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FLORICULTURE AND THE ENVIRONMENT

Growing Flowers without Methyl Bromide

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FLORICULTURE AND THE ENVIRONMENT

Growing Flowers without Methyl Bromide

UNEP

United Nations Environment Programme

Contents

How to use this Manual

This Manual is intended as a general guide for the implementation of alternatives to methyl bromide in the commercial production of cut flowers. It seeks to provide practical, easy to understand information, that can be used by growers, trainers, technical assistants and in general those persons involved in the phasing out of methyl bromide. For this reason an illustrative, simple to follow format containing actual examples that have proven useful has been chosen. The information contained may be used as part of training programs, workshops or other activities. However, this manual should be taken as a guide only, since specific alternatives need to be evaluated and adapted to meet local conditions.

The information herewith presented is based on actual experience in commercial farms, research findings and published books or reports. However, its authors or the United Nations Environment Programme cannot be held responsible for any failure or unforeseen outcomes resulting from its utilization.

Alternatives discussed have been organized in seven chapters:

- **Chapter 1** – is a general description on alternatives found useful for replacing methyl bromide with special mention to cut flowers.
- **Chapter 2** – is a detailed analysis of Integrated Pest Management (IPM), including examples and suggestions for its actual implementation in commercial flower production. Many experts consider IPM the only truly effective solution not only to the methyl bromide phase out but in general to sustainable production using lower amounts of pesticides.
- **Chapter 3** – gives more insight into steam sterilization as one of the best alternatives to methyl bromide. However, correct usage of steam is important and the best results are obtained when it is part of an IPM program. Problems that can be encountered when using steam are discussed. Actual examples of steam use in flower farms are presented.

♦ **Chapter 4** – presents step-by-step composting of plant residues, a source of beneficial microorganisms and organic matter that has proven effective in reducing the need of soil disinfestation. Further, compost is a good source of nutrients and its application to plants can replace chemical fertilizers to a certain extent.

♦ **Chapter 5** – focuses on cultivation on soil-less substrates, another alternative giving excellent results. Special mention is made to substrates proving useful in developing countries that do not have access to certain materials used in the developed world such as rock wool. Rice hulls, coffee husks and coconut coir are excellent options in tropical and subtropical environments.

♦ **Chapter 6** – describes demonstration, training and investment projects currently carried out on cut flowers by the Montreal Protocol's Multilateral Fund implementing agencies. Alternatives chosen, contacts and results when available are also included.

♦ **Annex** I. A compilation of important manuals and documents published by UNEP on the phase out of methyl bromide. Internet addresses and other publications that may provide further or more comprehensive information on the alternatives described can also be found.

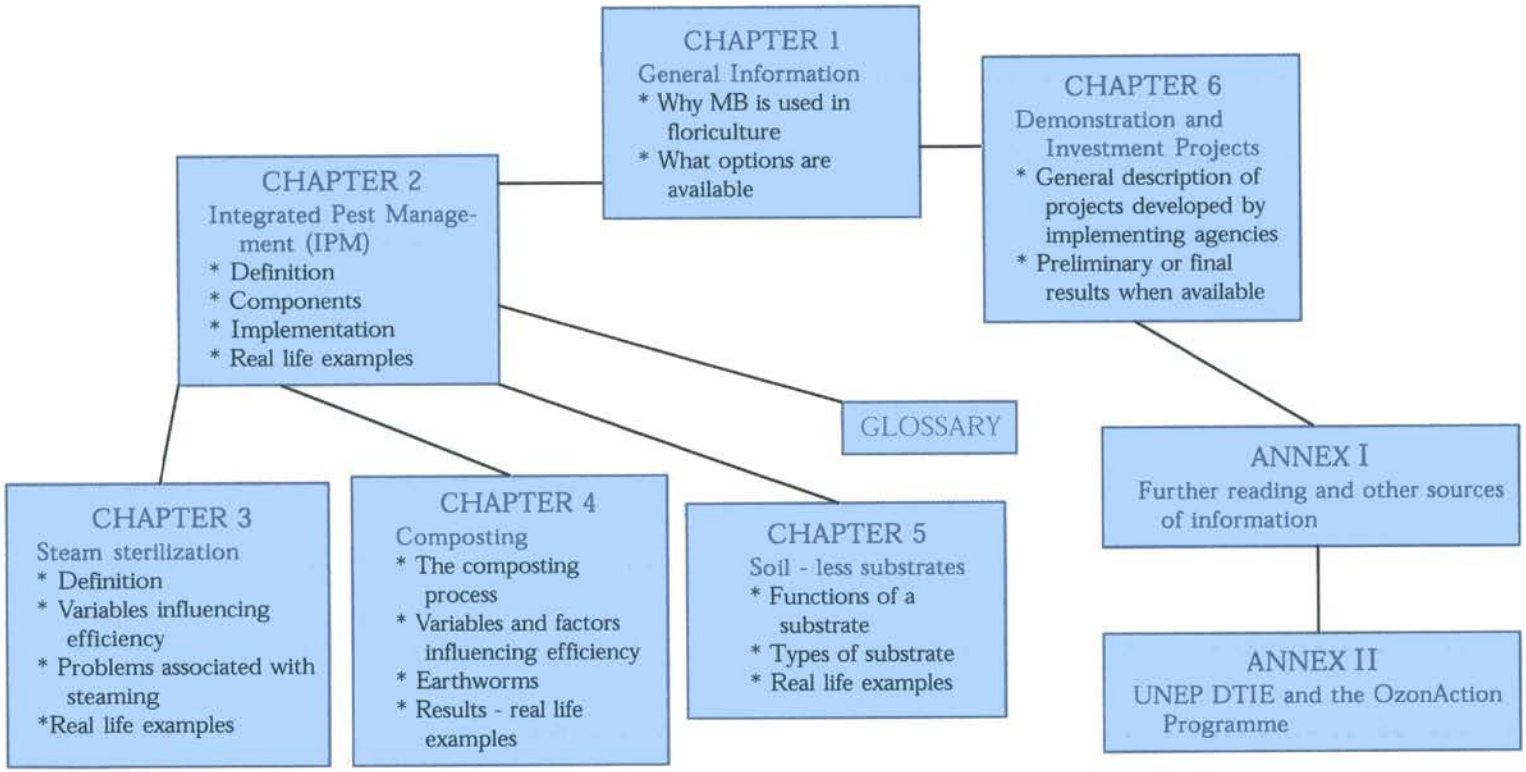
♦ **Annex** II- UNEP and the OzonAction Programme.

♦ A **Glossary** at the end of this publication where technical terms commonly used when describing the alternatives above are defined.

Information contained in this Manual may be freely used and translated into other languages for dissemination and educational purpose as long as the source is appropriately credited.

For a better understanding on how to use this manual please use the following Graph:

Graph. 1. How to use this manual

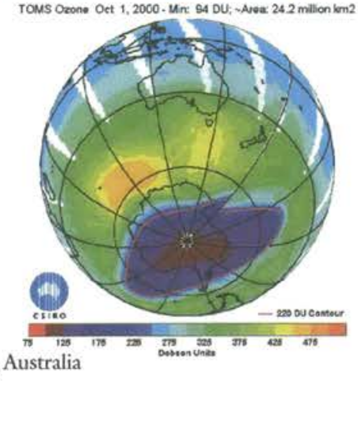


Introduction

Methyl bromide is a wide-spectrum soil fumigant that has been used for controlling serious pests and diseases of many crops for over 40 years. It is also useful in killing most weed seeds and other troublesome organisms such as rodents. Although its application requires special procedures, it disperses quickly and is ideal for soil fumigation in intensive, continuous production agricultural applications. Therefore its main use is thus as a soil fumigant, but it is also used for controlling pests of stored grains, and for disinfesting ships, building and even aircraft. Another application is that performed for quarantine reasons to avoid entry and/or spread of unwanted pests into a country.

Because of its high ozone depleting potential, the Parties to the Montreal Protocol included methyl bromide in the list of ozone depleting substances (ODS). This means that its production and use must stop within deadlines established under the Montreal Protocol (see table below). Depletion of the ozone layer causes increases in ultraviolet radiation, which increases the risk of skin cancer in humans and poses serious environmental hazards. Concerns about methyl bromide go farther – and include threats to the environment as a potential contaminant of soils and water sources, to soil biodiversity, as well as severe hazards to human health, including its acute toxicity and its recognition as a reproductive toxicant.

Illustration 1. Satellite image of Ozone Hole - 1st October 2000



Source: CSIRO, Canberra, Australia

In order to support this decision, UNEP, through its OzonAction Program, is committed to assisting countries in complying with the phase out. Presently over 167 countries are signatories of the Montreal Protocol. UNEP's Methyl Bromide Technical Options Committee (MBTOC) is a special committee created to help identify alternatives for all uses of methyl bromide. Further more, the Multilateral Fund, which provides financial and technical assistance to developing countries to phase out ODS, conducts demonstration and phase out projects, workshops and training, which provide financial assistance and focus on the phase out of methyl bromide in developing countries (See Annex I for more information).

The largest use category for methyl bromide is by far soil fumigation, accounting for about 76% of total worldwide consumption. It is mainly used as a pre-plant treatment in the production of high value export crops such as tobacco, cut flowers, strawberries, bananas, melons and some vegetables, notably tomatoes. However, alternatives to methyl bromide for all of these have been identified over the last years, which allow for successful production of top quality products.

Deadlines established by the Montreal Protocol for the phase out to methyl bromide in developed and developing countries appear in **Table 1**.

Countries may voluntarily decide on earlier reduction or phase out. This in fact has already happened with other countries besides the EU among them Switzerland, Colombia and more recently Argentina and Jordan (in August 2000). This decision in some cases is due to reasons other than the Montreal Protocol, such as the need for cleaner production and less hazardous practices as discussed in Chapter 1.

For agricultural uses for which an alternative has not been found by 2005, the Commission together with the Member States will consider critical uses and importation and use of methyl bromide may be permitted. The new EU schedule also calls for a freeze in QPS use of methyl bromide based on the average imported and produced during the period 1996-1998. The freeze will become effective on 1 January 2001.

Table 1. Methyl bromide phase out schedule

Non-Article 5(1) countries (developed countries)	* A freeze on production and consumption based on 1991 levels applies since 1995. * As of 1999, a 25% reduction in production and consumption based on 1991 levels. * As of 2001, a 50% reduction. * As of 2003, a 70% reduction. * As of 2005, complete phase out.
Article 5(1) countries (developing countries)	* As of 2002, a freeze on production and consumption based on the average in the period 1995-1998. * As of 2005, a 20% reduction. * As of 2015, complete phase out.
All countries	Quarantine and pre-shipment (QPS) are currently exempted from phase out. For example, this involves, treatments that are required by importing countries to prevent introduction of quarantenary pests or diseases that may be present in grains. Limited exemptions may be granted for "critical" and "emergency" uses.

The European Community has voluntarily accelerated its phase out schedule as follows:

- 25% cut in production relative to 1991 levels by 1999
- 60% cut by 2001
- 75% cut by 2003
- Total phase out by 31 December 2004.

However, use of methyl bromide in EU agriculture is permitted until 31 December 2005.

Chapter 1

Alternatives to Methyl Bromide in Floriculture

Why is methyl bromide used in cut flower production?

Commercial floriculture worldwide is characterized by high investment and high quality demands which often imply high pesticide usage. Consumers want perfect flowers – completely free of damage caused by pests and diseases. Furthermore, more and more flowers are being grown in tropical countries where the climate is benign and allows for year round production at accessible costs. The flowers are then exported to temperate countries. Increasing trade of flowers has lead to establishing stringent phytosanitary measures at ports of entry, in an effort made by corresponding authorities to avoid entry and spread of pests into their countries. Generally, this means that exporters are required to send flowers that are disease and pest free.

Most importantly though, in every country in the world where flowers are grown for commercial purposes, production is greatly affected by severe diseases that prevail and build up in the soil leading to tremendously high losses in yield and quality. Eradicating these noxious organisms from the soil can be difficult; they may even render whole areas unsuitable for the production of susceptible flowers, and make soil disinfestation mandatory. Traditionally, the treatment of choice has been fumigating with methyl bromide given its wide spectrum of action, its efficiency and its cost, which is usually lower than that of other fumigants.

Table 2 presents some examples of important soil- borne diseases and pests that affect flower production and cause high economic losses.

Table 2. Examples of soil-borne diseases and pests of cut flowers

Flower	Common name	Causal agent
Carnations	Vascular wilt Cyst nematodes, pin nematode, root lesion nematodes Symphyllans, Collembolans Slugs and snails	*Fusarium oxysporum* f.sp. *dianthi* *Heterodera* sp, *Paratylenchus* sp *Pratylenchus* spp Class Symphyllidae, Collembola Class Gastropoda
Roses	Crown gall Nematodes, root knot, lesion Symphyllans, Collembolans	*Agrobacterium tumefaciens* *Meloidogyne* sp, *Pratylenchus* sp Class Symphyllidae, Collembola
Chrysanthemum	Phoma root rot Fusarium wilt Nematodes - foliar, lesion, root knot Root and stem roots Crown gall Collembolans, symphylans Slugs and snails	*Phoma chrysanthemicola* *Fusarium oxysporum* f.sp. *chrysanthemi* *Aphelenchoides* sp, *Pratylenchus* sp, *Meloidogyne* *Pythium* sp, *Sclerotinia sclerotiorum*, *Rhizoctonia* sp, *Sclerotium rolfsii*, *Verticillium* sp *Agrobacterium tumefaciens* Class Symphyllidae, Collembola Class Gastropoda
Calla lily	Soft rot	*Erwinia carotovora*
Heliconias	Moko disease	*Pseudomonas solanacearum* race 1
Bulbs	Nematodes	*Ditylenchus* sp and others
General	Weeds Nematodes	*Oxalis* sp, *Cyperus* sp Several genera

Fig. 1. Beds treated with methyl bromide at a tropical flower farm in Costa Rica.

What are the options?

Upon learning about the methyl bromide phase out, many flower growers around the world have expressed deep concern, arguing that there no truly efficient alternatives to this fumigant and that, given the strict quality demands imposed on their products, they will go out of business.

However, producing flowers of excellent quality without methyl bromide is clearly possible and is already being done. The best example is Colombia, where initial trials with methyl bromide failed, forcing growers to look for alternatives thirty years ago. For many years Colombia has been the second flower exporter in the world after Holland, its production valued in more than US$600 million in 1999. Experienced, long time growers considered methyl bromide as an option when they first started growing, but abandoned the idea because a) it was too

Fig. 2. Colombian floriculture developed without methyl bromide. Certain conditions like high organic matter content in the natural soil can make this fumigant toxic to plants.

difficult and too dangerous to apply, and b) at the time it was perceived as being too costly. (Presently however, many growers around the world would not agree to this and actually consider methyl bromide as being cheaper than other alternatives).

Furthermore, the most valid reason for not using methyl bromide is the fact that due to the very high organic matter content in Colombian soils (18% is common). The bromine from the methyl bromide is fixed in the soil, leading to phytotoxicity problems that are difficult to solve. Although relatively recently a few growers have tried out methyl bromide (apparently with good results), the vast majority of Colombian flower growers (over 95%) do not use methyl bromide for soil disinfestation.

Substituting methyl bromide requires a grower to take a new approach towards producing flowers. There is no single replacement for this product; rather, a whole program, involving different measures which together lead to disease reduction is the answer. This strategy, known as Integrated Pest Management (IPM), will be discussed in detail in the following chapter.

In different parts of the world, several alternatives to methyl bromide are already in use in cut flower production, often with excellent results. Some of these appear in **Table 3**.

This manual will focus particularly on those alternatives found to be most suited to floriculture. Depending on circumstances related to environmental conditions, supplies, infrastructure available and others, one or another of these alternatives might be more suited for a particular grower. However, the best option is to combine them in a program so that together, they lead to the best results. This introduces us to the concept of IPM that is discussed in the following section.

IPM is by no means a new concept to agriculture, not even to floriculture. Even in the 1950's and 60's researchers were already talking about it and some growers were becoming interested in its implementation. However, over the last 15 years it has become a real option from a commercial standpoint for the reasons outlined above and documented case studies are available. Further, excellent publications on this topic are now available and should be consulted (see also Annex I for resources on methyl bromide alternatives).

Table 3. Examples of alternatives to methyl bromide used in cut flower production around the world

Production type	Alternative	Countries
Protected	Steam	Brazil, Colombia, Europe, US
	Solarization	Developed countries, Jordan, Lebanon, Morocco
	Biocontrol	Developed countries
	Substrates	Brazil, Canada, Europe, Morocco, Tanzania, US, Colombia
	Organic Amendments	Universal
	Crop rotation	Universal
	Resistant varieties	Universal
	Biofumigation	Developed countries (Spain)
	Metham Sodium	Developed countries, Jordan, Lebanon, Morocco, Colombia
Open field	Dazomet, metham sodium	Developed countries, Brazil, Costa Rica, Egypt, Jordan, Lebanon, Morocco, Tunisia
	1,3 Dichloropropene	Developed countries
	Chloropicrin	Developed countries, Zimbabwe
	Organic amendments	Universal
	Crop rotation	Universal
	Resistant varieties	Universal
	Solarization	Developed countries

Adapted from: Report of the Methyl Bromide Technical Options Committee. 1998 Assessment of Alternatives to Methyl Bromide. UNEP, 1999.

Additionally, after learning more about it, many growers will realize that in fact, they are already using many of the components of IPM:

- Irrigation systems that avoid sprinkling water and thus dissemination of some pests and diseases
- Buying cuttings, seeds or plants from reknown breeders or propagators that guarantee their health
- Using ventilation systems in greenhouse

These are all examples of practices that may be part of an integrated approach to controlling pests and diseases. The next step is organizing the information derived from these practices to make them part of a structured program that will lead to integrated management of pathogens affecting a particular crop.

Benefits of IPM

IPM leads to invaluable benefits that should always be highlighted when explaining it to growers: for example, overall reduction of pesticide usage that can easily be coupled with safe application of these chemicals. Growers using IPM have reduced the total amount of pesticides used by over 40%. This is a significant reduction, if compared with the old approach of spraying several times a week for pure prevention – without knowing first if pests are even present. It does not only result in a production approach that is more environment-friendly, but in the long run it also represents significant savings. The same can be said for other aspects of production – i.e. waste management, water usage and others. As with IPM there will always be benefits associated both with ecology and economics.

Chapter 2

Integrated Pest Management - the environment-friendly approach

IPM is the best approach for managing or controlling all phytosanitary problems. It is a proven and effective technology for flower growers in many parts of the world and offers an excellent alternative to MB and other soil fumigants, which are nevertheless toxic and may be restricted or at least limited in use in the near future.

Reducing pesticide usage is important since during the past years flower consumers all around the world are strongly encouraging growers to implement practices that are friendlier to the environment. In fact, eco-labeling programs such as the MPS from Holland, the Florverde program from Colombia, the Flower Label Program (FLP) from Germany and the Kenya Flower Label are becoming more and more widespread. Although there are differences, all these labels share a strong commitment for avoiding contamination with chemicals, preserving the ecology of the soil (which methyl bromide threatens) and reducing human health hazards associated with the application of chemicals. Some of these (MPS) specifically prohibit methyl bromide use. According to many experts in the industry, only those growers abiding by one or more of these programs will conserve a satisfactory share of the international market in the near future.

Three of the eco-labels or environmental programs currently used on cut flowers: Florverde (Colombia), MPS (The Netherlands) and the Flower Label Program (Germany)

Growers in many places are actively looking for practices that ensure a more sustainable production. The term "sustainable" applies to production methods that can be carried out for an unlimited period of time at the same site, without depletion of natural resources. This means that soils, water, air, natural populations of plants and animals including microorganisms need to be better preserved, and that substances which are potential contaminants and can be toxic to the them such as pesticides and fumigants should be used in far lower quantities.

In cut flower and ornamental plant production, IPM is the answer to rational use of pesticides in general and to better conservation of natural resources, as well as for eliminating methyl bromide. The essentials of IPM appear in **Table 4**.

What is IPM?

IPM encompasses a different approach towards pest and disease control. A first and essential condition is that the grower gathers information and learns how to use it. Pests and diseases attacking a crop must be well documented:

- How do they disseminate and reproduce?
- How is their life cycle completed?
- Which environmental conditions are best for their development?
- What varieties are most harmfully affected and which show resistance?

