ALTERNATIVES TO METHYL BROMIDE FOR CUT-FLOWERS

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ABSTRACT

The requirement to phase-out methyl bromide (MB) in the cut-flower sector needs more attention than in other sectors in order to identify fully effective solutions that are environmental friendly and technically sustainable. Resistant varieties, soilless cultivation, steam, soil solarization, biocontrol agents and chemicals have been evaluated as potential alternatives and can be considered as components of a global strategy to replace MB in cut-flower production.

Keywords: soil disinfestation, ornamentals, resistant varieties, soilless cultivation, steam, soil solarization, biocontrol agents, chemical control.

INTRODUCTION

Since 1994, two years after the inclusion of methyl bromide (MB) in the list of ozone depleting substances under the Montreal Protocol, intensive collaboration was established between the Italian Ministry of Environment and Territory and the Department of Plant Pathology of the University of Torino in order to identify short and long-term solutions to reduce the use of MB and to ensure compliance with the international and European requirements.

The research activities carried out by Di.Va.P.R.A. and financed by the Ministry for the Environment and Territory, have focused particularly on the Italian vegetable and ornamental crops due to the high consumption of MB in these two production sectors, which in 1994, were estimated to consume 6,970 tonnes for soil disinfestation.

The replacement of MB in the ornamental sector has became even more complicated than in the vegetable sector due to the specific features of the sector itself (Katan 2000). The intensive and highly specialized cultivation systems lead to a build-up of detrimental biological factors in the soil (fungi, nematodes, insects). The farms, located mainly in urban areas and usually of small size, make it difficult to use other chemicals not only because of their toxic properties, but also because of their unpleasant smell. Moreover, the high capital and operational costs oblige growers to reduce the risk of losses of production through the use of MB against soil-borne plant pathogens (Garibaldi & Gullino 1995; Katan 2000). Many other strategies that could be adopted to control soil borne pathogens (resistant varieties, innovative cropping systems, physical and biological soil properties management, climate control measures and field hygiene) are not yet considered by the growers as fully effective solutions (Gullino & Clini 1998, 1999).

AVAILABLE ALTERNATIVES

The research activities carried out by Di.Va.P.R.A. aimed to develop new, alternative technologies that would be reliable from technical, human health, economical and environmental points of view and feasible under different climatic and cultural situations. The results obtained, even if in some cases further confirmation and improvements are needed, represent effective mid- and long-term alternative solutions that will substitute for the use of MB.

Resistant varieties

Resistant or tolerant varieties to one or few specific pathogens (and races) are already available for several crop species. In most cases, new varieties are still being developed using plant breeding.

Table 1: Resistant clones to 4 pathotypes of *F.dianthi* selected in 1995-1999 (adapted from Minuto *et al.*, 2000).

Breeder company	Commercialized resistant clones (name of cultivar in brackets)	Not commercialized resistant clones
Taroni	3191 (Coralie)	2666, 25-XI, 1542, 40, 33, 2529, 140, 178, 66, 236, 252, 254
Santamaria	31 (Shiva)	2506, 237, 20965
Gigante	308 (Rigoletto), 687 (Tango), Alex (Alexander), Callas (Callas)	1519, 943
Di Giorgio	91QC51 (Oklahoma), 92QFS19 (Pamplona), D135 (Placido), D224 (Silvestro), D92 (Sulmona), D239 (Graziano), D233 (Torpedo), E49, B140 (Koala)	B201, B175, B118, C42, N392, D229, D236, D71, O145, O519, E104, E65, F189, F231, F99

The use of modern biotechnology is regarded as a quicker and more effective method for the introduction of resistance genes. The easy application of resistant plants which have minimal environmental impact, and the possibility of combining resistant plants with other control methods, makes resistant varieties a feasible alternative. The major limits are the limited spectrum of activity and the high cost of selection of multiple-resistant varieties with appropriate commercially acceptable quality and yield.

In Italy, resistance of carnation varieties selected by several Italian breeders has been determined annually to four pathotypes of *Fusarium oxysporum* f. sp. *dianthi* (1, 2, 4, 8). During the period 1995-1999, this programme showed that a large number of varieties were resistant to pathotypes 1 and 8, a low number were resistant to pathotypes 2 and 4 and a very limited number were resistant to all pathotypes (Table 1) (Minuto *et al.* 2000).

Soilless cultivation

Soilless cultivation is rapidly expanding in Italy on high value crops (rose, carnation, gerbera, basil, lettuce, for example) (Gullino & Garibaldi 1994; Serra 1994; Pergola & Farina 1995), albeit at a lower rate (200 Ha) as compared with Northern Europe (Van Os & Stanghellini, 2001). Soilless culture offers the advantages of increased productivity, easier yield quality management and reduction in conventional soil-borne pathogens. The environmental impact of open run-to-waste systems should be limited in order to reduce the release of nutrient solutions. In this regard the closed soilless systems seem to be the best solution, even when disinfesting the recirculating nutrient solutions increases the cost of investment. Moreover, the possible establishment of new diseases seems a real risk that needs to be taken into account (Stanghellini & Rasmussen, 1994).

To avoid the risks of diseases spreading, recent research evaluated active (metalaxyl, sodium dichloroisocianurate [Na-DIC]; UV radiation) and passive (slow sand filtration) systems to control *Phytophthora cryptogea* spread in a gerbera soilless crop (table 2) (Garibaldi *et al.* 2001). Metalaxyl application was able to provide good results but could be complicated to operate when the nutrient solution is completely discharged to waste in order to maintain an unacceptable level of chemical conditions (electric conductivity, pH). In this case, the environmentally negative risk could be due to the presence of chemical residues in a discharging nutrient solution. Moreover, the use of a chemical with specific mode of action such as metalaxyl increases the risk of the onset of disease resistance.

Use of chlorinated compounds, such as chlorine gas or Na-DIC, are sometimes recommended for the disinfection of nutrient solutions (Poncet *et al*. 1999) but these may not be suitable. In Italy, chlorine gas is considered toxic and therefore users must comply with strict storage, handling and transportation rules. Moreover, the risk of exposure to workers in increased when chlorine gas and chlorinated compounds are used. Finally, the results obtained highlight the risk of phytotoxicity caused by the application of a chlorinated compound such as Na-DIC. On the contrary, the encouraging results obtained using UV radiation or sand filtration seem to permit a non-chemical and successful phytosanitary management of recycled nutrient solutions.

TABLE 2: Effect of active and passive water disinfection against *P. cryptogea* on gerbera (cv Goldie) (adapted from Garibaldi *et al.*, 2001).

