ALTERNATIVES TO METHYL BROMIDE FOR USE IN CUT-FLOWER PRODUCTION

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ABSTRACT

Colombia flower exports were valued at about US$650 million in 2001 which made Colombia the world's second largest exporter. Growers initially considered methyl bromide (MB) as an option but soon abandoned its use because MB was too difficult and dangerous to apply, too costly and the soils rich in organic matter fixed bromine causing plant phytotoxicity. Depending on circumstances related to environmental conditions, supplies, available infrastructure and other factors, a number of MB alternatives are being used around the world to grow flowers including steam, solarization, biocontrol, substrates, organic amendments, crop rotation, resistant varieties, biofumigation, metam-sodium, 1,3-dichloropropene, dazomet and chloropicrin. The best results require integration of these alternatives. The paper highlights the advantages and disadvantages of steam, compost, soilless cultivation and fumigants for cut flower production.

Keywords: flowers, methyl bromide, steam, compost, soilless, fumigants, Colombia

INTRODUCTION

Commercial floriculture worldwide is characterized by high investment and stringent quality demands which often imply high pesticide usage. Consumers want perfect flowers – completely free of damage caused by pests and diseases. Additionally, more and more flowers are being grown in tropical countries where the climate is benign and allows for year round production at reasonable costs. The flowers are then exported to temperate countries. Increasing trade in flowers has lead to the establishment of stringent phytosanitary measures at ports of entry in an effort made by importing authorities to avoid accidental entry and spread of unwanted pests and diseases in 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 significant 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 fumigation with methyl bromide (MB) given its wide spectrum of action, its efficacy, and its cost which is usually lower than that of other fumigants.

Upon learning about the MB phase out, many flower growers around the world have expressed deep concern, arguing that there exist 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 MB is clearly possible and is already being done. The best example is Colombia, where initial trials with MB failed, forcing growers to look for alternatives thirty years ago. For many years, Colombia has been the second largest flower exporter in the world after Holland. Colombia's export production in 2001 was valued at around US$650 million. Pioneer growers initially considered MB as an option, but abandoned the idea, firstly because it seemed too difficult and dangerous to apply, but also because at the time it was a costly product. Furthermore, the most valid reason for not using MB was due to the very high organic matter content in Colombian soils (18% is common). The bromine from the MB was fixed in the soil leading to phytotoxicity problems that are difficult to solve.

ALTERNATIVES TO METHYL BROMIDE FOR COMMERCIAL FLORICULTURE

Substituting MB requires a grower to take a new approach towards producing flowers. There is no single replacement for this product; rather, a whole programme, involving different measures which together lead to disease reduction, is the answer. In different parts of the world, several alternatives to MB are already in use in cut flower production, often with excellent results. 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 or integrate them in a programme so that together, they lead to the best results.

Table 1: Examples of alternatives to methyl bromide used in cut flower production around the world (Pizano, 2001)[1]

Production type	Alternative	Countries
Protected	Steam	Brazil, Colombia, Europe, USA
	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)
	Metam Sodium	Developed countries, Jordan, Lebanon, Morocco, Colombia
	1,3 Dichloropropene	Developed countries, Colombia
Open field	Dazomet, metam 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

[1] Adapted from: MBTOC 1998: Methyl Bromide Technical Options Committee (MBTOC) 1998 Assessment of Alternatives to Methyl Bromide

Among these, the following alternatives deserve further comment, particularly in developing countries where a large part of commercial floriculture takes place today:

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 vapour 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. As a general rule, it is recommended to carry out treatment so that the coldest spot in the soil or substrate is held at 90°C for ½ hr.

If carried out properly, steam is probably the best alternative to MB, proving equally effective. Its utilization is not new to the industry; steam has been used in greenhouses for many decades. In fact, with the advent of soil fumigants, some growers abandoned this technique in their favour, due mainly to reduced costs and simplicity of application.

Many variables influence the success and cost effectiveness of steam, for example the boiler and diffusers used, soil type and structure and soil preparation (Morey 2001; Pizano 2001). Other problems may also arise in association with steaming itself, such as accumulation of soluble salts (particularly manganese), ammonium toxicity and recontamination. 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 whenever possible; and Practice hygienic measures that help prevent disease dissemination. Adding compost and / or beneficial organisms such as *Trichoderma* also gives good results (Carulla 2001).

