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Methyl Bromide Alternatives for North African and Southern European Countries

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ACKNOWLEDGEMENTS

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European Commission

CONCLUSIONS OF THE REGIONAL WORKSHOP ON METHYL BROMIDE ALTERNATIVES FOR NORTH AFRICAN AND SOUTHERN EUROPEAN COUNTRIES

The following conclusions represent a summary of the information presented at the workshop on Methyl Bromide Alternatives for North African and Southern European Countries, held in Rome, Italy on 26-29 May 1998.

1. Alternatives to methyl bromide are available for every current use of soil fumigation. Field trials have revealed a variety of new alternatives, many of which are cheaper and offer equal or better crop protection. It follows that methyl bromide can no longer be considered essential to Mediterranean horticultural production.

2. The phase out of methyl bromide is part of a wider reduction in chemical use in agriculture and a transition towards more sustainable biological/organic systems which many consumers now prefer. It is now know that methyl bromide need not simply be replaced by another chemical. Integrated pest management, solarisation, biofumigation and resistant varieties have considerable potential to replace methyl bromide while contributing to safer and better quality production.

3. While good alternatives exist, many farmers consider it economically risky to discontinue use of a familiar technology. The current priority is to work with farmers on demonstration and extension activities, technology transfer, information dissemination, and programmes to promote alternatives. Fumigation and pest-control companies could do more to encourage the adoption of alternatives. Known alternatives also need to be adapted to specific crops and local conditions. Community funding would greatly assist these activities and help build support for a complete phase out of methyl bromide in the Mediterranean region.

4. There are economic arguments for phasing out methyl bromide simultaneously in the European Community and in North Africa. Many alternatives which are successful in Southern Europe could also work in North Africa. Some bilateral projects under the Multilateral Fund to promote alternatives are already underway. The European Community and Southern Member States should co-ordinate efforts to assist the early phase out of methyl bromide in North Africa, particularly by sharing knowledge and experience about alternatives.

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Chapter 1
Workshop Report

1. BACKGROUND

Methyl bromide is an ozone depleting compound that is used globally to fumigate soil before planting crops, for post-harvest treatments, and for structural fumigation and quarantine treatments. During the past few decades, methyl bromide and other ozone-depleting substances have been released into the atmosphere in sufficient quantity to cause significant damage to the ozone layer. It remains critical to discontinue methyl bromide use, as the bromine from methyl bromide is over 50 times more destructive to the ozone layer on an atom-for-atom basis than chlorine from CFCs.

In 1992, the importance of replacing methyl bromide was recognized at an international level when methyl bromide was listed as an ozone-depleting substance by the Fourth Meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer. At that time, no date for phase out of methyl bromide was set, although annual production and consumption by signatories to the Protocol was to be frozen at 1991 levels by 1995 for industrialized countries (those not listed as Article 5 under the Protocol). In December 1995, the Seventh Meeting of the Parties to the Montreal Protocol agreed to phase out methyl bromide production and consumption by 2010 for industrialized countries.

In September 1997, a global phase out schedule for methyl bromide was agreed upon at the Ninth Meeting of the Parties to the Protocol. For developing countries (listed as Article 5) the Parties agreed to freeze methyl bromide production and consumption by 2002 at average 1995-1998 levels, reduce methyl bromide by 20% in 2005, and phase out methyl bromide use by 2015. Non-Article 5 countries are required to reduce methyl bromide consumption by 25% in 1999, by 50% in 2001, by 70% in 2003 and phase out use by 2005, except for quarantine and preshipment (QPS) and critical uses. QPS uses comprise roughly 22% of global methyl bromide consumption.

According to UNEP's Methyl Bromide Technical Options Committee (MBTOC), alternatives to methyl bromide have been identified for more than 90% of all methyl bromide uses. While no single substance can substitute for the wide range of methyl bromide uses, effective alternatives require a combination of pest management techniques to replace methyl bromide. The Integrated Pest Management (IPM) approach is one technique that depends primarily on using a combination of cost-effective and environmentally-safe alternatives to control pests. IPM and other alternatives are crop-specific, climate-specific, pest-specific or resource dependent. These techniques are being used successfully throughout Europe as a replacement to methyl bromide.

Given the fact that consumption of methyl bromide is being phased out on a world-wide scale, and that alternatives to methyl bromide are often crop-specific or climate-specific, alternatives to the pesticide on a regional scale must be implemented. One such region of interest is Southern Europe and North Africa.

In Africa, methyl bromide is used primarily for soil fumigation of high value export crops, including tobacco, cut flowers, strawberries and other fresh produce. Some Africa countries use methyl bromide for disinfestation of grain stocks and other durable commodities. Sometimes these treatments are part of preshipment or quarantine measures, required as a condition of entry to the country to which the commodity is destined. In 1996, approximately 4,268 tonnes of global methyl bromide was used in Africa.

The European Community used approximately 17,000 tonnes of methyl bromide in 1997. Ninety percent is used for soil fumigation, mainly in the production of tomatoes, strawberries, melons and cucumbers. The pattern of methyl bromide use for soil fumigation within the European Community is very uneven, with the southern countries of Italy, Spain, France and Greece accounting for more than 90 percent. By contrast, the use of methyl bromide for soil fumigation has been completely phased out in Sweden, Finland, Denmark, Austria, Germany and the Netherlands, which at one time were consumers of the chemical for horticulture and flower production.

2. OBJECTIVES

The major objectives of the workshop were to:

2.1 Briefly provide information about the role of methyl bromide in ozone layer depletion;

2.2 Discuss the implications of the new control measures on methyl bromide, especially for the participating African countries, as well as future trends in the phase out of this substance;

2.3 Describe and demonstrate the available alternatives to methyl bromide currently being used for specific applications in participating countries;

2.4 Present an overview of the cost effectiveness of these alternatives;

2.5 Exchange information on legislation and policy mechanisms to promote control measures within countries;

2.6 Catalyze regional strategies and the development of action plans for the methyl bromide users;

2.7 Provide background on financing sources to assist in methyl bromide phase out (i.e. bilateral cooperation, European Community funding mechanism such as LIFE II, MEDA, etc); and

2.8 Identify the need for demonstration projects.

3. EXPECTED RESULTS

The expected results of the workshop were:

3.1 An examination of measures necessary to reduce the phase-out schedule gap;

3.2 An increased awareness of the implications of methyl bromide control measures and the alternative technologies and substitutes that are available;

3.3 An initiation of national action plans on the use of alternative techniques including IPM;

3.4 An identification of the needs of the region for further information sharing, pilot demonstration projects and case studies for future implementation, including IPM techniques;

3.5 Recommendations on strategies/methodology for the transfer of information on available alternative technologies and approaches to various stakeholders (i.e. farmer groups) in the region;

3.6 A development of the interest of the EU private sectors in pursuing potential business opportunities in North Africa; and

3.7 An identification of expertise and capabilities in the region.

4. PARTICIPANTS

4.1 This regional workshop brought together countries in North Africa that needed "hands-on" information on how available alternatives work, with countries from Europe that are using alternatives to methyl bromide on a large scale.

4.2 There were a total of 71 participants in the workshop. Participating countries from North Africa included Turkey, Syria, Lebanon, Israel, Egypt, Tunisia, Algeria, Morocco, Jordan and Cyprus. Participating countries from Europe included Germany, Italy, Malta, Netherlands, Spain, Greece, Portugal and France.

4.3 UNEP-IE, Germany, Italy and The European Commission sponsored this workshop. Five other agencies, including bilateral agencies, were also present at the workshop.

5. METHODOLOGY

5.1 The workshop was organized into eight sessions to discuss specific topics related to the methyl bromide phase out, highlight the available alternatives, identify barriers that may be hindering adoption of alternatives and determine follow up actions that could help address identified problems. Topics covered in the sessions included alternatives for soil fumigation and post harvest applications, legislative and regulatory approaches, and sources of financial support. Organizing the presentations into sessions encouraged constructive discussions and provided an important opportunity for participants to exchange experiences and lessons learned.

6. CONTENT

6.1 The workshop was opened by Sen Edo Ronchi, Italian Minister of the Environment. In his Opening Statement, he welcomed the participants to the workshop and expressed his pleasure in co-organizing this with UNEP, GTZ and the European

Union. He acknowledged that Italy is a large consumer of methyl bromide (third globally) and that efforts are underway to eventually phase out use of the chemical. He also emphasized that Italy's long term goal is to replace methyl bromide with non-chemical alternatives. He expressed his concern about the possibility of methyl bromide use increasing in North Africa and other Article 5 countries, which can produce and use methyl bromide until 2015. Sen. Edo Ronchi concluded by stating the importance of bilateral agencies and others cooperating to provide assistance to North Africa and other developing countries in replacing methyl bromide with sustainable alternatives.

6.2 Dr. Peter Stoermer of GTZ gave a brief statement summarizing their agency's activities under the Montreal Protocol, particularly on methyl bromide activities. He also gave a status report on activities under the Multilateral Fund to promote alternatives to methyl bromide. He stated that only those Article 5 countries that have ratified the Copenhagen Amendment are eligible to receive assistance from the Fund. He emphasized the need to create partnerships as a means to ensure that the phase-out dates will be achieved.

6.3 Mr. Geoffrey Tierney welcomed the participants on behalf of the European Commission (EC). He mentioned that the meeting was also a follow-up to an earlier methyl bromide meeting organized in 1997 by the EC for Southern European countries, and he hoped that the Article 5 countries would benefit from the discussions and learn from the experiences of the European countries. He also reiterated that for the European Community, the phase out of methyl bromide is the last significant challenge faced for ozone layer protection under the Montreal Protocol. Many people believe that the Montreal Protocol has achieved its objectives and that the ozone layer is now safe, but he emphasized the considerable amount of work that still needs to be done to ensure full recovery of the ozone layer. He stated that the workshop provided an opportunity to exchange information about alternatives and develop strategies for moving forward.

6.4 Mr. Steve Gorman made a statement on behalf of UNEP and described the objectives of the workshop and its expected outputs. He expressed his appreciation to the Government of Italy and to the other partners for providing financial assistance to make this workshop possible.

6.5 Dr. Nick Van der Graaff of the Food and Agriculture organization (FAO) made a statement that the FAO is honored to host this workshop. He stated that the FAO also recognizes the urgency to phase out methyl bromide, and discussed the disadvantages of using methyl bromide, which included groundwater contamination, non-selectivity of pests and bromine accumulation. He also introduced the Global IPM Facility, a programme committed to the promotion of IPM in the pursuit of sustainable agricultural practices, which could play an important role in promoting alternatives to methyl bromide.

6.6 All the Sessions were successful in presenting the issues that needed to be considered and the discussions that followed clarified a number of issues.

6.7 The group went on a field trip on Thursday to Fondi, an area south of Rome, to visit four farms that used methyl bromide. The first visit was to the distribution market of Fondi where the participants were able to see the produce grown in the area, and in the other major agricultural areas of Italy. Italy has about 20,000 hectares of greenhouses that grow tomatoes, lettuce, zucchini, peppers, etc. 4,000 hectares of these greenhouses were in the Fondi area. Four farms were visited. In each farm, the participants were shown various techniques of soil fumigation. Most farmers used soil solarization; these treatments however, were still combined with specific doses of methyl bromide used under virtually impermeable film. At each farm visited, workshop participants made useful suggestions about alternatives that should be tried instead of methyl bromide.

6.8 The session held on the last day of the workshop was a follow-up to the 1997 Tenerife workshop and consisted of several interesting presentations highlighting effective alternatives. Presentations from Spanish and Greek experts showed that they have not been using methyl bromide in some of their agricultural production systems, especially for tomatoes and strawberries.

6.9 The expert from Greece also emphasized that soil solarization can allow the soil to be used up to 4 years after solarization has been carried out. He emphasized that a single solarization is an effective treatment against many soil pathogens.

6.10 The meeting was closed on Friday afternoon after a discussion of recommendations was made. Representatives of the Italian Ministry of the Environment and the EC ended the meeting with closing remarks.

7. RESULTS, CONCLUSIONS, RECOMMENDATIONS AND LESSONS LEARNED

The following recommendations were made at the end of the workshop:

7.1 **In considering agricultural systems, external costs, including environmental costs, should be taken into account when determining the costs of using methyl bromide as well as evaluating alternatives.**

7.2 **A number of presentations showed that methyl bromide can be substituted with alternatives similarly effective.** It is important to continue to highlight effective alternatives and show how they may be applicable to other countries or regions. One specific recommendation was to highlight specific examples in small brochures that could be disseminated to growers and other methyl bromide users. Another recommendation was to hold localized workshops for specific crops, where transfer of technology could occur on how to adopt specific alternatives.

7.3 **Transfer of technology was identified as being very important in promoting the widespread adoption of methyl bromide alternatives.** Information sharing on alternatives between Europe and North Africa should also continue and be increased. For example, other countries may learn valuable lessons from the experience of Spain, which has demonstrated that tomatoes can be grown successfully without methyl bromide.

7.4 **A recommendation was made that it would be useful to establish working groups to include participants from both North Africa and Southern Europe, to discuss specific issues and develop action plans to address any problems that are identified by the working groups.**

7.5 **Another conclusion was that it will be necessary over the short term to use chemical alternatives in combination with other alternatives to replace methyl bromide.** However, it was recommended that over the long term, a shift towards more environmentally friendly alternatives should occur.

Chapter 2
VEGETABLE PRODUCTION WITHOUT METHYL BROMIDE IN ITALY

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Soilborne plant pathogens (SBPPs) are the cause of major losses in intensive vegetable crop production in Italy. In fact, repeated plantings of the same crops (practice very common in the case of valuable crops) cause a build-up of detrimental biological factors in the soil. Fungi and nematodes create serious problems to the crops so that repeated treatments, to control them, are necessary. In these conditions, methyl bromide (MB) has been, and still is, a vital fumigant for soil disinfestation.

DI.VA.P.R.A. (in the North Italy) and the Department of Agrochemistry and Agrobiology (DIP.A.AGRO) of Reggio Calabria (in the South) worked since 1980 to develop alternatives for soil disinfestation and, more recently, to develop new solutions to reduce MB application in order to respect national and international regulation.

NORTH ITALY

In Northern Italy (Table 1) different experimental trials of soil disinfestation have been carried out using tomato, cucumber, basil and lettuce plants as host of *Pyrenochaeta lycopersici, Pythium ultimum, Fusarium oxysporum* f. sp. *basilici, Rhizctonia solani.* All of these trials were carried out in greenhouse and in open field, inoculating pathogens before treatments.

The main goal of the study on **tomato** (Table 2) was to determine if soil solarization (SS) can reduce disease incidence of corky root at this latitude and the effectiveness of reduced dosage of soil fumigants in combination with SS on corky root severity (Garibaldi and Tamietti, 1983; Tamietti and Garibaldi, 1987; Garibaldi and Gullino, 1995).

Soil solarization alone gives good results reducing the incidence of corky root on tomato and improving fruit production. The combination of SS with soil fumigant does not increase percentage (%) of healthy plants and fruit production.

Cucumber is not largely grown in Italy (Table 3); in Northern Italy it can be seriously damaged by *Pythium ultimum* particularly in greenhouse. This disease is normally controlled by soil fumigation or by steam. Different trials showed that disease is strongly reduced using SS alone (Minuto et al., 1994). The combination of two weeks of soil solarization and dazomet at low dosage (40 g/m^2) can easily reduce the incidence of the pathogen (Minuto et al., 1995).

The production of **sweet basil** takes place in the Riviera ligure. The intensive use of cultivation systems, coupled with increasing restrictions on the use of fungicides led to severe epidemics of *Fusarium oxysporum* f. sp. *basilici* as well as of *Rhizoctonia solani, Sclerotinia sclerotiorum, Microdochium tabacinum* which are the causal agents of basal rot.

The need to reduce the use of MB (a fumigant very effective against the mentioned pathogens) will challenge researchers and growers to implement effective and reliable alternatives or new MB application systems as the utilization of Virtually Impermeables Films (VIFs) (Gullino et al., 1996).

Against *R. solani* (Table 4) reduced dosages of MB (30 g/m^2) in combination or not with VIFs are enough to reduce disease incidence on basil.

Soil solarization appeared particularly effective (Table 5) against *R. solani* and *F. basilici.* (Garibaldi and Gullino, 1995; Garibaldi et al., unpublished; Minuto et al., 1994).

In two different trials it was observed that dazomet dosages of 50 -70 g/m^2 are enough to control *R. solani* and *F. oxysporum* f. sp. *basilici* (Minuto et al., 1995).

In greenhouse (Figure 6) the combination of dazomet with soil solarization can give good results as solarization or fumigation alone. This combination permits to reduce dazomet dosage up to 25 g/m^2 and length of solarization up to 7 or 14 days.

In open field (Table 7) also SS can reduce the incidence of *R. solani* giving the best results when applied in combination with dazomet. In this case 50 g/m^2 of dazomet are enough when combined with 30 days of SS (Minuto et al., 1995).

Lettuce - On this crop *R. solani* and *S. sclerotiorum* causes the main problem particularly in greenhouse. Different trials showed that disease incidence is easily reduced by MB. The utilization of VIFs (PP- BROMOTEC) permits to reduce MB dosages up to 30 g/m^2 (Table 8) giving good results against *R. solani* (Gullino et al., 1996).

The same results were obtained against *S. sclerotiorum* using conventional PE film or Virtually Impermeable Film (BROMOTEC).

In open field, the application of SS alone (30 days) or in combination with reduced dosages of dazomet (50 g/m^2) appears an efficient solution to reduce the incidence of *R. solani.* (Table 7) (Minuto et al., 1995).

SOUTH ITALY

In Southern Italy soilborne plant pathogens (SBPPs) such as: *Fusaria, Phytophthorae, Pythia, Phoma, Pyrenochaeta, Sclerotinia, Verticillia* and nematodes are largely widespread particularly in greenhouses.

In order to control those pathogens the growers, before setting on crops apply fumigants among which methyl bromide is the most popular, because no other chemical methods used has the same broad spectrum of activity. In greenhouses MB soil disinfestation showed very good results, so that its consumption reached a very high amount (Table 9).