Treatment	Percent of infected plants at days after transplant							
	158		211		218		224	
Sand filtration	2.9	a°	4.5	a	4.5	a	5.4	ab
U.V. radiation	3.7	a	5.4	a	6.3	ab	8.1	ab
Na-DIC *	3.6	a	22.5	a	35.1	b	41.4	c
Metalaxyl	0.0	a	0.0	a	0.0	a	0.9	a
Control	9.1	a	19.8	a	25.3	ab	33.4	bc

* 50 ppm until 03/30 and 10 ppm later on; ° Means of the same column followed by the same letter do not statistically differ following Duncan's Multiple Range Test (P =0.05)

Steam

Steam can achieve good results against several pests, diseases and weeds without any residue soil contamination and with minimal wait-period before planting. Its high efficacy causes a “biological vacuum” and the consequent risk of pathogen recolonization (“boomerang effect”). Moreover, a release of heavy metals, a decomposition of organic matter and consequently accumulation of ammonia, a solubilization of inorganic compounds and a modification of the solubility and availability of the nutrient elements, could cause unpredictable phytotoxicity problems. Steam adoption is currently available for small surfaces (benches, seedbeds, soilless cultivation, for example), firstly because it is generally applied with a discontinuous application method requiring some in-between time following treatments. Secondly, steam is a high energy-consumer (1.5-2.5 gasoline/m^2) and therefore contributes to the global warming.

Soil solarazation

Soil solarization, a well known hydrothermal process (Katan & De Vay 1991), could be adopted for cut-flower production in less intensive cropping system. This strategy takes no less than 4-6 weeks to be successful, either alone or combined with chemicals such methyl isotiocyanate generators. Unfortunately, the period of time for carrying out soil solarization can coincide with the growing season, reducing its possible application in practice.

Bench solarization and solarization in greenhouses are new applications that may help expand its use to even cooler climatic areas (i.e. North-Central Italy) and seasons (Gullino *et al.*, 1998; Katan, 2000) where solarization has not traditionally been used. Solarization offers many positive features, including an Increased Growth Response, relatively low cost and the preservation of the beneficial soil flora and fauna. Among the major constraints are climate and meteorological unpredictability, the large amount of irrigation water required to increase the thermal conductivity of the soil (especially sandy soils). In addition, solarization has a limited spectrum of activity against pathogens, particularly nematodes, compared to MB and steam treatments (Katan & De Vay 1991).

Biological control

Although several biocontrol agents (BCAs) have been successfully exploited to control soil-borne pathogens, at present they cannot be considered a viable alternative to MB for soil fumigation due to the very limited number of registered BCAs, their very narrow spectrum of activity, their short formulation shelf life and their low commercial availability (Fravel *et al.* 1999). Hopefully in the future, registered BCAs could play a role in soil disinfestation, when specific problems need to be solved (Garibaldi & Gullino, 1995). The most positive effects of using BCAs are the possibility of using them to control pathogens not yet controlled by other traditional methods, their low environmental impact (when recombinant micro-organisms are not used) and the total absence of chemical residues.

In cut-flower production, several microrganisms are now well-known as effective antagonists against soil-borne pathogens: antagonistic *Fusaria* are effective against *Fusarium* wilt of carnation and chrysanthemum; a selected strain of *Agrobacterium rhizogenes* can easily control the *Agrobacterium tumefaciens* infection, but unfortunately few of them are now registered in Italy and South European countries.

A strategy able to easily improve the transfer into practice of BCAs for cut-flowers could be their application combined with chemicals and/or resistant varieties. It has been demonstrated that antagonistic *Fusaria* can be applied combined with benzimidazoles, when naturally resistant to these fungicides, to control *Fusarium* wilt of carnation, improving the disease tolerance of adopted varieties (Table 3)

TABLE 3: Effectiveness of application of different BCAs against *Fusarium* wilt of carnation, artificially inoculated ($5x10^3$ CFU/g of soil), combined with chemical control and genetic resistance varieties at 92 days after the transplant (adapted from Garibaldi *et al*., 1990).

Varieties	BCAs 10^5 CFU/g of soil	Benomyl g/m^2	Disease index (0-100)		Percent healthy plants	
Manon	-	-	69	d	27	d
Cantalupo	-	-	49	c	38	cd
Manon	S*	-	45	c	47	c
Cantalupo	S	-	20	b	70	b
Manon	RB**	-	40	c	47	c
Cantalupo	RB	-	25	b	65	b
Manon	S	20	10	a	86	a
Cantalupo	S	20	4	a	95	a

*S = sensitive to benomyl; RB = resistant to benomyl**° See table 2.

Chemical control

The chemical products for soil disinfestation may have a “broad spectrum of activity” (fumigants) or a “more specific spectrum of activity” (fungicides and nematicides). Among the first group, the methyl isothiocyanate (MITC) generators are the most popular. Metham sodium as a liquid soil chemical, and dazomet as a solid, are effective for controlling weeds and soil-borne pathogens, principally fungi, and a limited number of parasitic nematodes species, but must be applied when soil temperatures are not below 12-15°C. Metam sodium’s use is relatively low cost when carried out by the growers themselves, but it has a low efficacy against several vascular diseases and some specific soil-borne pathogens. Nematodes can often be missed due to the non-uniform distribution in the soil or to the climate and meteorological unpredictability. Moreover the long waiting period between treatment and planting, the additional requirement for plastic mulch to improve efficacy and reduce environmental impact, and the need to dispose of the plastic, all reduce the grower acceptance of metam sodium.

Metam sodium, used recently in a gerbera greenhouse against root rot caused by *Phytophthora cryptogea*, showed that MB applied at 60 g/m^2 or at 40 g/m^2 under virtually impermeable film controlled root rot satisfactorily, while metham sodium applied at 192 g/m^2 without plastic mulch did not provide satisfactory disease control. Moreover, the same fumigant provided better results when applied at 96 g/m^2 under plastic mulch (Table 4) (Minuto *et al*. 2000). A more specific soil disinfectant, 1,3-dichloropropene (1,3-D) applied mainly by injection, provided effective control of nematodes, insects, some weeds and some pathogenic fungi. During the application of 1,3-D, the soil must remain covered with plastic mulch to improve its efficacy and to reduce worker exposure (Lamberti *et al*. 2000).

TABLE 4: Effectiveness of different soil treatments against *Phytophthora cryptogea* on gerbera (Albenga, 1997 - 1998) (adapted from Minuto *et al*., 2000).