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 requires much longer use of the boiler, more hand labour and fuel quantities that may render this to costly. However, steam can be used as an alternative to MB for flowers grown commercially, when it is part of an integrated management system that helps maintain diseases and pests at low levels of incidence. This allows for treatment of the first 30 cm of soil to be sufficient for reducing pathogen populations significantly. For example, the carnation wilt fungus *Fusarium oxysporum* f.sp. *dianthi*) can be controlled at costs comparable to those of fumigants (Table 2). Resistant varieties work well with steam, as they can be grown in areas where disease has occurred in the past (Carulla 2001).

Steam has other benefits when compared to fumigants, as these 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 135,000 exportable carnation flowers and about $10,000 dollars per hectare (Carulla 2001).

Compost

Originally implemented as a solution to large amounts of plant waste generated in flower farms, composting has now become 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. Compost contributes to restoring natural soil flora and increases water retention capacity.

Compost enriched with beneficial organisms such as *Trichoderma* provides very good control of soil fungi such as *Phoma* and *Pythium,* in *Dendranthema* ranges (Valcárcel 2001). These fungi 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. Costs of the compost programme, including spot treatment with fungicides (applied to disease foci as a drench) have been estimated at $4950/Ha (Rodríguez & Martínez 1996).

Growers also report fewer problems with soluble salts and an overall improvement in plant vigor and productivity. In *Dendranthema* nurseries, 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. However, it can also be applied during the cropping cycle of many flowers with excellent results (Pizano 2001).

Soilless substrates

Cultivation of cut flowers on raised beds and in artificial (inert) or soilless substrates (sometimes called hydroponic production) has been widely used for many years in several countries including 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 including no necessity to fumigate or the possibility of a limited amount of substrate requiring sterilization. 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 rockwool 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 soilless culture did not become widespread in tropical and subtropical countries where flowers are produced. For many years, when soilborne 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. Many times flower industries have developed around large cities where international airports are readily accessible for shipping their products. As cities have developed over time, land often becomes expensive and expansion of farms is restricted, hence new soil is no longer within easy reach. Broad-spectrum fumigants either will not be available (for example MB) or will be restricted in their use by other environmental or health concerns. 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 soilless production and economically feasible. Among these, rice hulls, coir (coconut fibre substrate), sand and composted bark, are possibly the most promising (Calderón 2001). Although setting up a soilless production system is expensive – around 47% more expensive than traditional ground beds - growers are able to compensate the extra cost through significantly better yields (20-25%) that result from higher planting density, optimum plant nutrition and better pest and disease control (Carulla 2001; Valderrama & La Rota 2001)

Fumigants

Trials and experiences with soil fumigants in floriculture have shown that their effectiveness varies with factors according to the pathogens to be controlled, the soil characteristics and crop species. These chemicals have been combined together or with other options such as steam with variable results (Arbeláez 2000).

Several fumigants are being evaluated as alternatives to MB, both by commercial growers in many countries, as well as in several demonstration projects conducted by the Montreal Protocol’s implementing agencies (Pizano 2001). The most promising results have been obtained with metam sodium, dazomet and 1,3 dichloropropene + chloropicrin.

Table 2 below presents costs of different treatments in Colombia. However, when determining the treatment of choice, cost is not the only factor to be considered as the environment, sustainability of production, health hazards and others also play an important role in this decision.

Table 2: Comparison of general costs for sterilizing the soil with several fumigants and steam in Colombia[1] (Carulla, 2001; Rodríguez & Martínez, 1996; Trujillo, 2001)

TREATMENT	US DOLLARS PER HECTARE[2]
Dazomet	$5,680
Metam Sodium	$5,120
Dichloropropene[3]	$8,695
Methyl Bromide	$5,030
Steam[4]	$8,479

[1] Figures in US dollars. [2] Includes general hand labor costs. [3] Usually in combination with chloropicrin. [4] Low disease incidence, in combination with integrated pest management.

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ALTERNATIVES TO METHYL BROMIDE FOR CUT-FLOWER PRODUCTION IN SOUTHERN SPAIN

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ABSTRACT

Evaluation of different physical, chemical and biological treatments of greenhouse plots naturally infested with *Fusarium oxysporum* f.sp. *dianthi* was achieved in two consecutive 2-year experiments planted with carnation cvs. Exotica and Master in July 1998 and July 2000, respectively. Steam treatment, and fumigation with Dichloropropene + Chloropicrin failed in Experiment 1 but they were very successful in Experiment 2, indicating their possible use as alternatives to MB. On the contrary, results of metham-sodium fumigation in Experiment 1 were very promising, but its application with injectors in Experiment 2 only produced satisfactory results a few months after planting, which was also the case using poultry manure amendment followed by plastic mulching for 4 weeks. The use of low dose of MB combined with VIF plastic tarping was almost ineffective in Experiment 1 but, when the dose was increased from 20 to 30 g/m^2 in Experiment 2, there was good disease control. The success of the treatments seemed to depend a great deal on the method of application. The combination of eradicative treatments with some degree of resistance in the carnation cultivars is highly recommended.