Carrying on four different trials in Sicilian plastic houses (Table 10), in soil naturally infested by fungi and nematodes it has been verified the possibility to reduce MB dosage and emission in the atmosphere by mulching soil with VIFs.

The above mentioned trials pointed out that it is possible to reduce the dosage of MB applying it under PE, and even more using VIFs. The use of VIFs enables to reduce the emission of MB in the atmosphere and the application rate. *P. lycopersici* and *V. dahliae* on eggplant were effectively controlled by MB (20 g/m^2) under VIFs.

Sclerotia of *S. sclerotiorum* buried in the soil were completely nullified by MB treatment (20 g/m^2) applied under VIFs. Nematodes were controlled by MB at the dose of 20 g/m^2. Greco (from Apulia) informally refers that MB at 10 g/m^2 under VIFs can control root knot nematodes.

The E. U. member states have agreed to phase MB out by the year 2005 (with a 50% reduction by 2001 and 70% by 2003, excepting critical uses). While the North African (N.A.) countries can use MB till 2015. So that the Mediterranean European Countries growers fear that their products will suffer seriously North Africa competition.

At present although some alternatives are available, there is not a single method to replace it. Instead of MB the fumigants that Italian growers can use in greenhouse are: metam-sodium and dazomet. Both need 20-30 days (or more) to realise a good soil treatment; moreover their activity appears less effective than that of MB, in controlling soilborne agents. The use of these chemicals, is unfavourable because of their toxicity to man and their residual in soil.

In Southern Italy, with suitable climatic conditions, the soil solarization (SS) was introduced, investigated, and successfully applied and the results obtained were presented in national and international meetings.

In 1989, an International Symposium on “New Application of Solar Energy in Agriculture” was held in Italy (Syracuse), and soil solarization represented the main subject at the Symposium (Garibaldi and Cartia, 1991; Cartia and Lo Giudice, 1991).

In 1995, the first National Congress on Soil Solarization took place in Latium; during the meeting experiences and results acquired all over Italy were discussed (Cartia, 1996).

In 1991 and 1997, the first and Second “International Congress on Soil Solarization” was held in Amman (Jordan) and in Aleppo (Syria), respectively (Cartia et al., 1991; Cartia, 1997a; Cartia et al., 1997a).

In 1997, the International Workshop on “Alternatives to methyl bromide for the Southern European Countries” took place in Arona (Tenerife) (Cartia, 1997b).

More recently, in **(March, 1998)** a “BARD Workshop on Management of Soilborne Plant Pathogens” was held in Jerusalem (Israel) (Di Primo and Cartia, 1998).

Soil solarization experiments in controlling pathogenic fungi were carried out in Southern Italy under experimental and commercial conditions.

EFFECT ON PATHOGENIC FUNGI.

The reduction of the disease caused by several soilborne pests (such as *Verticillia dahliae, Phoma lycopersici, Pyrenochaeta lycopersici, Phytophthora* spp., *Sclerotinia* sp., *Fusaria,* etc.) in Sicilian plastichouse were very considerable. Furthermore, the application of soil solarization in glasshouse for two consecutive years resulted in a complete control of stem-base necrosis (causal agents unknown) of pepper (Cartia *et al.,* 1988a).

The agent of corky root (*Pyrenochaeta lycopersici*) initially appeared very difficult to be contained (Cartia and Grasso, 1971). Soil fumigation with methyl bromide did not eradicate pathogen from infected soil and on the contrary SS resulted more active. In trials carried out for two consecutive years in a plastichouse devoted to tomato, corky root incidence reached the value of 60% in untreated soil at the end of the second year. A very low incidence was obtained using a low dosage (40 g/m^2) of methyl bromide in soil solarized or fumigated at the normal dosage (80 g/m^2) the year before, and even lower (less than 5%) by repeating for two years solarization or using alternatively methyl bromide (80 g/m^2) and soil solarization (Cartia *et al.*, 1988b).

In the past decade, *Fusarium oxysporum* f.sp. *radicis-lycopersici* (FORL), has been reported in North Italy. At present, this pathogen has become a major limiting factor in tomato production in South Italy (Sicily) (Cartia and Asero, 1994).

Soil solarization experiments carried out under commercial conditions in a plastic house significantly reduced the disease incidence of Fusarium crown and root rot compared with the control. The treatment induced a lower percentage of wilted plants (7,7%) in comparison to the untreated control (59,3%). The presence of FORL on tomato roots was 29,2% in solarized plots, 75,0% in not solarized plots (Cartia *et al.*, 1997b).

Soil solarization treatment carried out in open field for 30 days significantly reduced recovery and viability of the laboratory obtained sclerotia of *S. sclerotiorum,* buried at three different levels (5, 15 and 30 cm) in the soil.

After the treatment, at the depth of 5 and 15 cm, all the sclerotia were completely nullified and only few sclerotia were recovered at the depth of 30 cm, but not one of them was viable.

Experimental trials with a 50 days soil solarization treatment were carried out for two consecutive years in fields cropped with carrot (interested by soil sickness problems) and potato (affected by *Spongospora subterranea*). The SS treatment solved the problems in both cases increasing significantly the quantity and the quality of the yield (Cartia, unpublished).

Soil solarization has also been applied successfully in different regions of Southern Italy.

In Calabria, where *F. oxysporum* f.sp. *cepae* and *Sclerotium cepivorum* represent a limiting factor for onion cropped in open field, solarization significantly reduced the incidence of bulb rot agents and increased the marketable yield up to 64% (Polizzi *et al.*, 1995).

In Apulia, in open field, during solarization they were registered, at 20 cm depth, soil temperatures above 40 °C able to nullify the laboratory produced sclerotia of *Sclerotium rolfsii,* buried at this depth (Scarascia Mugnozza and Picuno, 1992).

In Campania, under plastic-tunnel conditions, during solar heating treatment, the maximum temperatures reached in tunnel air (60 °C) and in mulched soil at 10-cm depth (45-55 °C) were successful in reducing lettuce drop caused by *S. minor* and in increasing also total yield.

The combination of soil solarization with reduced dosage of chemicals may represent also an important integrated control strategy which helps to reduce mulching period for SS and pollutions problems.

In a Sicilian plastic house the efficacy of three rates of dazomet (25, 60 and 100 g/m^2), alone or in combination with a 30 days solarization period, (starting August 6th) on the control of the root-knot nematodes, (*M. incognita*) on pepper, were tested. The trials have confirmed the feasibility of reducing the dazomet rate of application. A slight synergsm between the nematocide and soil solarization has also been evidenced (Greco and Cartia, 1996).

Moreover, soil solarization was employed in combination with appropriate cultural practices, fungicides, biological antagonists.

The combination of organic amendments with SS, realized a non chemical approach to the improvement of the soil pest control. Its efficacy in solarized-amended soil is attributed to the combination of thermal killing and enhanced generation of biotic volatile compounds (Gamliel and Stapleton, 1995).

The effectiveness of SS with organic amendaments in the control of sclerotia of *Sclerotium cepivorum* and *S. rolfsii* was tested in Calabria, in a field trial carried out during July - August, 1997. The treatments were carried out for 12, 27 and 47 days amending the soil with chicken manure (1 kg/m^2) and covering it by transparent polyethylene or gas virtually impermeable film. The mortality of sclerotia buried at 15 and 30 cm depth in the soil was significantly increased by 12 or 27 days of “biofumigation” treatment, respectively. Adding chicken manure contributed to increase significantly the effectiveness of the treatments against both pathogens (Di Primo and Cartia, 1998).

A machine that covers an entire plot welding PE sheets by hot air stream was recently set up. The device is mounted on a tractor and a modified butan burner is used to realize the welding of the PE films. The machine can cover 0.25 hectares per hour requiring, in total, the assistance of 2 workers. We think that this tool will favour the diffusion of SS in open field.

EFFECT OF SOIL SOLARIZATION

Nematodes are spread throughout the soil profile explored by roots. During the solarization process lethal temperatures for nematodes are reached only in the 15-20 cm soil depth. In the same way, temperatures of 30-40 °C reached in the lower soil profile may suppress nematode populations.

In glasshouse, nematodes control on a pepper crop, by SS resulted as effective as MB (60 g/m^2) and DD (40 g/m^2) treatment. The combination 30 - days SS and MB (30 g/m^2) also gives very good control.

In Sicily, very often root-knot nematodes were eradicated in the 30 cm soil depth in plastichouse after a 30-45 day solarization period. This prevents nematode root infestation at early crop stage. Later, nematodes from deeper soil layer may migrate to the top and infest roots but this would not substantially affect the yield. In a few cases roots remained free from root-knot nematodes until the end of the crop cycle, even in heavily infested soil (Cartia *et al.*, 1997b).

In open field, satisfactory control of root-knot nematodes, *Meloidogyne* spp. have been achieved all over South and Central Italy.

The positive results obtained so far in controlling pathogens has encouraged the introduction of soil solarization in Southern Italy, also under commercial conditions. In order to promote the introduction of SS as a soil disinfestation method, Sicilian Government passed a law (in 1990) that subsidises growers (about 80% of the cost) applying the technique.

CONCLUSION

The application of reduced dosages of MB under VIFs in the practice can permit to reduce the emission of the fumigant into the atmosphere, thus providing a realistic short term solution which will permit to meet the restriction imposed by national and international regulation.

The results obtained in trials carried out in Northern Italy showed that soil solarization, particularly when conducted for 4 weeks under greenhouse conditions, represents a possible alternative to the use of MB for a number of crops (i.e. tomato, lettuce, basil), providing a satisfactory control of most soilborne fungi.

However, soil solarization did not always provide a sufficient disease control in open field, at Northern Italy latitude. In order to improve its efficacy and also, in some cases, to reduce its duration (from 4 to 2-3 weeks), solarization can be applied in combination with reduced dosages of MB or other fumigants (metham-sodium and dazomet).

Biofumigation can help to reduce the time of soil solarization application and improve soilborne pests control.

A good disease control can be achieved only applying an integrated pest management (IPM). Therefore further research and extensive work are necessary in order to optimize the existing tecnologies and integrate these, so that they may be commercially acceptable.

A three years duration project (named **POM Misura 2**), implemented under the supervision of the (DIP.A.AGRO) and financed by European Community is going to be set out, in a multiregional context, by researchers and the extension services from Apulia, Calabria and Sicily.

The main goal of this project is to optimize the tecniques alternative to MB and particularly to improve soil solarization studies in its knowledge and practice.

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Table 1. Experimental trials carried out by Di.Va.P.R.A. in greenhouse and in open field since 1978

Years	N° of trials	Crops	Pathogens	Authors
1978	2	tomato	Pyrenochaeta lycopersici	Garibaldi and Tamietti, 1983 Tamietti and Garibaldi, 1981
1981	1	tomato	Pyrenochaeta lycopersici	Garibaldi and Tamietti, 1983
1986	4	basil	Rhizoctonia solani	Tamietti and Garibaldi, 1987
1987	1	tomato	Pyrenochaeta lycopersici	Tamietti et al, 1987
1991	5	basil, tomato, cucumber	Fusarium basilici, Pyrenochaeta lycopersici, Pythium ultimum	Garibaldi and Gullino, 1995 Minuto et al., 1995 Minuto et al., 1994
1992	3	tomato	Pyrenochaeta lycopersici	Garibaldi and Gullino, 1995
1993	3	tomato, cucumber, basil	Pyrenochaeta lycopersici, Pythium ultimum, Rhizoctonia solani	Garibaldi et al., unpublished Garibaldi and Gullino, 1995 Minuto et al., 1995 Minuto et al., 1994
1994	3	basil, cucumber	Rhizoctonia solani, Fusarium basilici, Pythium ultimum	Gullino et al., 1996 Minuto et al., 1995
1995	1	lettuce, basil	Rhizoctonia solani, Fusarium basilici	Gullino et al., 1996 Minuto et al., 1995
1996	1	lettuce, basil	Rhizoctonia solani, Fusarium basilici	Gullino et al., 1996

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Table 2. Results obtained using soil solarization against Pyrenochaeta lycopersici on tomato. (Garibaldi and Tamietti, 1983; Tamietti and Garibaldi, 1987; Garibaldi and Gullino, 1995)

Treatment	1981 % of infected root	1991 yield n. of fruits/plant	1993 yield Kg of fruits/plant	% of infected root		% of infected root
				(**)	(***)	
Unmulched	82.5 b (°)	9.2 b	0.9 b	30.7 b	12.3 b	27.5 b
Mulched (30 days)	61.1 a	14.3 a	2.1 a	6.6 a	3.4 a	4.0 a

(**): 5 months after soil solarization
(***): 12 months after soil solarization
(°) Means of the same column followed by the same letter do not statistically differ following Duncan's Multiple Range Test (P = 0.05)

Table 3. Results obtained using soil solarization against Pythium ultimum on cucumber. (Minuto et al., 1994)

Treatment	% of infected plants 1991 1st crop	1991 2nd crop	1993 1st crop	1993 2nd crop	1993 3th crop
Unmulched	36.0 b (°)	32.0 b	76.0 b	97.0 b	87.0 b
Mulched (30 days)	3.3 a (°)	22.0 a	27.0 a	30.0 a	41.5 a

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

Table 4. Effect of soil disinfestation with MB against Rhizoctonia solani on basil (Albenga, 1995). (Gullino et al., 1996)

MB dosage (g/m²) - mulching film	cv Fine Verde % infected plants		cv Genovese % infected plants	
	1st crop	2nd crop	1st crop	2nd crop
Untreated	28.3 c (°)	55.3 c	17.0 c	50.0 c
30 - PE	7.7 b	15.3 b	5.7 b	7.3 b
30 - BROMOTEC	1.7 ab	0.0 a	0.0 a	0.0 a
30 - PP	0.0 a	0.0 a	0.3 ab	0.0 a
60 - PE	0.0 a	0.0 a	0.0 a	0.0 a

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

Table 5. Effect of soil solarization against Rhizoctonia solani and Fusarium basilici on basil cv "Genovese". (Garibaldi and Gullino, 1995; Garibaldi et al., unpublished; Minuto et al., 1994)

Treatment	1986 % infected plants R.solani	1991 F. basilici	1993 R.solani
Unmulched	73.7 b (°)	88.4 b	48.9 b
Mulched (30 days)	6.5 a	49.6 a	2.4 a

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

Table 6. Results obtained using soil solarization in combination with reduced dosages of Dazomet against Rhizoctonia solani on basil cv "Genovese" (Albenga 1993, greenhouse). (Minuto et al., 1995)

Treatment	Dosage (g a.i./m^2)	Soil mulching (days)	% infected plants
Untreated	-	-	36.4 c (°)
Solarized	-	30	2.2 a
Dazomet	25	-	34.1 c
Dazomet	50	-	22.8 b
Dazomet	25	7	1.4 a
Dazomet	50	7	7.1 a
Dazomet	25	30	0.9 a
Dazomet	50	30	0.6 a

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

Table 7. Results obtained using soil solarization in combination with reduced dosages of Dazomet against Rhizoctonia solani (Albenga 1994, open field). (Minuto et al., 1995)

Treatment	Dosage (g a.i./m^2)	Soil mulching (days)	basil cv "Genovese"	lettuce	
			% infected plants	% infected plants	Disease index (0-100)
Untreated	**-**	-	55.8 c (°)	69.5 b	28.0 b
Solarized	-	30	22.6 ab	54.7 a	16.0 a
Dazomet	50	30	18.1 a	54.4 a	16.0 a
Dazomet	50	-	28.5 b	64.5 ab	22.0 b
Dazomet	100	30	17.8 a	59.0 ab	18.0 a
Dazomet	100	-	27.1 b	54.5 a	18.0 a

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

Table 8. Effect of soil disinfestation with MB against Rhizoctonia solani on lettuce and on yield (greenhouse, Albenga 1995). (Gullino et al., 1996)

MB dosage (g/m^2) - soil mulching	% infected plants		Disease index (0-5)		Yield g/plant	
	1st crop	2nd crop	1st crop	2nd crop	1st crop	2nd crop
Untreated	83.3 b(°)	54.9 b	2.5 b	1.0 b	135 b	228 b
30 - PE	14.0 a	24.9 a	0.2 a	0.4 a	269 a	338 a
30 - BROMOTEC	16.0 a	37.2 ab	0.3 a	0.7 ab	279 a	326 a
30 - PP	14.2 a	32.6 ab	0.3 a	0.6 ab	286 a	318 a
60 - PE	21.4 a	26.3 a	0.4 a	0.4 ab	245 a	356 a

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

Table 9. Amount of fumigants used in greenhouse in various Italian regions (ISTAT, 1993).

Regions	methyl bromide	metam - sodium	Dazomet	Total amount (kg)
Abruzzo	22,471	5,732	4,020	32,223
Basilicata	119,951	3,800	500	124,251
Calabria	2,755	5,000	20,760	28,515
Campania	1,097,941	289,610	205,750	1,593,301
Latium	1,440,482	242,533	121,060	1,804,075
Marche	——	2,976	5,380	8,356
Molise	34	10,650		10,684
Apulia	60,316	43,695	22,952	126,963
Sardinia	316,297	40,592	6,190	363,079
Sicily	3,425,904	209,575	31,480	3,666,959
Italy	**7,114,130**	**1,350,291**	**790,347**	**9,254,768**

Table 10. Trials carried out in Sicilian plastichouse in soil naturally infested by fungi and nematodes using MB at three different rates and mulching soil with VIF and PE

Trials	SBBPs	MB rate	Results
1. **Tomato** 93 - June 94	• *P. lycopersici* • *M. incognita*	20, 40, 80 (g/m^2)	MB at the rate of 40 g/m^2 under PE Nov. appeared satisfactory in controlling both pathogens an increasing yield. (Cartia et al. 1995)
2. **Pepper** Jan. 94 - Jul. 94	• *S. sclerotiorum* • *M. incognita*	20, 40, 80 (g/m^2)	Pathogens can be eraticated from the top 30 cm soil with MB at the rate of 20 g/m^2 applied under VIF film or 40 g/m^2 under PE film. (Cartia et al.. 1996a)
3. **Eggplant** Feb. 95 - July 95	• *V. dahliae* • *P. lycopersici* • *Meloidogyne* spp.	20, 40, 60 (g/m^2)	Only a low rate of *Verticillium* wilt was observed on plots treated with MB at 20 g/m^2. Corky root incidence was reduced using both MB at 20 g/m^2 with VIF and 40 g/m^2 with PE covering film. MB at lowest rating (20 g/m^2) eradicated the nematode in the soil profile.(Cartia et al. 1996b)
4. **Tomato** Nov. 94 - June 95	• *M. incognita*	20, 40, 60 (g/m^2)	The nematode soil population density remained at negligible level until April and always at a level significantly lower than that of the control at the end of the crop cycle. No difference were observed among different rate of MB nor between the two plastic types.(Greco et al. 1997)

VIF = virtually impermeable film; P**E**= low density polyetylene film; **MB**= methyl bromide.