Treatment	Percent dead plants at days after transplant				Number of flowers per plant	
	106	213	310	386		
-/-/-	7.9 b°	11.2 c	26.1 b	44.5 b	22.1	a
BM/60/PE	3.0 a	3.1 a	11.4 a	17.2 a	19.0	b
BM/40/LMG	2.1 a	3.0 a	12.0 a	19.9 a	20.1	ab
MS/192/-	5.4 ab	6.1 b	15.5 a	30.2 b	19.6	ab
MS/96/PE	4.8 ab	3.3 a	13.1 a	26.2 ab	18.6	b
MS/96/LMG	5.7 ab	5.0 ab	13.2 a	26.5 ab	22.4	a

° Means of the same column followed by the same letter do not statistically differ following Duncan's Multiple Range Test (P =0.05)

CONCLUSIONS

The available alternatives evaluated to replace MB for cut-flower production still need an intermediate stage for testing the results obtained under experimental conditions on a commercial scale. The examples reported above indicate that there can be negative environmental effects and enhanced phytotoxicity risks. The availability of alternatives must be considered when evaluating the efficacy as the ability to transfer the treatment to growers is essential. Despite these comments, resistant varieties, soilless cultivation, steam, soil solarization, biocontrol agents and chemicals can all be considered as components of a global strategy that can replace MB in cut-flowers production.

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ALTERNATIVES TO METHYL BROMIDE FOR CUT-FLOWER PRODUCTION IN GUATEMALA

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ABSTRACT

The use of MB in Guatemala for crop production continued to increase until 1997 when a programme testing alternatives commenced. This study on *Anthirrynum sp*., commonly called Snap Dragon, showed that weeds were best controlled with either steam or metam sodium as alternatives to MB. Steam was the best at controlling damping-off disease. Metam sodium had little effect on *Pithium sp* and soil nematodes and therefore its future use is limited. Although steam cost 14% more than the regular dose MB, steam could be a benefit to some growers as production without synthetic chemicals is valued in some international markets.

Keywords: Guatemala, methyl bromide, *Anthirrynum,* steam, metam sodium, *Pithium*

INTRODUCTION

In Guatemala, methyl bromide (MB) is mainly used for production of crops such as melon, cutting flowers, tomato, broccoli, tobacco and seedlings. The consumption of MB increased from 43 tonnes in 1993 to 455 tonnes in 1997 due mainly to an expansion in the area planted with melon. Recently, MB consumption was reduced by approximately 50% compared to 1997 due to the availability of alternatives.

About 175 ha of cut-flowers from different species are planted in Guatemala of which 60% are treated with 42 tonnes of MB a year in order to minimise the risk of losses due to soil diseases. The objectives of this study were to evaluate alternatives to MB for the control of soil organisms capable of causing economic losses in the production of cutting flowers, and to determine the cost of production for each alternative evaluated

METHODOLOGY

The investigation was carried out in the fields of the Pamputik Company, located in Pastores, Department of Sacatepéquez, from May to September 1999. The variety of cut-flower used was *Anthirrynum sp*., commonly called Snap Dragon.

The following variables were analysed: Damping-off (*Pithium sp)*; presence of weeds, nematodes; production quality; and cost of treatments. A randomised complete block design with 6 treatments and 4 replications was used. The experimental unit was a 1 x 10 m plot. Each block was 90 m^2 and total area was 400 m^2. Steam was generated from a boiler. The treatments evaluated were: Steam at 90°C for 30, 45 or 60 minutes; Metam Sodium, 1000 l/ha (sodium monomethyl dithiocarbamate); average-dose MB at 232 kg/ha to reduce pathogens; and regular-dose MB at 464 kg/ha.

RESULTS

Control of weeds: Data were collected twice, 10 and 25 days after transplant. In the first data collection, steam treatments were statistically similar, regardless of time, to the metam sodium treatment. The regular MB treatment suppressed weeds but the average dose of MB was not significantly different to the control with a total of 1360 weeds per m^2. A similar situation occurred in the second data collection at 25 days.

Table 1: Weeds per m^2 , 10 and 25 days after transplant.

Treatments	10 days after transplant	25 days after transplant
Steam 30 minutes	20 b	27 b
Steam 45 minutes	18 b	19 b
Steam 60 minutes	05 b	10 b
Metam Sodium	12 b	19 b
Methyl Bromide 464 kg/ha	00 b	09 b
Methyl Bromide 232 kg/ha	1,360 a	1695 a

Duncan multiple range test

Control of "Damping-off" (*Pithium sp.)*: Steam and the regular dose MB controlled the pathogen adequately and reducing their incidence significantly. Metam sodium and the average MB treatments allowed the disease to increase significantly affecting 3 to 4% of the plants that died because of presence of *Pithium sp*. (Table 2).

Table 2: Control of Damping-off (%) with different treatments.

Treatments	Percentage damage
Steam 30 minutes	0.10 c
Steam 45 minutes	0.17 bc
Steam 60 minutes	0.20 bc
Metam Sodium	3.00 ab
Methyl Bromide 464 kg/ha	0.40 bc
Methyl Bromide 232 kg/ha	4.00 a

Duncan Multiple range test

Control of Nematodes: Although the analysis showed the presence of nematodes capable of damage the crop, the low populations did not represent a problem. *Rhabditis* nematode populations increased significantly after steam applications. They are reported to not be plant parasites but parasites of organic matter.

Production quality: This factor is determined directly by the length of the shoots and flowering vigour. With exception of the average MB dose, the treatments did not show significant difference in the quality obtained.

Cost per treatment: Steam treatments for 30, 45 and 60 minutes cost US$0.34 per m^2, 0.37 per m^2 and 0.42 per m^2 respectively. Metam sodium cost US$0.35 per m^2. Average dose MB cost US$ 0.26 per m^2 and the regular dose US$ 0.37 per m^2. This data demonstrate that steam has a similar cost to MB with similar efficiency and therefore can be considered as a good alternative.

CONCLUSIONS

Weed control, steam and metam sodium were all equally effective as alternatives to MB used at the recommended dose. Steam was the best at controlling damping-off. Reduced-dose MB cannot be recommended in place of an alternative. Metam sodium was a good choice for weed control but had little effect on *Pithium sp* and soil nematodes and therefore its future use is limited. Although steam cost 14% more than the regular dose MB, production without synthetic chemicals could be a benefit for some growers as it adds value in some international markets.

