It is used as a pre-planting fumigant and is effective for controlling arthropods, some weeds and soil-borne pathogens, principally fungi, and a limited number of parasitic nematode species. It is applied to the soil directly, or through the irrigation system, under transparent polyethylene mulch. Metham sodium must be applied when soil temperatures are between 15 and 30°C. The application rate is 100 ml / m^2 (with formulations at 32.7 % of a.i.). At high inoculum concentration, low soil temperatures, or for heavy soils it is necessary to increase the rate up to 800 ml / m^2.

Dazomet is a granular pre-planting soil chemical and has been reported to control weeds, nematodes and fungi. It requires mechanical distribution in the soil for good movement and efficacy. During the treatment the soil should be covered with plastic sheets. The application rate is 80-100 g / m^2 (with formulations at 99 % of a.i.).

1,3 dichloropropene (1,3-D)
1,3 dichloropropene is a liquid pre-planting fumigant that rapidly evaporates and diffuses as a gas through the soil. It is applied to the soil by injection and provides effective control of nematodes, insects, some weeds and some pathogenic fungi. During treatment the soil remains covered with plastic mulches.

1,3-D is usually applied in combination with other chemicals such as chloropicrin, metam sodium, etc. Application rate is 12-20 ml / m^2 (with formulations at 97 % of p.a.); higher rates are applied in heavy soils. It is applied using an injection device through injection nozzles mounted on two levels. Peristaltic pumps guarantee the distribution. The flow of the chemical depends on the velocity of the tractor. Since 1,3 dichloropropene is highly volatile, the plastic covering has to be put in position immediately after application. Uniform application of the chemical by adjusting the speed of the tractor and calibrating the nozzles of the application machine is highly recommended.

USEFUL BIBLIOGRAPHY

Anonymous. 1997. The Methyl Bromide Issue. Edited by C. H. Bell, N. Price, B. Chakrabarti, John Wiley & Sons Public. 412 pp.

Braun, L.A. and Supkoff, D. M. 1994. Options to Methyl Bromide for the Control of Soil-Borne Diseases and Pests in California with Reference to the Netherlands. Pest Management Analysis and Planning Program. *This publication can be found on the webpage:* http://www.cdpr.ca.gov/docs/dprdocs/methbrom/alt-anal/soilsol.htm

CSIC. 1997. Alternatives to Methyl Bromide for the Southern European Countries. [A. Bello, J.A. González, M. Arias and R. Rodríguez-Kabana, Eds.] 403 pp.

FAO. 1991. Soil Solarization. Edited by DeVay J.E., J.J. Stapleton, C.L. Elmore. FAO Plant Production and Protection Paper 109, 396 pp.

FAO. 1998. Soil Solarization and Integrated Management of Soil-borne Pests. [Stapleton J.J., J.E. DeVay, C.L. Elmore, Eds.]. FAO Plant Production and Protection Paper 147, 657 pp.

FAO. Global Report on Validated Alternatives to the Use of Methyl Bromide for Soil Fumigation. [Labrada, R. and Fornasari, L., Eds.]. FAO Plant Production and Protection Paper No. (...) (*in prep.)*

MBTOC. 1997. Report Technology and Economic Assessment Panel. UNEP, Nairobi, 221 pp.

MBTOC. 1999. Assessment of Alternatives to Methyl Bromide. UNEP, Nairobi, 275 pp.

Rodríguez-Kabana, R. and Calvet, C. 1994. Capacidad del suelo para controlar enfermedades de origen edáfico. *Phytoparasitica 20,* 211-224.

RUMBA (Regular Update on Methyl Bromide Alternatives). Newsletter regularly prepared and edited by UNEP.

UNEP. 1999. Methyl Bromide: Getting Ready for the Phase Out. Mass Market Paperback - 31 pp.

UNEP. 2000. Methyl Bromide Alternatives for North African and Southern European Countries.

UNIDO. 2000. Three Alternatives to the Use of Methyl Bromide in Tobacco: Non-Soil Cultivation, Solarization, and Low-Dose Chemicals. Demonstration project/UNIDO. Final Report 1998-2000 EMBRAPA-EPAGRI, Brazil, 54 pp.

USEFUL WEB LINKS

- ARS methyl bromide – USDA - ARS
  http://www.ars.usda.gov/is/mb/mebrweb.htm

- Environmental Working Group
  http://www.ewg.org/pub/home/Reports/Reports.html

- Food and Agriculture Organization of the United Nations
  http://www.fao.org/WAICENT/FAOINFO/AGRICULT/AGP/agpp/IPM/Web_Brom/Default/htm

- Ozone Action
  http://www.ozone.org

- Pesticide Action Network
  http://www.panna.org/panna/campaigns/mb.html

- Technology and Economic Assessment Panel
  http://www.teap.org/

- United Nations Environment Programme – Nairobi, Kenya
  http://www.unep.org/ozone/home.htm

- U.S. EPA methyl bromide phase out web site
  http://www.epa.gpv/docs/ozone/mbr/mbrqa.html