Chapter 3

ALTERNATIVES TO METHYL BROMIDE IN SOIL FUMIGATION OF TOMATO PRODUCTION IN MOROCCO

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ABSTRACT

Intensified cropping systems of vegetable crops and particularly tomato conducted under plastic houses resulted in high infestation of soilborne pests, especially Root-Knot nematodes, Verticillium *and* Fusarium *wilts. To control these pests, resistant-hybrids and grafted varieties with high horticultural potentials on resistant germplasms were extensively used. Also fumigant nematicides, such as Metam Sodium and Dichloropropene and non-fumigant, such as Organophophorus and Carbamates are widely applied. The failure of these methods had recently induced high usage of Methyl Bromide. The quantities of imported Methyl Bromide had increased from approximately 408 tons in 1992 to 1085 tons in 1996 and are used mostly in soil fumigation of tomato grown under plastic houses. The potential alternatives underway are steam pasteurisation, non-soil cultivation , solarization and optimal use of registered pesticides , all in combination with resistant and grafted varieties of tomato; and within an Integrated Pest Management Program.*

1. Introduction

In Morocco, vegetables are considered high value cash crops for growers and an important source of hard currency for the country. In a normal summer season, they are grown under field conditions, but off-season they are grown under plastic houses. The latter growing conditions are cash intensive.

The actual area of vegetable crops grown in open fields and in plastic houses, is estimated at 20.500, corresponding to 775.000 tons and 257.000 tons of export. As an indicator of an intensified cropping system, only 3700 ha of tomato are grown under plastic houses, producing more than 50% of both total production and total export. (18).

Because of the pressure to use land repeatedly and of the intensified cropping system to maximise profit from these crops, Root-Knot nematodes (*Meloidogyne spp.*) are actually a major constraint for tomato production. Along the Atlantic coast or in the southern part of Morocco, significant yield losses are caused by *Meloidogyne spp* or a complete failure of the crop is known to occur under heavy infestations.

This presentation is particularly concerned with the different methods available to control Root-Knot nematodes and will emphasise the potential alternatives to the use of Methyl Bromide in soil fumigation.

2. Background

2.1. National Reality Check of Root-Knot Nematodes

The first investigations were initiated by the International *Meloidogyne* Project (IPM), based at north Carolina State University in 1979. These investigations aimed at identifying the major species and showed the widespread of *M. Javanica*, a restricted distribution *of M. incognita* and a very localised presence of *M.hapla* (15 &17). Further investigations were oriented to study the population dynamics of these species on most of the vegetable crops, yield losses caused by *Meloidogyne spp* on vegetable crops and particularly on tomato. The studies conducted in the laboratory and under field conditions, showed that two or three generations were observed along the production period of each crop, but melon and tomato were the most favourable crops to *Meloidogyne spp*. multiplication (2).

These preliminary investigations carried out for the last twenty years emphasised the importance of soilborne diseases on tomato and highlighted several areas of research, to control these soil pests.

2.2. Current Management Programs: **Available technologies and limitations**

2.2.1. Root-Knot Nematode Resistance

Screening for resistance and development of resistant cultivars is at present an area highly emphasised in international agricultural projects and the integrated pest management programs. The resistance presently used in tomato breeding programs is originated from *Lycopersicon peruvianum* and was introgressed into edible tomatoes through the use of the embryo culture technique. This resistance to *M.javanica, M.incognita and M.arenaria* is controlled by 'Mi' gene and is eliminated when soil temperature rises above 28°C

Under Moroccan conditions, resistant lines of tomato have been extensively used to control root knot nematodes. These resistant hybrids are imported from Europe and combine resistance to *Meloidogyne spp*, and other soilborne pests such as *Fusarium oxysporum f.sp. lycopersici* and *Verticillium dahliae*. However, recent studies have revealed the presence of new strains of *M.javanica* able to develop on these resistant lines of tomato (3,5 & 11). Also under greenhouse conditions soil temperature could rise above 30∞C and could cause a failure of resistance to *Meloidogyne spp* . During this period a screening program of exotic germplasms of wild species of *Lycopersicon* for new resistance genes, was established with the University of California at Riverside. Findings from this program resulted in the selection of lines with resistance to *Meloidogyne spp* and holding the resistance under high soil temperature(4).

Until 1990, hybrid resistant tomatoes were largely used in Morocco and controlled soil pest. After this date, they were replaced by varieties susceptible to Root Knot nematodes; but with high export commercial qualities (Long shelf live). These varieties enhanced the multiplication of soilborne pests and limited their control to the chemical option.

For the last two years, the grafting on resistance germplasm stock was introduced as a partial solution for tomato and melon to control *Root-knot nematodes*, *Fusarium* and *Verticillium wilt.* This grafting was attempted on *solunum sp* resistant or tolerant rootstock. About 200 ha were cropped using grafted tomato and gave good results; but heavy infection of these rootstock were observed.

Along this recent program, field studies to evaluate the use of *Tagetes* to control *Meloidogyne sp* associated with tomato grown under plastic houses was initiated in 1997, in joint collaboration with the German co-operation (GTZ); promising results have been recorded.

2.2.2 Soil solarisation

Soil solarisation causes physical, chemical and biological changes in the soil and provides effective management of *Meloidogyne* and other soilborne fungi, particularly in hot climate areas. Under Moroccan conditions, fields tests carried out along the coastal area, during July-September 1982, showed a top-soil-layer temperature above 50°C and 43-49°C at the first 10 cm of the soil profile. In this study only growth stimulation of tomato was observed without any significant reduction of the soil infestation (1). However, in similar tests performed, in the southern part of Morocco, in July-August 1987, increased soil temperature by 8 to 12°C and reached 50°C in the first 5 cm -soil -layer and 44 °C at 20 cm-soil depth; and showed an average of 60% decrease. Laboratory tests to evaluate the effect of soil temperature on *Meloidgyne javanica* revealed that the pathogeny of this species is eliminated after one- two weeks of exposure to 40 °C , but only very significant reduction in hatching of eggs was observed after 3-4 weeks of exposure to 50°C (12 &16). Recently (1993-96), several trials on soil solarisation in combination with low dosage of Methyl Bromide were carried out along the Atlantic coast by the Ministry of Agriculture and showed the effectiveness of solarisation only when combined with low doses of Methyl bromide (18).

As a potential alternative, soil solarisation, at least in southern Morocco, is very promising. This technology could be enhanced if the best plastic quality is used and if combined with low nematicide doses. Hydroponics cropping system and hot water treatment could also be experienced.

2.2.3 Soil Fumigation

Because of the limitations of the control methods mentioned above, the use of nematicides increased from 300 tons in 1986 to 2000 tons in 1993 (14). The nematicides registered in Morocco are summarised in Table 1. Among these nematicides Mertam Sodium and methyl bromide are widely applied in soil fumigation of tomato grown under plastic houses. Because they are difficult to handle, the granulars are occasionally used at planting time, even in combination with resistant or tolerant varieties to root knot nematodes.

During the last ten years the extensive and repeated use of Dichlorpropene, Metam Sodium and the other granulars on tomato or other cash crops have resulted in an accelerated degradation of these pesticides and a failure to control *Meloidogyne spp.(6,7,8&13)*. In general Metam sodium and occasionally Dichloropropene are used as fumigants and organophosphorus and carbamates are crop used (Table 1). The application rates are very high compared to the recommended doses and the application techniques need improvement (10).

These failures to control root-knot nematodes associated with tomato growing under greenhouse conditions have encouraged the use of Methyl Bromide.

Table #1. Nematicides registered in Morocco

common name	formulation	period of application	*estimated cost (US$)	*treated area (ha/year)
1,3.Dichloropropene	**liquid**	**preplant**	**2000**	**400-500**
methyl bromide	**gas**	**preplant**	**4000**	**1000**
Metam sodium	**liquid**	**preplant**	**1000**	**1200-1500**
dazomet	**granular**	**preplant**	**1750**	**100**
enzone	**liquid**	**post plant**	**200**	**??**
carbofuran	**granular**	**post plant**	**100**	**20000**
cadusafos	**granular**	**post plant**	**550**	**800**
fenamiphos	**granular**	**post plant**	**500**	**1100**
izasophos	**granular**	**post plant**	**400**	**250**
ethoprophos	**granular**	**post plant**	**400**	**1000**
oxamyl	**granular**	**post plant**	**475**	**700**

* Association Marocaine Des Negociants Importateurs & Formulateurs de Produits Phytosanitaires (AMIPHY)

3 Current Uses of Methyl Bromide

3.1 Legislation and Supply of Methyl Bromide

Methyl Bromide was introduced for the first time in Morocco in 1952. The legislation limited its use in quarantine for controlling pests associated with agricultural products. At this stage, legislation is very critical and emphasises safety, effective use of Methyl Bromide in the fumigation centres and quality of equipment and personnel.

In 1987, the use of Methyl Bromide was extended to encompass soil fumigation. Measures concerning import, distribution and application of Methyl Bromide were taken. The distributors are the sole authorised institutions to apply Methyl Bromide.

The law highlights the safety rules of the applicators and therefore, Methyl Bromide must be applied only by well-trained and qualified technicians.

Methyl Bromide is imported by three private companies which are authorised to import, distribute and apply Methyl Bromide as a soil-fumigant. The formulation used in soil application is 98% Methyl Bromide and 2% Chloropicrin. Methyl Bromide is imported as a liquid, packed in pressurised steel cylinders of 60 kilograms. *The major suppliers are Israel "BROMINE & CHEMICAL LTD" , France "ELF ATOCHEM" and Belgium "MEBROM".*

Most of the consumption of Methyl Bromide is for soil fumigation and only a small amount (116 kg/year) is used for quarantine treatments. The estimates of Methyl Bromide import and consumption in Morocco for the last five years are summarised in Table 2. These estimates are a result of direct surveys and meetings with the directors of the companies and the quarantine centre in Casablanca.

Table #2. Global import and use of Methyl Bromide, in Morocco (9)

Year	**Quantity of MB imported for use in country (tons)**	**Estimated quantity used in country (tons)**
1996	1085	922
1995	1322	839
1994	887	630
1993	325	382
1992	408	333

3.2. Application methods: The Hot Gas Manual Method

In Morocco, the main method of application is the one commonly known as *hot gas method*. It is a soil surface application. Prior to application of Methyl Bromide, the soil surface is covered with a plastic sheet. Methyl Bromide is then vaporised in a heat exchange device and delivered as a gas to the field to be fumigated, in a perforated polyethylene tubing pre-placed on top of the soil before spreading the plastic sheet.

According to our surveys with the growers, the plastic sheet is either transparent with a thick film of 35mm for a single use or at least 60 mm for multiple uses. The latter is used in several locations every 15 days. In many cases the plastic sheet is black with a thickness of 40 mm. In general, the black plastic is used during hot summer days when soil temperature is above 25 °C. The application rate of Methyl Bromide varies from 70 to 90 g/m^2 depending on the pests present in the soil.

3.3. Quantities of Methyl Bromide Used

The area treated with Methyl Bromide increased from 630 to 922 hectares, for the last three years (Table 3). This increase in the treated area is confirmed by similar trends with a number of growers. Results of our surveys conducted with chemical companies and plant protection regional services summarised in Table 4 revealed that this number increased from 240 growers in 1993, to 974 growers in 1996.

Table #3. Real treated area (in hectares) with Methyl Bromide

Year	* Real treated area in hectares
1996	922.43
1995	839.13
1994	630

**: treated area including local and overall application of Methyl Bromide*

Table #4. Growers who used Methyl Bromide for soil fumigation in the country, for the last five years.

Year	Growers who used Methyl Bromide
1996	974
1995	742
1994	379
1993	240

In Morocco, Methyl Bromide is applied either locally, on seed bed, 80-100 cm wide, or as an overall treatment to the whole field. The first option is the most common. As an example, 4000 hectares were treated as a local application in 1996 compared to only 246 hectares as an overall application. This second technique uses approximately 700 Kg of Methyl Bromide per hectare compared to 300 Kg / hectare as local application.

Most of the crops requiring soil fumigation are those conducted under plastic houses and are summarised in Table #5. Occasionally, some soils of golf grasses, potatoes and nurseries, even conducted under open field conditions are fumigated. Soils reserved for vegetable crops and tomatoes especially are commonly treated with Methyl Bromide. Besides vegetable crops, other fruit crops such as banana, strawberries and carnations are also important and require pre-application of Methyl Bromide.

Table #5. Covered Crops grown on soil fumigated with Methyl Bromide

Name of crop	% of the total treated area in 1996
VEGETABLES	
Tomatoes	57.85
Melon	13.66
Others (watermelon, cucumber & potatoes)	?????
FRUITS	
Strawberries	10.96
Banana	6.78
Flowers & Ornamental plants	
Roses	????
Carnation	????
OTHER CROPS	
Nurseries	????
Golf grass	????

The period of application could be along the year but most of the treatments are concentrated in *June-August,* depending on the nature of crops grown under plastic houses.

The major soil pests controlled by Methyl Bromide are commonly *Root-Knot* *nematodes* for vegetable crops, ornamentals and fruit crops and occasionally *Fusarium* and *Verticillium* wilts.

These soil pests with their respective crops are summarised in Table 6.

Table #6. Pests controlled by Methyl Bromide in selected crops and commodities.

Crop name	**Pests controlled by Methyl Bromide**
Tomatoes	*Meloidogyne javanica & M.incognita* *Fusarium oxysporum f.sp lycopersici* *Verticillium dahliae*
Melon	*Meloidogyne javanica & M.incognita* *Fusarium oxysporum f.sp melonis* *Verticillium dahliae*
Cucumber	*Meloidogyne javanica & M.incognita* *Fusarium oxysporum f.sp cucumis* *Verticillium dahliae*
Strawberries	*Meloidogyne javanica & M.incognita* *Phytophthora fragariae*
Banana	*Meloidogyne javanica & M.incognita* *Radopholus similis* *Helicotylechus multicinctus*
Carnation	*Meloidogyne javanica & M.incognita* *Fusarium sp.*
Commodity name	Pests controlled by Methyl Bromide

The geographical distribution of locations concerned with Methyl Bromide are in some large irrigated areas along the Atlantic coast, north of Kenitra , Larache, north and south of Casablanca, south of El Jadida and in southern Morocco, in the Souss Massa Valley (see Map of Morocco, figure.1). The relative importance of the treated areas are summarised in Table 7. These data show that approximately 68 % of the total treated area in the country is in the Souss Massa.

Table 7. Geographical distribution of treated area with Methyl Bromide in 1996.

Region	Percentage
Agadir	67.80
El Jadida	14.32
Larache	11.42
Kenitra	3.53
Others	2.93

4. Existing and potential alternatives to Methyl Bromide

-Develop and improve soil solarisation using the most updated technology especially the quality of the plastic cover to enhance the soil thermal conductivity in combination with low doses of chemicals or biological controls, such as *Pasteuria penetrans;*

-Improve the application technology of the other existing fumigants, such as Metam sodium, Dichlorpropene and Basamid and other registered non-fumigants;

-Assess other formulation of fumigants and non-fumigants not yet registered in Morocco;

-Evaluate hot water treatment, especially in sandy soils, in the Souss Valley;

-Improve horticultural qualities of resistant hybrids of tomato and encourage grafting technology on resistant root stocks;

-Promote and encourage crop rotation practices to slow the build up of soil pests and protect the quality of soil resources;

-Develop an Integrated Soil Pest Management System for all crops grown under plastic houses.

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Chapter 4
EVALUATION OF VARIOUS BIOCONTROL AGENTS TO CONTROL PLANT-PARASITIC NEMATODES

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Comprehensive studies in our laboratory revealed the nematicidal potential of waste products from crustacean shells, or other proteinaceous compounds, for controlling species of several plant-parasitic nematodes. Control of *M. javanica* was compared in irradiated and non-irradiated soil to which the waste product was added indicated an active role by microorganisms.

Telluria chitinolytica sp. nov, and *Bacillus cereus,* new bacteria which were isolated, grown and identified in our laboratory, appeared to have potential as a bioagent for controlling *M. javanica, H. avenae* and *H. latipons*. After evaluation of the nematicidal capability in green and screenhouse experiments, commercial speed-seedlings of tomatoes were transplanted into one-meter diameter microplots which were filled with Meloidogyne javanica infested sandy loam soil. The soil had been previously mixed with 0.01% Clandosan or other amendments. Before planting, the tomato seedlings were removed from the cups, and each root-ball was soaked in bacteria suspension (about 10^8 cfu/ml). Root galling indices and fruit weights were recorded after 3 months. The presence of the bacteria in soil reduced galling indices and increased fruit weights as compared with the nematode-treated tomatoes that were not exposed to the bacteria. Intensive studies of the mode of action of these bacteria were carried out and the use of *T. chitinolytica* for phytonematode control was patented.

A fungal parasite was isolated from black-colored egg masses of *Meloidogyne javanica* on tomato roots. The fungus did not sporulate on any of the culture media tested or in the egg mass. Hyphal characteristics suggest that it is similar to the hyphomycete genus *Scytalidium.* Hyphae of the *Scytalidium*-like fungus (CBS 645.97

and IMI 368886) proliferated in the gelatinous matrix of the egg mass and penetrated the eggshell via a penetration pegs. Parasitism of the egg mass greatly lowered hatch rate of *M. javanica* juveniles *in vitro.* Application of the fungus to soil did not inhibit juvenile penetration into tomato roots. However, the nematode population in soil treated with the fungus was lower than in non-treated soil after one nematode generation.

Further screening for other amendments and potential microorganisms to control phytonematodes, like *Trichoderma harzianum,* are now in process.