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ALTERNATIVES TO METHYL BROMIDE FOR CONTROL OF ANNUAL AND PERENNIAL WEEDS

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ABSTRACT

Two field experiments were conducted in 2000 and 2001 in northern Greece to evaluate the effect of application time of methyl bromide (MB), metham sodium and dazomet against certain annual and perennial weeds. The first experiment was established on 21 November 2000 and the second on 13 June 2001. The results of the first experiment indicated that all fumigants at 4 months after treatment (MAT) gave excellent control of the winter annual weeds *Lamium amplexicaule, Stellaria media,* and *Veronica hederifolia* and very good control of the summer annual weeds *Chenopodium album*, *Xanthium strumarium,* and *Datura stramonium*. Also, all treatments at the same time reduced stem emergence of the perennial weeds *Cynodon dactylon, Sorghum halepense,* and *Convolvulus arvensis* by 85-100% compared with that of the untreated control. However, at 6 MAT, MB was the only treatment that reduced by 90-99% stem emergence of the three previously mentioned perennial weeds, while the *C. dactylon, S. halepense* and *C. arvensis* control obtained by the rest of the treatments ranged from 60 to 79, 9 to 49, and 62 to 84%, respectively. In the second experiment, all treatments at 1, 2, and 3 MAT gave excellent control of *Portulaca oleracea* and very good control of *X. strumarium* and *D. stramonium*. Metham sodium and dazomet, in contrast to the results of the first experiment, gave very good control of *C. dactylon* and *S. halepense* and similar to that provided by MB. These results show clearly that metham sodium and dazomet could possibly be used as an alternative to MB for weed control in vegetable production, but they should be applied in early summer rather than in late autumn for better weed control.

Keywords: Dazomet, metham sodium, methyl bromide, soil fumigants.

INTRODUCTION

A recent survey conducted in northern Greece indicated that the annuals *Amaranthus* spp., *C. album*, *Conyza* spp., *Digitaria sanguinalis*, *Echinochloa crus-galli*, *Galinsoga parviflora*, *Poa annua*, *P. oleracea*, *Setaria* spp., *Solanum nigrum*, *S. media, Veronica* spp.*,* and *Urtica* spp.*,* as well as the perennials *C. dactylon, Cyperus* spp. and *C. arvensis* were among the most commonly found weeds in greenhouses (Eleftherohorinos & Giannopolitis 1999).

Many of the abovementioned weeds are also commonly found in arable crops and in many vegetable crops grown under field conditions. They are considered to reduce crop yields and lower the quality of crop products by competing with crops primarily for soil nutrients and moisture but also for light and carbon dioxide. Some of these weeds affect crop growth indirectly by harboring insect, nematode and fungus organisms that attack crop plants. So, their control is basic for efficient and profitable agriculture.

Methyl bromide (MB) has been extensively used worldwide as a broad-spectrum fumigant in the production of many vegetable crops. This is because it is the most effective soil fumigant against nematodes, insects, diseases, and weeds. Concerning its herbicidal activity, results published in the literature and results of our recently survey conducted in greenhouses of northern Greece, indicate that MB has excellent efficacy against the annuals *Abutilon*, *Amaranthus*, *Avena*, *Chenopodium*, *Conyza*, *Datura*, *Digitaria*, *Echinochloa*, *Galinsoga*, *Papaver*, *Poa*, *Portulaca*, *Setaria*, *Solanum*, *Stellaria,* and *Urtica* and very good efficacy against the perennials *Sorghum, Cynodon, Cyperus,* and *Convolvulus* (Zhang *et al.* 1997).

Since most of the use of MB are going to be phased out by 2005, mainly because of the detrimental effect of MB on the ozone layer (Albritton & Watson 1992; Ohr *et al.* 1996), this research was conducted in Greece aiming to find alternatives to MB against weeds. The objective of this study was to evaluate the effect of application time and method of metham sodium and dazomet against certain annual and perennial weeds.

MATERIALS AND METHODS

Two field experiments were conducted in 2000 and 2001 on a silty clay loam soil of the University Farm of Thessaloniki, northern Greece. The first experiment was established in an area infested with natural populations of winter annual weeds (*L. amplexicaule, S. media*, *V. hederifolia),* summer annuals (*C. album*, *X. strumarium*, *D. stramonium)*, and the perennial *S. halepense*. The area of the second experiment was infested with natural populations of *X. strumarium*, *D. stramonium, P. oleracea,* and *S. halepense*. The area in both experiments was technically infested with *C. dactylon* and *C. arvensis* by spreading evenly and incorporating afterwards their underground propagation organs in soil.

The first experiment was established on 21 November 2000, while the second one on 13 June 2001. The area before their establishment was irrigated and four days later was cultivated with a rotovator in a 7-10 cm soil depth. The fumigants were applied afterwards to the soil according to the label instructions and to the recommended practices. So, metham sodium (Vapam 32.7 SL, 2,500 l/ha) was applied with the irrigation water (10 mm of water), while dazomet (Basamid 98 G, 600 kg/ha) and MB (680 kg/ha) were applied by even broadcast of its granules and by fumigation under polyethylene transparent sheet, respectively. The soil temperature at their application and during the following 12 days ranged from 12 to 16 and from 26 to 29^{o}C in the first and second experiment, respectively.

Immediately after their application, the plots treated with dazomet were cultivated with a rotovator in a 7-10 cm soil depth for its incorporation, and then all plots, except those treated with MB (covered with polyethylene transparent sheet), were irrigated with 10 mm of water. Four hours later, three of the six plots treated with dazomet were covered with a polyethylene transparent sheet. This was made to prevent loss of methyl isothiocyanate (MITC), the primary dazomet break down bioactive agent. The experimental area was irrigated for 12 consecutive days to keep the soil wet. The polyethylene transparent sheet was removed from the MB treated plots four days after its application, while that from the dazomet treated plots eight days later (12 days after its application). Then, all experimental plots were cultivated with a rotovator in a 7-10 cm soil depth.

A randomized complete block design was used in both experiments. There were three replications (plots) for each treatment. Plot size was 1.5 by 6.5m, and an alley 1m wide separated all plots. The efficacy of all treatments was evaluated by weed measurements in an 8m^2 area of each plot at 3, 4, 5, and 6 MAT in the first experiment, and at 1, 2, and 3 MAT in the second experiment. The data before the analysis of variance were square root transformed.