Key words: soil fumigation, soil solarization, soil steaming, biofumigation, inoculum density, disease progress curves, eradication

INTRODUCTION

Fusarium wilt (FW), caused by *Fusarium oxysporum* f.sp. *dianthi* (Fod), is one of the most important phytopathological constraints of carnation worldwide. Its importance in SW Spain, the largest area of carnation production in Europe, prompted the present work aimed at evaluating different physical, chemical and biological alternatives for reducing pathogen populations including FW to low levels in order to maintain profitable carnation yields.

Soil depth and temperature, as well as methods of application, determine the effectiveness of the chemical desinfestation of soil (Cebolla *et al.* 1984). A low density of pathogen propagules remain usually viable after chemical fumigation, mainly in deeper soil layers where the effectiveness of the treatment is reduced. Therefore, the complete control of Fod is not achieved (Ben-Yephet *et al.* 1994). Incomplete control frequently occurs when physical methods of desinfestation such as steam and soil solarization are applied mainly because the temperatures reached in the deep layers is not sufficiently high to kill them (Elena and Tjamos 1997).

FW has been commonly controlled by means of methyl bromide (MB) fumigation of the soil before planting, but due to its action in depleting the ozone layer, MB is being phased out. Its use will be reduced to 25% of 1991 levels in 2003 and prohibited in the European Community in 2005. Consequently, there is a need to search for alternative treatments than can control the disease. Until these are found, the standard dose of 100 g/m^2 has been reduced to 30 g/m^2, but complemented with the use of virtually impermeable films (VIF) which avoid its immediate release of MB to the atmosphere; otherwise high doses of application would be required.

Alternative methods to MB for disease control were evaluated in two different 2-year experiments conducted in 1998-2000 (Experiment 1) and 2000-2001 (Experiment 2) in a greenhouse naturally infested with the pathogen. Besides an untreated control, treatments with reduced dose of MB+VIF, metam-sodium, and Dichloropropene (1,3-D) + Chloropicrin applications, and soil steaming were tested in both experiments. Standard application of MB was also tested in Experiment 1, whereas the incorporation of poultry manure into the soil, followed by plastic tarping, was tested only in Experiment 2 (Table 1).

Table 1: Soil treatments applied in infested greenhouse previous to carnation planting

Experiment 1(1998/2000)	Experiment 2 (2000/2002)
Untreated control	Untreated control
MB (100 g/m^2)+ PE	MB (30 g/m^2)+ VIF
MB (20 g/m^2)+ VIF	Metham-Na (100 g/m^2)+ VIF Solarization
Dichloropropene + Chloropicrin (40 g/m^2)+PE	Solarization with CP-129 film
Steam (2 h)	Dichloropropene + Chloropicrin (40 ml/m^2)+ VIF Solarization
Metham-Na+Dichloropropene (80+40 ml/m^2) + PE	Steam (2.5 h)
Metham-Na + Aldicarb (80 ml + 10 g/m^2)+PE	Poultry manure (5 kg/m^2)+ CP-129 Solarization

PHYSICAL TREATMENTS

Since the usual dates of carnation planting in SW Spain are late spring to early summer, soil solarization does not seem to be feasible. Therefore, eradication of *F. oxysporum* f.sp. *dianthi* by soil heating was attempted by means of soil steaming. When this technique was applied to plots in Experiment 1, soil assays indicated very low levels of the pathogen in soil samples up to 30 cm depth. Disease symptoms began to show up ca. 3 months after planting cv. Erika, and DI increased with time up to 20% 5 months later and up to 80% 17 months after planting. In comparison, treatments in Experiment 2 seemed to be more effective, confirming complete loss of pathogen viability up to 30 cm depth, and disease onset occurred 4 months after planting carnation cv. Master, although disease progressed at a very low rate, reaching DI<16% at 17 months after planting.

Improvement in the method of soil steam application in Experiment 2 could account for the best disease control achieved. In addition, the use of a less susceptible cultivar could have also contributed to the results obtained.