Two isolates of *Trichoderma lignorum,* and the T-203 isolate ordinarily cultured by Mycontrol Ltd., were evaluated for their nematicidal activity. Preparations (2%,w/w) were mixed with sandy loam soil pre-infested with second-stage juveniles (J2) of *M. javanica.* The timing and mode of application of *Trichoderma* tested in 50-liter containers infested with about 2000 J2 per liter. Four seedlings – two of tomato and two of eggplant prepared by Mycontrol Ltd. – were planted in each container. The treatments were the following : **1.** control, nematode-infested, non-treated soil ; **2.** nematode-infested soil mixed with a *Trichoderma* preparation (1% w/w) 18 days before the planting of tomato plants enriched with *Trichoderma* in the root-ball. The parameters recorded at the end of the experiment were : top and root fresh weights, root-galling index, and fruit number and weight (tomato only).

In a short-term pot experiments, the 2 isolates of *T. lignorum* and the commercial T-203 isolate exhibited nematicidal activity, as expressed by the following parameters : **1.** increased top fresh weight (2.2-fold) ; **2.** decreased galling indices from 3.8.4.2 (in the control, nematode-infected plants) to 1.4-0.8 (in the *Trichoderma*-treated plants) ; and **3.** decreased number of eggs per gram root (ca. 8,000), as compared to nematode-infected, non-treated plants (ca. 42,000).

In the long-tem large-container experiment, a distinct difference in plant reactions was observed relative to the short-term experiment: in nematode-infested soil which had been previously exposed to the *Trichoderma* fungus, top fresh weights of both tomatoes and eggplants exhibited higher values (2.3 and 4 times, respectively) than in the non-treated control.

Part of this increase could be related to the enhanced-growth characteristics contributed by the incorporation of the *Trichoderma* fungus into the soil, as reported elsewhere. Galling indices of tomato or eggplant roots planted in the *Trichoderma*-treated containers were impressively reduced (0.2-0.5) as compared to the control, non-treated plants (4.2-4.5). However, in those plants whose root-ball had been treated with the *Trichoderma* preparation before planting and then exposed to nematodes, top fresh weight and root-galling indices were similar to those of their non-treated counterparts.

In an attempt to explain the nematicidal effect of the *Trichoderma* preparations, the contribution of the peat (one of the preparation components) was ruled out. A possible explanation was uncovered in experiments conducted under sterile conditions : preliminary characterization of the active component in the culture filtrate revealed a non-volatile, low molecular mass (<3000 Kda), and heat sensitive component. This component was active in a wide temperature range.

Thus in those experiments in which J2 were exposed to *Trichoderma* for 18 days prior to planning, maximum nematidal efficacy was observed; but when J2 were exposed to the fungus during planting, i.e. in treatments where *Trichoderma* had been assigned to the root-ball, no nematicidal activity was recorded. It is presumed, therefore, that nematodes exposed to *Trichoderma* preparations in the soil over a 10-day period undergo paralysis, which delays their reaching the young roots at the initial stage of the seedling's exposure to the J2. This delay enables the roots to " evade " the initial attack, explaining the differences in top height and fresh weight observed mainly in the early stages of plant growth. Moreover, the large differences obtained in root egg counts in the short-term pot experiments support the aforementioned supposition as well : only a few eggs were produced in the firsts cycle by females which developed from J2 whose entry into the roots was delayed by the presence of the *Trichoderma* fungus. In the control, however, development was as would be expected in a normal nematode life cycle under these conditions. In the second, third and fourth cycles, the initial differences fade, and therefore no differences were observed between galling indices in the long-term (4-month) container experiment.

CONCLUDING REMARKS

Although it is very difficult to estimate the probability of success to fulfill the various ideas described in this review into field practice, the controlling of soilborne pathogenic fungi and nematodes seems more and more feasible in the near future, using biocontrol agents and a combination of tactics. Moreover, as biological control is an integral part of the IPM philosophy, judicious use of Trichoderma in combination with other biocontrol agents and reduced amounts of biocides/fungicides, or other physical means (steam sterilization or soil solarization), can serve as a model for the introduction and implementation of other biocontrol means into IPM.

Chapter 5
PEPPER VARIETIES AND RESISTANCE TO SOIL-BORNE PATHOGENS

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SUMMARY.

Methyl bromide is used for controlling fungi, nematodes, bacteria, insects, weeds and rodents. As a soil fumigant, it is used in large quantities in the cash crops production in greenhouses and fields. However, this pesticide has been identified as one of the chemicals contributing to stratospheric-ozone depletion and is supposed to be phased out for most applications by 2010. Therefore, the use of resistant varieties of pepper as an alternative to methyl bromide for controlling soil-borne pathogens, such as root-knot nematodes (Meloidogyne spp.) and fungi (Phytophthora capsici, Verticillium dahliae and Fusarium oxysporum f. sp. vasinfectum) is discussed.

Pepper (*Capsicum annuum* L.) is a very important crop all over the world, being cultivated in nearly 1.3 million ha which gives an annual production of about 16.4 millions metric tonnes (FAO, 1997). China ranks first both for growing area (352,430 ha) and production (7,022,000 tonnes/year); Indonesia, Mexico and Turkey are also important pepper producing countries (Table I). Nearly 191,000 ha are devoted to pepper in the Mediterranean basin, giving a production of 3,522,000 tonnes/year, mainly in Turkey, Spain and Yugoslavia.

Several soil-borne pathogens are known to cause severe damage to pepper. Among them the most important appear to be the root-knot nematodes (*Meloidogyne* spp.) and the fungal diseases phytophthora blight (*Phytophthora capsici* Leonian) and verticillium wilt (*Verticillium dahliae* Kleb), especially when Phytophthora is not a problem anymore. Fusarium wilt (*Fusarium oxysporum* var. *vasinfectum* Atk.) can be important in some areas and several other soil-borne fungi may cause seedling damping-off and rot of crown and roots. *Pythium* spp., *Rhizoctonia solani* Kühn and *Sclerotium rolfsii* Sacc. should be considered among them. However, since the first three pathogens are the most widespread and the first two are of major concern in many pepper growing areas, breeding programs have been concentrated to identify and transfer sources of resistance in pepper cultigens. Resistance to these pathogens is discussed in this paper.

Root-knot nematodes. *Meloidogyne incognita* (Kofoid *et* White) Chitwood, *M. javanica* (Treub) Chitwood, *M. arenaria* (Neal) Chitwood and *M. hapla* Chitwood are the most important species of root-knot nematodes in the Mediterranean countries (Lamberti, 1979a). They cause severe damage to pepper with an estimated yield loss of about 12% (Sasser and Freckman, 1987). The tolerance limit of pepper to *M. incognita* is 0.16 egg/cm^3 soil at sowing and yield losses of 20 and 60% can be expected in fields infested with 0.5 or 4 eggs of the nematode/cm^3 soil (Di Vito *et al.*, 1985).

The control of these nematodes can be achieved by the use of nematicides, as methyl bromide, soil solarization and resistant varieties. Nematicides, including methyl bromide, are very effective for controlling nematodes (Lamberti, 1979b) but they are costly and may cause environmental pollution. Soil solarization is also effective (Cartia and Greco, 1987) but it is expensive because of direct (application of transparent plastic films) and indirect (fields must remain free of crops for 4-8 weeks in summer time) costs. The use of pepper resistant varieties would be a good alternative for controlling such pathogens because it is effective, safe and cheap. Therefore, a collaborative programme between our Institute and Prof. F. Saccardo (University of Tuscia, Viterbo, Italy), was begun several years ago to investigate the reaction of pepper lines to root-knot nematodes and to breed pepper for resistance to these pests.

To identify sources of resistance to Italian population of *Meloidogyne* spp., 113 accessions of *Capsicum* spp. were screened in glasshouse at 26 ±2°C. This revealed that: two lines of *C. chinense* Jacq. and one of *C. frutescens* L. were resistant to *M. incognita, M. javanica, M. arenaria* and *M. hapla* (Table II); nineteen lines of *C. annuum*, one of *C. chacoense* Hunz., eight of *C. chinense* and ten lines of *C. frutescens* were resistant to *M. incognita, M. javanica* and *M. arenaria*; two and one lines of *C. annuum* and *C. chinense*, respectively, were resistant to *M. incognita* and *M. javanica*; two and three lines of *C. chacoense* and *C. chinense*, respectively, were resistant to *M. incognita* and *M. arenaria*; one, four, and five lines of *C. chacoense*, *C. chinense* and *C. frutescens*, respectively, were resistant only to *M. incognita* (Di Vito *et al*., 1991; 1996).

The resistance to *M. incognita*, *M. javanica* and *M. arenaria* in the lines 'Tabasco' and 28-201 of *C. frutescens*, to *M. incognita* and *M. arenaria* in the lines 46-530/7 of *C. chacoense* and to *M. incognita* and *M. javanica* in the line 56-547/7 of *C. chinense* were found to be controlled by a single dominant gene. However, two dominant genes controlled the resistance to *M. javanica* in the line 46-530/7 of *C. chacoense* and that to *M. arenaria* in the line 56-547/7 of *C. chinense*. The resistance to *M. incognita*, *M. javanica* and *M. arenaria* in the accession P.I. 159256 of *C. annuum* is, instead, controlled by a single recessive gene (Di Vito and Saccardo, 1982; Di Vito *et al*., 1993b).

The resistance to root-knot nematodes in pepper is regulated by a hypersensitive reaction phenomenon. The second stage juveniles of the nematode enter the roots of resistant plants as readily as those of susceptible plants. However, after a few hours all the root cells around the nematode head die. This results in a barrier of necrotic cells which prevents nematodes from feeding and thus completing its life cycle. A similar reaction has been observed in other resistant plants, such as tomato, eggplant, etc.

It is noteworthy that the resistance to root-knot nematodes occurring in the lines of *C. annuum*, *C. chacoense*, *C. chinense* and *C. frutescens* has proved to be effective also at high soil temperature. Di Vito *et al*. (1995) evaluated the reaction of the resistant lines 92-3 of *C. annuum*, 32 of *C. chacoense*, 24, 28 and 56 of *C. chinense* and 79 of *C. frutescens* to *M. incognita* in growth chambers. The plants of these lines were inoculated with *M. incognita* and maintained in growth chambers at 26, 30, 34 or 38°C. One month later all resistant lines retained their resistance and no or very few galls were found on the roots. Therefore, resistance present in these lines can be also useful to control root-knot nematodes in countries with hot summer.

More than fifty new lines of pepper, resistant to *M. incognita*, *M. javanica* and *M. arenaria*, were obtained from crosses, backcrosses and selections of several pepper cultigens and the line 'Tabasco' of *C. frutescens*, through a breeding programme developed both in screenhouse and out of doors. The performance of the new inbreed lines 90010, 90180, 90533, 90701, and 90710 was compared with that of susceptible parents 'Quadrato Giallo', 'Yolo Wonder', 'Cayenne', 'Friariello' and 'Venus' in a field naturally infested with *M. javanica* in Southern Italy. The yield of these resistant lines increased by 55, 40, 39, 35 and 41%, respectively, when compared to that of their susceptible parents (Di Vito *et al*., 1993a). The final population densities of the nematode

4.3 eggs of *M. javanica*/cm^3 soil, instead, was much less than that at planting (5.8 eggs of *M. javanica*/cm^3 soil) in the plots planted with the resistant lines, while in the plots planted with the susceptible parent cultivars 'Quadrato Giallo', 'Yolo Wonder', 'Cayenne', 'Friariello' and 'Venus' it was as large as 110, 115, 160, 140 and 191 eggs/cm^3 soil, respectively, and 20-33 times that of the resistant lines.

Phytophthora blight is caused by *P. capsici*. The basal portion of the stem, the crown and the roots are attacked and the plant wilts suddenly, without yellowing. Under moist and warm weather conditions, fruits rot and leaf blight are also frequent. *P. capsici* is easily and quickly disseminated by surface water, and this aspect of the epidemiology must be taken into account to avoid new contamination or re-contamination of disinfested soil.

Sources of resistance have been identified in Mexican accessions of *C. annuum* since the sixties (Kimbe and Grogan, 1960). Smith *et al.* (1967) reported that the resistance of the accession P.I. 201234 is determined by two distinct dominant genes and it is inherited quantitatively. Resistance was also found in local lines of *C. annuum* in Brazil (Matsuoka *et al.,* 1984) and in the variety 'Serrano Criollo de Morelos' (SCM) in Mexico (Guerrero and Laborde, 1980). Pochard and Chambonnet (1971) crossed the resistant American lines with 'Yolo Wonder' obtaining the resistant line 'Phylo 636', which is used as a parental for hybrids. This resistance is partial and to be effective should be used jointly with adequate cultural practices and, if necessary, with chemical treatments. The resistance very effective at 16-22°C is much less at 28°C (Pochard *et al.,* 1976). Two phases, one of which is temperature-dependent and acts during the first step of infection, have been hypothesized (Pitrat and Clergeau, *in:* Messiaen, 1981). The host-pathogen relationship appears to be complex. Three components act at different stages of the disease evolution with different relative importance in different lines (Pochard *et al.*, 1983). French researchers found new partial resistance and pyramided them to increase the level of resistance available (Messiaen *et al.*, 1991), which at present has to be considered as moderate. Inheritance of adult plant resistance was studied by Reifschneider *et al*. (1992). Studying F_1, backcrosses and F_2 populations, these authors concluded that resistant/susceptible segregation ratios in F_2 fit a 2-gene model for resistance with dominant and recessive epistasis. Saccardo *et al*. (1986) attributed the resistance to several recessive genes.

Resistance to *P. capsici* in pepper is environment dependent (Cristinzio and Noviello, 1980); prolonged incubation periods and very high inoculum concentration can overcome resistance in resistant plants (Barskdale *et al.*, 1984; cf also Palloix *et al.,* 1988).

Cristinzio (1993) reviewed the work carried out in the world and in Italy. In northern Italy partial resistance was obtained in the crosses P.I. 201234 P X 'Quadrato d'Asti' (Tamietti and Bruatto, 1986). In southern Italy, where the lines developed in France were not resistant, new lines were obtained. The line 704, obtained by irradiation of 'Yolo Wonder' seeds, showed some non-specific resistance. Similar results were obtained in Bulgaria by irradiation of 'Kourtvska Kapiya' (Sotirova and Daskalof, 1983). Isolates of *P. capsici* from Southern Italy were used to screen wild lines of *C. annuum* from Mexico and of other *Capsicum* spp. Promising sources of resistance were found in the Mexican accessions of *C. annuum* and in some accessions of *C. frutescens*, *C. chacoense*, etc. Work is in progress to transfer these resistances to cultigens.

There is lack of information about the mechanisms of resistance. Studies on phytoalexins showed that capsidiol accumulation does not play a major role in resistance being this compound positively correlated with symptom severity (Molot *et al.*, 1981; Amateis *et al.*, 1993). Cell culture systems can be a good model to investigate on the earliest events of infection (Mozzetti *et al.*, 1997) and could provide a reliable tool to be used in searching for resistance sources and in screening for resistance.

Induced resistance can protect plants against infection. In the pepper-*P. capsici* system it has been shown that, beside avirulent isolates, also the b isomer of DL-b-amino-n-butyric acid can be an effective inducer of resistance able to protect plants against virulent isolates (Sunwoo *et al.*, 1996).

Verticillium wilt. *Verticillium dahliae*, a species pathogenic on many crops, induces a vascular disease, causing yellowing of leaves, which at the beginning can involve only one half of the leaves, from the central vein to the margin. Dwarfing of the plant or of some branches also can occur. Defoliation and wilting are the final symptoms. The fungus has relatively low *optimum* temperature, thus in some Mediterranean areas it appears late in the growing season. On the other hand the disease is expanding in some Mediterranean countries (Douira *et al.*, 1995) with yield losses up to 22% recorded in Israel (Tsror, 1998). The expansion seems to be related to rotation of pepper with other susceptible crops. The disease can become a major problem also when pepper is frequently grown on the same soil. Studies concerning the specificity of *V. dahliae* have been inconclusive and have generated conflicting reports. Recent research on biomolecular aspects and on vegetative-compatibility groups indicate that the genetic diversity in this fungal species is larger than previously deemed (Bao *et al.*, 1998).

Partial resistance was observed in France in parents used for resistance to *P. capsici* (e.g. PM 217) and in the Moldavian cv. Podarok (=PM 700) (Messiaen *et al.*, 1991).

Saccardo and Sree Ramulu (1977) found that accessions of *C. pendulum, C. frutescens* and *C. chinense* were relatively less susceptible. Resistance has not been found in accessions of *C. annuum* and *C. chacoense.* The lines obtained from the cross *C. annuum* X *C. chinense* showed, according to these authors, dominant heritability. Mutagenesis has given encouraging results in M_2 (Saccardo and Sree Ramulu, *l.c.*).

The importance of screening for resistance to *V. dahliae*, under low temperature conditions, in order to better differentiate the response among the tested lines, was stressed by Barriuso Vargas *et al*. (1992) and López *et al*. (1996). Temperature of 17°C was estimated as the most suitable for studying partial resistance in pepper.

Concluding remarks. At present there are various lines of pepper resistant to root-knot nematodes in which resistance is regulated by several dominant or recessive genes.

Many new inbreed lines of pepper resistant to root-knot nematodes can be used in breeding programmes to obtain new lines and hybrids. Also, they have shown good yield performance and, therefore, can be used without any further breeding for quality improvement. This resistance is retained also at high soil temperature. Therefore, the use of such resistant lines of pepper can be effective for controlling root-knot nematodes in greenhouses and areas were high soil temperatures are common.

Although promising sources of resistance have been found for resistance to fungal diseases, resistance available is only partial and environment dependent. However, continuos use of resistant varieties for controlling soil-borne pathogens may selected new pathotypes or races that can brake resistance. Therefore, an integrated pest management which considers the use of resistant varieties, soil solarization and low rates of methyl bromide applied under virtually impermeable plastic films, is the most desirable way to control soil-borne pathogens of pepper and other vegetables.

Nevertheless, more investigations are required to identify sources of resistance (Tab. IV) for fungi diseases and to understand the types of inheritance for their use in specific breeding programmes.