RESULTS AND DISCUSSION

In the first experiment, all treatments at 3, 4, and 5 MAT gave very good to excellent control of the winter weeds *l. Amplexicaule, s. Media* and *v. Hederifolia* (table 1). Also, all treatments at 4 MAT, gave very good to excellent control of summer annual weeds *c. Album*, *x. Strumarium* and *d. Stramonium* (Table 2). However, at 6 MAT, MB was the only effective treatment (98-99% control) against these weeds, while the control obtained with the other treatments was significantly lower. In general, metham sodium gave better control of the three summer annual weeds than dazomet covered with polyethylene transparent sheet, while dazomet applied with irrigation provided intermediate weed control. All treatments at 4 MAT reduced significantly stem emergence of the perennial weeds *C. dactylon, S. halepense* and *C. arvensis* compared with that of the untreated control (Table 3). However, at 6 MAT, MB was the only treatment that had reduced by 90-99% stem emergence of the three previously mentioned perennial weeds. Metham sodium at the same time reduced stem emergence of *C. dactylon, S. halepense* and *C. arvensis* by 79, 49 and 84%, respectively. The corresponding reduction due to dazomet applied with irrigation was 62, 9, 62%, while that caused by dazomet covered with polyethylene transparent sheet was 60, 16 and 64%.

In the second experiment, all treatments at 1, 2, and 3 MAT gave excellent control of *P. oleracea* and very good control of *X. strumarium* and *D. stramonium* (Table 4). Metham sodium and dazomet applied either way, in contrast to the results of the first experiment, caused significant reduction of *C. dactylon* and *S. halepense* stem emergence and similar with that provided by methyl bromide (Table 5). Their efficacy against *C. arvensis* was not evaluated due to its low density recorded in all plots.

These results show clearly that metham sodium and dazomet could possibly be used as an alternative to MB for weed control in vegetable production. However, although both are typically applied in the fall, the results of this study showed clearly that their application in early summer provided better weed control compared with that obtained after their application during autumn. The better soil environmental conditions that prevailed after their application in early summer may favor seed germination and bud sprouting of weeds and consequently increase their susceptibility to the fumigants applied. It is well known that weeds at seed germination or bud sprouting stage are more vulnerable to most chemicals used than at seed or bud dormancy.

It is worth mentioning that some of the following considerations should be taken into account before widespread use of dazomet and metham sodium (Noling & Beker 1994): 1) They must be applied in large quantities which is difficult to handle, 2) They depend on irrigation for their activation after application, 3) They have a reduced effectiveness against some common weeds (*Solanum* and *Cyperus*), *4*) They are readily leached and consequently have a high potential for groundwater contamination, 5) They have a short residual activity which means a short lasting weed control efficacy (particularly against summer weeds after their application in fall).

Table 1: Efficacy of fumigants tested against the annual winter weeds (Experiment I).

Treatments	*S. media*			*V. hederifolia*			*L. amplexicaule*		
	Plants/8m^2								
	Months after treatment								
	3	4	5	3	4	5	3	4	5
Methyl bromide	1b[1]	3b	5b	0b	0b	0b	0b	0b	0b
Metham sodium	0b	2b	3b	0b	0b	0b	0b	0b	0b
Dazomet (irrigated)	1b	3b	4b	0b	0b	0b	0b	0b	0b
Dazomet (covered)	1b	2b	5b	0b	1b	2b	0b	1b	2b
Control	24a	135a	138a	18a	32a	37a	19a	63a	67a

[1]Treatment means of the same column followed by the same letter are not significantly different according to the LSD test at P=0.05.

Table 2: Efficacy of fumigants tested against the annual summer weeds (Experiment I).

Treatments	*C. album*			*X. strumarium*			*D. stramonium*		
	Plants/8m^2								
	Months after treatment								
	4	5	6	4	5	6	4	5	6
Methyl bromide	3b[1]	1c	1d	0d	0b	0b	0b	0c	0d
Metham sodium	1b	2bc	2cd	5c	29a	46a	0b	0c	5c
Dazomet (irrigated)	3b	4bc	5bc	11bc	21a	22a	1b	6b	6bc
Dazomet (covered)	3b	6b	8b	14b	38a	40a	0b	10b	12b
Control	36a	62a	53a	38a	48a	44a	20a	28a	24a

[1]Treatment means of the same column followed by the same letter are not significantly different according to the LSD test at P=0.05.

Table 3: Efficacy of fumigants tested against the perennial weeds (Experiment I).

Treatments	*S. halepense*			*C. dactylon*			*C. arvensis*		
	Stems/8m^2								
	Months after treatment								
	4	5	6	4	5	6	4	5	6
Methyl bromide	0c[1]	0d	1c	0b	2d	12c	2bc	10b	15c
Metham sodium	0c	10c	57b	0b	9cd	43bc	0c	14b	23bc
Dazomet (irrigated)	2bc	11c	103a	5b	27c	84b	2bc	15b	54b
Dazomet (covered)	5b	27b	95ab	5b	59b	90b	4b	29b	49b
Control	44a	89a	113a	83a	203a	222a	47a	122a	144a

[1]Treatment means of the same column followed by the same letter are not significantly different according to the LSD test at P=0.05.

Table 4: Efficacy of fumigants tested against the annual summer weeds (Experiment II).

Treatments	*P. oleracea*			*X. strumarium*			*D. stramonium*		
	Plants/8m^2								
	Months after treatment								
	1	2	3	1	2	3	1	2	3
Methyl bromide	0b[1]	0b	0b	0b	1b	1b	0b	2c	2c
Metham sodium	0b	0b	0b	0b	1b	1b	0b	1c	3c
Dazomet (irrigated)	0b	0b	0b	2b	3b	3b	1b	22b	25b
Dazomet (covered)	0b	0b	0b	0b	0b	0b	0b	1c	2c
Control	11a	19a	23a	18a	33a	34a	298a	260a	263a

[1]Treatment means of the same column followed by the same letter are not significantly different according to the LSD test at P=0.05.

Table 5: Efficacy of fumigants tested against the perennial weeds (Experiment II).

	C. dactylon			*S. halepense*		
Treatments	Stems/8m^2					
	Months after treatment					
	1	2	3	1	2	3
Methyl bromide	0b[1]	0b	2b	1b	7b	10b
Metham sodium	0b	1b	7b	0b	0b	1b
Dazomet (irrigated)	0b	8b	14b	1b	8b	8b
Dazomet (covered)	0b	4b	12b	0b	0b	0b
Control	22a	101a	158a	56a	237a	390a

[1]*Treatment means of the same column followed by the same letter are not significantly different according to the LSD test at P=0.05.*

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INTEGRATED PEST MANAGEMENT AND BIOLOGICAL CONTROL USED IN THE PRODUCTION OF GERBERA IN HUNGARY

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ABSTRACT

Integrated Pest Management (IPM) is possible in gerbera production in Hungary. It is very important to stop using dangerous chemicals in order to encourage the settlement of natural predators from neighbouring unsprayed areas and to improve the predator-pest ratio by using selective chemicals unharmful to predators. The efficacy of plant-protecting agents such as Chess and Confidor are fast decreasing. IPM can lower the risk of resistance developing. Contrary to the practice in the Netherlands, in Hungary it is possible to start a biological control effort in summer by encouraging predators to settle and reducing the cost of crop protection.