CHEMICAL TREATMENTS

Several possibilities were tested in experiments 1 and 2. In the first one, MB was applied at 100 g/m^2 and subsequent tarping with transparent PE (standard treatment) and a reduced dose (20 g/m^2) was tested in combination with VIF plastic. Since the only MB treatment permitted now is MB at 30 g/m^2 followed by VIF plastic tarping, this was the reference treatment applied in 2000 (Experiment 2). The satisfactory results obtained in Experiment 1 with the standard application of MB contrasted with the poor results obtained with the reduced dose of MB+VIF. The latter treatment reduced DI to ca. 60% by the end of the experiment, as compared to the reduction to 20% achieved by the standard dose of MB. Results from Experiment 2 suggested that a dose of 30 g/m^2 with VIF plastic can reach complete control of the FW of carnation for the first 6.5 months after planting but DI reached ca. 23% 10 months later.

The soil treatments with metam-sodium were applied with irrigation water to seal the fumigant into the soil in Experiment 1, and with an injection system in Experiment 2. In addition, the dose of 80 g/m^2 used in Experiment 1 was increased to 100 g/m^2 in Experiment 2. However, the reduction of the pathogen in the soil up to 30 cm depth was not complete (6% in the upper layer) in the latter, in contrast with the reduction to undetectable levels achieved in Experiment 1. This brought about good control of FW in carnation (symptoms initiated ca. 9 months after planting, and final DI was ca. 30%) in Experiment 1, whereas disease onset occurred 4 months after planting and final DI was over 50% in Experiment 2. This poorer results could be attributed to inadequacies in the application system used in this experiment compared with that used in Experiment 1.

On the contrary, the application of 1,3-D + Chloropicrin in the irrigation system (Experiment 1) was much less effective (symptoms initiation ca. 3 months after planting, and final DI over 50%) than when it was injected in Experiment 2 (delay of symptoms appearance to 9.5 months after planting, and final DI of 12%), this treatment being more effective than MB.

CULTURAL AND BIOLOGICAL TREATMENTS

Since poultry manure is common in the area of carnation production, a treatment in Experiment 2 consisted of incorporation into the soil 5 kg/m^2 of fresh poultry manure followed by tarping with plastic for 4 weeks. The reduction of populations of *F. oxysporum* f.sp. *dianthi* in the soil was similar to that achieved by the MB ($30 g/m^2$) + VIF treatment, probably due to the high temperature (45-52ºC) achieved in the soil. Consequently, there was a delay of 3 months in the initiation of symptoms compared to the untreated plots, and final DI was slightly under 50%, a moderate result in comparison to the effects of steam or the 1,3-D + Chloropicrin treatments.

INTEGRATED CONTROL

Due to the difficulties encountered when searching for methods of controlling soilborne plant pathogens such as *F. oxysporum* f.sp. *dianthi*, the integration of several methods with partial effectiveness seemed to be essential. T his approach was followed in Experiment 2 to some extent, since plastic tarping at the time of treating soil with fumigants or organic amendments increased the soil temperature over the 4 week period to close to solarization temperature, even though the time of tarping was not optimal in this regard.

Recently, Eshel *et al.* (2000) emphasized the importance of integrated control combining short duration (8 days) solarization and fumigation at low dose, and found relevant the sequence of these two methods of control in order to have synergic effects.

Other important approaches to study are the combination of eradication methods of control and the use of carnation cultivars with a high degree of resistance to the pathogen (Ben-Yephet *et al.* 1997), and the combination of those with the use of biocontrol agents, mainly non-pathogenic *Fusaria*, *Trichoderma* and *Streptomyces* (Gullino 1997; Pizano 1997).

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THE USE OF METHYL BROMIDE ALTERNATIVES IN CUT-FLOWER PRODUCTION IN PORTUGAL

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ABSTRACT

The cut-flower industry has grown steadily in Portugal in the last two decades. Today, about 1800 growers occupy an area of 1140 ha, of which 402 ha are outdoors. The main flowers produced in mainland Portugal are carnations, pinks, roses, gladioli, and gerbera. In Madeira Island and in the Azores, exotic flowers are produced, mostly *Strelitzia*, *Anthurium*, *Heliconia*, *Protea, Ornithogalum* and orchids. In 1999 Portuguese-exported flowers and live plants were worth € 12.4 million. Soilborne fungi, mainly *Fusarium oxysporum*, *Verticillium* sp., *Phytophthora* sp., *Sclerotinia* sp., *Rhizoctonia solani, Armillaria* sp. and *Rosellinia* sp., and plant parasitic nematodes, mostly *Meloidogyne hapla*, *M. incognita, M. javanica*, *Pratylenchus coffeae*, *Pratylenchus* sp., *Zygotylenchus* sp. and *Radopholus similis* seriously impair the cut flower production. Experiments so far conducted in mainland Portugal indicated that soil solarization, alone or combined with low doses of chemicals to control soilborne plant pathogens, is an alternative to the use of methyl bromide.