With information like this at hand, a program can be developed that will reduce pest or disease populations using different tools. In essence, IPM involves making use of all possible resources - not just chemical control - to reduce and prevent the incidence and effects of a given disease or pest. All of these contribute in some way to pest reduction and lead to far less usage of chemical pesticides, even though on their own, they rarely provide a complete cure. To many researchers and growers, IPM is at present the only real and long lasting solution to severe diseases and pests attacking many crops.

How efficient is it?

In its practical application IPM leads to excellent results not only by improving the efficiency of the business but because over time, it repre sents significant savings both in natural resources and in money. In fact, over recent years growers and researchers have obtained such good results with this strategy that IPM is being taken further and the concept of Integrated Crop Management (ICM) is starting to be introduced.

ICM means that, because everything a grower does – watering, fertilizing, cultural practices, etc. – can affect the dispersal and development of pests and diseases, these practices should also be taken into consideration when establishing phytosanitary controls or programs. For example, drip irrigation may be a way to reduce the dispersal of certain pathogens by splashing water; some fungi develop better when the plants are fertilized with an ammonium form of nitrogen than when nitrates are used, etc.

The main components of IPM are presented below. In the following section, each of these is described in detail. It is extremely important to keep in mind that each by itself will rarely provide sufficient control of a problem. Rather, it is through a combination of these techniques that sufficient control will be achieved.

IPM for the control of pests and diseases in floriculture is a proven technology in many countries. For example, in the case of fusarium wilt of carnations, Colombian growers using this approach report losses of only 1 - 2 % per year due to this disease, as compared to 20 - 40% and more when relying on soil disinfestation only. It also means less overall pesticide usage – not only reduced use of soil fumigants. This has clear benefits in protecting the environment, improving worker safety and in reducing production costs in the long term.

1. Scouting or Monitoring

Put simply, scouting is the basis of IPM. In very simple terms, scouting or monitoring means going through the crop looking for symptoms or actual presence of a pest or disease that is known to cause problems in the flower crop. By scouting his crop, a grower or a technician can not only learn about the different pests and diseases attacking his plants (fortunately he usually faces no more than three or four although they can be serious), he can also detect them quickly and maybe even find out what their source is. It is essential to detect pests and diseases at the earliest stage possible, treating foci as soon as they

Table 4. The main components of Integrated Pest Management

1. Monitoring (scouting)
- Human resources - trained personnel that can detect and identify problems in the field
- Mapping - Identification of affected areas (foci) and pests or diseases present
- Collecting information - establishing an action threshold
- Evaluation and decisions - whether, when and where to apply control measures, which may range from "no action" to pesticide use.

2. Control by exclusion
- Plant quarantines and revisions
- Disease-free plant material

3. Cultural control
- Avoiding weeds and other plants that act as alternate hosts
- Crop rotation
- Good ventilation that reduces disease (caused by fungi for example)
- Keeping greenhouse covers in good condition and growing areas clean
- Choosing fertilization and watering practices that discourage pest development
- Restricting passage of workers and vehicles from diseased to healthy areas

4. Physical control
- Insect traps (yellow, blue) to reduce and monitor populations
- Screens and other barriers that restrict insect entrance
- Aspirators or vacuum cleaners that trap insects
- Rouging diseased plants and treating localized infestations
- Soil sterilization with steam before planting
- Disinfestation of shoes, tools and others
- Soil-less substrates
- Solarization

5. Biological control
- Biopesticides (many are now commercially available)
- Biocontrol agents many times used at an experimental level but with good perspectives
- Incorporating compost and/or beneficial organisms to the soil

6. Genetic control
- Resistant varieties, available for some pests and diseases

7. Chemical control
- Soil fumigants and other pesticides
- Disinfectants

appear and using options different to chemicals whenever feasible. A grower must fully understand the importance of scouting: it is essential to assign specific funds within the budget of his operation to its implementation.

A good scouting program requires:

Training

Employees should be specially assigned and trained to this task. They should be able to concentrate on details and be careful observers. Scouts must learn to distinguish symptoms of a particular disease or pest as early as possible. Visual aids such as slides, pictures or illustrations as well as on – site demonstrations are very useful.

Photo: Asocolflores.

Fig. 3. Scouting for pest and diseases at a Colombian chrysanthemum farm.

Some people are natural talents at scouting. It makes sense to assign them to do this job. But it is also useful to give some training to everyone working on the farm. Packers, pickers, sprayers and others can be of great help in pointing out early symptoms of a pest or disease if they know how to spot them. Remember that the sooner a problem is detected the easier it will be to control it.

Mapping

Mapping should be done for all cropping areas. Scouts should do their job on a map or plan of the area they are searching. Knowing when and where a disease or pests occurs is very helpful as it may allow for spot treatment so that often it is not necessary to treat the whole area but just those specific places

Photo: Asocolflores.

Fig. 4. Mapping and record keeping are essential to IPM.

where the pest occurs. This will help in reducing pesticide usage. It also becomes very important historical information for the future: for example, knowing where a carnation variety that became diseased with wilt in the past was grown will help the grower to avoid planting that bed again with the same or another susceptible variety. It indicates which varieties are most susceptible to a problem, and when that problem typically arises (for example, during dry or wet weather; cold or warm days or nights). Finally, it determines whether a particular problem may be coming from the neighboring farm, or the garbage dump.

Scouts should be trained to evaluate or grade the amount of damage they see. A number can be assigned to a severe problem and another to a slight one (for example, 1 for severe, 2 for medium, 3 for slight damage). Color-coding is also a good idea (i.e., red for badly affected, yellow for medium severity, green for slight). On the map, the numbers or colors will give a good idea of what is happening with a particular problem, how it is spreading, which varieties it is affecting, etc.

Establishing an action threshold

For major pests and diseases where immediate action is required, it is important to establish an action threshold. Even though quality demands for cut flowers are very high – everyone wants perfect flowers – many times a grower can wait until a problem becomes significant before it is necessary to apply a particular treatment. For example, many growers have found that they can tolerate low populations of thrips before they need to apply pesticides. By monitoring populations they can establish their personal tolerance threshold beyond which they will initiate control actions. An action threshold is more practical than a "damage threshold", because it depends on the farmer's own experience and risk assessment. A damage threshold needs lots of calculations. Historical information gathered as described before becomes essential in establishing such a threshold and proves extremely valuable over time. It can also help a grower decide to apply preventive treatment before a problem becomes too serious.

Evaluating information and making decisions

Scouting information is the basis upon which managers or supervisors can make important decisions: if and when a pesticide or fumigant should be applied; which varieties (and even flower species) should be used for new plantings; what problems to expect according to weather conditions. For example, wet soils encourage the development of soil fungi such as *Rhizoctonia* and *Pythium*, while certain pests like spider-mites prefer hot, dry environments.

2. Control by Exclusion

For a pest or disease to occur, three things must be present at a given time:

A susceptible host,
A virulent pest or disease agent and,
Adequate environmental conditions.

Their occurrence can be substantially and even entirely avoided if a pest simply does not come into contact with its susceptible host (during a susceptible stage). The environment may also be modified (see section 3 on Cultural Control below). Two successful alternatives in this respect are:

Plant quarantines and inspections

The introduction of a new variety or any foreign plant material to a country or even a growing area should be subjected to careful observation. Many times governments have specific programs and legislations to this respect, which require both the importer of the plants or seeds as well as the exporter or supplier to comply with regulations to guarantee the health of the foreign plant.

However, a grower can also carry out his own quarantine program, keeping new material confined until he is sure of its health status. Presently, simple tests can be carried out to determine the presence of certain fungi and viruses in cuttings, rootstocks and even seeds before they are planted on the farm. Therefore, contaminated plant material can be eradicated before it causes damage.

Disease-free plant material

The importance of using healthy plant material cannot be stressed sufficiently. The most efficient way to disseminate many pests and diseases is through plant material, especially when propagation is achieved by vegetative means (i.e. cuttings). Only too often, appar-

Photo: Asocolflores.

Fig. 5. Tissue culture is the most efficient way of obtaining disease-free plant material.

ently healthy seeds, cuttings or rootstock carry low populations of a noxious organism that develops into an epidemic once plant age and/or environmental conditions are appropriate. Many severe diseases have been introduced this way into previously clean growing areas and even other countries. Plant material can be tested at specialized labs. Growers also may request certified materials from their suppliers. This certification is usually given by agricultural government agencies.

3. Cultural Control

Many cultural practices can discourage or retard the dissemination of a problem. Most of these practices deal with keeping cropping areas clean, but also with trying to manipulate the environment so it is not conducive to disease (but does not harm the plant either). The specific strategy chosen will depend on the particular pest or disease to be controlled, the growing conditions, the species of flowers and varieties grown and other factors. The following examples help illustrate this:

Weed control

Many common weeds (and also plants not considered weeds) also act as alternate hosts for pests and diseases. So while crop plants are being treated, pests may be surviving on otherwise harmless weeds, only to go back to the crop once the effect of the chemical – or other treatment - has passed. In many instances, weeds are a pest and need to be eliminated anyway. This is the case of species like *Oxalis* sp and *Cyperus* that are presently controlled with methyl bromide in flower farms of some countries. If the cost of hand weeding is acceptable then this option should be considered. In any case, do not wait with weed control until after the plants start flowering and seeding.

Crop rotation

Certain pests and diseases are very specific for their host and will die in its absence. In such cases, it may be a good idea to rotate the affected crop with a different one for some time. The period depends mainly on the pathogen's survival ability when its host is not present. In floriculture however, there are not many cases where this is a real option. Some flowers like roses, for example, have productive cycles that are far too long for rotation to be feasible (5 to 10 years). In other cases, the disease agent survives for very long periods of time even though a susceptible host is not there, readily becoming infectious as soon as it is replanted in the same site. This is the case of fusarium wilt, crown gall (*Agrobacterium*) and many others. Still in other cases (i.e. nematodes), the host range of the pathogen is so large that rotation does not lead to any significant population reduction.

Ventilation

When plants are growing too close together, air circulation between them is poor and relative humidity builds up. This encourages development of many fungi such as *Botrytis* and mildews. Rather than applying more pesticides, air circulation can be improved to reduce disease incidence, for example, through adequate crop density. When growing inside a greenhouse, this point is especially important. Greenhouses that are too large or too low for example, are more difficult to ventilate and may get too warm, which encourage pest outbreaks.

Greenhouse maintenance

If investment is made in a greenhouse it should be kept clean and in good condition. Greenhouses are there to provide a better environment for plants to grow in, but also to help avoid conditions that encourage pest or disease development. Many rusts and other

Photo: Marta Pizano.

Fig. 6. General sanitation and greenhouse covers kept in good condition help to maintain good plant health.

fungi such as gray mould (*Botrytis)* for example, will only germinate on plants if there is free water on the leaves, no matter how high the relative humidity. A well-ventilated greenhouse with covers in top condition will help avoid free water to a very large extent. Greenhouses also permit using tight screens that can keep most insects out.

Sanitation

Keep greenhouses and any other growing range free of plant debris, as many pests survive and breed in it. Rouging or removing diseased plants or plant parts can reduce or prevent dissemination of a problem.

Fertilization and Watering

To start with, healthy and well-nurtured plants are more resistant to pests and diseases than stressed ones. However, fertilization and water can directly affect development and dispersion of many soil-borne pests (nematodes, fungi like *Fusarium* and many others). Here are some examples:

- Irrigating by gravity may very well be the most efficient way to spread a soil-borne fungus and even some nematodes and weed seeds to all cropping areas
- Good soil structure and watering only according to the plant's needs (for example, measuring soil humidity with the aid of tensiometers) ensures proper drainage and helps avoid excess of moisture in the soil – which favors disease development.
- Acid pH levels deter growth of bacteria while basic ph levels deter fungi. So whenever possible (remember to take the plant's preference for a given pH range into consideration), bringing soil pH up or down – or choosing a growing site that has the desired pH - is a good way of discouraging disease.
- Drip irrigation, if suitable for the particular flower species grown, can minimize spread of certain insects, some nematodes and fungal spores, which occurs with sprinkling water.
- Researchers have found that growth of some fungi like *Fusarium*, which cause wilt and root rot diseases of many plants and flowers like carnations and chrysanthemums, is larger when plants are fertilized with ammonium forms of nitrogen than when nitrates are applied.

Restricting access to greenhouses or within growing areas

Most soil-borne organisms are obviously disseminated with soil. For this reason, workers walking from a diseased area to a healthy one may contribute to disseminating the problem by carrying it on their feet. The same applies for visitors or vehicles coming to the farm. Even pets or children allowed in greenhouses may act as 'vectors'. This can be avoided by restricting movement inside growing areas. Whenever possible, assign employees to a specific area only. If employees must move, consider using a disinfectant solution between areas to dip shoes in – some growers even use lime that has a very high pH and kills fungi.

4. Physical Control

Physical controls include all barriers or non-chemical treatments that reduce, prevent or kill diseases or pests. The following examples illustrate this point and even though some of them are not in themselves alternatives to methyl bromide they are well worth considering as part of an IPM program:

Sticky traps

Flying insects like thrips and leafminers are attracted by certain colors, bright yellow in particular. Blue and white are also attractive to thrips. Traps, consisting of square pieces of cardboard or hard plastic coated with a sticky substance are placed throughout the greenhouse

Photo: Natalia Martínez and Rodrigo Rodríguez.

Fig. 7. Yellow traps attract a wider spectrum of insects. Large traps like these help reduce insect populations.

Photo: Marta Pizano

Fig. 8. Blue sticky traps attract thrips and help to estimate populations of this insect.

among the plants. Sticky preparations of different kinds are available in the market but even vegetable oil will serve for this purpose. Adults will fly towards the traps and stick to them, allowing scouts to count them and, along with information on the damage caused establish an action damage threshold as described before (i.e., between one and five adults per week and per half hectare no pesticides need to be applied; between six and ten adults one application is carried out and above that a preventive program is in order). However, some growers also use long strips of yellow and/or blue sticky plastic inside and around growing ranges that help reduce insect populations and entrance from outside sources. As a general rule, 1-2 sticky traps per $100m^2$ should be used of growing area.

Although sticky traps are mostly useful in the control of aerial pests, the life cycle of some of these pests include one or more stages that occur in the ground (i.e., thrips pupate in the soil). As a result, traps like these may contribute indirectly to reduce damage caused by soil-borne problems.

Insect screens

When growing under a greenhouse – especially the kind that has wide openings like polyethylene houses – it is possible to install fine mesh screens that keep even very small insects from entering. Since some of these insects like thrips and aphids are vectors of some viruses, their exclusion is doubly beneficial. One problem associated with screens is their typically high cost that makes them suitable only for areas needing extra health care such as propagation beds. Another major problem is the fact that air circulation is substantially restricted which increases air humidity inside the greenhouse leading to other disease problems.

Photo: Natalia Martinez and Rodrigo Rodriguez.

Fig. 9. Fine mesh screens such as this one can keep insects from entering a greenhouse.

Aspirators or vacuum cleaners

Aspirators that work in a similar way to a home vacuum cleaner are used in countries like Colombia and Ecuador to "clean the house" several times a week. When directed over and under the foliage of plants, the hoses of these machines suck insect adults and immatures, sending them into a bag which is later placed in hot water killing them. This has proven an efficient non-chemical option to chemical control, although it does require access to electricity in the flower range.

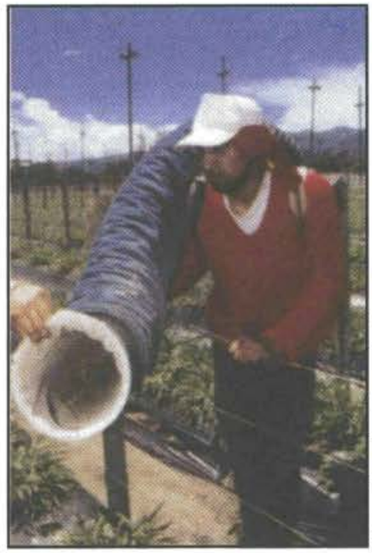


Fig. 10. Vacuum cleaners significantly help to reduce flying insect populations. Above, a worker showing the results of vacuuming in Ecuador.

Treating disease foci

Once a plant or group of plants affected by a particular problem is found through scouting, it is most important to follow an eradication program that takes into account the pests' specific characteristics. In the case of fusarium wilt of carnations for example, the diseased plants and all neighboring plants in a diameter of about 1m are carefully pulled out, bagged and taken out of the greenhouse to be incinerated.

The rouged area is then treated with formaldehyde, steam, lime or a systemic fungicide to prevent or at least retard dispersion of the fungus to other plants. Treated foci should be well marked on the flower range maps used by scouts.

Fig. 11. Spot treatment of Fusarium wilt of carnations.

Steam sterilization of soil or substrates

If properly conducted, steam sterilization is probably the only alternative with effects truly comparable to those of methyl bromide. However, for it to be effective in the long run, it should be coupled with a thorough IPM program. Steam sterilization is discussed in detail in Chapter 3.

Soil-less substrates

Although in many parts of the world flowers are grown on ground beds, growers everywhere are turning to raised, or otherwise isolated beds filled with different kinds of substrates that are normally free of pests and diseases and can be easily treated for re-use. This technology has been used for many years in countries like Holland where the soil is not suitable for ground cultivation. However, recently new substrates that are locally available to growers are being adapted in other countries. Examples of such experiences are discussed in Chapter 5.

Other barriers

According to the nature of the disease or pest controlled, other barriers can be used at the entrance of greenhouses or flower farms. For this purpose, many growers build shallow ditches filled with a disinfectant solution through which vehicles or people pass before coming into contact with growing areas. Lime powder is also used, even on the passage between healthy and diseased areas.

Photo: Marta Pizano.

Fig. 12. Lime is used to make a barrier between contaminated and clean areas. Due to its high pH, it kills fungus spores.

Photo Natalia Martínez and Rodrigo Rodríguez.

Fig. 13. Workers walking through a disinfectant solution to clean feet of possible pathogens.

Plastic mulches

Plastic film placed as a ground cover with holes that allow only desired plants to come through are a good option for controlling weeds and also some insects and fungi. The film is generally black to block out light that is necessary for the germination of weed seeds but also of other organisms. Mulch of this type is also used to increase the amount of light available to plants. Therefore, two-ply plastic film that is black on the underside and white on top is used – which actually maximizes light intensity while keeping weeds and other noxious organisms at bay. This system has been used successfully to grow flowers like *Limonium* (especially the *perezzi* type) that need high amounts of light to produce stems of the desired height.

Photo: Marta Pizano.

Fig. 14. Plastic mulch such as this on limonium beds, is black on the underside to help prevent weed germination and white on top to increase luminosity.

Solarization

By placing clear polyethylene over moist soil during hot, sunny days, the temperature at the top layer of soil can reach temperatures over 50°C. When these climatic conditions are continuous for several days or weeks the high temperatures will reach as deep as 30 cm into the soil, killing many soil-borne fungi, nematodes and bacteria and thus greatly reducing their harmful potential.

Solarization is a proven technology in many disease situations. However, when dealing with intensive year-round production like that of cut flowers, a treatment that takes several weeks is not economically feasible. The alternative is highly dependent on environmental conditions. Pathogens may only be partially killed if these conditions do not occur as expected.

5. Biological Control

In recent years, a considerable amount of research has been devoted to biocontrol in many parts of the world. Even though currently results obtained in the laboratory are often better than those achieved in the field under commercial situations, work with some biocontrol agents and systems is very encouraging and can be incorporated into IPM programs with excellent results. Additionally, commercial formulations of biocontrol agents that are easy to use are becoming increasingly available to growers.

Biopesticides

Presently, trials are being conducted and commercial formulations of pesticides based on live organisms (plant extracts, insect eggs) are now available. Examples of these are neem extract (from the neem tree, *Azadirachta indica*), nicotine extract, garlic and chili pepper extracts, *Bacillus thuringiensis* and others, which mainly act as insecticides. Although they will not provide complete control, their contribution to the overall reduction of harmful organisms is beneficial.

Trap crops

Also interesting are experiences with repellent and trap crops. These are plants that either repel pathogens or attract them, keeping them away from the crop. Good results have been reported in Kenya and Morocco with marigolds (*Tagetes)* as nematode trap plants, and garlic plants have been reported as repellants for nematodes.