KEY WORDS: Biological control, chemical agent, plant-protecting, gerbera, integrated pest management (IPM).

INTRODUCTION

Floratom Ltd is one of the biggest firms in Hungary growing gerbera, tomato and sweet-pepper in South Hungary. It has a 25 000 m^2 (25 ha) protected area. Thermal water is used for heating. Biological control has been successfully adopted in the 22 ha vegetable area in the past ten years. IPM methods have just started recently in the 3 ha gerbera area. Before IPM, a number of pesticides and fungicides were used efficiently including metomil, dimetoat, pymetrozine, methamidofos, abamectine, deltamethrin, bifenthrin and buprofezin. With chemical resistance developing to reduce the efficiency of production, the final change was the introduction of a new pest (*Liriomyza huidobrensis*) which pressed us into an examination of our chemical control methods.

THE EFFICACY OF PLANT-PROTECTING AGENTS

The chemical pest management was changed to integrated pest management (IPM) in the summer. The efficacy of the plant protecting agents against white fly, red spider mite, thrip, aphids, and leafminers is shown in Table 1.

Table 1: The efficiency of plant protecting agents. + = inefficient; ++ = little efficacy; +++ = mild (moderate) efficacy; ++++ = good; +++++ =excellent

Tradename	Generic name	White fly	Red spider	Thrip	Aphids	Leaf miner
3i 58	dimetoat	+	+	++	++++	+
Admiral	pyriproxifen	++++	+	+++	+	+
Andalin	flucycloxuron	+	+++	+	+	+
Apollo	clofentezine	+	+++	+	+	+
Applaud	buprofenzin	+	+	+	+	+
Aztec	triazamaat	+	+	+	++++	+
Chess	pimetrozin	+	+	+	+++++	+
Confidor	imidacoprid	++	+	+++	+++++	+
Decis	deltametrin	+	+	++	++	+
Lannate	metomil	++++	+	+++	+++++	+

Tradename	Generic name	White fly	Red spider	Thrip	Aphids	Leaf miner
Nissorun	hexythiazox	+	+++	+	+	+
Nomolt	teflubenzuron	+++	+	+	+	+
Orthene	acefaat	+	+	+++	++++	+
Pentac	dienochloor	+	++	+	+	+
Pirimor	pirimicarb	+	+	+	+++	+
Sanmite	pyridaben	+++	+++	+	+	+
Talstar	bifenthrin	+	+	++	+	+
Tanaron	metamidofos	+	+	+++	++++	+
Torque	fenbutatinoxid	+	+++	+	+	+
Trigard	cyromazine	+	+	+	+	++++
Unifosz	diclorfosz	+	+	++++	++++	++
Vertimek	ablamectine	+	+++	+++	+	++++

During the changeover period, only chemicals with low persistency were used to prevent high pest numbers. Their low persistency made it possible for natural enemies to settle. During the changeover period, the following plant-protecting agents were used: Cyhexatin, Biosoap, Vertimec, Mach, Admiral, Trigard, Micotal, Addit and Dipel. Since there was a well-established, biologically-balanced tomato area close to the gerbera production area, the natural enemies could settle very fast in the gerbera area. The natural enemies settled in the following sequence: *Eretmocerus eremicus*, *Diglyphus iseae*, *Phytoseiulus persimilis*, *Aphidius colemani*, *Orius laevigatus*, and *Macrolophus caliginosus*.

At the end of August and in September, the cotton moth (*Helicoverpa armigera*) caused the biggest problem. The flowerloss was about 20%. This problem occurred because the moth laid its eggs directly onto the bud and Dipel (*Bacillus thuringiensis* var. *Kurstaki*) was not able to reach the eggs. We plan to introduce *Timalia* (*Alcippe morrisonia*) next year.

In Octobe we tried to reduce the thrip and white fly populations to a low level for planting next spring. Micotal and Addit were used three times and Admiral once. Trigard 1 l/ha was applied for leaf miner control in winter. At the end of February, natural enemies of white fly, red spider mite, thrips, aphids, leaf miner were begun to be introduced (Table 2).

Table 2: Introduction rates of natural enemies in 2001

Pest	Natural enemy	Intr. rate no/m^2	Interval	Frequency	Start
Whitfly	Eretmocerus e.	3	Weekly	Five times	March
	Macrolopus c.	0,5	Weekly	Twice	March
Red spide mite	Phytoseiulus p.	6	Weekly	Twice	February
Thrips	Amblyseius c.	100	Every 4 weeks		February
	Orius l.	0,5	Every 2 weeks	Twice	March
	Hypoaspis a.	100		Once	February
Aphids	Aphidius c.	0,5	Weekly	Three times	February
	Rhopalosiphum p.	5/ha	Every 2 weeks		January
	Aphidius e.	0,15	Weekly	Three times	February

Pest	Natural enemy	Intr. rate no/m^2	Interval	Frequency	Start
Leaf miner	Diglyphus i.	0,1	Weekly	Three times	March

Macrolophus population was so large in June that it endangered the flowers and a drip Imidakloprid treatment was applied in order to prevent significant flower loss.

CONCLUSIONS

The only disadvantage of biological control so far noted has been the occurrence of sugar disease, a disorder known only from literature and not from the everyday practice. This is a little-known disease which destroys the plant only after the fruit fly has bred. Fruit fly is a vector and a catalyst in the development of the infection. A sweet section flows out from the picked flower stem and a bacterium species multiplies in this sweet fluid. This brown and white sweet-smelling, foamy, mass appears on the surface and the fruit fly breeds on this mass.

The most important activities to control sugar disease in gerbera are to reduce root pressure (early stop and late start of the irrigation, adjust the vegetative-generative balance early in the life of the young plant), to trap fruit fly with fermenting material, and to remove affected plants.

METHYL BROMIDE ALTERNATIVES FOR CUT-FLOWER PRODUCTION IN CHIPIONA

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ABSTRACT

Cumulative yields of carnation cultivars Erika and Master over an 18 and 13 month period, respectively, in a greenhouse infested with *Fusarium oxysporum* f.sp. *dianthi* and with different soil disinfestation treatments showed that some of the treatments were possible alternatives to methyl bromide (MB). Dichloropropene + chloropicrin, and metham-sodium, were the fumigants providing yields similar to MB. Steam for 2.5 h was also highly effective. The application technique determined the success of these treatments. In order to improve the effectiveness of alternative fumigant treatments and, more importantly to get consistent results, a careful application technique in combination with other control methods was strongly recommended.