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Table I. Area and production of pepper and in the most important pepper producing countries (FAO, 1997).

Country	Area (ha)	Total yield (ton)	Average yield (kg/ha)
World	1,332,000	16,393,000	123,000
Mediterranean basin	191,000	3,522,000	184,000
China	352,430	7.002.180	199,250
Indonesia	200,000	460,000	23,000
Mexico	110,165	1,289,700	117,070
Turkey	61,200	1,170,000	191,176
Spain	24,600	858,500	384,984
Yugoslavia	23,566	157,000	66,621

Table II. Reaction of pepper lines of *Capsicum* spp. to Italian populations of *Meloidogyne* spp. in glasshouse at 26 ±2°C.

Capsicum	**Lines**	Number of lines resistant			
species	**tested**	***M. incognita***	***M. javanica***	***M. arenaria***	***M. hapla***
C. annuum	22	21	21	19	0
C. baccatum	3	0	0	0	0
C. baccatum pendulum	9	0	0	0	0
C. chacoense	24	4	1	3	0
C. chinense	29	18	11	13	2
C. frutescens	26	16	11	11	1
Total	113	55	47	46	3

Table III. Inheritance of resistance in lines *Capsicum* spp. to some Italian populations of root-knot nematodes, *Meloidogyne* spp.

***Capsicum* spp. and line**	**Resistant to**	**Number and type of gene**
C. annuum P.I. 159256	*M. incognita, M. javanica, M. arenaria*	One recessive
C. chacoense 46-530/7	*M. incognita, M. arenaria*	One dominant
" "	*M. javanica*	Two dominants
C. chinense 56-547/7	*M. incognita, M. javanica*	One dominant
" "	*M. arenaria*	Two dominants
C. frutescens Tabasco	*M. incognita, M. javanica, M. arenaria*	One dominant
" 28-201	*M. incognita, M. javanica, M. arenaria*	One dominant

Table IV. Some sources of resistance to major soil-borne pathogens in pepper.

Pathogens	**Sources of resistance**
Meloidogyne spp.	*Capsicum annuum, C. chacoense, C. chinense* and *C. frutescens*
Phythophthora capscici	*C. annuum, C. chinense* and *C. frutescens*
Verticillium dahliae	*C. annuum, C. chinense* and *C. frutescens*

Chapter 6
ALTERNATIVES AND POTENTIAL ALTERNATIVES TO METHYL BROMIDE FOR DISINFESTING DURABLE COMMODITIES

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ABSTRACT

Methyl bromide continues to be an important fumigant for durable commodities where time is a constraint because there is, at present, no suitable alternative for use in such situations. Phosphine is now the most widely used fumigant for durable commodities and had replaced methyl bromide in many countries even before environmental concerns arose about methyl bromide. The principal disadvantage of phosphine is the relatively long fumigation period necessary, which has been increased to five days in recent years to combat the threat of insect resistance. Several other gases are being investigated as possible substitutes for methyl bromide but, even if any are found suitable, commercial introduction may take several years because of delays regarding registration. Carbon dioxide and modified atmospheres can be used to disinfest durable commodities but the time to complete such treatments is measured in weeks rather than in days. Non-chemical techniques that may prove useful as alternatives to methyl bromide fumigation include the use of heat and cold but are energy intensive and likely to be considerably more costly than fumigation. There have been relatively few real advances in the search for new alternatives to methyl bromide for disinfesting durable commodities. The exemption from controls on the fumigant under the Montreal Protocol for treatments conducted for pre-shipment and quarantine purposes is a recognition of this situation.

METHYL BROMIDE AS A FUMIGANT FOR DURABLE COMMODITIES

Methyl bromide has been used as a fumigant for at least 50 years to control insect pests causing damage and loss during the handling and storage of grain and other low moisture content durable commodities. A major advantage of the chemical is the relatively short treatment periods that can be employed, and which can be as little as 24 hours. This property causes methyl bromide to be very popular where time is a constraint. The fumigant is widely used in situations where speed of treatment is important such as for commodities moving in trade, and particularly in international trade involving shipping, where delays can result in high cost penalties. Quarantine regulations or contractual agreements frequently require treatments to be conducted at short notice, and to avoid delays in exporting commodities shippers need fumigation to completed as quickly as possible.

In addition to its use for pre-shipment and quarantine purposes methyl bromide continues to be used routinely in some countries for quality maintenance of commodities stored for local use or, in some circumstances, immediately following their importation. This continued use probably results from the many years over which the fumigant has been used, its role in local commodity management and storage systems, and its familiarity to those applying it. In some countries there may also be local regulations that commodities found to be infested must be fumigated with methyl bromide.

ALTERNATIVES AND POTENTIAL ALTERNATIVES TO METHYL BROMIDE FUMIGATION

The Methyl Bromide Technical Options Committee in its 1994 report (MBTOC, 1995) noted 20 alternatives or potential alternatives to fumigation of durables with methyl bromide and stressed that the choice of alternative was very dependent on the commodity to be treated and situation in which the treatment was to be carried out. In the 1997 update report of methyl bromide and alternatives (TEAP, 1997) wider use of existing alternatives was reported to be the major advance in the treatment of durables, particularly the use of phosphine fumigation. A table showing some of the more important alternatives to methyl bromide fumigation is given below.

PHOSPHINE

Phosphine is now the most widely used fumigant for disinfesting grain and products and is likely to be so for the foreseeable future. It has replaced other fumigants including methyl bromide in many situations, particularly those where a treatment period of at least five days is not a limiting factor. The long exposure period, however, makes phosphine unsuitable for fumigations conducted for quarantine and pre-shipment purposes. Other disadvantages of phosphine are that it is more suited to use at higher temperatures (preferably >15°C), and it has a corrosive action on

Principal alternatives to methyl bromide for disinfesting durable commodities

Method	Category	Comments
Phosphine	Fumigant	5-day exposure necessary; insect resistance an emerging problem
Carbon dioxide	Fumigant	Weakly insecticidal; exposure period two weeks or longer depending on temperature; high gas concentrations must be maintained
Nitrogen or exhaust burner gas	Controlled atmosphere	As for carbon dioxide
Organophosphorus and pyrethroid compounds	Contact insecticide	Preventative rather than curative
Activated silica dusts	Insects die from water loss	As for contact insecticides
Heat	Physical method	Temperatures need to be > 50°C; can be direct replacement for methyl bromide; energy intensive
Cold	Physical method	Very low (-15°C) temperatures necessary for rapid disinfestation; energy intensive; cooling more commonly used just to reduce insect damage and multiplication
PH_3 + CO_2 + Heat	Combination method	For structures only; essential to protect electrical equipment against phosphine corrosion
Irradiation	Physical method	Public perception of danger to be overcome; transport problems where large quantities of commodity to be moved to irradiation plant
Insect predators; pathogens; pheromones	Biological control	Methods used aim to reduce the need to fumigate

some metals including copper. Advantages of phosphine are that it is not strongly sorbed by most commodities, it diffuses and penetrates well, and leaves little or no chemical residues. It can, therefore, be used to disinfest most commodities including cereals and cereal products such as wheat flour (which it penetrates better than methyl bromide) legumes, dried fruits and beverage crops. Proprietary formulations of aluminium and magnesium phosphide generating phosphine are available as tablets, sachets containing granules, or as matrix plates. Exposure of these formulations to atmospheric moisture causes phosphine to be liberated. Total release of gas may take from 24 to 48 hours, or longer, depending on the temperature and to some extent on the humidity. Phosphine can be used in most situations where methyl bromide is used including bag stacks under sheets, silos, ships, rail wagons and in freight containers.

There have been suggestions that phosphine may have harmful long-term health effects on workers continually exposed to the gas (Joyce, 1989), and it is possible that this factor could lead to restrictions in the use of phosphine in the future. A more immediate problem with phosphine, however, is posed by the threat of insect resistance in several major pests of stored product. This topic has, in the last decade, been the subject of research and investigation by many workers who have conducted surveys of insect susceptibility to the fumigant, particularly insects from developing countries (Heron, 1990; Rajendran and Narasinhan, 1994; Sartori *et al.,* 1991; Taylor, 1989; and Zettler, 1993). Ineffective sealing of enclosures to be fumigated, causing repeated exposure of insects to low concentrations of fumigant, has encouraged the selection of resistant strains of particular pests, especially *Rhyzopertha dominica* and *Tribolium castaneum* (Mills, 1983). Although the potential for phosphine resistance was predicted as long ago as the early 1970s (Champ and Dyte, 1976), Zettler (1997) reports that, despite the increase in frequency and intensity of resistance among pest populations, control failures in the field rarely occur, and when they do, they can usually be managed by the use of existing alternative technologies which may include methyl bromide. Currently, therefore, with a few exceptions, good management of phosphine has enabled it to remain an effective fumigant for grain. There is a definite need, however, for continued monitoring of insects for resistance and for the employment of strategies that avoid the conditions that can lead to resistance. These include conducting fumigations only when necessary, and only under conditions which will ensure complete control of all developmental stages of insects. The use of alternative insect control techniques, when possible, will also help to reduce insect selection pressure on phosphine.

As an alternative to using phosphine alone, techniques have been devised for applying the fumigant in a mixture with carbon dioxide. Winks (1993) has reported extensively on the use of low concentrations of phosphine (ca. 2.5%) in carbon dioxide for fumigating grain in silos that are not completely gas-tight. The technique, known as SirofloS), delivers the gas mixture from pressurised cylinders and is reported to have been widely adopted in Australia in grain silos that are not sufficiently gas-tight for effective fumigation using conventional phosphine fumigation. The new system functions by maintaining a pre-determined fumigant concentration over several weeks, the technique being designed to avoid insect resistance to phosphine by ensuring complete insect mortality. The Australian system has not yet been adopted extensively elsewhere, a major constraint at present being that the cylinderised gas mixture is only manufactured in Australia. This situation may change in the future and the application of phosphine in carbon dioxide may be more widely used.

Traditional methods of generating phosphine for use in fumigation have been with solid preparations of aluminium or magnesium phosphide which release the gas by the action of atmospheric moisture. On-site generation of phosphine for use in large-scale treatments is currently under development. The Horn Generator is reported to be capable of rapid production of at least 5000g of phosphine per hour from magnesium phosphide. It is suggested that the rapid production of phosphine from the Horn Generator may enable the overall fumigation time-period to be shortened. The Generator has not yet been registered in the USA where test programmes are in progress (Horn 1997).

OTHER GASES (FUMIGANTS)

Of the 16 chemicals listed by Bond (1984) as fumigants, only methyl bromide and phosphine are now widely used for disinfesting durable commodities. The remainder have been discarded, principally because of hazards to human health or because methyl bromide and phosphine were found to be more effective.

There are several older fumigants that might be re-introduced such as hydrogen cyanide and carbon bisulphide, but their use has ceased in many countries (probably because methyl bromide and phosphine were preferred) and their registration has lapsed. Re-registration of these chemicals may, however, prove difficult because some of the toxicological data now required is not available. Ethyl formate was previously used to treat grain but its use is now restricted to dried vine fruits in countries where it is permitted. It is reported to be currently under investigation in Australia.

Although sulphuryl fluoride is used extensively in the USA as a fumigant to control termites in buildings, the egg stage of many insects is very tolerant of the gas requiring high concentrations and leading to unacceptably high residue levels in treated commodities. Current recommendations, therefore, are that sulphuryl fluoride should not be used for any food commodity treatments (MBTOC, 1994). Recent investigations by Bell (1997) suggest that extending the exposure period to 48 hours may permit the use of lower concentrations of sulphuryl fluoride when fumigating commodities.

Although carbon dioxide is often included in treatments termed controlled or modified atmosphere treatments the gas does exert a low strength insecticidal action and for this reason may be considered a fumigant. Annis (1987) has published data on the toxicity of carbon dioxide to a wide range of insect pests of stored products. Major drawbacks of using carbon dioxide as a fumigant are, the long exposure period required, 2-8 weeks depending on the temperature, and high gas concentrations (>40%), making it essential that enclosures are very gas-tight. Carbon dioxide has been used routinely since 1985 in a system developed for disinfesting bagged rice in Indonesia (Natareja and Hodges, l990). The Natural Resources Institute has recently completed investigations into the suitability of carbon dioxide for fumigating maize in concrete silos in Kenya and a workable technique has been devised. (Brice, *et al.,* 1997). The availability and cost of carbon dioxide locally, is likely to be a major consideration in decisions to adopt its use.

New fumigants that are under investigation as potential alternatives to methyl bromide include carbonyl sulphide (Desmarchelier, 1994), methyl phosphine (Chaudhry, *et. al., 1997)* and cyanogen (Desmarchelier *et al.,* 1995). Indications are, that to date, investigations have not proceeded far beyond laboratory trials. The cost of obtaining registration for new fumigants for treating food commodities is likely to be very high, and the amount of field testing required suggests that it might be five to ten years before any gases found suitable were to become commercially available.

ALTERNATIVES TO FUMIGANTS

CONTROLLED ATMOSPHERES

Controlled atmospheres using burner gas or nitrogen provide a viable alternative to methyl bromide fumigation for grain, but suffer from the same disadvantages as carbon dioxide. Because oxygen concentrations have to be less than 1% for treatments to be effective, enclosures to be disinfested must be very gas-tight in order to maintain the low oxygen content for periods up to several weeks depending on the temperature. Nitrogen-based controlled atmosphere treatments are, however, already in commercial use in an Australian export grain terminal, in bins originally designed for methyl bromide fumigation (Cassells, *et al.,* 1994). The use of sealed storage as a technique for controlling insects in grain, using the hermetic principle, has been practised for many years, the oxygen concentration being depleted by the action of micro-organisms and insects. This technique is often considered to be more suited to use in tropical and subtropical climates (Navarro, *et. al.,* 1994). The effective use of hermetic storage has been reported for wheat, in Israel (Navarro, *et. al.,* 1993) and for barley, in Cyprus (Navarro, *et. al.,* 1993; Varnava and Mouskos, 1997).

CONTACT INSECTICIDES

Application of chemical insecticides directly to certain types of commodity is practised in some countries and may reduce the need to employ fumigation. However, the current approach in many countries to reducing the application of chemicals to food commodities, and in particular, those chemicals which leave residues in food-stuffs, suggests that direct admixture of contact insecticides with grain will decrease in the future, and therefore be unlikely to be acceptable as a substitute for fumigation. Also, few new chemicals are likely to be developed for treating grain because of the increasing costs involved in their registration. There are, in addition, potential problems with insect resistance in several countries to some of the contact insecticides currently used (Jermannaud, 1994), although, at present, the magnitude of resistance has not resulted in substantial control failures in the field. There is evidence that contact insecticides used as surface sprays are not as effective as previously thought, and that their regular application in grain does not reduce the frequency with which fumigations need to be conducted (Gudrups, 1996).

PHYSICAL CONTROL METHODS

There are several physical methods of controlling insects that might be used for disinfesting grain, including the application of heat or cold, and the use of irradiation. For cold treatment, if rapid disinfestation is required, very low temperatures are necessary (- 15°C or less). Even at 4°C, adults of many insect species can survive for many months although immature stages may be killed. Insect species of tropical origin, such as *Sitophilus oryzae,* are particularly sensitive to cold and may be controlled more easily than more cold-tolerant pests such as *Cryptolestes* spp. Cooling, therefore, is typically used to prevent insect damage and multiplication rather than as a disinfestant (MBTOC, 1994).

Commodity treatment by heating is one of the few technologies available which is capable of matching the speed of treatment that can be attained using fast-acting fumigants such as methyl bromide. Temperatures needed are of the order of 50 to 70°C, and for this reason care has to be taken not to damage heat sensitive products. Insect control by the use of heat (32-37°C), in combination with low levels of phosphine (65-100 ppm) and carbon dioxide (4-6%) for periods of approximately 36 hours has been reported by Mueller (1994), and proposed as a treatment method for flour mills and similar structures. Particular care is necessary, however, in such treatments, to take account of the corrosive properties of phosphine since its attacks copper and exposed electrical equipment could be severely damaged. Further care is necessary to ensure that the exposure of insects to low concentrations of phosphine by the combination method does not increase the selection pressure for resistance. The combination method has been evaluated in a commercial situation in Canada with encouraging results (Marcotte, 1996).

Control of insects infesting stored products by irradiation has been proposed as a potential alternative to fumigation, and is already in use, commercially, in some situations. Tilton and Brower (1987) have summarised the radio-sensitivity data on 40 species of stored-product insects and discussed the possible use of irradiation disinfestation of grain and grain products for quarantine purposes. There are, currently, no approved quarantine standards for irradiation to date (MBTOC, 1994).

Inert dusts, particularly those based on activated silicates are finding increasing use as grain protectants. They are most effective in conditions of low humidity where they result in the mortality of insects by desiccation. Although grain protectants generally are not direct substitutes for fumigants because they cannot be used to disinfest grain directly their use, rather like the use of contact insecticides, can prevent or avoid the conditions that lead to the need to undertake fumigation. A general review of inert dusts with perspectives for their future use has been given by Golob (1997).

Further development of most of these physical disinfestation techniques will be essential before they are widely adopted, and a major constraint to their introduction in some countries may be the high energy requirement, possibly resulting in much greater costs than fumigation. Public concern in some countries regarding the use of irradiation will have to be allayed before this method of disinfestation could be widely adopted as an alternative to fumization.

BIOLOGICAL CONTROL OF INSECTS

Biological methods, such as trapping with the aid of pheromones, and sometimes in combination with the use of chemicals, may offer potential for long-term reduction of insect populations in storage buildings (Trematerra, 1994; Pierce, 1994), although such methods are generally preventive rather than curative, and it is for the latter purpose that fumigants are most often used. However, where employment of biological control methods is able to reduce insect population levels, this might reduce the need for curative methods such as fumigation.

The use of predatory insects, parasitoids and insect pathogens has been discussed at length in the MBTOC Report (1994) and these are described as having long-term potential to provide protection to stored products. Such methods of insect control, as with the other types of grain protectant, would be used to prevent the need for fumigation and are likely to find application in specific situations rather than for general use.