Biocontrol agents

Many biocontrol agents have been reported, with varying efficiency. These include fungi and bacteria that are parasitic to pathogenic fungi (i.e. *Streptomyces, Pseudomonas fluorescens,* non-pathogenic forms of *Fusarium oxysporum* which act against the carnation wilt pathogen, *Agrobacterium radiobacter* used against the crown gall bacterium), predatory nematodes that attack parasitic ones, fungi that attack insect larvae and eggs (for example, *Verticillium lecanii*) and others. Results obtained when using these agents may vary with environmental conditions, chemical and structural characteristics of the soil (i.e. pH, temperature, humidity) and other factors.

Growers in several countries are also using solutions of beneficial organisms, which basically contain yeasts, bacteria such as *Streptomyces*, and several genera of fungi naturally occurring in soils. These solutions are sometimes prepared directly at the farm in simple "fermentation units" that simply consist of large tanks where cultures of these microorganisms are increased by adding sources of sugar and nitrogen (i.e. molasses and milk). The procedure is not difficult but requires controlling temperature to a certain extent and above all extreme cleanliness.

Photo: Natalia Martínez and Rodrigo Rodríguez.

Fig. 15. Beneficial organisms can be cultured directly by a grower (original strains are obtained from specialized labs).

Photo: Marta Pizano.

Fig. 16. Broth rich in beneficial organisms ready to be applied to compost or soil.

Trichoderma sp is one of the biocontrol agents that is not new but is currently generating new interest among flower growers mainly due to its wide range of action. Extensive research on the potential of this fungus for controlling diseases has been conducted on many crops, including ornamentals. Strains and species of *Trichoderma* can promote vigorous root formation and can prevent infection of roots by several fungal pathogens like *Rhizoctonia*, *Pythium* and *Fusarium*. It is also quite flexible in its adaptability to different kinds of soil, and works on many flower crops. Commercial formulations of *Trichoderma* are now available. They are applied for example after soil steaming or together with compost containing other beneficial microorganisms.

Biofumigation

Some plants particularly those belonging to the Cruciferae (a family whose members include cabbage, cauliflower, broccoli and Brussels sprouts) as well as other families, will give off substances that act as natural pesticides when used as a ground cover or mulch or are incorporated in the soil. In fact, some of these substances are actually the same as contained in fumigants like metham sodium. Although still mostly experimental, results with this alternative are encouraging in some countries like Spain.

6. Genetic Control

Researchers in many parts of the world, but particularly Holland, France and Israel, are also devoting significant amounts of time and money to the breeding of varieties of several flower species possessing different degrees of resistance to their most severe pests and diseases.

With respect to soil-borne pathogens affecting flowers, perhaps the best achievements have been made with carnations resistant to fusarium wilt. Presently, a wide range of commercially acceptable, high yield varieties with various degrees of resistance to *Fusarium oxysporum* f.sp. *dianthi*, (the causal agent of this disease) are available. In this case, resistant varieties are a very valuable tool as they can be grown in areas were the disease has been previously present (this information is obtained from the monitoring programs) leaving those that are susceptible but are still grown for marketing reasons for cleaner areas.

Rootstocks used for grafting rose plants differ in their susceptibility to *Agrobacterium tumefaciens* causal agent of crown gall. This is an important factor to consider.

In fact, variability of response to a particular pest or disease is naturally frequent among cultivars of a given species, not only of flowers but also of plants in general. This is very important information that should be documented by each grower from experience and observation.

7. Chemical Control

Trials and experiences with soil fumigants have shown that their effectiveness varies with factors like the pathogens to be controlled, soil characteristics and crop species. Whatever the case, it is important to keep in mind that they can be (and should be) used as part of an IPM strategy so that control does not rely on their use only. In fact, some examples of where these chemicals have been combined with other options for sterilizing the soil, i.e., steam, have shown variable results.

Additionally, these fumigants should be used with great caution because they are biocides (they kill both beneficial and noxious organisms in the soil, disrupting its natural balance), and hazardous to human health and toxic to the environment. Restrictions imposed on floriculture at the international level could well mean limitations or even banning on the use of these products.

Even though methyl bromide has been the chemical fumigant of choice for eliminating soil-borne pathogens in most flower producing countries, there are a number of different products that provide good control. These have been used for many years and are presently being evaluated as alternatives to methyl bromide in several countries (see Chapter 6). Among such products, the most promising results are being obtained with Metham sodium, Dazomet and 1,3 Dicloropropene. A general description of these fumigants follows.

Table 5. Soil fumigants that can be used for soil disinfestation in floriculture.

Common name	Commercial names	Pests controlled
Metham sodium	Vapam, Buma, Trimaton, Busan	Wide spectrum. Soil fungi, nematodes, weeds and insects.
Dazomet	Basamid, Allante, Dazoberg	Germinating weeds, nema todes (not the cyst kind), soil fungi and insects
1,3 Dicloropropene	Telone-II, Telone C-17, Telone C-35, Nematrap, Nematox	Mainly nematodes and insects, some soil fungi and weeds especially if combined with chloropicrin

Precautions and health protection standards should always be observed when using these products, as well as for re-entry and re-planting times. Application of these products – just like any other pesticide – should only be carried out wearing protective masks, gloves, uniforms, and other protective gear. Always read the label of a chemical product carefully; it contains recommendations, suggested rates, emergency procedures and other important information.

Metham sodium (Sodium N-methyldithiocarbamate dihydrate)
The best known commercial names for this product are Vapam® and Buma® although Trimaton®, Busan® and Unifume® are also used in different countries. Metham sodium is a wide-spectrum soil fumigant used for the control of many genera of fungi (*Verticillium, Fusarium, Pythium, Rhizoctonia, Phythophthora, Sclerotinia*), nematodes (most species), weeds (most species) and arthropod pests (sypmhylans, collembola and many others). It may be applied by different methods but when treating beds, injection into the soil is preferred. It should be used during the pre-plant stage and should not be used near growing plants, as fumes are phytotoxic, nor close to irrigation lines or when temperatures are above 32 °C. Soil to be treated should be well prepared and slightly moist to ensure susceptibility of weed seeds (moisture encourages germination). The re-planting period is normally about 14 days, but can be much longer in heavy soils, soils with high organic matter content or when soil temperatures fall below 15 °C. Metham sodium is highly toxic and poses considerable human and animal health hazards. In the USA it is listed as a known carcinogen and a developmental toxin.

Dazomet. (Tetrahydro-3,5, dimethyl-2H-1,3,5-thiadiazine-2-thione). It is commercially known as Basamid® but other commercial names include Allante® and Dazoberg®. It is a pre-plant soil fumigant effective against germinating weeds (many species), nematodes (root-knot and many other genera but not *Meloidogyne* cyst nematodes), soil fungi (*Pythium, Fusarium, Rhizoctonia, Verticillium, Phythopthora* and others) and arthropods (especially stages that occur underground). It is incorporated into the soil at a depth of 20 to 25 cm; soil should be moist (recommended is about 50% of water holding capacity). After application the soil should be flattened and "sealed" with a light application of water or covered with canvas or polyethylene. Dazomet is toxic to growing plants but does not accumulate in the soil; it should not be used at temperatures above 32 °C. The re-planting waiting period is between 10 and 40 days depending on the soil type and temperature. It is essential that all toxic vapors have disappeared at the time of planting. Dazomet contains high levels of nitrogen so it may have an added benefit as a fertilizer. Again, safe application standards should be observed to minimize human and environmental health hazards.

Dichloropropene. (1,3-dichloropropene)
Commercially known as Telone-II®, Telone C-17®, Telone C-35®, Nematrap® and Nematox® among others, this is a soil fumigant basically effective against nematodes and soil arthropods. It is particularly effective against cyst nematodes like *Meloidogyne* sp. especially in loam, sandy soils. It is also active against some soil fungi and weeds, especially when compounds like chloropicrin are included in the formulation, in which case it has shown good results for the control of fusarium wilt of carnations. Telone is injected 15 to 20 cm into the soil at the pre-plant stage (deeper injection may improve results in some cases). The soil is compacted immediately after application and often covered tightly with canvas or polyethylene. After treatment, the soil should be ploughed in to improve aeration and get rid of toxic fumes. Waiting periods before pre-planting vary greatly depending on whether shallow root or deep roots are grown, soil type, moisture and other factors. It should not be used on very heavy soils. Constraints related to wet soils and low temperatures do not affect performance of this product to such an extent as is the case with metham sodium and dazomet. Telone is a potential contaminant of water; it poses considerable acute human and animal health hazards. In the USA it is listed as a carcinogen.

Real - life examples

Taken all of the above into consideration, IPM programs can then be made to fit a particular pest or disease according to its life cycle and epidemiology at a particular site and for a particular plant.
The following checklist or questionnaire will help in designing such a program:

- **Is the problem identified?** If a grower is not sure what the problem is, help should be sought. Samples of the affected plants (and the surrounding soil) should be taken to a plant pathology and entomology lab that can identify the problem and provide recommendations for its proper management.
- **What is known about the pathogen's life cycle?** Where do the different stages develop? How does it disseminate? (by air, on the soil, in water?) What kind of environmental

conditions favor it (Temperature, relative humidity, light, pH, etc?) How does it survive (In the soil, on weeds, on plant debris?) What is its host range?

- **How can the problem be recognized?** What are the early symptoms of infection or infestation? Where should one look for them (i.e., the undersides of the leaves, the whole plant, on the lower stem)?
- **What information should scouts gather?** (Weather, variety, location, other)
- **What should be done if the problem is found?** Are instructions clear to those involved?
- **What is the source of the plant material being used?** Is there a guarantee of its health status? Would it be worth checking on it?
- **Have any resistant varieties been developed?** Which varieties are the most susceptible?

Finding answers to these questions may require some research and studying, as well as having discussions with experts and other growers. The information gathered will take the grower to the next step – designing a training program to help those in charge of the scouting recognize the problem at the earliest stage possible. It will also provide the necessary tools to select and implement prevention, eradication and treatment measures. Even so it may at first appear difficult and requires what could be considered as "investment in knowledge". Over time, most IPM practices become routine and help save 40% or more of pesticide costs.

To illustrate the points above, following are examples for managing two diseases attacking carnations and roses all over the world and which are controlled with methyl bromide in many countries.

A. An IPM program controlling fusarium wilt of carnations

Fusarium wilt or vascular wilt of carnations is the most serious disease affecting this flower. It may become limiting to such extent that it simply puts a grower out of business or forces him or her to look for new land on

Photo: Germán Arbeláez.

Fig. 17. Carnation plants killed by fusarium wilt.

which to grow carnations. Once the disease is well established it is too difficult and costly to eradicate. For this reason, the best (and possibly the only) option is to take a preventive approach.

Following are answers to the checklist above, which will help in designing an IPM program for its control:

1.Causal agent:	*Fusarium oxysporum* f. sp. *dianthi*
2. Host range:	Although *Fusarium oxysporum* is a large species, it is composed by numerous special forms or *forma specialis* each one being very specific for its host. For example, *F.o.* f.sp *dianthi,* only attacks plants of the genus *Dianthus.*
3. Life cycle:	The fungus is soil-borne. It reproduces asexually by spores. Three spores types are known – microconidia, macroconidia and chlamydospores, the latter being the survival (resistant) form. It can remain latent in the absence of its host for several decades. The fungus penetrates through the roots and blocks the conducting vessels of the roots and stems (xylem), interfering with the plant's water and nutrient uptake. It grows at temperatures between 15 and 30° C with an optimum of 27° C. Optimum pH is around 5 and it thrives on high nitrogen levels.
4. Dissemination:	By air, especially in field production or when diseased plants are left untreated. In contaminated water used for irrigation. On plant material (cuttings), which can appear to be healthy. On soil -particles adhered to tools, shoes, vehicles, plant parts or machinery. By contact (or grafting) between roots of plants.
5. Symptoms:	Symptom expression is very much influenced by temperature and humidity. Early infection is evidenced as one-sided wilting that occurs during warmer times of the day and a yellowish off-color in one or more shoots, typically also on one side of the plant only. As the disease progresses, it wilts and eventually kills entire plants, which acquire a dry, straw colored appearance. When stems are cut open a brown discoloration of internal vessels is apparent.

6. Other information:	A good selection of resistant varieties is commercially available. It is important to mark the diseased area clearly and proceed to treat quickly. The diseased varieties and the exact location where they were growing should be marked in a map for future reference. Also note the degree of damage (or susceptibility) present in each variety. The age of the diseased plants is also important: young plants that develop disease may have been carrying it from the cutting stage.

With the above information, a suggested strategy is presented in the Table below:

Table 6. IPM for fusarium wilt of carnations (*Fusarium oxysporum* f.sp.*dianthi*)

A. Quarantine and Inspection	* **Disease – free plant material.** * **Inspection of cuttings** (disease indexing) before planting. * Do not plant where the disease has been known to occur before.
B. Monitoring	* **Disease scouts** trained to detect earliest symptoms. * **Mapping with all pertinent data** – variety, degree of affection, site. * **Historic information for decision making** – which varieties to grow on the future, source of plant material, etc.
C. Cultural control	* **Crop sanitation** – treat disease foci quickly. Lift diseased plants and about 1m of surrounding plants (even if symptomless) carefully and incinerate. Treat soil with lime, steam or formaldehyde. * **Management** of **fertilization** (especially nitrogen sources). pH control (alkaline detracts the fungus). * **Restricted access to greenhouses**. If possible, assign different employees to areas where the disease is present and avoid their entrance into healthy areas. This is especially important if propagation of cuttings is carried on the premises.

Table 6. (continued)

D. Physical and mechanical	* **Soil steaming** is an excellent option and control is economically feasible if disease level is low. Treat previously diseased sites longer. * **Substrates** - use only clean or sterilized in raised or isolated beds. Rice hulls are giving good results in carnations.
E. Biological and genetic control	* **Resistant varieties** are commercially available. Use these preferably on sites where the disease has occurred in the past. * **Antagonists** to the wilt fungus have been reported, among them *Trichoderma*. It is ideal to incorporate these to the soil directly after steaming, and repeat applications two or three times during the season to maintain high populations. Adding organic amendments rich in beneficial organisms (i.e., compost) is also a very good option.
F. Chemical control	* **Disinfectant solutions** may be placed in shal low ditches at farm entrance, greenhouse en-trances or between diseased and healthy areas. Lime is also effective. * **Soil fumigants** – Vapam (metham sodium), Basamid (dazomet), and 1,3 Dichloropropene (Telone) have shown good activity against this fungus.

B. An IPM program for controlling crown gall of roses

Fig. 18. Crown gall of roses caused *by Agrobacterium.*

Crown gall is a disease affecting a large number of plants that is distributed worldwide. Its effects on roses vary with environmental conditions at the growing location and other factors such as the strains of bacteria present but it can be devastating, causing very large losses in productivity by decreasing plant vigor and greatly impairing quality. Following is important information on this disease on which an IPM program can be based:

1. Causal agent:	*Agrobacterium tumefaciens*
2. Host range:	Over 60 plant families have been reported as susceptible hosts to the crown gall bacterium. Common hosts beside roses are chrysanthemums, asters, tomato, sunflowers, many fruit trees and shade trees.
3. Life cycle:	The bacterium enters the plants through wounds, or openings either natural or caused by pruning, grafting and other cultural practices, or made by soil-borne pests (i.e., collembolans, symphyllans, some nematodes). A plasmid associated with it is transferred into the genome of the host cells, transforming them into tumor cells of disorganized growth. According to the environmental conditions (mainly temperature), tumors develop in a few weeks to several months. Galls enlarge and, particularly when located at the base of the stem or at the grafting point, may restrict growth of the plant and normal absorption of nutrients from soil. The bacterium is more active during warm weather and may go latent during colder periods. If a host is absent bacterial populations decrease but may survive in soil for two years or more.
4. Dissemination:	On tools (i.e., pruning knives). When galls break down in the soil, bacteria are released and can be disseminated in soil or water. In rootstocks or young plants which may be apparently healthy, but actually carry a low number of bacteria.
5. Symptoms:	Galls are usually observed just below the soil surface in the crown region of the plant. They are also frequent on roots and less common on aerial plant parts. Initially they are small, rounded, with a smooth surface and light green or white in color. Later they grow into irregular shapes and become darkened and woody. Symptoms on aerial plant parts are easily mistaken with those caused by other problems i.e., nematodes and nutrient deficiencies.
6. Other information:	*Agrobacterium* sp. are composed of many strains and their variability is very high. This may lead to control measures not giving consistent results. Rootstocks

used for grafting differ in their susceptibility to *A. tumefaciens*. *Rosa multiflora* and *R. manetti* have been reported as the most susceptible. Another solution used by growers in areas where the effects of this disease are severe, is the use of tissue - cultured plants that do not need to be grafted. Biocontrol with some strains of *A. radiobacter* has given good results. Copper formulations and some antibiotics give some control, however phytotoxicity can be a problem especially with some varieties under certain climatic conditions.

As in the previous example, an IPM program based on the above information can be developed with the following considerations:

Table 7. IPM for crown gall of roses (*Agrobacterium tumefaciens*)

A. Quarantine and inspection (exclusion)	* **Disease – free rootstocks** or plant tissue cultured plants (not grafted). * **Carefully inspect** plants upon arrival.
A. Monitoring	* **Scouts** trained to detect earliest symptoms of diseases. * **Mapping** with all pertinent data – variety, degree of affection, site. * **Historic information** for decision making - which varieties to grow on the future, source of plant material, etc.
B. Cultural control	* **Crop sanitation** – treat disease foci quickly. Lift and discard diseased plants, remove soil around roots to discard as many galls as possible. * **Disinfect tools** – wash cutting or pruning tools and disinfect frequently (i.e., dipping in alcohol or a sodium 0.5% hypochlorite solution, flaming). * **Avoid wounding** tissue as much as possible. This includes control of soil-borne pests like nematodes. * **Restricted access** to greenhouses. If possible, assign different employees to areas where the disease is present and avoid their entrance into healthy areas.

Table 7. (Continued)

	* **Rotate** with monocotiledoneous crops (i.e., corn) if commercially feasible (rotation should last three years or more).
C. Physical and mechanical control	* **Soil steaming** – is an excellent option, should be coupled with addition of compost or similar amendment * Growing on **substrates** that are clean and/or can be sterilized. Coconut coir, composted bark, rockwool and others have been used successfully.
D. Biological and genetic control	* **Use resistant rootstocks.** *Rosa multiflora* and *R. manetti* have been reported as very susceptible. None of the rootstocks presently used are known to be immune * **Antagonists** to crown gall have been found, particularly strain No. 84 of *Agrobacterium radiobacter*. Rootstocks and seedlings can be dipped in a suspension of this bacterium. Unfortunately, some strains of *A. tumefaciens* have become resistant to strain 84. A new strain (K-1026) is being used, as it does not transfer resistance to pathogenic *Agrobacterium* strains. Adding organic amendments rich in beneficial organisms (i.e., compost) is also a very good option.
E. Chemical control	* Copper based pesticides and several anti biotics i.e., streptomycin and oxytetracycline provide some control but should be used cautiously due to possible phytotoxicity. In some countries there are regulations that re strict the use of these compounds. * **Soil fumigants** – Vapam (metham sodium), Basamid (dazomet) and 1,3, Dichloropropene (Telone) are wide-spectrum biocides that can be used.

The multidimensional approach

As we have seen, alternatives to chemical control (or better still, to methyl bromide) are numerous and varied. Nevertheless a grower might think it too complicated to design an IPM program for each and every pest affecting his crop, particularly since he may be growing more than one flower species.

However, if the above examples are analyzed, it is clear that many of the procedures carried out with the aim of detecting and even controlling one pest or disease are in fact able to control most of the rest. For example, it is not difficult for scouts to spot more than one problem at a time. This leads us to the concept of the **multidimensional approach**, or a comprehensive solution that actually aims to reduce all noxious agents simultaneously and maintain acceptable plant health and product quality.

To make a multidimensional approach the following steps are important:

1. **Inventory of pests and diseases affecting a particular crop**. A decision must be made as to which problems require most attention and which imply the higher risk. Experience is invaluable in this respect, but fortunately information is generally abundant. Along with this list, documentation on each pest as described before is necessary (e.g., host range, symptoms, epidemiology, etc).