Key words: carnation, Fusarium vascular wilt, soil fumigation, soil steaming, soil solarization

INTRODUCTION

Due to methyl bromide (MB) being phased, there is a need to find efficient alternatives to control soilborne pathogens in carnations grown on the NW coast of Cadiz and Low Guadalquivir crop areas. Environmental concerns related to ozone layer depletion obligates avoidance in the use of MB which has been easily applied for many years.

This work aimed to compare carnation yields in plots naturally infested with *Fusarium oxysporum f. sp. dianthi* (Fod) which were treated with several desinfestation treatments, including standard treatments of MB, in an effort to find alternatives to MB.

MATERIAL AND METHODS

Two greenhouse experiments (Exp. 1 and 2) were established in 1998 and 2000 that were known to have infested soil which subsequently received the treatments indicated in Table 1 in June of each of these years. Soil amendment consisted of cow manure applied before the treatment applications in 1998, and disinfected sheep manure applied after the treatments in 2000. The same greenhouse, infested with Fod and located in CIFA Chipiona, Cádiz, was used for both experiments. Carnation cvs. Erika (highly susceptible to Fod) and Master (susceptible to Fod) were planted in early July 1998 and 2000, respectively.

Except for MB and the steam application, the treatments tested in Exp. 1 were applied by means of a specific localized irrigation system. A precision injection pump was used for the chemical applications conducted in Exp. 2. The experimental plots had 3 and 1 raised bed in Exp. 1 and 2, respectively, but the same area (5 m, with 124 plants) of the central bed was used in both cases for yield data. These were collected twice each week. The experimental design was 4 completely randomised blocks.

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

Treatments	Experiment 1(1998/2000)	Experiment 2 (2000/2002)
A	Untreated control	Untreated control
B	MB 98% at 100 g/m^2 + PE 50µm	MB 98% at 30 g/m^2 + VIF
C	MB 98% at 20 g/m^2 + VIF	Metham-Na 40% at 100 g/m^2 + VIF Solarization
D	Dichloropropene 81.9% + Chloropicrin 65.5%, at 40 g/m^2 + PE 50µm	Solarization with CP-129 film
E	Steam (2 h)	Dichloropropene 81.9 % + Chloropicrin 46.5% at 40 ml/m^2 + VIF Solarization
F	Metham-Na 40% + Dichloropropene 95% at 80 + 40 ml/m^2 + PE 50µm	Steam (2.5 h)
G	Metham-Na 40% + Aldicarb 10% at 80 ml + 10 g/m^2 + PE 50µm	Poultry manure at 5 kg/m^2 + CP-129 Solarization

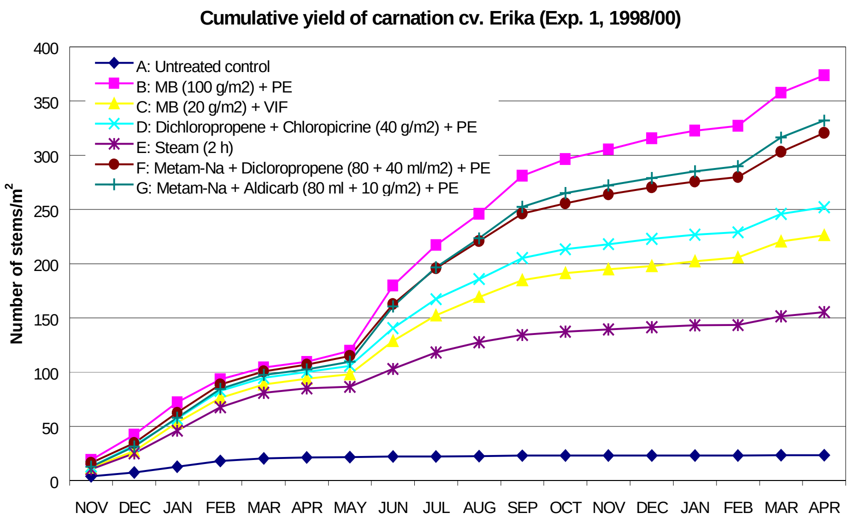
RESULTS

Both experiments were harvested from November and a sharp increase in yield was observed in June. Insignificant yield was obtained from untreated plots (Figures 1 and 2).

Experiment 1 (1998 to 2000)

Maximum yield corresponded to the treatments of MB (100 g/m^2) which reached 374 stems/m^2 for the duration of the 18 months of harvest. A reduction of 11-15% final yield corresponded to the treatments of metam-sodium + Aldicarb and metam-sodium + Dichloropropene (1,3-D), and 33% was the yield reduction for the treatment of 1,3-D + chloropicrin. A lower yield was obtained with MB (20g/m^2 + VIF treatment), and maximum yield reduction (59%) was observed in the steam treated plots which had a cumulative production of 155 stems/m^2 only (Figure 1).

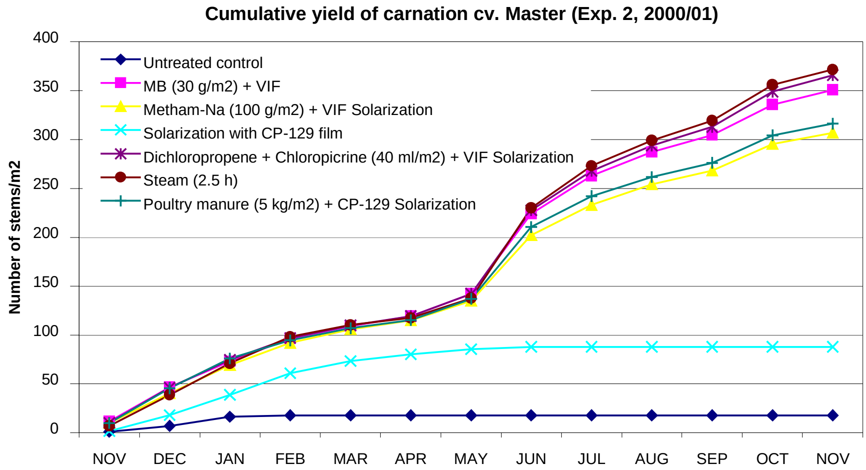
Figure 1: Cumulative yield of carnation cv. Erika (Exp. 1, 1998/2000)



Experiment 2 (2000-2001)

The yields harvested over a 13 month period were slightly more than 350 stem/m^2 for the treatments of steam, 1,3-D + chloropicrin, and MB30 + VIF. The vigour of the plants was superior in the first two treatments. A reduction of 10-13% from those values was observed for the treatments of metam-sodium + VIF and poultry manure + CP-129 (Figure 2).