SUMMARY AND CONCLUSIONS

Methyl bromide continues to be an important fumigant during the 1990s for disinfesting durable commodities. Although it is clear that there are alternative treatment methods for many of the uses of the chemical, and that these have been identified by the Methyl Bromide Technical Options Committee, it is equally clear that for some uses no alternatives exist at present. These uses are mostly where it is essential, or highly desirable, to complete treatments quickly, particularly where commodities are internationally traded. The lack of suitable alternatives to methyl bromide in these situations is recognised in agreements under the Protocol for exemptions from control for treatments conducted for quarantine and pre-shipment purposes.

Phosphine is undoubtedly the most important and, in some cases, the only available replacement for methyl bromide at present. It had already replaced methyl bromide as a fumigant for grain in many countries even before environmental concerns about ozone depletion arose, and there is now probably only limited scope for further extending the use of phosphine as a replacement for methyl bromide. In some countries, grain storage and handling systems have been developed that rely upon the quick treatment that is possible using methyl bromide, and a change to phosphine fumigation will require considerable modifications to the systems in place. Constraints to the introduction of phosphine into such systems may not be technical, but mainly economic and, in some situations. due to a reluctance to discontinue the use of a fumigant which is familiar and effective. Phosphine will, however, remain a major fumigant for durable stored products for the foreseeable future and its use will probably increase in situations where treatment time is not a constraint. The use of cylinderised phosphine mixed with carbon dioxide as a grain fumigant, and presently employed mostly in Australia, may become more widespread. The only significant limitation on phosphine usage in the future is likely to result from insect resistance, and where alternative disinfestation techniques, possibly including the use of methyl bromide, will be required.

The costs of some alternatives to fumigation, particularly those using heat or cold where high energy levels are necessary, may dictate the speed of their introduction into commercial practice. Costs may also be a major factor in the introduction of any new fumigants developed and those responsible for marketing them will need to be certain that the high cost of obtaining registration is worthwhile, particularly in view of the intense research and development into non-chemical methods that is likely.

Many of the other alternatives to methyl bromide proposed are intended to avoid the need to fumigate by preventing rather than curing infestation. Many of these alternatives may function in integrated pest management systems but there is always likely to be a need for rapid disinfestation methods where commodities found to be infested can be treated over a short timescale either to prevent further damage and loss or to prevent the introduction of unwanted pests.

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Chapter 7
MAKING THE RIGHT CHOICE

Friends of the Earth

Madrid, Spain

For many years, Friends of the Earth International has been working not only for the fight against the ozone layer destruction, which implies the reduction of gas emissions that affect the ozone layer, but also for its regeneration. This struggle implies having a positive global attitude towards the anthropogenic practices of production and consumption, with respect to the environment, within the framework of the environmental concept that our organization created and developed.

We only have one Earth, and we all have to share its resources, so it seems to be right and fair that all of us might equally enjoy it. Therefore, we can not agree with these positions that insist on maintaining the privileges of rich countries concerning the use of resources and the untenable production of waste and pollution.

We can neither agree with other certain positions; lesser developed countries are also making big errors: they believe that by copying the production and consumption patterns of rich countries, they will reach the same level of “social welfare”, wealth or development. If all the planet inhabitants had the same way of life as the average man in an industrialized country, we would need many more planets to produce resources, to absorb waste and maintain the present systems of life.

This simply signifies that, the northern countries can not go on using this pattern, nor can the southern countries copy this pattern; we have to use equity policies within the frame of sustainable development: the consumption of resources in the industrialized countries must be reduced so that the non-industrialized countries might reach similar levels of development without going beyond the ecological limits of the earth.

This is the frame in which we, FRIENDS OF THE EARTH, have set up our campaign for the ozone layer protection, and now we are focusing on the removal of Methyl Bromide use.

The methyl bromide arrived in our countries through big multinationals. They presented it to us as the great panacea that would increase the productivity of our fields, and since then, it has been an essential product for many farmers. They gave up the farming techniques they had been using year after year, –some of them are centenary- obtaining good results, and started to use methyl bromide, impoverishing the acquired knowledge without evaluating its permanence and productivity.

Now, according to us, the farmers must use non-chemical methods, which FRIENDS OF THE EARTH supports, because the soils are impoverished, methyl bromide makes them a wasteland, and therefore, they really must return to former agricultural techniques.

But there is no other alternative. The Montreal Protocol fixed a date in 2005, for the industrialized countries to stop using methyl bromide, and in 2015, the non-industrialized countries will also have to give it up. And during the next Convention meeting, in November 1998, it might be planned to advance the dates to 2001 and 2005, as FRIENDS OF THE EARTH proposes.

From our point of view, based on the opinion of experts and scientists, methyl bromide –which use is totally unnecessary- is prejudicial for the soil, toxic for living beings and destroys the ozone layer.

Moreover, we think that the use of methyl bromide curbed the good work of the research about the method to develop the agrarian production. The present crisis concerning methyl bromide demonstrates the false progress that this convenient use caused among the farmers.

On one hand, we believe that if the affected countries had started to solve this problem many years ago, now, not one country would be against the changes in agriculture practices, because the alternatives would have already been tested, and the enterprises that use methyl bromide would have had enough time to change their methods. So that now, they would not be pressuring any farmers and governments.

On the other hand, even nowadays, many farmers (and the workers who apply it) do not really know the negative repercussions of the methyl bromide on their own health, and on the people living near their fields. And they are almost unaware of its effects on the ozone layer. At best, they only know that this substance will be prohibited by the law within a few years, and for the moment, nobody told them which substance will substitute it.

We have to mention that the consumers are totally unaware of this problem, because up to now, nobody informed them about the existence of this biocide, neither where or why it is used, nor the effects it has on the ozone layer.

From now on, the users of methyl bromide must be alerted, for them to chose, if possible, non-chemical alternatives. The consumers of products containing bromide, must also be alerted, so that they could demand clear information about the farming products they consume. They also should request the governments to take measures in order to promote changes of agricultural practices, so that the farmer could stop using bromide without loosing the capacity of production.

Those are the three axis of our campaign, to which we are devoting our efforts, and that is why we are here today.

We all know that in the Mediterranean countries, agriculture plays a great role, not only concerning the direct or indirect jobs, but also concerning the agricultural products the people consume. Thus we should take better care of it, protect it from the chemical products, go back to traditional agricultural practices, make a better use of water, etc. In short, we should promote and practise sustainable agriculture, which has little to do with the methods we use at the moment. Yesterday it was the PBCP and the EDB, today it is the methyl bromide, tomorrow it will be another pesticide. What are we waiting for to change things?

We know that in Spain, Italy and many other countries, some creative farmers do not use pesticides, but they have an important production. Unfortunately, in Spain for example, the majority of this production (75%) is exported, because the internal demand is not sufficient. And it is mainly exported to north European countries, where the consumer is well informed and is able to chose.

Those facts invite us to reflect on two points.

The first one is that the consumer has very little or no information about the agricultural products he consumes, and does not know if they have been treated with methyl bromide or any other kind of pesticide. And he is not aware that ecological or biological agricultural products exist, because those products do not reach the usual market, they are only sold in small specialized shops and at high costs. Then, his demand is still mainly traditional, but he does not choose it. The market imposes it.

The second point is: the farmer who does not use pesticides does not have a true channel of commercialization. There are no facilities for those products to be known and demanded by the consumer.

Even if today a type of consumer demands those products, knows them and can choose them, this demand must increase; in order to do so, the prices have to be cut and the products must be more accessible. So, in a promotion plan of sustainable agriculture, first of all, the farmers would require incentives to sell their production. That is to say, mechanisms that would facilitate the arrival of the product to the consumer, and at a good price.

Within this framework, it is clear that eco-labelling should be a method to keep the consumer informed and give him the possibility to choose. The tax on production and use of chemical products should serve to equalize prices, facilitate the commercialisation of untreated products, and help the farmers that contribute to the sustainability of the planet.

To conclude, we could say that:

1. Methyl bromide is not necessary.
2. The northern countries as well as the southern countries have other alternatives, therefore it is not worth fixing different dates to stop the use of this pesticide.
3. It is possible and necessary to advance to 2001, the date established during the last Protocol meeting. The countries present here have the opportunity to lead this position, not as a limitation but to the contrary. The countries that first stop using bromide will be more competitive.
4. The governments must not take half measures, talking about reduction of doses or use of plastics, but they have to face what will be our future agriculture, by assuring the transference of technology, the training of farmers and informing consumers.
5. The media should give more importance to the education of the consumer, providing information about the factors that affect directly the everyday life of citizens, such as the use of products, and should not exclusively focus on important events or great ecological disasters.
6. The consumers and citizens associations usually have to demand clear information about the products of consumption, and then put in practice their capacity to chose and decide, using the appropriate means in each case.
7. The northern countries must give up their double standard: they must stop using methyl bromide in their agriculture, and stop demanding the southern countries to use it for their export products.

8. Finally, the Montreal Protocol must urgently regulate and eliminate the use of methyl bromide in quarantine, as up to now, it did not happen because of the strong influence of the international markets.

Rome, 27 May 98

Chapter 8
ECO-LABELLING IN CUT FLOWER PRODUCTION

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MPS

Milieu Project Sierteelt
Floriculture Environmental Project

ENVIRONMENT AS A MARKET FACTOR

- Flowers and plants symbolize the environment
- Consumers are showing a growing concern for the environment
- Concern for the environment can provide competitive edge
- Concern for the environment will continue in the future

PARTICIPANTS ARE OBLIGED TO:

- Enter into an agreement
- Register data every 4 weeks
- Submit figures
- Submit to inspection by an independent organization; SGS AgroControl
- Supply additional data on the nursery

STANDARDS

- Environmental Cluster (Pilot Groups)
- Theme
- Hectare
- Full Year ➔ 13 periods
- Entire growing period
- Variation in real usage:

LOWER LIMIT UPPER LIMIT

STANDARDS

- Based on reality
- Range between lower and upper limits for each environmental theme
- Determined per group of crops
- 20% of nurseries (probably) in Mk A in first classification round
- Maximum score 100 points
  - 40 for crop protection
  - 30 for energy
  - 20 for fertilizers
  - 10 for waste

REGISTRATION UNITS

THEME	UNITS	PER
Crop protection agents	Kg active ingredient	ha
energy	GJ	ha
fertilizers:		
- N	kg	ha
- P	kg	ha
waste	separated	nursery

MPS DEVELOPMENTS:

- MPS - A,B,C
- MPS - “Milieukeur”
- MPS - Ecology

INSPECTION

1. Administrative inspection (forms correctly completed and submitted at correct time)
2. Desk analysis (specific and indiscriminate)
3. Inspection of nursery (by independent organization)
   visual inspection
   examination of invoices
   interviews
   sampling

PARTICIPATING NURSERIES

1995	2205
1996	2533 + 15% (including Belgium)
1997 (exp.)	2750 + 9% (including Belgium)
1998 (forecast)	3500 + 27% (exclusive of bulbs and trees not supplied to auctions)

TARGETS

- In the year 2000, participation of 80 to 90% of all floricultural growers
- World standard
- Based on registration system

INTERNATIONAL DEVELOPMENTS:

- MPS is internationally well accepted
- Fixed contracts with Belgium and Denmark
- Negotiations with Kenya, Israel, Zambia, Tanzania, Zimbabwe, Ecuador and Colombia

PRINCIPLES OF THE INTERNATIONAL SYSTEM: (1)

- Four themes (crop protection agents, energy, fertilizers and waste)
- Assessment of the themes on a scale 4 : 3 : 2 : 1
- Registration and standards per m2 (acre), energy (transport distance)

PRINCIPLES OF THE INTERNATIONAL SYSTEM: (2)

- Standards: based on environmental clusters or further research
- Crop production agents: national legislation plus MPS rules
- Inspection: according to the Dutch system

PROCEDURE:

- Start of feasibility study
- After evaluation one year at the most: accessible for other nurseries
- Official qualification

AFTER THE TRIAL PERIOD:

- An official qualification four times a year
- Allowed to use the name MPS
- Surveys of the usage and qualification figures

Chapter 9

TRANSFERRING LAB RESULTS INTO VIABLE DEMONSTRATION PROJECTS

C. Martin

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From the lab to growers, is a difficult gap to fill because fundamental research has its own motivation which is often very different from the growers' troubles. Managing viable demonstration projects for environment friendly techniques are specific in that economical and technical factors which are usually the main motives for action are secondary considerations for demonstration projects.

Therefore, I will try to share the experience of Agriphyto as a partner among others to handle similar demonstration projects utilizing solarization and integrated pest management for production of vegetable crops in the south of France.

Two different aspects will be taken into account:

- To prove practical efficiency of the new alternative technique versus the old solutions.
- To develop arguments to show that this alternative will be effective in the future for agricultural production.

On the basis of the example concerning Agriphyto, I will try to emphasize the following important key points:

1. The importance of including all partners in the demonstration project from the beginning, including first, the growers or their direct representatives, workers, marketing representatives, industry related to the project (e.g. for solarization, the plastic industry) and of course research experts.
2. It is important to adopt a step by step process in order to prevent the demon-

stration project from proceeding too quickly so that it fails. A demonstration project must begin in an experimental site then in a production site with not more than 5 growers involved. Then bigger diffusion can occur with the time scale of the planning in years or more precisely in terms of the crop.

3. A permanent feedback from the beginning and from all the partners involved must help to clearly identify the major bottlenecks in order to be able to solve them in due time before a new step is done.
4. Parallel to the demonstration project itself, applied research on these bottlenecks is important to be carried out at the same time. Research people as well as technicians of all origin have in that occasion a new opportunity to contribute to the final success of the project.
5. Technical data have to be collected at each step of the project in order to convince the extension service people of the legitimacy of their action for as many criterions as possible. Provided that enough data is available, a multi data analysis is a useful statistical tool to do the job.
6. For the growers, technical data is not always sufficient, bearing in mind the strength of St Thomas' syndrome who wanted to touch before believing. So all types of direct communication by meeting, visiting of plots, videos of new techniques, leaflets etc. should be given greater use than unreadable scientific reports or publications.
7. Last but not least, the final step of the demonstration project, just before a large diffusion, has to be sponsored with a direct economic impulse. The implication of commercial partners and industry or public subsidies could be of some help for the grower's decisive spur to join the demonstration project.
8. A follow up action or "After Sale Service" must be developed in order to answer old or new questions well after the project has been completed. If there is no commercial interest in this project, a follow up system should be organized by the local authorities.

Of course all these key points are of no interest if the means involved are not well integrated with each of our specific regional work habits. With this essential condition, this integrated Demonstration Management System will help meet the future challenges of Mediterranean agriculture.

Chapter 10
STATUS OF METHYL BROMIDE ALTERNATIVES FOR SOIL FUMIGATION IN SOUTHERN EUROPE

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INTRODUCTION

Soilborne pathogens are cause of major losses in several economically important crops grown in Sourthern Europe. Disinfestation represents a crucial practice in intensive horticulture in order to combat soilborne plant pathogens as well as weeds and arthropod pests, and maintain productivity at high levels. It is usually carried out in glass- and greenhouses, and sometimes also in the open field on high value crops (Garibaldi and Gullino, 1995).

Soil disinfestation is usually carried out by using steam or other physical measures, chemical fumigants or solar heating (Katan, 1984).

Chemical fumigants have been used for years, due to their relative low cost and broad spectrum of activity: among them, methyl bromide (MB) has been widely applied, due to the extremely wide spectrum of its biocidal activity (Vanachter, 1979).

Use of fumigants has been, since a longtime, considered as potentially hazardous; as a consequence, many restrictions have been imposed in order to regulate and reduce their use. Some effective fumigants have been lost during the recent past due to the environmental hazard. The same is true for some of the fungicides used as soil treatment, although somehow at a lower level. Many of the currently available fumigants are very strictly regulated in most countries.

The inclusion of MB among substances that deplete the ozone layer led to increasing restrictions in its usage, in preparation to its phasing-out, currently scheduled for 2005 in developed countries (Bell *et al.,* 1996; Ristaino and Thomas, 1997).

This may have a major impact on southern European horticulture, particularly in areas where MB has been and still is widely applied as pre-plant soil fumigant on a number of economically important crops (Gullino and Clini, 1998).

This paper will focus on the status of chemical alternatives to MB for soil fumigation.

CHEMICAL ALTERNATIVES TO MB FOR SOIL FUMIGATION

There are a reasonable number of chemicals that have actual or potential roles as at least partial replacement for MB in pre-plant soil fumigation. Some of them are reported below.

Dazomet. It is a granular soil chemical, effective against soil fungi, weeds and nematodes. It requires uniform mechanical distribution into the soil in order to ensure good movement. Moreover, optimal soil temperature and moisture levels are necessary in order to achieve good disease control. It acts through decomposition into methyl isothiocyanate.

Metam-sodium. It is a liquid compound, applied through irrigation or drenching; its active ingredient is methyl isothiocyanate. It is effective against some weeds and soilborne fungi and a limited number of nematodes. Its level of efficacy is strictly dependent upon the method of application, soil temperature and moisture. Application of metam-sodium in irrigation water provides good control: its efficacy can be improved by covering the soil with plastic sheet. Injection of metam-sodium, on the contrary, can provide inconsistent results due to uneven distribution of the chemical into the soil.

Chloropicrin. It controls most soilborne pathogens (Van Berkum and Hoestra, 1979) but provides unsatisfactory control of nematodes and weeds. It has been mostly applied in mixture with MB or with 1,3 dichloropropene. Only recently it has been widely tested alone as pre-plant soil fumigant. In countries such as Italy where such a compound is still classified as war gas, it cannot be used in agriculture.

1,3 dichloropropene (1,3 D). It provides effective control of nematodes and suppresses some weeds and soilborne fungi. Accelerated degradation by soil microorganisms after repeated application and presence in the air and in shallow groundwater have been reported. Its usage is strictly regulated in some countries: for instance it can be applied only in the open field and safety equipment for workers during its application can be required.

Sodium tetrathiocarbonate. It has been recently developed for soil disinfestation: it decomposes in the soil releasing carbon disulphide (Young, 1990). It controls to some extent certain soilborne fungi and nematodes. It is registered in some countries but it offers erratic results.

Formaldehyde. It can be used, wherever admitted, as a soil drench with good results against some fungi and bacteria (Murray, 1989).