2. **Creating a simple matrix.** On one axis, list IPM strategies that can be carried out at the farm. On the other, list the most important pests identified in step 1. The result will be a chart from which valuable information can be derived as is shown in the examples below which were actually supplied by a grower carrying out a thorough IPM program. **Chart 1** is a proposed matrix for roses, while **Chart 2** has been filled out for the particular case of chrysanthemums. The latter is more complicated, given the number of pests and diseases affecting this flower. The examples below are applicable to any flower species. Note that this matrix takes into consideration not only soil-borne pests and diseases but all relevant pathogens affecting this crop. According to the particular problems affecting a crop at a particular location, these matrixes may exclude some of the organisms considered below or others may be added. Each grower must decide this from his own experience.

Illustration 2. The Multidimensional Approach

A. List of Pests and Diseases affecting Crop

↓

B. Create matrix of strategies for each pest

↓

C. Create customized IPM program

Table 8. Integrated Pest Management for *Rosa*

Crop: Roses

		DISEASES									PESTS					
		FUNGI							Bacteria	Virus	INSECTS			Mites	OTHER	
Action	Method	PMIL	BSP	BOT	DMIL	RUS	CAN	VER	AGR	RMV	THR	GRU	BOR	SPM	NEM	SLU
Exclusion	Regulatory Cultural Clean Plants															
Eradication or Reduction	Cultural Biological Trad. Chemical Org. Comp. Physical															
Host Plant	Res. Varieties Cultural															
Direct Protection	Biological Trad. Chemical Org. Comp.															
Scouting																

Source: Jaramillo, F. 1997 Integrated Pest and Disease Management. In: Floricultura y Medio Ambiente, Ediciones Hortitecnia, Bogotá, Colombia.

Conventions
PMIL = Powdery mildew
BSP = Black spot
BOT = Botrytis
DMIL = Downy mildew
RUS = Rust
CAN = Canker
VER = Verticillium
AGR = Agrobacterium

RMV = Rose Mosaic Virus
THR = Thrips
GRU = Grubs
BOR = Borers
SPM = Spidermites
NEM = Nematodes
SLU = Slugs

Trad. Chemicals = Traditional chemicals
Org. Comp. = Organic compounds

Table 9. Integrated Pest Management for *Dendranthema*

Crop: pompom chrysanthemum

		DISEASES																			PESTS								
		FUNGI													BACTERIA			VIRUS			INSECTS					MI	OTHER		
Action	Method	wr	bot	ste	asc	riz	pyt	Scl	cru	ph	fus	ver	sep	mil	agr	ew	pse	stu	mv	tsv	lfm	thr	ap	wfl	bor	sm	ne	sin	Slu
Exclusion	Regulatory	X																											
	Cultural																												
	Healthy	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Eradication or reduction	Cultural		X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X		X
	Biological				X				X												X	X							
	Trad. Chem.	X	X	X	X	X	X	X	X			X	X		X					X	X	X	X	X	X	X	X	X	X
	Org. comp.	X			X	X			X					X		X			X	X	X	X	X	X	X	X	X		X
	Physical			X								X					X				X	X	X	X					X
Host plant	Res. Variet	X							X																				
	Cultural	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X												
Direct protection	Biological				X*	X*	X*		X*												X	X	X				X*		
	Trad. Chem.	X	X	X	X	X	X	X	X	X				X	X	X					X	X	X	X	X	X	X	X	X
	Org. comp.		X	X		X	X			X					X		X				X	X	X	X	X				X
Scouting		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Source: Jaramillo, F. 1997 Integrated Pest and Disease Management. In: Floricultura y Medio Ambiente, Ediciones Hortitecnia, Bogotá, Colombia.

Conventions

WR = White rust
BOT = Botrytis
STE = Stemphyllium
ASC = Ascochyta
RIZ = Rhizoctonia
PYT = Pythium
SCL = Sclerotinia
CRU = Common rust
PH = Phoma

FUS= Fusarium
VER = Verticillium
SEP = Septoria
MIL = Mildew
AGR = Agrobacterium
EW = Erwinia
PSE = Pseudomonas
STU = Stunt viroid
MV = Mottle virus

TSV = Tomato spotted wilt virus
LFM = Leafminers
THR = Thrips
AP = Aphids
WFL = Whiteflies
BOR = Borers
SM = Spidermites
NE = Nematodes
SIN = Symphyllans
SLU = Slugs

X* = Compost amendment
Trad. Chem = Traditional chemicals
Org. comp. = Organic compounds
Res. Variet. = Resistant varieties
Healthy pl. m. = Healthy plant material

Chapter 3

Steam sterilization (Pasteurization) —

Pasteurization or steam sterilization of the soil is a process by which pests, diseases and weeds present in the soil at a given time are killed by heat. Although dry heat can in theory be applied with very similar results, steam is preferred because it diffuses more efficiently through the soil and is generally more cost effective.

In very simple terms, steam sterilization involves injecting or otherwise diffusing hot water vapor into the soil with the aid of a boiler and conductors such as metal or hose pipes in order to kill noxious soil-borne organisms. The soil needs to be covered with canvas or a resistant plastic sheet to keep the steam in contact with it.

If carried out properly, steam is probably the best alternative to methyl bromide, proving equally effective. Once again, its utilization is not new to the industry; pasteurization has been used in greenhouses for many decades and most books on greenhouse management address it in detail. In fact, with the advent of soil fumigants some growers abandoned this technique in their favor, due many times to reduced costs (see below) and simplicity of application.

Many variables influence the success and cost effectiveness of steam (i.e. the boiler and diffusers used, soil type and structure, soil preparation and others) as discussed below. Further, it is important to note that steam is always more effective when a limited amount of substrate is treated but not the ground soil. This is due to the depth at which harmful organisms can be found in the soil, which too often is either out of the reach of steam or can be reached only at extremely high costs. Heating the soil at depths of more than 30 cm require much longer use of the boiler, more hand labor and fuel quantities that may render this an economically unacceptable alternative.

However, steam can be used as an alternative to methyl bromide for flowers grown commercially on ground beds if certain factors are taken into consideration. The most important factor is using steam as part of an IPM system that helps maintain diseases and pests at a low level of incidence. This allows for treatment of the first 30 cm of soil to be sufficient for reducing pathogen population significantly.

Because steam – just like any wide-spectrum soil fumigant – is a general biocide, it will kill all living organisms, good and bad, if properly used. This leaves space for pathogens that are either reintroduced or left inside the soil to reproduce and disseminate without any competition from naturally occurring microorganisms. For this reason, steam also works best when beneficial organisms and/or organic matter (i.e., compost) are added to the soil immediately after treating. However, any grower undertaking composting on site (in his own farm), should be aware that it has to be properly prepared in order to avoid re-infestation of the soil with pathogens and other problems.

1. Length of treatment

The success of steam is based on the fact that living organisms have relatively low thermal death points. This means that they do not need to be exposed to such high temperatures to die as shown on **Illustration 3**.

Achieving the required temperature throughout the soil however can be difficult, as steam diffusion may be affected by several factors that are outline below. For this reason, it is best to be on the cautious side, and provide a good margin both in time and temperature to ensure that pathogens and weed seeds are properly eliminated. As a general rule, experts recommend conducting treatment so that the coldest spot in the soil or substrate is held at 90°C for ½ hr.

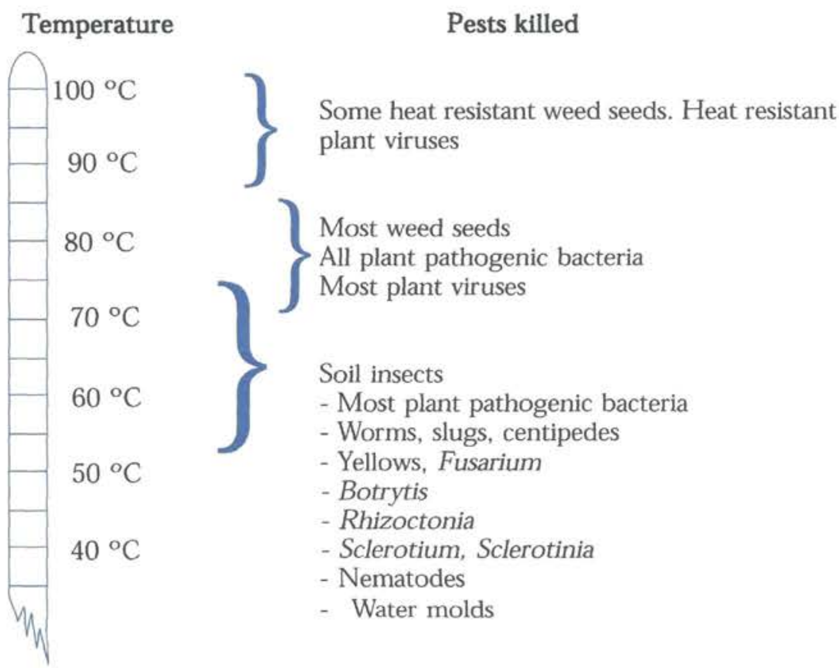
Photo: Marta Pizano.

Fig. 19. Temperature reached by the soil should be measured with a long steam thermometer as shown here.

The coldest spot is usually right behind the point of steam injection, but it is nevertheless necessary to check the temperature in different places. To do this, long stemmed thermometers are used

– the steam should penetrate as deep as treatment is desired. One resourceful grower found that he could obtain good results when a raw potato placed on the coldest spot had been thoroughly cooked. This helped avoid difficulties sometimes encountered when trying to teach employees how to read a thermometer accurately.

Illustration 3. Thermal death points of several plant pests



After: Mastalerz,1977.

2. Boilers and diffusers

Many types of boilers are commercially available, offering different options to the growers. The best advice on choosing the correct boiler is possibly that obtained from a reputable supplier. Substantial literature that covers the mechanics of pasteurization with steam is also available. It should be noted that in countries where good manufacturing firms are not available, actual experience from companies or farms growing under similar conditions is very useful and communication should be encouraged. Boilers can cost several thousand US dollars, sometimes even tens of thousands so adequate selection of the right machine for a grower's particular needs is very important. Some parameters that should be considered before investing in a boiler are:

Photo: Guillermo Castellá.

Fig. 20. An injection type boiler in Argentina. Steam is forced into the soil through a platform.

Photo: Marta Pizano.

Fig. 21. Coal boiler in Colombia.

Boiler capacity

The amount of soil or substrate to be treated will determine the capacity of the boiler needed. Other factors are the time available for treating and whether there is a need or not to move the boiler around (see below). However, large growers often prefer to buy several smaller boilers that can work simultaneously rather than having one large machine that is difficult to move.

Efficiency of steam pasteurization is usually low - about 50% - which means that large amounts of heat are lost from the boiler itself, the diffusers, and the covers. As a general rule, each HP unit in a boiler treats 2m^3 substrate and takes 2.5 hr to achieve 90°C. This number, extrapolated to the approximate volume of soil that needs to be treated (for example per hectare) will provide an approximate capacity of the boiler (or boilers) to be used. (Note: 1 boiler HP = 33,475 Btu/ hr).

High or low pressure

Both high (75–100 psi) and low (10–15 psi) boilers are available. Pressure is necessary to deliver the right amount of steam from the boiler to the substrate; however, very high pressure leads to steam escaping into the air without diffusing properly through the substrate. Pressures of 15 to 18 psi are recommended in most cases. Negative pressure steaming is another option. It is preferred in Holland due to reduced hand labor and its efficiency in heavy and sandy soils.

Diffuser type and diameter

Different types of diffusers (conductors) are available that deliver steam from below the soil surface - usually buried pipes or rakes that dig into the soil - or above (large metallic plates with openings or porous canvas hose that are placed on top of the soil). When applicable, their diameter should always be correlated to the pressure at which the boiler operates. As a general rule, high-pressure boilers require thinner pipes (diameter under 5cm) and low pressure thicker ones (diameter over 5 cm). Openings or perforations in pipes should be made every 15 cm so steam is evenly distributed throughout the soil. Steam diffuses following an oval-shaped trajectory; if these ovals overlap (which they do, when holes occur every 15 cm), good coverage is achieved.

Fig. 22. Steam delivered through buried pipes is forced through the soil and kept from dissipating with canvas covers.

Photo: Marta Pizano.

In general, buried pipes are preferable to superficial diffusers when steaming ground beds. Pipes can be buried to achieve deeper treatment while steam coming from a superficial source will only travel 20 to 30 cm into the soil. Thus, the latter are more adequate for treating raised beds or limited amounts of substrates or potting mixes. Buried pipes should be placed at about two thirds of the desired depth of treatment. In either case, beds should be covered tightly during the process to prevent steam from escaping.

Photo: David Cheever.

Fig. 23. Raised beds should be covered tightly with canvas or plastic before steam is forced into the substrate.

Covers

In general, vinyl or canvas is used to cover the soil or substrate while treatment takes place. Polyethylene is usually too weak to make a good cover as it tears easily. The cover should fit snugly over the soil or substrate; if treating raised beds, it should fall well over their borders. Chains, pipes or other heavy materials are often placed along the borders to help avoid covers from inflating and letting steam out.

Fuel

Boilers that run on electricity, gas, diesel, crude oil and even coal are available. The fuel most suited to a grower's needs will depend on what is available – and how much it costs. Presently however, some countries have regulations that restrict the use of coal boilers because of the risk of causing air contamination. In this sense, the height of the smokestack is important: it should be tall enough to ensure that gases are swept well away from the greenhouse where they could cause injury to plants.

Movable or stationary

For ground beds, and even large raised or isolated beds, it is important to have a movable boiler that can be taken around and between greenhouses. Movable boilers can either be pulled with a tractor or mounted on a truck to be transferred from one working site to the other. Stationary boilers are more useful for steaming substrates or mixes that are later used for filling pots, flats or other containers. Pasteurized media should be manipulated as little as possible to avoid recontamination as discussed below.

3. Soil or substrate to be treated

Soil moisture

Soil that is too wet is slow to pasteurize because it takes too long to heat the extra water. On the other hand, soil that is too dry will have air pockets that interfere with steam movement so that some areas are not properly heated. This is dangerous since pests or weed seeds present at those precise sites will not be killed, and will be free to reproduce rapidly in absence of competitive organisms normally present that have been greatly reduced by pasteurization. The best moisture content is that defined as "field capacity". A soil or substrate is said to be at field capacity when it is neither wet, not dry. Seedlings are typically planted when the growing medium is at this stage.

Soil texture

In order to ensure good steam diffusion, soil should be loose, not compacted and free of large lumps or agglomerates. Once again these lumps interfere with the passage of steam, resulting in areas that are not properly heated. Soil that is going to be steamed should be well-prepared and as free as possible of plant debris and other crop residues.

Soil type

Just like water, steam travels with more difficulty in some soil types than in others. Clay soils are the most difficult to treat and may take considerably more time to treat properly than loam or sandy soils. To some growers very heavy soils are a true limitation to steaming.

4. Common problems associated with steaming

Accumulation of soluble salts

High temperatures increase the solubility of many compounds particularly phosphates, and elements like manganese, zinc, iron, copper and boron. As a result, their levels in the soil or substrate will often be higher than before steaming. Although most salts can be leached, try to keep this practice to a minimum as it increases risks of water and soil contamination. Above all, it is important to adjust fertilization programs to soil analyses performed before planting.

Manganese toxicity

Many soils naturally contain very high quantities of manganese, but usually only a small amount is available to plants – the manganous ion or Mn^{++}. However, high temperatures that are used for steaming enhance the conversion of unavailable to available manganese. High manganese is toxic by itself, causing leaf tip burn especially in older leaves; it also interferes with iron uptake so iron deficiency symptoms are common when manganese is high. In preventing manganese buildup it is important not to over-steam the soil (the longer soil is exposed to high temperatures the more manganese will be converted). Since high pH levels (alkaline conditions) favor the reverse conversion - from available to unavailable forms - another approved practice is to add lime before steaming.

Ammonium toxicity

High levels of ammonium can be released by soils or substrates high in organic matter after pasteurization. Examples of such soils are those that have been amended with manure or compost and decomposed peat. In nature, nitrogen exists in soil in two basic forms: ammonia and nitrates. Under normal conditions, ammoniac nitrogen is continuously converted to nitrate nitrogen by certain soil bacteria as shown below. There is a mixture of both forms, which is usually the best situation for plant growth. Plants can usually tolerate high amounts of nitrate nitrogen much better than excess ammonium, which is often toxic to them.

During pasteurization, these bacteria are almost completely killed. However, the rate at which they re-colonize the soil is not the same: while ammonifying bacteria have built up a sizeable population in just a couple of weeks, releasing significant amount of ammoniacal nitrogen, nitrifying bacteria will only reach levels where they can stabilize ammonium after about six weeks.

$$\text{Organic matter} \xrightarrow{} \underset{NH_3+}{\overset{\text{Ammonifying bacteria}}{\text{Ammonium}}} \xrightarrow{} \underset{NO_4}{\overset{\text{Nitrifying bacteria}}{\text{Nitrate}}}$$

(Source: Nelson, 1998)

Plants affected by excess ammonia will appear yellow and sometimes burnt. The problem will pass as soon as nitrates reach normal levels and can be prevented – and to a certain point corrected – by leaching. Organic amendments should be added after steaming and not before. This problem does not occur normally in substrates such as peat moss that are naturally low in nitrogen.

Recontamination

An area that has been thoroughly sterilized with steam may not remain that way for very long afterward. In fact, any microorganism entering the sterile medium will be free to reproduce without any competition. It is therefore very important to avoid recontamination of treated soil. Some helpful guidelines to prevent this are:

* **Use only disease-free plant material.**
* Replant treated areas as quickly as possible. Ideally, as soon as the soil cools off.
* Avoid disrupting or manipulating the soil as much as possible
* Observe hygienic measures such as those described in Chapter 2 on IPM. Make sure workers, tools and others do not come from infected areas. Disinfect tools and shoes when possible.
* Add well treated compost and / or beneficial organisms carefully, when soil is still lukewarm.

Applied examples

One of the most frequent concerns about steaming the soil is cost. Since steam sterilization can be very costly, this concern is justified. However, within an IPM program costs can be reduced so they are comparable to those of fumigating with chemicals. The following examples illustrate this point.

Soil pasteurization for the control of fusarium wilt of carnations

In the following case study, general costs of sterilizing the soil with steam and several soil fumigants for the control of vascular wilt of carnations caused by the fungus *Fusarium oxysporum* f. sp. *dianthi*, were compared. It should be noted that this grower conducts a thorough IPM program in order to keep disease incidence as low as possible and steaming to 30 cm in depth. Otherwise, steam treatment costs will triple. It will become necessary to inject steam at least 80 cm into the soil, which requires very long periods of time, as shown in the case study appearing at the end of this Chapter. An additional consideration is that the approach for managing this disease should always be preventative since losses of 8% or more will make production of this flower completely non-profitable.

Table 10. Comparison of general costs for sterilizing the soil with several fumigants and steam

FUMIGANT	COST PER HECTARE*
Dazomet (Basamid®)	$5,680
Metham Sodium (Vapam®, Buma®)	$5,120
Dichloropropene (Telone®)	$8,000
Methyl Bromide (MeBr)	$5,030
Steam**	$6,970

Figures in US dollars. Data supplied by Jardines de los Andes and Flexport de Colombia, Bogotá, and Cultivos Miramonte, Medellín, Colombia (Rodríguez-Kabana and Martínez, 1997)

* Includes general hand labor costs

** Low disease incidence

In addition to costs being comparable to those of fumigants, other benefits to steam sterilization are observed, as soil fumigants usually require a waiting period – sometimes at least thirty days - before replanting can occur, while steamed soils can be replanted immediately. This sole fact adds one whole month of flower production to steamed areas, representing nearly 200,000 exportable flowers and around $15,000 dollars per hectare.

Flower growers using steam also report more vigorous and productive plants. Even better, they have been able to grow carnations in the same farm for over twenty years with losses of only 3% or less, which accounts for truly sustainable production. Not many flower growers can tell this story given the aggressiveness and virulence of this pathogen in Colombian soils, which have forced growers to change to a different crop.

If not done properly however, steam sterilization can end up being a frustrating and extremely costly experience. **Table 11** presents costs of treating a one hectare plot with steam for the control of fusarium wilt of carnations when:

a) Disease incidence is low (steam injected at 30 cm),
b) Disease incidence is of medium severity (steam injected for half the treatment at 30 cm and half at 80 cm) and
c) Disease incidence is high (all the treatment conducted at 80 cm).