Figure 2: Cumulative yield of carnation cv. Erika (Exp. 2, 2001/2002)



DISCUSSION AND CONCLUSIONS

Our results showed that there were two kinds of alternative treatments to MB. Firstly, the steam treatment of soil, and secondly, the use of other fumigants based on metam-sodium or chloropicrin, both well know for their fungicidal properties. In all of these treatments, a lack of consistency appeared in the results of Exp. 1 and 2. This could be explained by the different requirements in the application technique that must be adapted to the specific formulations in the case of the fumigants and to a suitable duration for the steam treatment in order to achieve temperatures lethal to inoculum in lower layers of the soil. Implementation of this treatment presents, however, difficulties in the cropping systems used in the area and also there are economic disadvantages. In order to improve the effectiveness of alternative fumigant treatments and, more importantly to get consistent results, a careful application technique and combination with other control methods, such as the use of less susceptible carnation cultivars, is strongly recommended.

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CLOSED SOILLESS TECHNIQUES FOR CUT-FLOWER PRODUCTION AS AN ALTERNATIVE TO METHYL BROMIDE IN MEDITERRANEAN CONDITIONS

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ABSTRACT

Two experiments were carried out using carnation and gerbera to demonstrate the technical and economical viability of using closed soilless systems under Mediterranean conditions to eliminate the use of MB in cut flower crops. High yield, high-quality cut-flowers and a good economic rate of return were obtained when carnation and gerbera were grown using soilless cultivation.

Keywords: Soilless cultures, closed systems, carnation, gerbera

INTRODUCTION

Conventional intensive horticulture in the European Community, and specially along the Mediterranean shores, has contributed to the pollution of the environment (Ramos, 1993; Baille, 1993; López-Gálvez and Naredo, 1996; Walle and Sevenster, 1998). Intensive horticulture's use of pesticides, plastics and nutrient leachates is an agricultural activity that contaminates the environment by polluting the soil, the underground water reservoirs and the atmosphere.

One possibility is to cultivate by substituting the use of conventional natural resources such as water, fertilizers, petroleum derivates such as fuel, pesticides, fumigants (such as methyl bromide (MB)), plastics and others, with technological inputs (Marfà 1994). Soilless techniques do not result in a higher energy consumption than the conventional techniques used in horticulture because soilless techniques eliminate the use of soil fumigants such as MB which can destroy the ozone layer (Rodríguez-Kabana 1996), and they allow the use of plastics and other energy-consuming products more efficiently.

The open soilless techniques result in a lot of leachates accumulating in the ground. As such, the sustainability of the open soilless techniques is not clear since a high quantity of leachates is wasted to assure a steady level of salt in the root zone. For instance, in a tomato crop grown on rockwool during winter in Almeria (southeast of Spain), the estimated leachate volume was 1250 $m^3.ha^{-1}$ (Ramos 1993). For a rose crop grown on perlite in the French Mediterranean coast, the estimated leachate was 2000 $m^3.ha^{-1}.year^{-1}$ (Baille 1993).

To overcome these problems, closed soilless techniques which involves recycling nutrient solutions must be used. In the Mediterranean countries, the open soilless techniques were recently introduced and the technical and agricultural limit for recycling is the water quality.

In order to show the technical and economical viability of closed soilless systems under Mediterranean conditions to potential users, some experiments on a commercial agriculture scale were conducted at the Cabrils Research Center of IRTA on carnation and gerbera, two important crops in the Mediterranean floriculture industry.

MATERIAL AND METHODS

Grow bags filled with expanded perlite were used for growing gerbera and carnation in a 300 m^2 glasshouse. A closed soilless system was used to collect, filtrate, desinfect, return to closed system and adjust the leachates to their original composition automatically. The automatic equipment prepared nutrient solutions with five concentrate solutions and nitric acid. The equipment reconstituted the nutrient solution automatically. The desinfection unit consisted of two filters and a UV lamp. The watering frequency was established automatically using a radiometric sensor and an electro-lysimeter, acting simultaneously and complementarily.

In the first year, carnation was grown using this system. The density of plants was 17.7 m^{-2} and the crop was grown corresponding to a late planting. The average leachate fraction during the growing period was 29%. The electrical conductivity (EC) of the water used was 1 $dS.m^{-1}$. In the second year gerbera was grown. The density of plants was 5.75 m^{-2}. The average leachate fraction was 26.5%. The average EC of the water was 0.6 $dS\text{-}m^{-1}$.

RESULTS

In the carnation crop, the total water dose was 990 $L.m^{-2}$, the total volume of leachate was 208 $L.m^{-2}$ and the volume of leachate wasted was only 20 $L.m^{-2}$. In the gerbera crop, the total water dose was 795 $L.m^{-2}$, the total volume of leachate was 211 $L.m^{-2}$ and the volume of leachate wasted was zero.

The nitrate nutrient balance was 1915 and 686 $kg.ha^{-1}$ in carnation and gerbera, respectively; 691 and 319 $kg.ha^{-1}$ were recirculated; and 41.5 and zero $kg.ha^{-1}$ were wasted. The phosphate nutrient balance was 626 and 278 $kg.ha^{-1}$ given to carnation and gerbera, respectively; 226 and 127 $kg.ha^{-1}$ were recirculated; and 27 and zero $kg.ha^{-1}$ were wasted. The potassium nutrient balance was 3134 and 1704 $kg.ha^{-1}$ given to carnation and gerbera, respectively; 924 and 652 $kg.ha^{-1}$ were recirculated; and 2.4 and zero $kg.ha^{-1}$ were wasted. The yield obtained in the carnation crop was 9.7 flowers per plant which is the same as 172 m^{-2} and for gerbera the yield obtained was 37 flowers per plant which is the same as 213 m^{-2}. The calculated internal rent rate of the crops was 20% and the net actual value was € 74.12 per m^2.

CONCLUSIONS

The closed soilless technique in Mediterranean conditions for growing carnation and gerbera:

- Used average water quantity which resulted in high yield, high-quality cut-flowers and produced a high rate of return for the grower;
- Required no large technical preparation;
- Recycled leachates automatically and efficiently disinfected them;
- Obtained very high water and nutrient-use efficiencies; and
- Eliminated completely the use of MB.

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