Other compounds under study. Among others, inorganic azides (Na or K azides), bromonitromethane, 2 - furfuraldehyde and methyl iodide are in the initial stages of development (Annis and Waterford, 1996). Some of them could be available in the future, when registration requirements are completed. However, it is not expected that this will happen shortly. The pesticide industry is currently one of the most heavily regulated: requirements for registration are now amongst the most demanding with regard to both quality and quantity of data. Pesticide behaviour in soil and water, toxicity to a wider range of aquatic animals, effects on soil organisms and soil processes are required. Moreover, only a few companies are prepared to cover the very high investment necessary to develop new fumigants.

CRITICAL ASPECTS IN REPLACING MB WITH OTHER FUMIGANTS

From a technical point of view, soil disinfestation must be carried out in a way that has effective results at an acceptable cost. Under these perspective, fumigants are often the method of choice, due to their relative low cost and broad spectrum of activity. It is easy to predict that, at least in the early stages, in most cases MB will be replaced by other fumigants. This will happen because growers need to rely on good efficacy and the transfer of new technologies occurring in most southern European countries is still limited. Economical considerations will also be taken into account by growers: non chemical alternatives to MB are often more expensive than the chemical ones.

Metam-sodium and dazomet, besides being used on protected crops, are increasingly applied in open fields. They are effective against many pathogens and pests. MIT generating fumigants are probably most effective for the control of damping-off, collar and root pathogens, nematodes, soil inhabiting insect pests and weed seeds. They are, on the contrary, less effective against some vascular wilt pathogens or against any pathogen when the inoculum is extremely high (Fletcher, 1984). The results offered by dazomet and metam-sodium are often disappointing or incomplete: this is mostly due to their uneven distribution in the soil. Moreover, often the admitted dosages give only a partial control of some diseases. Various attempts have been made to improve the efficiency of application and the distribution of MIT generating compounds by formulation in different ways, improving application techniques and covering the soil after their application with plastic sheets.

Fumigants showing a more restricted activity, such as 1,3-dichloropropene, are increasingly applied in open field crops, especially against nematodes on potato and sugarbeet and against replant problems.

Chloropicrin, whenever registered, could be applied on certain crops. For instance, it is expected to provide a useful alternative to MB on strawberry.

The longer time interval between application and planting required by currently available MB alternative fumigants can be a negative feature for certain cropping systems.

Some of the fumigants might have several potential environmental negative side effects. Fumigants and fungicides and/or their degradation products may reach the environment (atmosphere, soil, water,...) or may accumulate in edible parts of the plants, leading to the presence of unwanted residues. However, by adopting modern application practices for fumigants, such as mulching and use of lower dosages, some of the environmental problems should be, at least partially, reduced.

CONCLUDING REMARKS

Soil and substrate disinfestation remains an essential practice in modern intensive horticulture. Currently no single chemical provides an alternative to pre-plant use of MB in terms of consistency of results, spectrum of activity and level of efficacy against target pests. In many cases depth of soil penetration, poor dispersion of the chemicals under various conditions, narrow range of temperatures at which they are effective result in inconsistent results (Rodriguez-Kabana, 1998). Although total yield may not be negatively affected, the quality and production patterns might often be influenced.

A combination of chemicals and other control methods is therefore necessary to replace MB. The only partial activity of most of MB alternatives stimulated research on combination of different methods of soil disinfestation. Of special interest is the combination of metam-sodium or dazomet with reduced length soil solarization, since it shortens the duration of soil mulching from 4 to 2 weeks, makes this technique applicable under marginal climatic situations and increases the spectrum of activity of both solarization and MIT generators applied alone.

Improvement in application technology can permit a better use of fumigants, greatly reducing atmospheric pollution and all associated hazards (van Wambeke, 1992). Probably, in the long run, certified applicators might be required for fumigants application.

Using a combination of control measures appears, at present, as an attractive and realistic strategy. The combination of soil solarization with cultural measures and reduced dosages of chemicals should be considered a vital and applicable alternative to MB in southern Europe for several crops.

Realistically, for more years, we will still need fumigants and harmonization of regulation is needed in order to provide European growers the same tools. A strong effort must be, however, put in order to avoid their exclusive use as replacement to MB and to promote their application at reduced dosages into sound IPM programmes. To do so, an efficient extension service is necessary.

ACKNOWLEDGEMENT

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Chapter 11
FUTURE REGULATORY APPROACH IN THE NETHERLANDS

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HISTORY

- Early 80’s Maximum annual consumption 3000 tonnes
- 1992 Ban on use for soil sterilization
- Since 1992 MeBr only allowed for
  - -stored product protection
  - -structural fumigation
  - -quarantine & pre- shipment

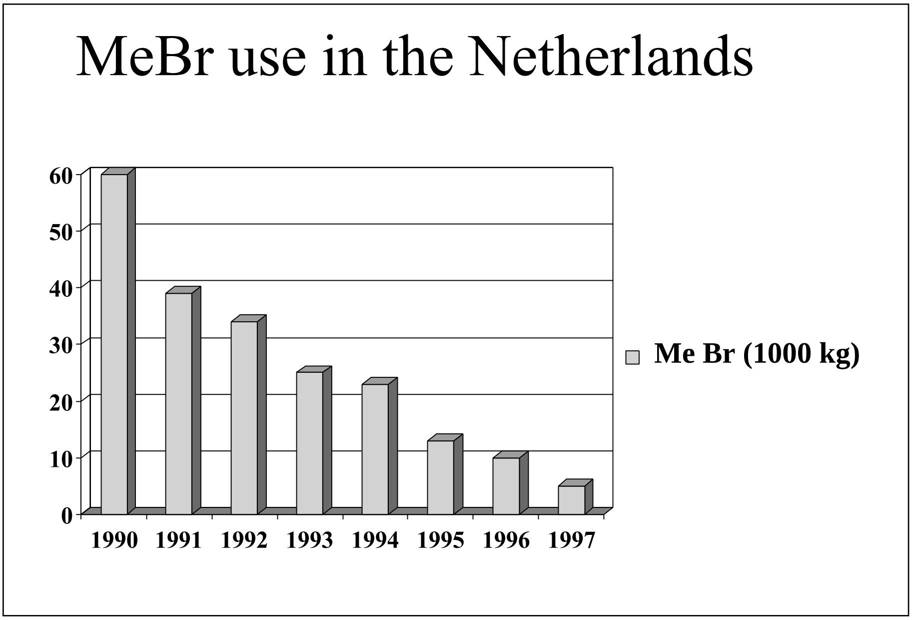
METHYL BROMIDE FUMIGATION

- Notification
- Central register
- Database with information on:
  - -Quantities of fumigated produce
  - -Quantities of MeBr used
  - -Volume of fumigated object
  - -Location
  - etc
- Baseline information for effective reduction schemes

ANALYSIS OF CURRENT USES AND POTENTIAL ALTERNATIVES

1994-1997
Dutch Ministry of Environment

- Current uses in the Netherlands
- Identification of potential alternatives
- Pilot tests with selected alternatives



MAJOR CAUSES FOR USE REDUCTION

- Preventive measures
- (strict) enforcement of
  - notification system
  - distance requirements
- stimulation of alternative

TABLE 1. MAJOR PRODUCTS AND CURRENT MEBR USE (KG) IN THE NETHERLANDS

	1993	1994	1995	1996
Groundnuts	10,720	9,583	2,906	1,021
Cocoa beans	4,910	5,827	2,328	2,700
Containers (Sirex)	-	3,616	2,774	2,690
Structures	2,666	2,507	1,991	339
Nuts / Seeds	691	1,363	1,303	208
Rice	1,430	1,575	718	973
Coffee	704	815	451	251
Pet food	1,167	505	424	3,205
Grain	3,021	40	65	216
Others	3,262	1,020	747	544
Total	28,571	26,851	13,707	12,147

CONSULTATION GROUP

- Regulatory affairs
- Bottlenecks
- Alternatives

PHASE-OUT PROPOSAL

January 1, 2000

Critical applications exempted
Quarantine and Pre-shipment included

Determination of critical applications recently started

Chapter 12

LEGISLATIVE AND REGULATORY APPROACHES IN THE EUROPEAN COMMUNITY

Geoffrey Tierney

European Commission

Rome, 26-29 May 1998

METHYL BROMIDE

- Legislative and regulatory approaches in the European Community
- Geoff Tierney, European Commission DG XI.D.4

Good afternoon, Ladies and Gentlemen

My name is Geoff Tierney and I am working for the European Commission Directorate General (DG) XI, which is that part of the Commission responsible for environmental protection and nuclear safety.

My responsibilities there include negotiation of the Montreal Protocol.

PHASING OUT METHYL BROMIDE IN THE EU

- Where are we now?
- What difficulties remain?
- How can they be addressed?

I am very pleased to be able to give you an update on the development of MBr phaseout policy in the European Community.

I should emphasise at the start that Community policy is undergoing change and that it is not yet clear precisely what will emerge. The Commission is in the process of adopting a new regulation on ozone-depleting substances but, until it is formally adopted (which we hope will be during June 1998), I cannot say definitely what it will contain.

Further, as you will know, the Council of Ministers and the European Parliament can make changes to a Commission proposal as it passes through the various procedures on its way to becoming Community law. Therefore, although I can outline for you some of the factors we are considering and the options we have, I cannot yet say definitely when the Community will phase out methyl bromide nor under what conditions.

METHYL BROMIDE IN THE EUROPEAN COMMUNITY

- Second largest consumer - c16,000 t in 1992
- Soil fumigation - 90%
- Commodity fumigation - 3%
- Structural/space fumigation - 3%
- Feedstock - 4%

Although there is only one Community producer of methyl bromide, we are a significant consumer of this ozone-depleting pesticide. Only the United States consumes more in any year.

Most of our consumption is for soil fumigation. It is therefore appropriate that this workshop is concentrating on alternatives to methyl bromide for use on soils.

METHYL BROMIDE IN THE EUROPEAN COMMUNITY - SOIL FUMIGATION

- Sweden, Finldand, Denmark, Netherlands, Austria, Germany ≈ 0
- Belgium (2%), UK (2%), Portugal (3%), Greece (7%), France (8%)
- Spain (28%) Italy (50%)

Although the Community as a whole is a major consumer, the pattern within the Community is very diverse.

A group of countries have more or less phased out entirely their use of methyl bromide except for a few quarantine and pre-shipment uses and structural fumigation. Among these we should note the Netherlands, which was once a major consumer for soils but has now phased out this use without inflicting irreparable damage on its horticultural industry. Some of the lessons learned from phaseout in the Netherlands and other Member States will be useful in helping to phase out consumption in the rest of the Community.

A second group of countries has some modest consumption, mainly concentrated in particular regions or on particular crops. In some cases consumption is already decreasing as alternatives are being commercialised.

The greatest consumption is in Italy and Spain where it seems that several types of intensive fruit and vegetable production now use a great deal of methyl bromide.

METHYL BROMIDE IN THE EUROPEAN COMMUNITY - SOIL FUMIGATION

- Tomatoes (37%)
- strawberries (21%)
- melons & cucumbers (11%)
- other veg & fruit
- cut flowers
- nurseries & seedbeds

As you might expect, methyl bromide use is concentrated in the intensive cultivation of certain produce. Nearly 70% is used for tomatoes, strawberries, melons and cucumbers. Therefore, we should focus our attention on these types of cultivation when it comes to identifying good alternatives and disseminating information about them to farmers.

COMMUNITY POLICY FRAMEWORK

- EU Treaty
- EU policy shall aim at a high level of protection
- environmental damage should be rectified at source

- Fifth Action Programme
- aim to integrate environment and other policies including
- assisting farmers to move to IPM methods
- a significant reduction in pesticide use by the year 2000

Community policy on methyl bromide does not exist in a vacuum. The Community Treaty places a high priority on environmental protection, particularly since the Amsterdam summit last year. According to the Treaty, we must aim for a high level of environmental protection (incorporating the precautionary principle) and should rectify environmental damage at source (incorporating the polluter pays principle).

We can also see that the Community is now trying to integrate environmental protection into all Community policies and instruments. This means that, for example, agricultural policy should promote environmentally-sound, sustainable agriculture. An important part of this policy is to assist farmers to move to Integrated Pest Management (IPM) and to reduce significantly the Community's use of pesticides by the year 2000. You can all appreciate the relevance of these policies for the early phase-out of methyl bromide which is one of the most toxic and environmentally damaging pesticides still in widespread use.

REGULATION 3093/94

- Freeze on production and placing on the market in 1995
- Maximum 10,344 odp tonnes
- equals 17,240 tonnes

- 25% cut 1998
- Maximum 7758 odp tonnes
- equals 12,930 odp tonnes

The Community's current ozone-protection policies can be found in Council Regulation 3093/94. As far as methyl bromide is concerned, there was a freeze in production and consumption in 1995 at 1991 levels, as required by the Montreal Protocol Copenhagen Amendment. The Community also implemented this year (1998) a cut in production and consumption of 25%. This means that there is now an absolute quantitative limit on the amount of methyl bromide which can be placed on the Community market (by the producer and/or by import) in any year. That limit is 7758 odp tonnes (12930 metric tonnes).

Following the exemptions in the Protocol, these limits do not apply to methyl bromide used for feedstock or quarantine/pre-shipment.

REGULATION 3093/94

- All precautionary measures practicable shall be taken to prevent leakage from fumigation installations and operations where methyl bromide is used
- Licensing of imports of MBr

The regulation also contains provisions requiring the control of leakage and the licensing of imports.

From the leakage control article, it can be seen that the use of Virtually Impermeable Films (VIF) and other methods to improve containment and reduce emissions are already mandated by the regulation “where practicable”.

REVISION OF THE REGULATION

- Phaseout of production and consumption of MBr
- 2005?
- 2001?
- Critical use exemption - where technically & economically feasible alternatives are not available
- emergency use exemption

As I said previously, Regulation 3093/94 is currently being revised to bring it up to date so the Community can meet its new obligations under the Protocol. For methyl bromide, in order to be in compliance with the Montreal (1997) Amendment, we need to introduce a complete phaseout of production and consumption, except for exemptions for critical uses and for emergency use.

Some Member States would like this phaseout to be as early as 2001 while others would prefer to wait until 2005 as required by the Protocol. We need to await the outcome of the negotiations and procedures for adoption of the regulation before knowing what the decision will be.

Whichever date is chosen, the exemption for critical uses will be important. It is this exemption which should reassure farmers that where there is no technically or economically feasible alternative available, they may continue to use MBr under the temporary exemption. The onus will be on potential users to demonstrate that they have tried alternatives and, for some reason, they are not suitable. In such cases,if the competent authority of the Member State is satisfied, a temporary exemption could then be authorised.

This is an important safeguard for agriculture which should enable the early phaseout of a large majority of methyl bromide use throughout the Community.

MBR PHASEOUT POLICY

- Where alternatives exist use them
- Where alternatives do not yet exist, find them - in in the meantime use the critical use exemption
- Critical uses - determined by Member State then reviewed by the Community and Commission
- Critical uses - must use emission reduction technology

  Hence, whatever the final date chosen for phaseout, the Community's policy on methyl bromide is rather clear.

- We need to enable farmers and growers to find out about and change to using alternatives now where they already exist.
- We need to focus our research effort specifically on those few types of horticulture where alternatives are not yet obvious.
- We need to direct demonstration and extension work to areas which still rely on methyl bromide to enable phaseout there
- We need to identify any critical uses and discuss ways to ensure that methyl bromide will remain available for them while it is needed
- We need to ensure that all remaining users of MBr use emissions reduction technology and, where possible, change to a low dose regime with lower frequency of application.

THE SEARCH FOR ALTERNATIVES

- EC alternatives workshopes
- Experiences of member States
- International R&D (MBTOC)
- Scope for financial help?
- Also reduction of doses and frequency of application

Much of the necessary work to phase out methyl bromide successfully is already underway. Last year's workshop in Tenerife and this workshop here in Rome are important occasions to review progress and the availability of alternatives. Some Member States such as Denmark, Germany and the Netherlands have developed alternatives which could be more widely known and used. Alternatives already in use in the Southern Member States should be more widely publicised and acknowledged. We benefit from the guidance and advice of the Methyl Bromide Technical Options Committee and their extensive network of expertise. We also have opportunities for some financial help for necessary research, demonstration and extension work, whether from the Community or from national governments.

And, while alternatives are being brought into use, we should always encourage the use of lower doses and reduced frequency of application.

SCOPE FOR REDUCTIONS

- According to the Prospect Report (1997)
- possible reduction of 25% by using lower doses
- possible reduction of 50% by modifying authorisations
- possible reductions up to 50% by reducing frequency of doses

Here I show a couple of calculations to show the kind of reductions in consumption which are possible now using the alternatives and techniques already available. This work was done for the Commission by Prospect Consulting during 1997 (copies of their report are available from me).

The possible reductions from using lower doses and reduced frequency of application are given. The report also reminds us that the use of Methyl Bromide must be authorised by Member State governments for particular purposes under existing pesticide legislation. The report suggests that reduction of up to 50% would be possible if these authorisations were modified and brought up to date to reflect the current availability of alternatives.

SCOPE FOR REDUCTIONS

- If 30% of sites use dose-reduction measures, 30% dose-reduction + lower frequency and remaining 40% use alternatives, overall reduction would be 80% across the Community
- (Prospect Report 1997)

Here we can see that if 30% of users changed to lower doses, another 30% changed to lower doses plus reduced frequency and the remaining 40% of users changed to alternatives, the overall effect on Community consumption would be a reduction of 80%.

The report argues that this could be done with no damaging effect on productivity of profitability and while maintaining the soil in a healthy condition.

SCOPE FOR REDUCTIONS

- If 40% of sites use dose-reduction measures and lower frequency and remaining 60% use alternatives, overall reduction would be 90% across the Community
- (Prospect Report 1997)

Here we can see that if 40% of users changed to lower doses plus reduced frequency and the remaining 60% of users changed to alternatives, the overall effect on Community consumption would be a reduction of 90%. This would depend on whether or not we believed that 60% of current users could now change to alternatives.

In this context, we could recall that the advice from TEAP and the MBTOC has been that alternatives now exist for anything between 75% to 90% of current uses of methyl bromide.