Keywords: Portugal, Madeira Island, Azores, cut flower, *Meloidogyne*, *Pratylenchus P. coffeae*, *Radopholus similis*, *Zygotylenchus*, *Fusarium oxysporum*, *Phytophthora*, *Verticillium*, *Sclerotinia, Rhizoctonia*, *Armillaria, Rosellinia*.

INTRODUCTION

Portugal lies on the extreme western border of the European continent. It is rimmed on the east and north by Spain and on the west and south by the Atlantic Ocean. To the west and south-west lie the Atlantic islands of the Azores and Madeira, which are part of metropolitan Portugal. Occupying about 15% of the Iberian Peninsula, Portugal has a total area of 88,500 km^2. Despite its small size, the country displays a great diversity of geographical features. It is divided by the Tagus River between a northern mountainous region with narrow valleys and the southern plains and tablelands with broad river basins and few hills.

There are three major ecological regions. The NW or Atlantic region, roughly embracing the littoral and coastal uplands northwards from the Tagus River, which enjoys a mild climate with abundant and reasonably well-distributed rainfall, a cool winter and relatively short summer dry period. This is the most intensively farmed region in the country. The Northeast region, locally known as Trás-os-Montes, consisting of a number of ecologically different zones, depending on altitude and the relative influence of the Atlantic, Continental and Mediterranean-type climates. Finally, the southern zone of Alentejo comprising that part of the country south of the River Tagus and extending north to include part of the Beira Baixa, has essentially a milder Mediterranean-type climate with rainfall decreasing as one proceeds southwards.

Madeira, composed of the islands of Madeira and Porto Santo, lies in the Atlantic about 1,000 km south-east of continental Portugal. It has an area of 796 km^2 and its climate is influenced by the trade winds with mild, Mediterranean type conditions and relatively high temperatures. Precipitation, rare in summer, seldom exceeds 640 mm.

The Azores archipelago, composed of nine islands in three widely separated groups, lie in the Atlantic. The island nearest to Portugal, São Miguel, is 1,190 km from Cabo da Roca. With a total area of 2,305 km^2, the Azores also have a mild climate, moderated by the Gulf Stream, and an average precipitation of 1,143 mm annually.

THE CUT FLOWER INDUSTRY IN PORTUGAL

Owing to favourable edaphic and climatic conditions occurring in the country, cut-flower production in Portugal has been increasing steadily since the sixties (Lança *et al.* 1988; Barroso & Monteiro 1997; Pires 1999). The most important crops are carnations, pinks, roses, gladioli, gerbera, chrysanthemum and lilies. Exotic flowers such as the anthurium, the strelitzia, the orchid and the protea are produced mainly in the Madeira and Azores islands.

The size of the cut-flower farms owned by ca. 1,800 growers varies between 0.05 ha and 20 ha, and most of the greenhouses are not heated. Portuguese foreign trade of live plants and flowers, excluding foliage, attained € 53.5 million in 1999. Flower exports, mostly to Holland, France, United Kingdom, Germany and Spain, were worth € 12.4 million (Anon. 2001).

Data related to the production of cut flowers in the nine Portuguese agrarian regions are presented in Table I.

Table 1: Cut flower production in Portugal.