The difference among the three is mainly due to the depth at which steam is injected, which greatly influences fuel and energy costs. Under severe disease circumstances, the fungus has reached high populations levels in the soil, and much more time is required to reach the necessary temperatures to kill the spores.

Table 11. Steam sterilization costs per hectare, for the control of fusarium wilt of carnations according to disease incidence

	Low incidence	Medium incidence	High incidence
1. Direct costs			
Hand labor	2,003	3,258	8,010
Fuel	3,379	5,491	13,515
Maintenance	109	177	435
Equip. depreciation	318	517	1,270
Other materials*	262	429	1,051
2. Indirect costs			
Boiler transportation	165	165	165
Energy	742	1,208	2,968
TOTAL	**$ 6,980**	**$ 11,245**	**$ 27, 415**

Figures in US dollars, data supplied by Flexport de Colombia, Bogotá, Colombia
* Tents, rakes, pipes and tubing and others

Table 11 illustrates the importance of preventing disease spread and build up, which can only be achieved efficiently through IPM. In this particular case, outbreaks of fusarium wilt are carefully recorded during the production cycle. Afterwards, when the crop has been uprooted and the soil is steamed before replanting, those sites are treated to a further depth (60 – 80 cm). This kind of spot treatment is economically feasible to a certain point. It is certainly possible in this particular farm where losses due to fusarium reach only 2-3% of the production. When the crop is re-planted, resistant varieties are located where the outbreaks occurred in the past, leaving susceptible ones for cleaner areas.

Chapter 4

Composting

Originally implemented as a solution to large amounts of plant waste generated in flower farms, composting is now becoming more and more popular because the rich organic amendment obtained not only is an excellent fertilizer but also contains high amounts of beneficial organisms that prevent and help control soil-borne diseases.

Plant refuse - resulting from pruning, discarded or broken flowers but in larger quantities when renovating plantings - was once considered a problem by flower growers who did not quite know what to do with tons and tons of old plant material. Piles of such refuse will be generated at different spans of time, when roses, carnations, chrysanthemums or others have to be pulled out once their productive period has ended; this may happen as frequently as every four months or after even ten years (see **Table 12**). Experts have calculated that on average, one can expect 2.25m^3 of plant refuse per ha under cultivation each day.

Table 12. Volume of plant residue resulting when pulling out one hectare of flowers

Flower type	Tons per Ha	Frequency
Carnations	25/Ha	Every 2 years
Chrysanthemums	9/Ha	Every 14 weeks
Roses	30/Ha	Every 5 - 10 years
Gypsophyla	5/Ha	Every 22 weeks

Source: Dimensión Ambiental de los cultivos de flores (Asocolflores, 1991)

It has become clear that old alternatives such as burning, dumping or simply burying were damaging to the environment and required space and labor and were costly. As a result, growers in many parts of the world have started turning to composting and processing with the help of earthworms.

They found these methods to be an excellent solution to the problem. It soon became apparent that the rich humus resulting from these processes is an effective fertilizer that also helps restore natural soil flora by controlling soil-borne pests and pathogens and increasing water retention capacity.

1. The composting process

In very general terms, composting - which is normally carried out in the open field - requires piles of plant material of proper depth to be left for a given period of time during which a process of decomposition occurs. To accelerate the process, plant material is usually cut or chopped into pieces. Environmental conditions are of great importance (see page 73). Depending on the plant types processed, composting will take between 4 and 5 months.

As soon as composting starts taking place, the temperature inside the piles will go up, reaching around 60°C. This temperature can be considered a natural pasteurization process, killing most of the harmful fungi or bacteria, which may be present in the plants. Temperature peaks will occur roughly every four weeks, but the peak will be lower each time a cycle takes place. This "bell" curve is a good indication of when it is necessary to aerate the composting material (see **Graph 2**).

Learning to tell when the compost is mature is very important since immature compost applied to the soil can result in phytotoxicity to crop plants due to high amounts of ammonia. Experience is the best teacher in this respect.

Following is a summary of the steps followed when composting plant material:

Photo: Marta Pizano.

Fig. 24. A small chopper like this one can process a good amount of rose waste material.

Chopping (cut) plant material

Small, uniform pieces will decompose more rapidly and evenly. However, the appropiate size depends on the amount of water in the plants (very watery stems like those of *Alstroemeria* are difficult to cut) and the machinery available.

Building piles

Make layers starting with sand or another material to provide good drainage; follow with alternate layers of plant material, rice hulls or other porous material for good aeration and a source of nitrogen (i.e., cow or pig manure; if these are not available, a liquid formulation of nitrogen also brings good results).

Fig. 25. Piles that were prepared for composting.

Fig. 26. As shown here, compost piles may be covered to avoid excessive wetting. Holes should be put in film for gas exchange.

Covering

Place polyethylene film directly on top of piles or place piles under a plastic roof. Some growers place piles out in the field. The objective of this step is to keep a good level of humidity inside the piles. In a rainy location a roof is usually a good idea. If film is used holes should be cut to allow for gas exchange to take place.

Turnover

According to temperature evolution (see **Graph 2**), it will be necessary to turn piles over about every four weeks. This is essential to ensure proper aeration of piles.

Fig. 27. Steam coming out of compost piles is evidence of the high temperatures reached in this process, guaranteeing natural pasteurization.

Harvesting

Compost will be ready to use after three or four turnovers (about 3 or 4 months) according to flower type and environmental conditions.

About every four weeks, temperatures inside piles reaches a peak (initially this peak is quite high – about 60 °C – afterwards it is lower), when respiration and metabolic activity of microorganisms is highest. At this point, it is important to aerate the composting material by turning it over so adequate oxygen content is ensured. Turnovers can be achieved by hand with a shovel but very large piles may require a tractor and hoe. Steam coming out gives an indication of how hot the piles are inside.

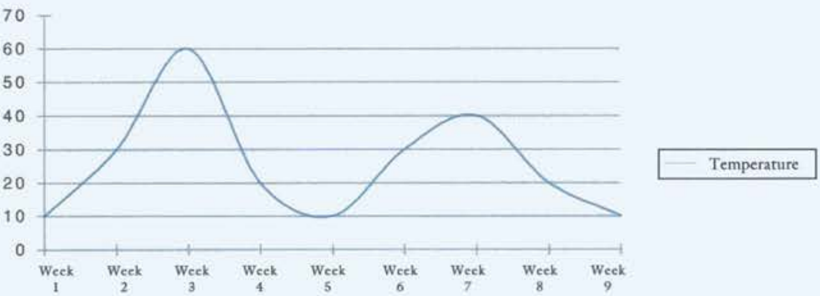

Photo: Marta Pizano.

Fig. 28. Compost piles at different stages in Colombia. The black, moist substrate in the front is ready for use.


Photo: Marta Pizano.

Fig. 29. Compost ready for use in Zimbabwe.

Graph. 2. Evolution of temperature inside compost piles (schematic representation).



Source: Moreno, M. Jardines de los Andes, Bogotá, Colombia, 1999.

2. Important factors to consider

The processes just described require important considerations within a company's infrastructure:

Collection of plant material

A good program for classifying and gathering plant refuse is essential. Materials of different origin - plastics, wires, rubber bands and others - will obviously not decompose and may cause problems later in the process. Once again, this requires proper training. Provide bins, bags or any other containers where plant material can be placed. Make sure this material is taken frequently to the composting site – daily, weekly or whenever is adequate for the size of a given operation. Also note that all plant material can be used – this includes grass clippings, weeds and other plants or plant parts (except for clearly diseased plants discarded as part of disease control programs).

Photo Natalia Martínez and Rodrigo Rodríguez.

Fig. 30. An adequate space for plant refuse provided outside of a grading shed.

Photo: Marta Pizano.

Fig. 31. Composting is very difficult if plant material is left to accumulate as shown here, or there is poor sorting of waste materials.

A chopping site

An adequate place for chopping the plants is important. Also, quantities of plant material generated by a given operation should be considered. If plant material accumulates it may become too difficult to process. This may require cutting every day or every week to the volumes produced. Again, do not let large amounts of plant material sit unattended – this may lead to rotting which interfere with proper results.

Photo: Marta Pizano.

Fig. 32. A large composting operation in Kenya.

Composting site

Ample, well-ventilated areas where compost piles can be placed should be selected. The composting site should not be a dump. It should be clean and well aerated, easily accessible and agreeable to work in. It is important that employees understand the reason for composting, why it is done and what are its benefits.

Time of application

The ideal time to apply compost is at the pre-plant stage, used as a soil amendment that is incorporated right after steaming, together with beneficial organisms such as *Trichoderma* or mixtures of bacteria, yeasts etc., that will help restore the soil's microflora. This is easy to do with short cycle flowers such as chrysanthemums. However, growers in many countries apply these materials directly on beds planted with roses, carnations, and even tropical flowers such as heliconias. Compost is lightly incorporated into the soil, taking care to not injure or disrupt plant roots.

Photo: Marta Pizano.

Fig. 33. Application of compost to recently steamed soil. A diesel run mobile boiler is at the back.

Photo: Natalia Martínez and Rodrigo Rodríguez.

Fig. 34. Compost in bags ready to be applied to rose plants.

Other important factors not associated directly with infrastructure and company organization but to the composting process itself are:

Size and consistency of plant fibers

Plant material, which is very large or very tough, is difficult to turn into compost and will only do so after a very long time. It also takes up a significant amount of space. The solution is to chop it into pieces or even mash or triturate it with the help of special machines, which will reduce volumes by about 70%. Further, it is advisable to process different flower types separately, or at least to put together those that seem compatible. For example, the composting process occurs at different rates for alstroemerias and roses, the former having a higher water content.

Harmful gases or liquids

Gas or liquid given out by decomposing plant material may have a disagreeable smell and may even be harmful to the environment. This is due to the fact that the plant material has almost always been exposed to pesticides and chemical fertilizers. However, proper aeration and collection of liquids is the solution to this problem. Keep in mind that a foul smell and/or flies around the compost piles are a clear sign that the composting is not working adequately and the process should be revised. Please note however, that it is normal for compost or humus to generate liquid effluents, which in fact contains nutrients and beneficial microorganisms and may be applied back to the crop. Collection of these effluents is more efficient if terrain on which piles are placed is slightly sloped.

Adequate content of microorganisms

The proper microorganisms will help the composting process occur much more efficiently and in less time. Although bacteria and fungi normally associated with plants are generally sufficient, sometimes mixtures of yeasts, beneficial bacteria like *Streptomyces* and certain fungi, which enhance the process and speed it up, are added. These beneficial organisms can be grown directly on the premises in large containers, using simple media consisting of milk or yogurt, a source of sugar such as molasses and a nitrogen source. Labs providing these organisms usually supply technical assistance in this respect.

Proper environmental factors

For compost to develop properly, adequate pH, temperature, humidity and oxygen content must be established. Bacteria and fungi will die if there is inadequate moisture; a level of 30 to 40% humidity is needed and sprinkling of compost piles with water is often required. Some growers cover compost piles with polyethylene film to keep moisture in. In this case, perforations are necessary to provide aeration.

Proper aeration is further achieved by turning the plant material over every three or four weeks. Some growers insert pieces of pipe in the piles that act as "breathing holes" with good results. Pile height is also important, and should not go over 1.60 m or oxygen content will go below optimum in the center and bottom, allowing undesirable anaerobic conditions to take place.

Maturity

Experience is the best teacher in learning to recognize the adequate maturity stage at which compost can be harvested. Compost that is ready is deep black (or even, red according to the location) in color, spongy and moist and clearly smells like soil. Application of immature compost has been known to be harmful to plants, probably due to high levels of ammonium being present. It also may still contain weed seeds, pests and diseases in proportions that are too high and would cause a re-infestation of the soil.

3. Earthworms

Although compost can be used directly as a fertilizer or soil amendment with excellent results, some growers prefer to carry out an initial composting stage and then feed the partially processed plant material to earthworms. The species most frequently used is *Eisenia foetida* commonly known as Californian or red earthworm, which turns the compost into a rich, moist black compound by feeding on it. Some growers

Photo: Marta Pizano.

Fig. 35. The common red earthworm, *Eisenia foetidia.*

call this material "humus"; others prefer the term "vermi-compost" or worm compost. The pros and cons of using straight compost or processing it further are summarized below:

Table 13. Advantages and disadvantages of using compost or humus

	Humus	Compost
Texture	Fine	Coarse
Nutrients	Readily provided to plants	Not as readily provided
Consistency	Smooth, uniform	Rough, uneven
Water Retention Capacity	Excellent	Good
Effect on Soil structure	Not significant	Improves significantly
Cost	Higher, needs more space and time	Lower than for humus
Types of plants processed	Some with difficulty (i.e. dendranthema) and amendments have to be added	The majority of plants compost easily

When earthworms are used, they are kept in special "beds" which are generally quite shallow (60 to 80 cm high) and supply an adequate environment (see below). To maintain a neutral pH proper aeration and temperature are of special concern. Some growers also keep special earthworm "nurseries" where the worms multiply and are fed and cared for between working intervals. Nurseries are usually smaller containers kept at warm temperatures, where worms are supplied with extra feedings, consisting of manure, preparations of microorganisms and plant fiber which can come from old paper or cardboard. Other growers do not think this step is necessary. In either case, earthworms can help recycle waste paper from offices.

Environment control is particularly important if using earthworms. They are very sensitive to lack of moisture; pH for earthworms should be neutral, and although both compost and humus usually have a pH around 8, acid substrates will be harmful to earthworms and should be corrected with amendments such as Calcium Carbonate. Earthworms feed mainly on fungi so it is important that conditions favor their development. Toxicity to earthworms is easily observed, (as they will turn white) while healthy worms are bright red in color.

Results

How efficient is composting? How beneficial? Is it costly? Worthwhile? These are questions often asked by growers who have never tried this alternative. Firm believers cite many benefits including substitution of 50% of chemical fertilizers, less need (or none even) for soil sterilization, higher productivity and many other factors. Below are some documented experiences:

Table 14. Substitution of inorganic (chemical) fertilization with humus in a rose nursery in Colombia

	Traditional	Humus
% Substitution	0%	50%
Cost ha/month*	$350	$320

* Includes processing, hand labor, and transport, application to plants, fertilizer and other materials. Does not include cost of chopper or of the land dedicated to humus production. Costs in US dollars.
Source: Valderrama, H., 1996 Las Flores S. A., Bogotá, Colombia

50% of traditional fertilizers were replaced in this case with humus, which in itself represents a 10% savings. Other growers quote savings of up to 20%. However, additional benefits were observed:

* High salts, which often affect roses, were much less of a problem as the humus provided a better nutrient balance in the soil.
* Between 15 and 20% less water was needed (watering needs are carefully monitored with tensiometers in this farm). This is due to improved water retention capacity from the humus.
* Better soil structure and drainage.
* Vigorous, healthy plants which were more productive. This is no doubt due to the factors outlined above, but also to the microorganisms coming with the humus, which restore a natural balance and compete with pathogens and pests.

Table 15. Compost as a fertilizer and soil amendment in a *Dendranthema* nursery

Amount of compost applied:	30 Tons/Ha
% Substitution of chemical fertilizer:	50%
Water retention capacity:	increased by 30 - 40%
Cost reduction:	15 - 20%
Soil sterilization:	None

Source: Jaramillo, F. and Valcárcel, F. 1998. Jardines de los Andes, Bogotá, Colombia

This grower reports that the greatest benefit is recuperating the soil with composting. After many years of growing mums in the same soil, he started having problems with soil fungi such as *Phoma* and *Pythium*, which are associated with monoculture, poor soil structure and aeration and deficient water management. Addition of compost has virtually eliminated these problems and no soil steaming or fumigation is now necessary, which represents not only big savings but also a much friendlier approach towards the environment. One of the reasons for this effect is better drainage and aeration, which deter development of these fungi. There is also, a better balance in the soil provided by beneficial microorganisms contained in the compost that will compete with pathogens and not let them reproduce as quickly.

Similarly to the above examples, there are fewer problems with soluble salts and an overall improvement in plant vigor and productivity. In *Dendranthema* culture, compost is easily incorporated into the soil as cropping cycles are short (about four months) and plants have to be completely removed and new ones put in. Growers in Costa Rica apply humus to chrysanthemums during the cropping cycle with excellent results.

Another interesting case study was documented in Mexico, where some chrysanthemum growers have started to use compost amended with *Trichoderma* sp, botanical extracts obtained from *Tagetes* (marigold) and a compound mix of marine algae. This system is used as an alternative to methyl bromide to control fungi such as *Phythopthora* sp, *Rhizoctonia solani* and *Pythium* sp, as well as white grubs (*Phyllophaga* sp).

Although this system requires growers to learn new production techniques, they consistently end up saving around 40% of the costs involved in traditional fumigation with methyl bromide. Furthermore, they report obtaining a higher proportion of first grade stems.

To growers using composting successfully, this alternative provides an answer to several problems. However, there are still some problems: For example, carnation growers are always reluctant to apply carnation compost once again to carnation plantings, as they have no guarantee that it will be completely free of *Fusarium oxysporum* f.sp. *dianthi*. Others argue that population reduction is so significant that excellent control should still be achieved with a proper IPM program.

Table 16. Cost comparison between methyl bromide and compost for the control of soilborne diseases in Mexico (US$/m²)

Inputs	Amended compost	Methyl Bromide
Methyl Bromide	0	0.33
Plastic fumigation sheets	0	0.16
Chemical fertilizer	0	0.01
Pesticides	0	2.49
Compost	0.18	0
Trichoderma	*0.02*	*0*
Botanical insecticides, other biologicals*	0.21	0
Other fixed costs**	1.53	1.53
Labor***	1.82	1.82
Total cost without labor	**1.94**	**4.52**
Total cost with labor	**3.75**	**6.34**

Source: Trueba, S. 2000. In: Case Studies on Alternatives to Methyl Bromide. UNEP

* Foliar nutrients, botanical insecticides and virus control

** Electricity, water, soil, plastic greenhouse covers

*** Most of the labor is provided by the grower's family. Costs calculated in small farms.

Chapter 5

Soil-less substrates

Cultivation of cut flowers on raised beds and in artificial (inert) or soil-less substrates (sometimes called hydroponic production) has been widely used for many years in several countries such as Holland and Israel. The reasons for using them have generally been associated with the presence of poor soils that are not suited for flower or vegetable production.

Raised or otherwise isolated beds have several advantages, in particular having the ability to properly sterilize a limited amount of substrate. Better control of plant nutrition is also possible. In the past, growers in the developing world often considered this option too costly and "high-tech". Materials such as rock-wool and even peat moss were often not available and needed to be imported. Concrete raised beds and floors are usually very expensive. These factors, together with the availability of plentiful extensions of fertile, rich soils, explain why soil-less culture did not become widespread in tropical and subtropical countries where flowers are produced. For many years, when soil-borne diseases that were difficult to control caused economic losses, a grower would simply plant the next crop on "new" soil, leaving the infested areas for producing a different non-susceptible species.

However, in recent years this situation has started to change for several reasons. Many times flower industries have developed around large cities where international airports are readily accessible for shipping their products. However, as cities have develop over time, land often becomes expensive and expansion of farms is restricted, hence new soil is no longer within easy reach. Wide-spectrum fumigants either will not be available (for example methyl bromide) or are restricted in their use by other environmental or health concerns (for example, risk of water contamination, or causing cancer or birth defects). Steam is too costly as a control measure for soils already containing high populations of pathogens. These reasons have stimulated flower growers to look for materials and systems that are locally available, suitable for soil-less production and economically feasible.

Experience is showing that soil-less substrates are a good alternative to methyl bromide, especially if used as part of an IPM program.

A good substrate should fulfill four functions:

- Provide an anchor for plant roots,
- Hold nutrients,
- Hold water, and
- Provide good gas exchange (aeration).

Often a substrate by itself does not provide all four conditions so mixtures are used. For example, sand provides good aeration but does not hold water or nutrients that drain readily. On the other hand, clay holds water so well that oxygen content is reduced sometimes to levels harmful to plants. For this reason, growers normally make up a rooting (or potting) mix, combining different elements in order to achieve a substrate that can perform the functions described.