Agrarian regions (Number of growers)	Acreage (ha)		Usual soil treatments	Crops produced
	Protected	Outdoors		
Beira Litoral (160)	149.5	49.1	Methyl bromide, dazomet, metam-sodium, fenamiphos, oxamyl, ethoprophos, Ret-Flo Px 357	Carnations, pinks, roses, gerbera, chrysanthemums, lilies, bulbs
Alentejo (58)	3.8	40.2	Methyl bromide, metam-sodium, dazomet.	Carnations, pinks, gladioli, lilies, chrysanthemum, gerbera.
Entre Douro e Minho (781)	230.0	106.0	Metam-sodium, dazomet, steam	Carnations, pinks, roses, gerbera, gladioli, lilies, Alstroemeria
Beira Interior (37)	1.3	3.7	Methyl bromide, dazomet	Carnations, pinks, gladioli, zinia gerbera
Algarve (66)	27.0	17.0	Dazomet, metam-sodium	Carnations, pinks, roses, gerbera
Trás-os-Montes (151)	41.7	1.6	Dazomet, metam-sodium	Carnations, pinks, gladioli, gerbera, Gipsophila
Ribatejo e Oeste (286)	250.0	70.0	Methyl bromide, dazomet, metam-sodium	Carnations, pinks, roses, gladioli, gerbera, Gipsophila, tulips, chrysanthemum and lilies
Azores (60)	5.0	69.0	Usually no soil treatments are made	Carnations, roses, Anthurium, Gerbera, Protea, Strelitzia, Hydrangea
Madeira (180)	30.0	45.0	Dazomet, propamocarb, carbendazim, fosetyl-Al	Protea, Strelitzia, Heliconia, Ornithogalum, Anthurium and orchids
Total:	**738.3**	**401.6**		

Soilborne plant pathogens

The occurrence of edaphic plant pathogens, mainly nematodes and fungi, frequently constrains cut-flower production in Portugal. The root-knot nematodes *Meloidogyne hapla, M. incognita,* and *M. javanica* have been found associated with the decline of various crops such as roses, carnations, and strelitzia (Reis 1985). Root lesion nematodes (*Pratylenchus* spp.) affect the development of carnations, *Dahlia* and glasshouse grown *Alstroemeria*. The bulb and stem nematode *Ditylenchus dipsaci* seriously affected a carnation crop. Root damage caused by *Zygotylenchus* sp. was found in *Gypsophila elegans* plantations. The foliage of chrysanthemums and dahlias were found sporadically invaded by the leaf nematode

Aphelenchoides ritzemabosi. *Anthurium* production in Madeira Island was seriously affected by *Pratylenchus coffeae*, *Pratylenchus* sp. and by the burrowing nematode *Radopholus similes*, introduced recently in the island with imported *Athurium* propagation material (Cravo & Pestana 2001; Pestana & Cravo 1999). Attempts to eradicate *R. similis* from the island have been unsuccessful so far.

Plant pathogenic soilborne fungi also frequently impair the production of many crops. In mainland Portugal, the more troublesome fungi are *Fusarium oxysporum*, *Verticillium* sp., *Phytophthora* sp., *Sclerotinia* sp. and *Rhizoctonia solani.* In Madeira Island, *Pythium* sp., *Verticillium* sp., *Armillaria* sp. and *Rosellinia* sp. are the most damaging soil fungi, the last two occurring frequently in *Proteaceae* groves established in soils previously occupied by forest trees (Moura & Rodrigues 2001; Sardinha 2001).

DISCUSSION AND CONCLUSIONS

The control of soilborne plant pathogens is not an easy task. So, to control diseases caused by soilborne plant pathogens, many carnation, pink, lily and gerbera producers use methyl bromide (MB) in their greenhouses because no other chemical method available has the same broad spectrum of activity. However, soil solarization can be an alternative to MB for the disinfestation of those soils.

Data related to soil solarization trials so far conducted in localities ranging from northern to southern Portugal indicate that this technique can give satisfactory to good control of the major soilborne plant pathogens such as phytoparasitic nematodes *viz*. *Meloidogyne* spp., *Pratylenchus* spp., fungi, *e.g*. *Fusarium oxysporum* f. sp*. gladioli*, and weeds. Nevertheless, the high number of foggy mornings occurring in August in the littoral and coastal uplands of mainland Portugal diminishes the effectiveness of soil solarization. In these cases, the efficacy of the incorporation in the soil of small doses of appropriate agrochemicals before solarization should be studied.

Within mainland Portugal in the hottest months (June, July, August) the monthly average daily global solar radiation reaching the land varies between 22.9 MJ m^{-2} and 28.8 MJ m^{-2} (Reis 1997; Reis 1998). This impressive amount of free and inexhaustible energy can profitably be used to disinfest sick soils without the danger of causing environmental hazards. Soil solarization studies must be pursued in Portugal in order to optimise our knowledge and practice of this technique for use in many diverse ecological zones.

Data on the effectiveness of soil steaming to disinfest soils is still very scarce in Portugal. More information is needed relating to its efficacy according to exposure time, soil type and target micro-organisms.

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