Of these properties, only the first of these functions (anchorage) is inherent to a substrate. That is, it is not influenced by external factors such as handling and crop management. The other functions – aeration, water holding capacity and nutrient retention - are influenced by factors like compaction, watering and pH and should be managed by the grower. Although in some cases the actual weight or "bulk density" of the substrate is also important to prevent plants from toppling over, plants growing in light substrates may be supported with wires or nets (see example on page 85).

For many years growers have known that natural soil is not necessary for successful crop growth. Physical and chemical properties of the soil can be found in other materials and nutrients and thus supplied to plants in other ways. In fact, plants can even be grown directly in water amended with fertilizers. This process is called hydroponics. However, soil is a good buffer and can make up for fertilization mistakes since it usually contains at least some of the nutrients needed by plants. Soil-less systems require much closer control of nutrient level. This can be achieved with the help of electrical conductivity (EC) and pH meters and soil and foliar analyses.

2. Types of Substrates

Traditionally, many kinds of substrates have been used by the greenhouse industry. Of these, peat moss, sand, bark and inert materials such as vermiculite and rock-wool are the most common. They are often used together in different combinations and proportions.

In recent years, a substantial amount of research and experimentation has been devoted to alternative substrates in response to different problems. Peat for example, is a natural material obtained from marshes in northern countries. There are concerns that continuous harvesting of peat may be harmful, as it is formed very slowly and not replaced readily. Further, imported peat is generally too expensive for countries where it is not produced. Rock-wool does not pose environmental concerns and is very long-lasting but is not readily available in many countries and would have to be imported at prices often too high to be feasible for large-scale production. It becomes clear that, as in so many other instances, learning to adapt technology to local conditions is essential.

Examples of new materials being studied are rice hulls, coconut fibers, compost, different kinds of bark and sawdust. Volcanic scoria and pumice stone have also been used for a number of years. Following are some characteristics of these materials:

Coir

The fibrous material found between the outer surface and the inner hard shell of a coconut that is known in botany as the *mesocarp*, contains long, resistant fibers that are used to make different kinds of materials like stuffing, twine, filters and brushes. Shorter, shredded fibers, dust and pith which are left over are being used in horticulture as a rooting substrate known as "coir". Coir can be compressed when wet and dried for easy,

Photo: Marta Pizano.

Fig. 36. Orchids grown on coconut husks in Costa Rica.

light, long-distance shipping and re-hydrated when ready to use. Coir has been compared to peat in its performance although there are some differences; due to its finer texture it does not provide such good aeration, but its re-wetting capacity is significantly better. Physical and chemical properties of coir vary with the source of origin. Many growers are using coir in combination with other materials, but good results have also been obtained when using it alone i.e., for gerbera production in the Netherlands, for ornamental and cut flower production in Côte d'Ivoire (see **Table 19**, p. 89). It is likely that the use of this material will become much more common in the coming years.

The entire coconut "bark" (the mesoderm and the outer layer or ectoderm) is often used for growing orchids in Costa Rica and other countries. These plants do not require a proper substrate since they are epiphytes (they grow on top of other plants and trees). Coconut bark provides the ideal anchorage for them, and nutrition is supplied almost entirely in the way of foliar applications.

Rice hulls

Rice hulls are a secondary product of rice mills. They are readily available at accessible prices in rice producing areas. Rice hulls are not truly inert (or non-reactive) but they possess good aeration and water retention capacity. They are an efficient substrate for growing carnations in Colombia (see below), anthurium in Costa Rica and other flowers elsewhere. For many years, rice hulls have been added to the ground soil to improve aeration and drainage.

Photo: Marta Pizano.

Fig. 37. Anthurium growing in rice hulls in Costa Rica.

Photo: Floraculture International.

Fig. 39. Hydroponic culture of roses in Kenya.

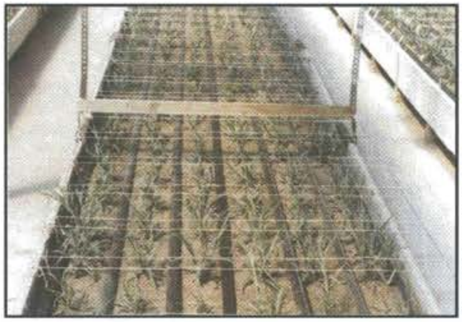


Photo: Marta Pizano.

Fig. 38. Carnation grown in sand beds in Holland.

Bark and sawdust

Bark, sawdust and wood shavings of many kinds can be used as substrates and in fact, are used in many parts of the world as a replacement for peat. They should be partially composted (bark may need to be shredded or otherwise cut in small pieces) since in their fresh state the rate of decomposition is high and they may contain toxic substances derived from wood such as resins and tannins. This is more important in the case of sawdust. Composting of these materials is handled in basically the same way as discussed in Chapter 4. In general, local sources should be used since the only significant cost of bark and sawdust is that of transportation.

Compost

Straight compost can be used as a substrate with excellent results, as long as parameters like pH, ammonium content and others are under control. Due to the many benefits of compost, most growers prefer to combine compost with other materials or add it to ground beds as discussed in Chapter 4. Compost has excellent water retention capacity and cation exchange capacity and provides important amounts of nutrients.

Photo: Marta Pizano.

Fig. 40. Carnations growing in bags filled with pum-ice stone in Kenya.

Photo: Marta Pizano.

Fig. 41. Rose culture on rockwool substrate in The Netherlands.

Volcanic rock (scoria, pumice stone), vermiculite and others

Many other materials are used as rooting substrates, alone or in combination with other materials. They are usually lightweight, provide good aeration and some (e.g. vermiculite) have a very good water retention capacity. They can also provide substantial amounts of some elements, primarily potassium and magnesium. Some of these materials are inert (non-reactive) and will basically provide anchorage. Crop handling should then be conducted in a similar way to that of a hydroponic system. Interesting results have been obtained in Kenya when growing carnations in bags filled with pumice stone. The naturally high pH of this material restricts development of the fusarium wilt fungus.

Sand

Sand is most often used as an ingredient of rooting substrates due to its ability to improve drainage and aeration. While seldom used by itself, excellent results have been obtained in Israel by using sand alone.

3. Pest and Disease Control

Simply isolating plants from the soil does not prevent the occurrence of soil-borne diseases and pests. They can still occur, sometimes with even more severity if the feeding solution is re-circulated. Therefore, recommendations made before to avoid recontamination of a pasteurized substrate should be observed (see Chapter 3). Soil-less substrates should be used as part of an IPM program.

Substrates can be re-utilized once the cropping cycle is over, as long as weeds, pests and diseases present in high proportion from the previous crop are eliminated. Steam is usually a very good, cost effective option for this purpose, often being much cheaper than treating the ground soil (see Chapter 3 on steaming).

Real life Examples

1. Growing carnations in rice hull substrate in Colombia

In recent years, carnation growers looking for alternatives to control fusarium wilt in Colombia, have been successfully experimenting with an interesting system that offers the advantages of artificial substrates placed above ground but without the high costs associated with construction of raised beds and the necessary infrastructure. In this system "beds" are made out of heavy polyethylene film directly on the ground; this material provides isolation from the soil. The beds are then filled with partially burnt rice hulls to a depth of 15 to 20 cm. The substrate is burnt to eliminate possible pests or pathogens and improve texture. Burning is easily achieved simply setting fire to dry rice hull piles and then sprinkling water to kill off the flames. However, in some countries there are restrictions to this practice due to air contamination and special furnaces need to be used (these are often available at rice mills supplying the material). Carnation plants are then grown in these beds following the usual cultural practices.

Photo: Marta Pizano.

Fig. 42. Polyethylene bed filled with partially burnt rice hulls for growing carnations in Colombia.

So far, growers report a significant reduction of losses caused by *F. oxysporum*, particularly on those varieties which are highly susceptible, passing from loss levels as high as 45% to only 3% in one production cycle. Similarly to other hydroponic systems, this method poses other problems mainly related to fertilization and watering, and close monitoring of these two parameters is required.

A grower wishing to transform traditional ground beds into this system should follow the steps below. It should be noted that this system can serve as a model for other equally suitable substrates.

Table 17. Step-by-step mounting of polyethylene rice-hull filled beds for growing carnations

* Level the ground with a slope between 0.5% and 1%.
* Mark bed boundaries and install stakes of wood or other similar material at an approximate distance of 1m between them. Line the stakes properly and maintain the slope.
* Compact the ground soil, which should be moist.
* Fix a wire of caliber 10-12, or a thick nylon chord (for example of the kind used for curtains) to secure the polyethylene in place.
* Spread the polyethylene giving form to the bed; handle it as when making a greenhouse roof, fixing borders with staples. Leave an opening at the lower end of the bed so effluents or leachates can come out.
* Wash empty polyethylene with a disinfectant solution beds to remove dirt and debris. This also serves to check if the inclination is correct – no puddles should form.
* Fill the beds with burnt rice hulls; take care not to contaminate it with dirt or soil. Keeping ground soil moist helps prevent this problem.
* Leach rice hulls with plenty of clean water to remove ash and reduce pH.
* Install net props with their corresponding stands. For carnations, 4 or 5 layers of netting are used, depending on the variety.
* Apply abundant water. The beds are ready to plant.
* Drip irrigation lines should be installed one week after planting.

From Arreaza, P. 2000. In: Pizano, M. 2000 (Ed.) Clavel. Ediciones Hortitecnia Ltda.

Factors to consider

High pH

One of the problems of rice-hulls is their naturally high pH (between 7.5 and 9.0), which is due to oxides formed by burning; high pH limits availability of many minor elements. This situation can be corrected by adding 12 to 15 kg of Calcium Sulfate per m^3 of hulls directly in the beds or before filling.

Irrigation systems

Initial watering with a hose to keep foliage turgid after transplanting the rooted cuttings and encourage root development may be carried out as is done when growing carnations on ground beds. The second week after transplant drip irrigation lines may be installed in the traditional manner. However, good results have been obtained with flat hose lines that have holes every 10 cm; one line every other plant row should be used. Water movement occurs much faster vertically within the rice-hull substrate so this irrigation system ensures better and more uniform humidity. In either case, irrigation is required more frequently than when growing directly on the ground. Environmental conditions as well as the quantity of the effluents coming out at the end of the bed should be considered when determining the amount of water that is needed. Tensiometers and evapotranspirators will provide more precise information.

Fertilization

As stated before, special attention should be paid to fertilization when using soil-less substrates and it is a good idea to perform frequent foliar and substrate analyses. Specialized equipment to determine specific nutrient needs is also available, although many times not within reach in some areas. At any rate, it is essential to be able to measure at least basic parameters like the pH and EC. Whenever possible, nitrate (NO_3) and potassium (K) measurements should be taken, both from the feeding solution and the leachates coming out of the bed.

Differences between these two points are extremely helpful for establishing adequate watering and fertilization programs. For example, too little or no effluent indicates that not enough water is being applied and too much effluent indicates that excessive amounts were used, under those particular environmental conditions. Excessive moisture promotes development of soil fungi and reduces the oxygen content of the substrate. Effluents should be between 5 and 20% of the total volume applied. The same rule can be applied to nitrate and potassium content.

The following Table contains fertilization recommendations for carnations grown in rice-hull substrate.

Table 18. Recommended nutrient contents (ppm) for carnations grown in rice-hull substrate

ELEMENT	VEGETATIVE GROW	REPRODUCTIVE ELONGATION	CROPPING PEAK to OFF-PEAK
Total N	210	100	50
Total nitrate	180	100	50
Total ammonia	30	0	0
P	40	50	15
K	100	240	50
Ca	180	200	100
Mg	50	60	30
S	>70	>90	>30
Cu	0.3	0.3	0.3
Zn	0.3	0.3	0.3
Mn	0.05	0.05	0.05
Fe	6	5	5
Bo	0.6	0.8	0.6
Mo	0.06	0.06	0.06

Source: Arreaza, P. 2000. In: Pizano, M. 2000 (Ed.) Clavel. Ediciones Hortitecnia Ltda.

Conductivity of the fertilization formula will be in the range of 1.5 to 4.0 mmhos/cm depending on its exact composition pH should be between 4.0 and 5.5.

Props and planting density

The rice-hull substrate is very light, and at depths of only 15 cm, carnation plants require a larger amount of support to grow straight and not fall over. Traditional netting, which is knit at the farm so it adjusts to the planting density of choice, can still be used. However, many growers are now in favor of manufactured nets, which have become commercially available. These usually come in 15 x 15 cm, 10 x 10 cm and 7 x 7 cm squares, one plant fitting in each square. According to the planting density used, some rows may be left empty. Possible options are: two rows full followed by one left empty; one empty row followed by one full row. Planting density normally varies between 23 and 30 plants per m^2 of greenhouse, somewhat lower than the traditional density for ground bed production.

Yield

The estimated yield for the first crop is on the average of 5.5 flowers per plant. According to the plant density and distribution this will lead to an approximate production per hectare between 1'260, 000 flowers (density of 23 plants/m^2) and 1'650, 000 flowers per hectare (density of 30 plants/m^2).

2. Growing cut flowers in coconut substrate in Côte d'Ivoire

Coconut substrate or coir was first tried in Côte d'Ivoire by a large flower farm concerned with high costs of methyl bromide in the area, as well as environmental and worker safety hazards. Results at this farm were very encouraging. The grower was not only able to control nematodes by using this substrate, but also produced excellent yields of very adequate quality. Coconut waste is readily available in Côte d'Ivoire as a by-product of the coconut oil industry, and growers have found that trunk pieces and old leaves can be ground together with bark to make an adequate substrate (the proportion of trunk waste should not go over 10%).

In this particular case, plants are grown in pots placed on benches 10 cm above the ground soil to prevent infestation from nematodes and other soil pests, but growers from other countries fill beds with this substrate and grow cut flowers in much the same way as described for the rice hull substrate.

Table 19. Estimated costs of coconut substrate vs. methyl bromide fumigation in Côte d'Ivoire.

	Cost of substrate US$/Ha	Cost of MB US$/Ha
Total	900 - 1,200	1,800 - 2,000

Source: Pacaud, J.M. 2000. In: **Case Studies on Alternatives to Methyl Bromide. UNEP 2000.**

Besides costs, this grower cites other benefits when using coconut substrate such as:

* No need for a waiting period before planting (which is necessary after fumigating with methyl bromide).
* More uniform plant growth and better flower quality.

* No worker safety issues and even new employment opportunities associated with the production and sale of this substrate.

Chapter 6

Demonstration and Investment Projects

The Montreal Protocol's Multilateral Fund is providing developing countries with financial and technical assistance in phasing out methyl bromide. Under the Fund, approximately 58 demonstration and investment projects are being carried out to evaluate and implement alternatives for crops and commodities using methyl bromide in developing countries. As of 2001, approximately 38 projects will be completed, evaluating the performance of a wide range of alternatives in a variety of climatic conditions. Some of these demonstration projects focus on identifying alternatives to cut flowers.

These projects include seminars, workshops and/or training sessions to disseminate the results to extension staff, growers and other persons who are involved in the methyl bromide issue. Other activities carried out are non-investment projects, which focus on information dissemination, policy development and technical assistance. Four implementing agencies are responsible for implementing these projects in cooperation with the governments in each developing country: UNDP, UNEP, UNIDO and the World Bank.

Reports of these projects and workshops are valuable sources of information. Those reports that are in print are included in the Reference Section at the end of this Manual. More detailed information on the results of demonstration projects can also be obtained by visiting UNEP/UNIDO's joint website on alternatives to methyl bromide, which can be found on the UNEP website.

When this Manual went into print, results were available from several demonstration projects, including projects carried out in Argentina, Guatemala and Kenya, which are presented below. Preliminary results are also provided for projects conducted in Costa Rica and the Dominican Republic. **Table 20** contains information on how to contact the implementing agencies and national counterparts for each project, so that those interested may obtain updated information.

Demonstration projects are aimed at evaluating different alternatives that can then be used by growers to replace methyl bromide if results are satisfactory and their implementation economically feasible. The following Table briefly describes such projects:

Tabla 20. Demonstration projects carried out by the Montreal Protocol's implementing agencies to evaluate alternatives to methyl bromide in floriculture.

Country	Reasons for MB usage	Implementing agency	National counterpart	Alternatives chosen	Results	Contacts
Argentina	Fusarium wilt of carnations (*Fusarium oxysporum* f. sp. *dianthi*), fusarium crown rot of lisianthus (*F. solani*), weeds, nematodes	UNIDO	INTA – National Institute of Agricultural Technology of Argentina	Soil fumigants: metham sodium, dazomet Steam Solarization	See below	* Antonio Sabater de Sabates, UNIDO asabater@unido.org * Juan Carlos Zembo Horticultura, INTA Facultad de Ciencias Agrarias y Forestales Universidad Nacional de la Plata Calle 60 s/N y 119 1900, La Plata ARGENTINA E-mail: zembo@inta.gov.ar
Costa Rica	Weeds (*Cyperus* sp), Nematodes, Moko disease (*Pseudomonas solanacearum*) of heliconias and other tropicals.	UNDP	Regional Institute of Toxic Substances Research (IRET), at the National University of Costa Rica	Low dose soil fumigants (metham sodium, dazomet, 1,3 dichloropropene) Steam sterilization Organic soil amendments (humus).	Preliminary see below	* Suely Carvalho, UNDP suely.carvalho@undp.org * Fabio Chaverri IRET – National University of Costa Rica Tel (504) 277-3584 fchaverr@una.ac.cr
Dominican Republic	Weeds, nematodes	UNIDO	Junta Agroempresarial Dominicana (JAD)	Low dose soil fumigants, (metham sodium, dazomet) Steam	Preliminary see below	* Guillermo Castellá, UNIDO gcastella-lorenzo@unido.org * Mr. Abraham Abud, JAD. Euclides Morillo No. 51 Arroyo Hondo, Santo Domingo DOMINICAN REPUBLIC Tel. (809) 563 6178 Fax (809) 563 6181 jad@codetel.net.do
Ecuador		World Bank				* Steve Gorman, World Bank. sgorman@worldbank.org
Guatemala	Weeds, nematodes	UNIDO		Crop rotation, volcanic substrates, biofumigation, composting	See below	* Antonio Sabater de Sabates, UNIDO asabater@unido.org * Antonio Bello Centro de Ciencias Medioambientales. CSIC Serrano 115 dpdo. 28006 Madrid, SPAIN Tel: 34 91 554-0007 Fax: 34 91 564-0800 ebvb305@ccma.csic.es

Country	Reasons for MB usage	Implementing agency	National counterpart	Alternatives chosen	Results	Contacts
Kenya	Fusarium wilt of carnations (*Fusarium oxysporum* f.sp. *dianthi*), crown gall of roses (*Agrobacterium tumefaciens*), nematodes, weeds	UNIDO	Horticultural Crops Research Authority (HCDA)	Low dose soil fumigants, (metham sodium, dazomet) Steam	See below	* Paolo Beltrami, UNIDO pbeltrami@unido.org * Mark Okado, HCDA okado@swiftkenya.com
México	Fusarium wilt of carnations (*Fusarium oxysporum* f.sp. *dianthi*), nematodes, weeds	UNIDO	Ozone Protection Unit, National Institute of Ecology (Secretariat for the Environment and National Resources and Fisheries - SEMARNA). The Faculty of Agronomy at Sinaloa University	Solarization alone and in combination with organic matter or manure Low dose fumigants (metham sodium, chloropicrin, dazomet,1,3 dichloropropene) alone, mixed and combined with solarization	Not yet available	* Marcela Nolazco, Mexican Ozone Office mnolazco@un.org.mx * Guillermo Castellá, UNIDO gcastella-lorenzo@unido.org
Syria		UNIDO				* Guillermo Castellá, UNIDO gcastella-lorenzo@unido.org

Investment projects are aimed at complete phase-out of methyl bromide usage in a specific sector (i.e. floriculture) and incorporation of alternatives. At present, an investment project has been initiated in Zimbabwe as described bellow.

Table 21. Investment projects carried out by the Montreal Protocol's implementing agencies to evaluate alternatives to methyl bromide in floriculture.

Country	Reasons for MB usage	Implementing agency	National counterpart	Alternatives chosen	Results	Contacts
Zimbabwe	Crown gall of roses (Agrobacterium tumefaciens), nematodes, weeds	UNIDO	Export Flower Association of Zimbabwe – EFGAZ, and Blackfordby Agricultural Institute of Zimbabwe	Steam Organic amendments	Not yet available	* Guillermo Castellá, UNIDO gcastella-lorenzo@unido.org * Helen Wolton, Ruwa, Zimbabwe lfe@pci.co..zw

Argentina

Project description

With increasing flower production for the large local market of Buenos Aires, the capital of Argentina, methyl bromide usage has also increased. One of the novelty products that has gained popularity is lisianthus (*Eustoma grandiflorum*) a crop that can be severely attacked by a disease known as basal rot, caused by the fungus *Fusarium solani*. Methyl bromide has efficiently controlled this disease in the past. Trials were conducted at the University of La Plata Argentina in coordination with UNIDO to determine the best alternatives to methyl bromide for the control of this disease. The following treatments were compared using three replicates:

1. Carbendazim (concentrated emulsion, 50%)
2. Procloraz (concentrated emulsion, 45%)
3. Steam (15 cm deep)
4. Metham sodium (flowable liquid, 32%)
5. Dazomet (98%, granulated)
6. Methyl bromide (98% liquid fumigant)
7. Check (no treatment)

Results

Results were evaluated on the basis of two parameters: percentage of diseased plants and density of *F. solani* in the soil. Yield or productivity was also estimated, taking into consideration the number of stems harvested as well as their quality.

Methyl bromide, steam, dazomet and metham sodium gave similar control levels when population density of the pathogen in the soil was measured. These four treatments were significantly better than the rest in two sampling instances.

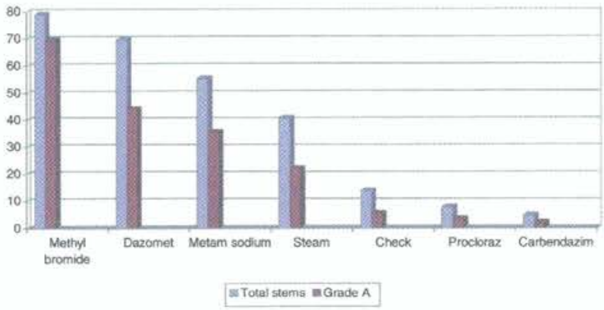
Table 21 and **Graph 3** below present percentages of diseased plants for each treatment and the ratio of harvested stems to premium quality flowers respectively. (Premium or grade A flowers have stems that are 50 cm or more in length and 4 mm or more in diameter).

Table 22. Percentage of lisianthus plants affected with *Fusarium solani* when using different alternatives.

Treatment	% Affected plants
Carbendazim	100.00
Procloraz	94.43
Check	89.76
Steam	36.97
Metham sodium	12.00
Dazomet	3.66
Methyl bromide	0.00

Source: Fernandez et al., 2000. In: Alternativas al uso del bromuro de metilo en frutilla, tomate y flores de corte. Buenos Aires, Argentina, 4 y 5 de Mayo 2000 (Proceedings)

Graph. 3. Percentage ratio total between flowering stems and premium quality stems harvested for the different alternatives



Evaluation of Alternatives

It is apparent from the results that lisianthus production in soils, which are heavily infested with *F. solani*, is only commercially feasible if they are treated before planting. In these trials, fungicides did not give good results when compared to fumigants, possibly due to the wide spectrum nature of the latter. Among the fumigants used, there were no significant differences in the level of control achieved or the resulting yields and crop quality.

Although steam was efficient in reducing the population density, production in steamed soils did not result accordingly. This is probably due to insufficient depth or length of treatment or both, which can allow for rapid re-colonization of the substrate. However, steam is still worth considering as a feasible alternative.

Kenya

Project description

Kenya is a large cut flower supplier for the European market, growing mostly carnations and roses. The project was carried out by the Horticulture Development Authority of Kenya (HDC) in conjunction with UNIDO. The site is located inside Sulmac one of the largest flower farms in that country. The first stage of the project was geared at evaluating alternatives to methyl bromide for the control of fusarium wilt of carnations, one of the most important reasons why growers in this country use this fumigant.

A relatively wide range of alternatives was selected, and the project was developed under conditions as close as possible to the commercial environment. The team working on this project carefully and continuously recorded percentages of diseased plants, marketable stems and others. IPM practices were thoroughly implemented in this project.

The following treatments were compared for their effectiveness in controlling fusarium wilt of carnations:

Photo: Marta Pizano.

Fig. 43. At the UNIDO project in Kenya, culture on pumice stone (shown here) is being evaluated.

1. No treatment (check)
2. Methyl bromide at 67.7 gr/m²
3. Methyl bromide at 30.0 gr/m²
4. Dazomet (83.3 gr/m²)
5. Metham sodium (1200 lt/Ha)
6. Steam + compost + *Trichoderma*
7. Solarization + dazomet (3 wk plus half dosage of fumigant)
8. Soil-less substrate (gunny bags filled with organic medium)
9. Soil-less substrate (gunny bags filled with inert medium)
10. *Trichoderma* + dazomet (half dose)
11. *Trichoderma* only
12. *Trichoderma* + metham sodium (half dose)
13. PGA (biopreparation)

Results

Results were measured on the basis of two parameters: Yield and quality of the plants (number of marketable stems of two different grades), and num ber of diseased plants present (plants uprooted after becoming diseased). Results obtained up to week 45 of production appear in **Graphs 4 and 5** below.

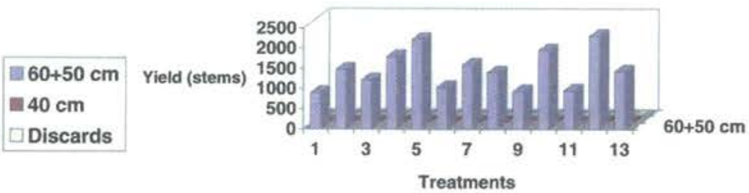
During the first stage of the project, metham sodium gave the best results – better even than those obtained with methyl bromide - possibly due to the sandy soil in the area in which this fumigant works very well. It is also very interesting to note that when the bio-control agent *Trichoderma* sp. was added after treating with either metham sodium or dazomet at reduced dosages, an enhanced control effect seems to have taken place. This is probably due to the fact that this fungus is a rapid colonizer that can become established before noxious organisms develop to disease-inducing levels. *Trichoderma* alone did not work as well, probably because it cannot reproduce as rapidly when competitive organisms are also present in the medium.

Steam gave good results but recontamination is a problem as it occurs very quickly. This however can also be a problem when using methyl bromide. Some problems were encountered with the boiler itself.

Similarly, the use of substrates seems to have been affected by factors such as an organic medium of poor characteristics, i.e. immature compost that induces ammonium – related phytotoxicity problems in carnation plants.

Results obtained with the plant growth promoter (PGA) in treatment No. 13 also seems to have been affected by certain variables (possibly soil pH and others) but sufficient documentation is not available to support this observation.

Graph. 4. Cumulative mean yields up to week 45. Carnation crop submitted to 13 treatments as described above



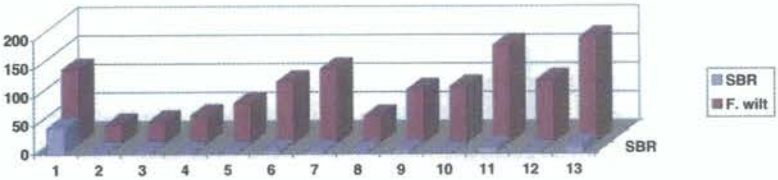
60 + 50 cm is the best marketable quality

*40 cm stems are second grade

*Discards do not meet export quality standards

Source: Jack Juma and Ruth Othino, Naivasha, Kenya, 2000.

Graph. 5. Cumulative uprooted stems to week 45



SBR are diseased stems affected by diseases different to fusarium wilt, most commonly *Rhizoctonia* stem and root rot

Source: Jack Juma and Ruth Othino, Naivasha, Kenya 2000

Evaluation of Alternatives

- Some of the results seem to be influenced by the actual implementation of the treatment, although the existence of four replicates allows for stronger conclusions.
- Solarization failed and this can be explained in terms of the variable climatic conditions present in the Naivasha area, where it is difficult to get several consecutive weeks of continuously strong sunlight and dry weather. This is necessary to get the soil temperature sufficiently high at enough depth to kill noxious organisms efficiently. Furthermore, solarization is not a practice easily accepted by flower growers due to the intensive nature of the business that is characterized by year-round production.
- Even though metham sodium and dazomet are giving promising results, growers should be warned that these too are powerful chemicals posing hazards to the environment and human health and should be used with pertinent precaution.
- IPM is being implemented correctly within the project, that is, scouting, data registration, action thresholds and others are being carried out. This is also essential to its success.
- Steam will be better assessed in a new trial where compost of good quality and maturity is used and beneficial organisms like *Trichoderma* are added. Steps to avoid recontamination will be carefully observed.
- Inorganic substrates (pumice stone) seem like an interesting option and could be steamed for re-use.

The second stage of this project will look more closely at the most promising alternatives (artificial substrate, fumigants at reduced dosages amended with *Trichoderma* and possibly steam). Trials for the control of problems associated with other flowers will also be considered.

Guatemala

Project description

A demonstration project was carried out in 1998 – 1999 by UNIDO in Guatemala, where methyl bromide was being used mainly for the control of nematodes on roses, tobacco and horticultural crops such as melons, broccoli and tomatoes. Biofumigation and composting were selected as a feasible alternative to methyl bromide under these conditions.

Because technical knowledge and support were not sufficient, UNIDO consultants were initially engaged in identifying those species of nematodes causing the most problems and training the national counterparts on simple methods of soil nematode analysis. It was found that in the case of roses the most persistent genus was *Meloidogyne* sp. *Rotylenchulus reniformis*, the "reniform nematode" was found infesting melons in high populations.

Efficient alternatives to methyl bromide were implemented using a combination of crop rotation, volcanic substrates, nematicides and incorporation of "green manure" mostly of plant species such as mucuna or carnavalia that help reduce diseases through the emission of gases and by enriching the soil with beneficial organisms.

Costa Rica

Project description

Fig. 44. Trials with steam, organic matter amendments and fumigants in Costa Rica.

The Costa Rican project carried out by UNDP, has produced preliminary results. Methyl bromide is mostly used in Costa Rican floriculture to get rid of weeds (*Cyperus* sp, *Portulacca oleracea*), nematodes (*Melo-*

ydogyne sp, *Pratylenchus* sp) and pathogenic fungi (*Fusarium* sp, *Phythopthora* sp) and bacteria (*Erwinia* sp, *Pseudomonas solanacearum*). In recent years overall methyl bromide consumption in Costa Rica has increased, and it is estimated that floriculture alone uses about 125 tons per year or about 15% of total country consumption.

The project was designed to demonstrate five alternatives to methyl bromide in cut flower production in open fields, greenhouses and seed beds. Implemented within an IPM strategy, these alternatives are:

1. Solarization – applied 3 months before planting
2. Steam
3. Organic amendments – compost or organic by-products applied immediately before planting)
4. Low dose soil fumigants (metham sodium, dazomet, 1,3 Dichloropropene)
5. Selected non-fumigant pesticides. Nematicides (terbufos, cadusafos, carbofuran); Herbicides (glifosate); Fungicides (carboxin, captan, etridiazol).

Demonstrations are being conducted at commercial flower farms located in the Central Valley of Costa Rica, a representative area of cut flower production, growing *Dendranthema* (chrysanthemum) and ornamental plants. The University of Costa Rica with UNDP is coordinating the project. An economic assessment of each alternative, in comparison to methyl bromide will be conducted.

Dominican Republic

Project description

The demonstration project in the Dominican Republic is currently being conducted at a commercial flower farm growing *Liatris* (gayfeather) in the Constanza Valley where most of the flower production takes place. In the initial stage, three alternatives are being compared to methyl bromide (70 g/ m²):

1. Dazomet – at a rate of 40 g/m²
2. Metham sodium – at a rate of 100 ml/ m²
3. Steam - 98°C at a depth of 20 cm

Results will be evaluated on the basis of fungal populations of *Alternaria, Penicillium, Aspergillus, Rhizopus, Fusarium* and *Trichoderma,* before and after treatment, compared to a non-treated check. At this point, metham sodium and steam are giving encouraging results. Another set of samples will be taken at harvest. Weeds were counted and identified before application of treatments and will be again at harvest time. Other variables considered will be stem length and flower quality.

This project is being conducted by the Dominican Agroindustry Board (JAD) in conjunction with UNIDO.

Recently, new investment projects have been proposed for methyl bromide phase-out in floriculture sectors of countries like Uganda and Uruguay.

Annex I

Further reading and other sources of information

Many excellent publications are available that address methyl bromide phase out, alternatives to methyl bromide, IPM in floriculture and other related issues in more detail. Below are some useful titles that may provide further insight into these topics. This is by no means intended to be a comprehensive list. These publications are also on UNEP DTIE's website. Some useful websites where more information can be found are also listed.

UNEP DTIE OzonAction Programme's Methyl Bromide Publications

* *The Methyl Bromide Information Kit,* has been created to enhance awareness among national policymakers and other stakeholders about methyl bromide use, alternatives and phase-out deadlines, and encourage the shift to alternatives and the development of policies to support a rapid transition from methyl bromide. The kit includes (1) a brochure describing the methyl bromide issue and the importance and benefits of ratifying the Copenhagen Amendment (*Methyl Bromide: Getting Ready for the Phase Out,* available in English, French and Spanish); (2) a television public service announcement that can be aired and shown in national television and in movie theatres and (3) a poster depicting aspects of the methyl bromide issue.

* *Healthy Harvest: Alternatives to Methyl Bromide* is a 15-minute video that provides an overview of the methyl bromide issue and the action to be taken to phase it out under the Montreal Protocol. It highlights many cost-effective and environmentally sustainable alternatives that are available for the major applications of methyl bromide, mainly for soil fumigation and post-harvest uses. The video can be used to raise awareness among the general public and

methyl bromide users about the importance of phasing out methyl bromide to protect the ozone layer. This is available in English, French and Spanish.

* *Protecting the Ozone Layer, Volume 6: Methyl Bromide* summarizes the current uses of methyl bromide, the availability of substitutes and the technological and economic implications of transitioning away from methyl bromide. It is based upon the original reports of the UNEP Methyl Bromide Technical Options Committee and is the sixth volume in UNEP's Protecting the Ozone Layer series. It can be used by National Ozone Units, other government agencies and methyl bromide users as a technical resource for replacing methyl bromide. This is available in English, French and Spanish.

* *Methyl Bromide Phase-out Strategies: A Global Compilation of Laws and Regulations* provides an overview of the various policy options that can be taken to replace methyl bromide and outlines existing policies on methyl bromide in over 90 countries. The Compilation can be used by National Ozone Units, Agriculture Ministries and Pesticide Control Authorities to assist in the development of national action plans for methyl bromide phase out.

* *Towards Methyl Bromide Phase Out: A Handbook for NOUs* is a user-friendly handbook that presents options and ideas to facilitate the transition to methyl bromide alternatives and to assist countries in designing and implementing plans to phase out methyl bromide and promote alternatives. This is available in English, French and Spanish.

* *Inventory of Technical and Institutional Resources for Promoting Methyl Bromide Alternatives*, provides a listing of existing institutes, NGOs and programmes in the agricultural sector working to promote effective and environmentally sustainable agricultural practices. This publication can be used by governments, implementing agencies, bilaterals and other stakeholders to identify project partners for methyl bromide phase-out activities.

* *Case Studies of Alternatives to Methyl Bromide: Technologies with Low Environmental Impact* is a case study compilation that pro-

vides methyl bromide users with information that will assist them in selecting commercially available, low impact (i.e., environmentally friendly) alternatives, including information on performance, yields and farmer satisfaction. The document focuses on crops/ uses where such alternatives have already been successfully implemented. Each case study provides cost-benefit information, costs of conversion and supplier information for alternative inputs identified.

Other UNEP publications containing information on alternatives to methyl bromide in floriculture are listed below:

2000. UNEP, GTZ, European Commission. *Methyl Bromide Alternatives for North African and Southern European Countries.* Proceedings of a workshop by same name held in Rome, Italy, May 26 – 29, 1998. United Nations Publication, 244 pp.

1998. UNEP. *1998 Assessment of Alternatives to Methyl Bromide.* Methyl Bromide Technical Options Committee (MBTOC). 354 pp.

Other useful publications

Many books, manuals, scientific articles and others are available on greenhouse management, substrates, pests and diseases, IPM and other important topics. Also of importance are numerous workshops congresses and symposia on alternatives to metyl bromide, substrates, soil sterilization, biocontrol, IMP and other relevant topics. Following are several titles that have proved useful for the preparation of this manual as well as to growers following the strategies described.

Agrios, G.N. 1998. *Plant Pathology* 5Ed. Academic Press, New York, NY, USA

Ballis, C. (Ed) 2001. International Symposium on Composting of Organic Matter. Acta Horticulturae 549. International Society for Horticultural Science.

Bar-Tal, A. and Z. Plaut (Eds) 2001. World Congress on Soilless Culture: Agriculture in the Coming Millenium. Acta Horticulturae 554. International Society for Horticultural Science.

Bello, A., J. A. González, M. Arias and R. Rodríguez-Kabana 1998. *Alternatives to Methyl Bromide for the Southern European Countries.* Proceedings of a Workshop by the same name held in Tenerife (Canary Islands, Spain, 9-12 April, 1997). Gráficas Papillona, Valencia, Spain 404 pp.

Enhgelhard, A.W. (Ed). 1989. *Management of Diseases with Macro and Microelements.* APS Press, St. Paul, MN 217 pp.

Gill, S., D.L. Clement and E. Dutky, 2001. *Plagas y Enfermedades de los Cultivos de Flores – Estrategias Biológicas.* Ball Publishing – Hortitecnia, Bogotá, Colombia 304 pp.

Gullino, M.L., Katan, J. y A. Matta (Eds) 2000. International Symposium on Chemical and Non-Chemical Soil and Substrate Disinfectation. Acta Hort 532. International Society for Horticultural Science.

Hall, R. 1996. *Principles and Practices of Managing Soilborne Plant Pathogens.* APS Press, St. Paul MN, USA, 330 pp.

Jarvis, W.R. 1992. *Managing Diseases in Greenhouse Crops.* APS Press, St. Paul, MN 288 pp.

Kennedy, G. G.. and T.B. Sutton 2000. *Emerging Technologies for Integrated Pest Management.* APS Press, St. Paul. MN, USA, 526 pp.

Maloupa, E. y D. Gerasopoulos (Eds) 2001. International Symposium on Growing Media and Hydroponics. Acta Horticulturae 548. International Society for Horticultural Science.

Mastalerz, J.W. 1977. *The Greenhouse Environment.* The effect of environmental factors on the growth and development of flower crops. John Wiley and Sons, New York, USA, 629 pp.

Nelson, P.V. 1998. 5 Ed. *Greenhouse Operation and Management.* Prentice Hall, New Jersey, USA, 637 pp.

Pizano, M. 1997 (Ed.). *Floricultura y Medio Ambiente: la Experiencia Colombiana.* Ediciones Hortitecnia Ltda., Bogotá, Colombia, 352 pp.

Pizano, M. 2000 (Ed.). *Clavel.* Ediciones Hortitecnia Ltda. Bogotá, Colombia. 181 pp.

Reed, D.W. 1998. *Water, Media and Nutrition for containerized greenhouse crops.* Ball Publishing, Batavia, IL, USA.315 pp. (Spanish edition also available).

Szmidt, R.A.K. (Ed)1998. International Symposium on Composting and Use of Composted Material in Horticulture. Acta Horticulturae 469. International Society for Horticultural Science.

Thomson, W.T., 1999. *Agricultural Chemicals.* Book III - Miscellaneous Chemicals. Thomson Publications, Fresno, CA, USA. 189 pp.

Websites

The OzonAction programme's website is located at www.uneptie.org/ozonaction.html. Important and complete information on alternatives to methyl bromide, related activities and resources is continuously updated.

The *RUMBA (Regular Update on Methyl Bromide Alternatives)* newsletter and forum can be joined by visiting http://www.uneptie.org/ozat/pub/rumba/main.html or by writing to rumba-request@lists.unep.fr .

The United Nations Environment Program Division of Technology, Industry, and Economics (UNEP DTIE) is providing RUMBA as a service to the Montreal Protocol community to promote information exchange and stimulate discussion about the methyl bromide phase out.

A website specially designed to present the results of the Multilateral Fund's demonstration projects has recently been launched. Progress of projects and results where available as well as contacts can be obtained here. The website can be found at www.uneptie.org/unido-harvest

Annex II

About the UNEP DTIE OzonAction Programme

Nations around the world are taking concrete actions to reduce and eliminate production and consumption of CFCs, halons, carbon tetrachloride, methyl chloroform, methyl bromide and HCFCs. When released into the atmosphere these substances damage the stratospheric ozone layer — a shield that protects life on Earth from the dangerous effects of solar ultraviolet radiation. Nearly every country in the world — currently 172 countries — has committed itself under the Montreal Protocol to phase out the use and production of ODS. Recognizing that developing countries require special technical and financial assistance in order to meet their commitments under the Montreal Protocol, the Parties established the Multilateral Fund and requested UNEP, along with UNDP, UNIDO and the World Bank, to provide the necessary support. In addition, UNEP supports ozone protection activities in Countries with Economies in Transition (CEITs) as an implementing agency of the Global Environment Facility (GEF).

Since 1991, the UNEP DTIE OzonAction Programme has strengthened the capacity of governments (particularly National Ozone Units or "NOUs") and industry in developing countries to make informed decisions about technology choices and to develop the policies required to implement the Montreal Protocol. By delivering the following services to developing countries, tailored to their individual needs, the OzonAction Programme has helped promote cost-effective phase-out activities at the national and regional levels:

Information Exchange

Provides information tools and services to encourage and enable decision makers to make informed decisions on policies and investments required to phase out ODS. Since 1991, the Programme has developed and disseminated to NOUs over 100 individual publications, videos, and databases that include public awareness materials, a quarterly newsletter, a web site, sector-specific technical publications for identifying and selecting alternative technologies and guidelines to help governments establish policies and regulations.

Training

Builds the capacity of policy makers, customs officials and local industry to implement national ODS phase-out activities. The Programme promotes the involvement of local experts from industry and academia in training workshops and brings together local stakeholders with experts from the global ozone protection community. UNEP conducts training at the regional level and also supports national training activities (including providing training manuals and other materials).

Networking

Provides a regular forum for officers in NOUs to meet to exchange experiences, develop skills, and share knowledge and ideas with counterparts from both developing and developed countries. Networking helps ensure that NOUs have the information, skills and contacts required for managing national ODS phase-out activities successfully. UNEP currently operates 8 regional/sub-regional Networks involving 109 developing and 8 developed countries, which have resulted in member countries taking early steps to implement the Montreal Protocol.

Refrigerant Management Plans (RMPs)

Provide countries with an integrated, cost-effective strategy for ODS phase-out in the refrigeration and air conditioning sectors. RMPs have to assist developing countries (especially those that consume low volumes of ODS) to overcome the numerous obstacles to phase out ODS in the critical refrigeration sector. UNEP DTIE is currently providing specific expertise, information and guidance to support the development of RMPs in 60 countries.

Country Programmes and Institutional Strengthening

Support the development and implementation of national ODS phase-out strategies especially for low-volume ODS-consuming countries. The Programme is currently assisting 90 countries to develop their Country Programmes and 76 countries to implement their Institutional-Strengthening projects.

For more information about these services please contact:

Mr. Rajendra Shende, Chief,
Energy and OzonAction Unit
UNEP Division of Technology, Industry and Economics
OzonAction Programme
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75739 Paris Cedex 15 France
Email: ozonaction@unep.fr
Tel: +33 1 44 37 14 50
Fax: +33 1 44 37 14 74
Website:
www.uneptie.org/ozonaction

About the UNEP Division of Technology, Industry and Economics

The mission of the UNEP Division of Technology, Industry and Economics is to help decision-makers in government, local authorities, and industry develop and adopt policies and practices that:

· are cleaner and safer;
· make efficient use of natural resources;
· ensure adequate management of chemicals;
· incorporate environmental costs;
· reduce pollution and risks for humans and the environment.

The UNEP Division of Technology, Industry and Economics (UNEP DTIE), with its head office in Paris, is composed of one centre and four units:

· The International Environmental Technology Centre (Osaka), which promotes the adoption and use of environmentally sound technologies with a focus on the environmental management of cities and freshwater basins, in developing countries and countries in transition.

· Production and Consumption (Paris), which fosters the development of cleaner and safer production and consumption patterns that lead to increased efficiency in the use of natural resources and reductions in pollution.

· Chemicals (Geneva), which promotes sustainable development by catalysing global actions and building national capacities for the sound management of chemicals and the improvement of chemical safety world-wide, with a priority on Persistent Organic Pollutants (POPs) and Prior Informed Consent (PIC, jointly with FAO).

· Energy and OzonAction (Paris), which supports the phase-out of ozone depleting substances in developing countries and countries with economies in transition, and promotes good management practices and use of energy, with a focus on atmospheric impacts. The

UNEP/RISØ Collaborating Centre on Energy and Environment supports the work of the Unit.

· Economics and Trade (Geneva), which promotes the use and application of assessment and incentive tools for environmental policy and helps improve the understanding of linkages between trade and environment and the role of financial institutions in promoting sustainable development.

UNEP DTIE activities focus on raising awareness, improving the transfer of information, building capacity, fostering technology cooperation, partnerships and transfer, improving understanding of environmental impacts of trade issues, promoting integration of environmental considerations into economic policies, and catalysing global chemical safety.

Glossary

Action threshold –A level or degree of damage reached in a crop that warrants the implementation of a control measure, for example, the application of a pesticide. Action thresholds are mainly determined through monitoring (scouts, sticky traps, sampling, etc) and may vary according to the crop grown. In the case of flowers, this threshold tends to be very low due to their aesthetic value.

Ammonifying organisms – a group of organisms, mainly bacteria, fungi and Actinomycetes that convert nitrogen present in the soil into ammonia, as part of the natural cycle of nitrogen.

Antagonist – A microorganism capable of producing a toxic metabolic product that can kill, injure or otherwise inhibit another microorganism in its proximity. Thus, populations of antagonists may deter populations of other sensitive microorganisms.

APHIS (Animal and Plant Health Inspection Service). The authority in charge of plant and animal health issues in the United States, dealing with plants or flowers imported into that country. APHIS has stations throughout the United States and in many countries around the world.

Biocide – any agent or compound that kills all living organisms present in the soil or substrate when entering into contact with them. Steam and methyl bromide are called biocides as they kill a wide spectrum of organisms.

Biocontrol agent – A microorganism that is capable of partially or totally destroying another.

Biofumigation – a process in which plant residues are incorporated in the soil after the cropping cycle has ended, and left to decompose. During this process, the plant material produces certain gases mostly of isothiocianate that act as natural pesticides and eliminate substantial amounts of noxious organisms present in the soil.

Biological Control – Partial or total destruction of one microorganism population by another.

Biopesticide – A pesticide obtained from natural sources, i.e. Neem extract or nicotine extract.

Bulk density – the ratio of the weight or mass or a dry soil or substrate to its bulk volume. Expressed in gr/cm^3 or lbs/cu. Ft.

Carbendazime – 2(methoxycarbonylamino)-denzimidazole. A compound of benzimidazole, used as a systemic fungicide. Frequently used commercial names for this product are Bavistin®, Derosal®, Kemdazin®.

Coir – A soil amendment or substrate composed of coconut fiber and obtained from coconut husks. It has a good water holding capacity and is presently being used for "hydroponic" culture.

Compost – an organic material obtained from partially decomposing organic matter, i.e. plant residues. The decomposition process is called composting.

Control by exclusion – A pest or disease control strategy that is based on preventing the pathogen to come into contact with its susceptible host, for example with screens that keep flying insects out of the greenhouse, special disinfestations processes, etc.

Crop rotation – A control strategy in which a crop that is susceptible to a particular soil-borne pest or disease is grown in alternate cycles with another that is resistant or not susceptible to that pathogen. For certain pathogens needing close contact with their host in order to survive, the period when the host is not present can greatly reduces their population in the soil.

Crown gall –A disease of many plants caused by the bacterium *Agrobacterium tumefaciens.* The bacterium induces the formation of irregular, thick galls that may girdle plant stems and deter from the plant's esthetic appearance. It also reduces plant vigor and productivity. Bacteria are soil-borne and may remain in infected soil for long periods of time.

Cultural Control – Control measures based on adapting cropping methods to reduce pest or disease inoculum. For example, by reducing planting, density air circulation between plants is increased and humidity is lower, reducing the incidence of some diseases.

Chemical Control – Control of a pest or disease that is achieved through the application of a pesticide or otherwise a compound of chemical origin.

Damage threshold –The level of damage that warrants a control action because it signifies losses of economic importance. A damage threshold requires economic calculations sometimes difficult for a grower so working with an action threshold may be a better approach.

Dazomet - Tetrahydro-3,5, dimethyl-2H-1,3,5-thiadiazine-2-thione. A pre-plant soil fumigant that is effective against many species of weeds, nematodes (except cyst), soil fungi and arthropod pests. Commercially it is best known as known as Basamid®, but it has other commercial names like Allante® and Dazoberg®. It is being used as an alternative to methyl bromide in many places.

Dichloropropene - 1,3-dichloropropene. Commercially known as Telone-II®, Telone C-17®, Telone C-35®, Nematrap® and Nematox® and others. It is a soil fumigant basically effective against nematodes and soil insects. It is particularly effective against cyst nematodes especially in loam, sandy soils. It is also active against some soil fungi and weeds, especially when formulated together with compounds like chloropicrin.

Diffuser – A device such as a pipe or a hose used to conduct steam from its source (boiler) to the substrate to be treated (i.e. the soil)

Drip Irrigation – An irrigation system where water is delivered to the plant directly on the soil or substrate, usually through small emitters or tubes.

Earthworms – Worms usually belonging to the species *Eisenia foetida,* used to further process composted plant material in order to produce "vermicompost" or "humus", a rich, organic matter substance that can be applied to plants as a soil amendment and as an organic fertilizer.

Effluents – Substances, usually liquids, that come our of compost and humus piles. They are generally rich in nutrients and beneficial organisms and can be put back into the soil as an amendment.

Electrical conductivity (EC) – ability of a solution to conduct electricity that is due to suspended ionic solutes. It is used as a measure of the content of soluble salts in water. Each salt has a unique EC value. It is expressed in different units, for example dS/m (deciSiemens per meter) or micromhos/cm.

Foliar analysis – A laboratory analysis to determine the nutrient content of leaf tissue.

Fumigation – A process in which a chemical (fumigant) is injected or otherwise incorporated into the soil or substrate with the aim of eliminating pests and disease agents present in them.

Fusarium wilt –A disease of many plants caused by the fungus *Fusarium oxysporum*. The fungus presents many special forms or *formae specialis* that are very specific in their pathogenicity towards particular hosts. Thus *f.sp. dianthi* only attacks plants belonging to the carnation genus. Fusarium wilt can be devastating, killing plants and inducing very high losses. The fungus is soil-borne and can remain viable for very long periods of time even when its host is not present.

Genetic Control – Control of a disease or pest that is based on making the host resistant to it through breeding, hybridization or other form of genetic recombination

Glifosate – N-(phosphonomethyl) glycine. A fosforic acid compound used as a brad spectrum, pre-emergence herbicide. Best known commercially as Roundup® but it is also marketed under many other names.

Graft – Usually the plant joined to a rootstock, placing cut surfaces together to form a living union. Grafting may occur naturally between fungi, plant roots and others.

Ground beds – Beds made directly from the natural (ground) soil in which flowers are grown.

Humus – An organic amendment or substrate obtained by feeding partially composted plant material to earthworms.

Hydroponic culture – Literally speaking it is the cultivation of plants in water or liquid culture. Cultivation in soil-less substrates is frequently referred to as "hydroponic culture".

Infection – The process by which a pathogen enters the plant tissue and becomes established in it inducing symptoms and developing or completing its life cycle in association with it. It is a relationship between two live organisms that ends when either of them dies.

Infestation – The survival of a pathogen in association with a non-living entity, i.e. the soil, tools or machinery.

Inorganic – A substance or compound that does not have carbon as its base. In reference to fertilizers, the term makes reference to most mineral salts. When referring to substrates or amendments and to synthetic materials like vermiculite.

Insect screen – A mesh, net or other kind of screen that is placed over greenhouse openings to prevent flying insect pests from entering growing areas.

Integrated Pest Management (IPM) – A pest control scheme that involves a series of alternative control measures and not only chemicals. Cultural, physical, biological and regulatory methods are among others implemented, each of them contributing to some extent to reduce pest populations and damage.

Mapping – Recording data – mainly about pest or disease incidence in a crop – on a map or plan of a cropping area (i.e. a greenhouse range).

MBTOC - Methyl Bromide Technical Options Committee. A Committee established by the Montreal Protocol "to identify existing and potential alternatives to methyl bromide". It is compromised of 35 to 40 members, both from developed and developing countries.

Metham sodium - Sodium N-methyldithiocarbamate dihydrate. Metham sodium is best known commercially as Vapam® and Buma® although Trimaton®, Busan® and Unifume® are also used in some countries. It is a wide-spectrum soil fumigant used for the control of many genera of fungi, nematodes (most species), weeds (most species) and arthropod pests (sypmhylans, collembola and many others).

Methyl bromide - A wide-spectrum, gaseous soil fumigant that has been used for many years to rid the soil or substrate of noxious diseases, pests or weed seeds. It is also used to fumigate structures and commodities. Methyl bromide was listed under the Montreal Protocol as an ozone depleting substance in 1992.

Monitoring – Keeping track of disease or pest occurrence with the aid of scouting, sticky traps and others.

Monoculture – The continued growing of a same plant or crop over a prolonged period of time.

Nematode- Minute, mostly microscopic "worms", some of which live in the soil as saprophytes but which may be parasitic to plants.

Nitrifying bacteria – In the naturally occurring cycle of nitrogen, bacteria of the species *Nitrosomonas,* that convert ammonia present in the soil to nitrites and a second group, the *Nitrobacter* species that convert nitrites into nitrates. Together with the ammonifying microorganisms, these bacteria keep nitrogen forms balanced.

Organic – A substance or compound having carbon as its base. For example, compost is of organic nature.

Pasteurization – A process through which – generally by means of heat – living organisms for example in the soil or substrate are selectively killed. In general, harmful organisms are killed in much higher proportion than beneficial ones.

Pathogen – An organism, usually microscopic, capable of causing disease in a host plant. Bacteria, viruses, fungi and nematodes are usually referred to as pathogens.

Peat moss – an organic substrate composed of partially decomposed mosses, reeds and sedges formed in swampy areas. The most commonly used peat moss is that from *Sphangum* moss coming from northern bogs in Canada and Europe. Peat is widely used as a seeding and potting substrate and as a soil amendment.

Pest – An organism, usually an insect, mite or slug, that feeds on a susceptible host plant.

pH – pH is defined as "the negative logarithm of the hydrogen ion concentration". It is a value that describes the acidity or alkalinity of a solution so that a pH 7 is neutral, below that it is acid and above basic or alkaline.

Phloem – Conducting tissues inside the plant's stem, responsible for transporting plant juices (assimilates) that have been processed in the leaves by photosynthesis.

Physical Control – A control strategy that uses physical methods – for example steam, heat, vacuuming, screens, barriers and others – to reduce a pest or disease population.

Phytosanitary – Making reference to plant health.

Phytotoxicity – Causing harm or being toxic to plants.

Plant quarantine – When plants coming from an outside source and that represent a potential source of pest or disease are kept in isolation during a certain period of time in order to avoid contamination of existing crops in that area.

Planting density – Quantity of plants grown per unit area, for example per m^2.

Procloraz – N-propyl-N-(2-(2,4,6-tricholophenoxy)ethyl)-imidazole-1-carboxamide. A carboxamide compound used as a protective and eradicating fungicide. Common commercial names for this fungicide are Octave® and Sportak®.

Quarantine and Pre-shipment (QPS) – Treatment or fumigation applied "directly preceding and in relation to export to meet the phytosanitary or sanitary requirements of the importing country or existing phytosanitary or sanitary requirements of the exporting country" (MBTOC 1998 Assessment).

Raised beds – Beds or containers for growing plants, which are isolated from the soil. Examples of raised beds are benches or elevated beds.

Recontamination- The process by which pests or pathogens re-.enter the soil or substrate after these have been sterilized or disinfested.

Resistant varieties – Plant varieties that are able to resist attack of a pest or pathogen. They may be naturally resistant or made resistant through breeding or another form of genetic recombination. Levels of resistance vary from 0 (completely susceptible) to 100% (immune) with degrees in between.

Rice hull substrate – A growing medium or substrate made of rice husks, a by-product of rice mills.

Rootstock – A plant, generally having certain desirable properties such as hardiness or resistance, upon which another of the same species and having other qualities is grafted.

Rouging- Discarding plants due to disease or other problems.

Sanitation – Eliminating or otherwise avoiding contamination of growing areas with a pest or disease, for example by destroying plant residues.

Scouting – A practice in which trained personnel inspect plants and cropping areas with the aim of detecting the presence of pests or diseases as soon as they occur.

Soil aeration – Amount of air or oxygen contained in a soil or substrate. It is defined by the air space or air porosity in that substrate (defined as the percent volume of substrate that is filled with air).

Soil analysis – A laboratory analysis to determine the content of mineral elements and some chemical characteristics such as pH and EC.

Soil-less culture – A growing method in which plants are cultivated in a substrate providing anchorage and allowing them to absorb water and nutrients.

Soil permeability – the capacity of a soil or substrate to let water pass through.

Soil-borne microorganism – A microorganism that passes the majority of its life cycle in the soil or substrate, most frequently in contact with underground plant parts.

Solarization – A process in which moist soil is covered with clear polyethylene and exposed to hot, sunny days for a period of several days or weeks. Depending on the conditions, the top layer of soil (as much as 30 cm) can reach temperatures of over 50°C that kill many pests and disease agents.

Soluble salts – Salts that are soluble in water. Among them are most inorganic fertilizers (ammonium, nitrate, phosphates, sulfates) and mineral salts (e.g. sodium bicarbonate) dissolved in irrigation water.

Steam sterilization – The process of injecting water vapor or steam into the soil or surface in order to kill soil-borne pests and pathogens.

Stem vessels – Conducting tissues inside the plant stem that transport water and nutrients to all other plant parts.

Sticky trap – A piece of cardboard, plastic or other suitable material, usually yellow, blue or white to attract flying insects. Traps are covered with a sticky substance such as oil so insects will stick to them, giving a grower a fairly accurate idea of the insect population and allowing him to establish an action threshold.

Substrate – The material in which a plant grows. May be composed of natural soil or be completely soil-less in nature (or somewhere in between).

Sustainable production – A cropping scheme that allows for continued and successful production on the same site over a prolonged period of time, with minimum harm effected on renewable resources (i.e., air, water, soil)

Thermal death point – The temperature at which a microorganism is killed.

Thrips – Very small flying insects belonging to the Order Thysanoptera that have piercing, sucking mouthparts, which they use to feed on plant tissues. Thrips are not only directly harmful to plants, they also act as vectors of some viruses like the Tomato Spotted Wilt Virus and others, themselves causing serious plant damage.

Toxicity – When the concentration of a nutrient or chemical is high enough to cause plant damage.

Trap crop – A crop that attracts a certain pathogen or pest and can be used to reduce populations of that organism. For example, marigolds (*Tagetes* sp) may act as trap crops for nematodes. Some plants on the contrary repel certain pathogens and can be planted around susceptible crops as a protective barrier.

Vector – An organism capable of transmitting a disease from one susceptible host to another.

Vermiculite – An inorganic component of growing media made from a mica-like ore of aluminum-iron-magnesium silicate that is heated to a high degree causing the layers to expand into a structure that resembles an accordion. It has a very good water holding capacity.

Virulence – The degree of pathogenicity, that is, the ability of a pathogen to cause disease.

Volcanic rock – Also known as scoria or pumice stone. An inorganic substrate used in soil-less culture.

Worker protection standards (WPS) – A set of measures that should be observed in order to reduce health hazards for workers. WPS and occupational health are part of the social welfare legislation in many countries.

Xylem – Conducting vessels inside the plant stem that transport water and mineral elements absorbed by the roots towards the leaves, where they will be processed by photosynthesis.

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