The problem is not that we do not have the alternatives. This workshop and last year's workshop in Tenerife makes it obvious that the alternatives exist. It is more a problem of telling farmers about them and persuading farmers to use them.

CONCLUSION

- Methyl bromide can be phased out quickly in the European Community
- Alternatives are economically and technically available for a majority of current uses
- Remaining uses can be protected by a temporary exemption

So, in conclusion, the issues surrounding Community policy could be summarised like this:

- Methyl bromide needs to be phased out quickly. It is the most ozone-depleting of the substances remaining in use.
- The US and Canada have agreed to 2001. Some Member States would like us to follow that example. It is not clear from any analysis why phasing out MBr in the Community should be any more difficult or take any more time than phasing it out in the US.
- The alternatives are already known in most cases. The number of uses for which the alternative remains unclear is very limited. As has already been said, there is an alternative for each existing use of MBr currently in successful use somewhere in the Community. It is simply a question of spreading the information more widely, adapting the alternatives to local conditions and encouraging farmers to have the confidence to change.
- Even after phaseout, any uses where technically and economically feasible alternatives do not exist can be protected by a temporary exemption until such time as alternatives become available.
- In these ways, the Community can achieve its objective of phasing out methyl bromide without damaging agriculture and horticulture which currently relies on it.

NEXT STEPS

- Complete evaluation of alternatives
- Identify any critical uses

- Take steps to reduce consumption and emissions
- Plan now for the day when MBr will no longer be available
- Do not become dependent on something which has no future

What then are the next steps?

There is further work here for regulators and policy makers, for soil scientists, and particularly for agricultural development and extension workers. However, the crucial decision-maker is the farmer, who needs to make plans today concerning what to do when MBr is no longer available. It does not help these farmers to be told that MBr will remain available indefinitely or that it is useful to oppose the international or Community phaseout. These messages tend to increase the risk that farmers will be unprepared for the phaseout which will inevitably come in a few years. Community consumers will be increasingly resistant to buying produce grown with methyl bromide, whether because of its ozone-depleting potential, or from a more general desire to avoid pesticides. Supermarket chains will respect this trend and change their buying habits accordingly.

Therefore, the concluding message has to be that methyl bromide will be phased out rather soon, that users will have to move to alternatives, that these should increasingly be IPM/biological solutions rather than simply swapping one chemical for another. All this can be successfully accomplished while maintaining the quality and competitiveness of Community agriculture.

The Commission will continue working with the Member States to achieve these objectives.

Chapter 13

ACHIEVEMENTS AND DIFFICULTIES IN THE 25 YEARS OF RESEARCH ON APPLICATION OF SOIL SOLARIZATION

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INTRODUCTION

The term SOIL SOLARIZATION MEANS a nonchemical soil disinfestation method able to exploit solar energy for heating the soil, affecting mainly the inoculum potential of soilborne pathogens but also exercising many other beneficial effects. Solarization is based on trapping solar irradiation by tightly covering for a month or more the wet soil, usually with transparent polyethylene or impermeable plastic sheets. Soil solarization is considered as comparable or superior to methyl bromide fumigation in the temperate regions.

Solarization is a hydrochemical process involving physical changes. the most apparent one is THE MAXIMUM SOIL TEMPERATURE elevation of 10-15 C above normal depending on the soil depth up to the point where the propagules of most soilborne pathogens are vulnerable to the heat and controlled either DIRECTLY by THE HEAT, OR BY CHEMICAL AND BIOLOGICAL processes generated in the heated soil .Chemical changes and beneficial biological alterations IN THE MICROFLORA COMPOSITION OF THE SOIL, taking place during and even after the removal of the plastics from the mulched soils

UNDER THE SUITABLE SOIL AND WEATHER conditions, Soil solarization CONTROLS A LARGE VARIETY OF PATHOGENS, WEEDS AND PESTS as shown below.

Pathogens Pests or Weeds not controlled	Pathogens Pests or Weeds partially controlled	Pathogens Pests or Weeds controlled
Heat tolerant fungi Monosporascus sp. Macrophomina phaseoli		Vascular wilt fungi Verticillium dahliae formae specialis of Fusarium oxysporum
		Pythiaceous fungi Pythium spp. Phytophthora spp.
		Root rot pathogens Pyrenochaeta lycopersici Rhizoctonia solani
		Sclerotia forming fungi Sclerotinia sclerotiorum S. minor Sclerotium rolfsii S. cepivorum
		Bacterial diseases Clavibacter michiganensis subsp. michiganensis
Root knot nematodes Meloidogyne spp.		Various Nematodes
Weeds Melilotus sulcatus	Weeds Cyperus rotundus	Several Weeds

PARAMETERS OF SOIL SOLARIZATION

One of the most important and rather neglected parameters of Soil solarization is that a) exercises a long-term effect leading to a prolonged disease control furthermore solarization b) enhances plant growth c) and increases yield.

Although thousands of hectares are solarized every year in many countries, the potential for its use is much higher than that.

MAJOR LIMITATIONS OF SOIL SOLARIZATION

Its major limitations are the climate dependency and occupation of land for several weeks. And here come the questions.

1. Are these limitations the reason why farmers do not broadly adopt solarization application or is it because solarization is not backed by commercial companies, and therefore its implementation and adoption by farmers is a slow moving procedure
2. How can scientists help towards the solution of the problems? Do we have to invent new adaptation procedures for its implementation? Do we have to further elucidate the mechanisms involved in solarization to provide potential tools for its improvement? It seems that understanding the weakening phenomenon will enable us to a better determination of optimal combinations of Solarization with other control agents.

IMPROVEMENT OF SOLARIZATION

Solarization can be improved in various ways.

A very promising approach is its combination with other pest- management methods, such as organic amendments producing volatiles that accumulate under the plastic sheets.

Furthermore the Biological control aspects of soil solarization are also very important to be considered. Indeed the effect on the survival and increase of natural thermo-tolerant antagonists is pronounced. Disturbances in the biological equilibrium of the soil microflora, following soil disinfestation with soil fumigants or steam are known to be drastic and undesirable. Application of soil solarization, however, favours the survival and increase of several heat-tolerant micro-organisms able to act as antagonists against soilborne pathogens. Fungi, such as, *Talaromyces flavus* and *Aspergillus terreus* are considered as potential fungal antagonists of *V. dahliae* in solarized olive groves, artichoke, eggplant, or tomato fields. Solarization favours establishment of added antagonists, such as *Trichoderma* spp, *A. terreus*, saprophytic *Fusaria*.

The survival of thermophilic genera of *Bacillus, Actinomyces*, as well as the build-up of fluorescent pseudomonads and other populations of rhizosphere bacteria were reported. The efficacy of soil solarization can be improved also by combination with no-pesticide organic amendments incorporated into the soil before mulching. This can be related both to the release of toxic materials by combination of heating and biological activity and to positive changes in soil microflora .

PROSPECTS AND DIFFICULTIES OF SOIL DISINFECTION.

Innovative approaches are desperately needed by the farmers and are under great demand by the consumers. Accumulating data support the view that research towards exploiting soil solarization by combining various antagonists could be one promising approache. This could also result in reducing duration of solarization thus making the method more acceptable by the farmers. Soil solarization in combination with biocontrol agents could exploit the weakening effect imposed by solar heating and could prolong its effectiveness. Solarization is also a model for introducing a new technology into traditional agriculture of developing countries.

SOLARIZATION with Sprayable Plastic Polymers

Applying plastic films for soil mulch requires special mulching equipment and involves special procedures. The edges should be buried to hold the film in place, and in continuous mulch treatment the sheets are glued together. It is not possible to change the mulching pattern during work, and capacity of area coverage is limited.

Plastic mulches must be removed from the fields before crop growth or after harvest; removal is expensive and labour-intensive.

Plastic residues are often left in the field and can cause problems to agricultural practices and machinery of future crops.

Soil mulch for solarization using spray applications of degradable polymers offers a feasible and cost-effective alternative to plastic tarps.

The polymer is applied by spraying the desired quantity. The polymer composition forms a membrane film which can maintain its integrity in soil and elevate soil temperature. Nevertheless, the membrane is porous and allows overhead irrigation.

In experiments it was found that certain spray mulches were able to raise soil temperature and retain soil moisture under summer conditions. Soilborne populations of phytopathogenic fungi were significantly reduced by the process of solarization. Solarization using this procedure was as effective as solarization using plastic film, in controlling Verticillium wilt and common scab in potato, and peanut pod wart in peanut, during two consecutive crops. Sprayable polymers for Solarization enable combining solarization with fumigants at reduced dosage, or organic amendments (bio-fumigation), for improved pest control, solarization and Biological Control of *Verticillium dahliae* and other vascular wilt parasites.

Rhizosphere or endorhizosphere bacteria with preferential ability to occupy the root tips and exercise antifungal activity against *Verticillium dahliae* are of primary importance. Selective media such as 523 were used to isolate mainly endorhizosphere *Bacillus*. 18 antibiotic producing out of 500 bacterial isolates isolated from tomato root tips grown in SOLARIZED SOILS demonstrated *In vitro* ability to form antagonistic zones against *V. dahliae* in dual cultures.

In planta glass-house evaluation performed with eggplants, demonstrated that two endorhizosphere bacterial isolates designated as K-165 and 5-127 were the most efficient in reducing symptom development by 40-70% compared to the untreated controls two months after transplanting. These isolates further evaluated under field conditions as seed dusting delayed or reduced symptom expression caused by Verticillium wilt and increased yield by 25% in field grown potatoes.

Application of a bacterial culture suspension of K-165 through the irrigation system of tomatoes grown under plastic house conditions showed that the rhizoplane and the vascular tissue harboured the antagonist more than two months after the application at figures over 10^4/g fresh weigh of roots. Both antagonists could also occupy rhizosphere and endorhizosphere of eggplants grown under glasshouse conditions as it was shown by using rif^R mutants of the isolates at various stages of plant growth.

These two endophytes, beyond their antibiotic producing ability, their chitinolytic activity and their ability to produce indole-butyric acid could act as inducing agents to activate induced systemic resistance (ISR). Indeed PGPR originating from solarized soils may exhibit biological disease control through eNHANCEMENT OF HOST defence RESPONSES WHEN THE PGPR Soil Solarization AND BIOFUMIGATION AGAINST *Sclerotium cepivorum* IN SOUTHERN ITALY.

Sclerotium cepivorum causes white bulb rot of *Allium* spp.. Solarization carried out for 45 days, from July to August, reduced significantly the disease incidence and increased the total marketable yield. Soil SOLARIZATION AND BIOFUMIGATION alone or combined with a soil amendment consisting of chicken manure at 1 kg/m (biofumigation), low density polyethylene sheet (LDPE) or BLACK gas virtually impermeable film (VIF). Biofumigation carried out by mulching soil with PE film achieved complete kill of the sclerotia of *S. cepivorum,* buried at the two tested depths, after both 12 and 27 days. However, biofumigation carried out by mulching the soil with VIF and the addition of chicken manure to the soil, enhanced significantly the effectiveness, as soon as 12 days after treatment and resulted in the sclerotia mortality at the two tested depths.

IN CONCLUSION

Based on the reported data, TILL NEW SYNTHETIC FUMIGANTS COULD REPLACE methyl bromide IT SEEMS THAT SHORTENING OF THE DURATION OF Solarization SHOULD BE ONE OF THE MAIN RESEARCH AND APPLICATION TARGETS.

In our most recent experiments in the Peloponesse area of Hellas we have just established several short-term Solarization experiments to evaluate effectiveness of the method against serious soilborne pathogens. *Fusarium oxysporum* f.sp. *cucumerinum*, Fusarium oxysporum f.sp. radicis cucumerinum, *Fusarium oxysporum* f.sp. *niveum* and *Verticillium. dahliae*. This could be obtained by using IMPERMEABLE PLASTICS AND COMBINING Soil Solarization WITH BACTERIAL ANTAGONISTS ALREADY AVAILABLE in the market or those selected and evaluated in our department.

Chapter 14
BIOFUMIGATION AND ORGANIC AMENDMENTS

A. Bello[(1)], J.A. López[(1)], R. Sanz[(1)], M. Escuer[(1)], J. Herrero[(2)]

SUMMARY

Biofumigation uses volatile substances from the biodegradation of organic amendments and by-product residues as fumigants for the control of soilborne pathogens, that furthermore would solve serious environmental problems which these products can originate. The effectiveness of biofumigation is increased when it is incorporated within an integrated crop management system, prolonging its effect in time through crop rotation and fallow, the use of resistant and tolerant varieties, grafting, solarization, cultural practices in general, biological control agents and low doses of chemical. The possibilities for the development of biofumigation techniques are as diverse as the types of by-products available for the preparation of amendments. Their uses can be limited by the availability of organic amendments and the cost of transportation. Vegetable crops in Valencia, peppers in Murcia, Valencia and Castilla-La Mancha, cucumbers in Madrid, melons and vineyards in Castilla-La Mancha, strawberries in Huelva, tomato and bananas crops in the Canary Islands, fruits and citrus in Valencia and crops in sand-covered soil in various areas, were chosen as integrated production system models where biofumigation is efficient in nematode control.

Keywords: *Meloidogyne*, soilborne, vegetables, methyl bromide, Spain

INTRODUCTION

Organic matter, through its processes of biodegradation, is an alternative to methyl bromide (MB) in the regulation of soilborne pathogens. The biodegredation of organic matter is based on the same principles as fumigants such as MB, the only difference being that instead of releasing synthesized chemical gases, the gases are the result of the decomposition of organic matter, the agroindustrial by-products of soil

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organisms, or those which are found associated with organic matter. This process has been defined as biofumigation (Bello *et al.*, 1996a, 1997a, b, c, d). It is included in the non-chemical alternatives to MB by MBTOC (1997), which emphasizes the concept of biofumigation, applied until now only to isothiocyanate emissions that decompose *Brassica* roots and act as fungicides and insecticides (Kirkegaard *et al.,* 1993; Matthiessen & Kirkegaard, 1993; Angus *et al.,* 1994). On the other hand, to prolong the effect of biofumigation for the duration of the crop, it is necessary to manage the system's key elements, especially plants and the environment, through an integrated crop management (ICM) design, which should take into account the social and economic reality of each area, as well as its particular agroecological characteristics (Rodríguez-Kábana & Canullo, 1992; Bello, 1998).

A wide variety of organic matter has been tested as amendments to the soil to control nematodes, phytoparasitic fungi and weeds. These include cattle manure, residues from the paper and forestry industries, residues from the fish and shellfish industries, numerous by-products from agricultural, food and other industries, as well as residues from plants with allelopatic compounds (Cook & Baker, 1983; Hoitink, 1988; Stirling, 1991; Bello *et al.*, 1996 a, 1997a, b, d). The effectiveness of an organic amendment against nematodes and other soilborne pathogens depends on the chemical composition and physical properties determined by the type of organisms involved in its biodegradation in the soil.

When organic matter is added to the soil, a sequence of microbiological changes is produced, with an initial microbiological proliferation that depends on the sources of energy added. The decomposers serve as a source of nourishment at the same time as they increase the nematophagous fungi and free-living nematodes which in turn increase the number of predator nematodes and microarthropods, omnivorous nematodes, fungi, protozoans, algae and other organisms (López Fando & Bello, 1997). The increase of the microbiological activity produces a rise in the enzyme levels of the soil (Huebner *et al.*, 1983; Canullo *et al.*, 1992).

The action of microorganisms on the organic matter during its decomposition can produce a great quantity of chemical products that aid in the control of soilborne pathogens. Ammonia, nitrates, hydrogen sulfide and a great number of volatile substances and organic acids can produce a direct nematicidal effect on the hatching of the eggs or the mobility of juveniles. Phenols and tannins are nematicides at certain concentrations (Mian & Rodríguez-Kábana, 1982 a,b,c). It is, however, difficult to determine whether a single component is responsible for the high death rate of the nematodes.

Nitrogen is a constituent of almost all the organic matter used to amend soils. The quantity of ammonia produced varies with the levels of N in an organic substrate. A relationship also exists between the contents of N in an amendment and its nematicidal effect. The N content is not the only factor considered when organic matter is used as a nematicide. Carbon is also important, since the metabolization of nitrogen depends on carbon for the microorganisms to convert nitrogen into protein and other compounds. In the absence of carbon sources, ammonia and nitrates can accumulate and may cause phytotoxicity (Culbreath *et al.*, 1985; Rodríguez-Kábana *et al.*, 1987; Stapleton *et al.*, 1989).

Biofumigation treatments can contribute to the control of soil-originated diseases particularly when combined with other alternatives. For example, combining soil amendments with solarization has been studied. This combination offers great potential in the increase of the effectiveness of corrections against pathogens and reduces the necessary quantities of organic matter per hectare (Horiuchi *et al.*, 1982; Ramírez-Villapudua & Munnecke, 1984; Stapleton & de Vay, 1986; Katan & de Vay 1991; Gamliel & Stapleton, 1993; Bello *et al.*, 1998).

The major problem in the use of organic amendments is the heterogeneity in the composition of the matter used for its preparation (Stirling, 1991). The normalization of the composition of the correction, for example, its quality control, is an area of development that requires the appropriate methodology. Some organic corrections have the potential for accumulating harmful compounds and for increasing the level of the inoculum of certain soilborne pathogens (Cook & Baker, 1983; Rodríguez-Kábana, 1986).

BIOFUMIGATION AS AN ALTERNATIVE TO MB IN SPAIN

The European Union (EU) is the second highest consumer of MB in the world, only consuming 26% of the world total in 1992. Spain is the second highest MB consumer in the EU, with a consumption of 4191 t (at present Spain does not use MB in tobacco production). Italy remains the highest consumer with a consumption of 7000 t, of which Sicily alone uses 2000 t in tomato crops (Fig.1). MB consumption in Spain affects less than 10,000 ha and is fundamentally used in vegetable and strawberry crops. Vegetable crops use 55% of Spain's total MB consumption (2265 t), pepper crops consume 29% (1206 t); followed by strawberry crops that consume 33% (1399 t), of which 10% (431 t) corresponds to nurseries. Cut flower crops consume 9% (393 t) of MB, and only 3% (134 t) is used in replanting citrus, raspberry and others (Bello, 1997; Bello & Tello, 1998) (Fig. 2).

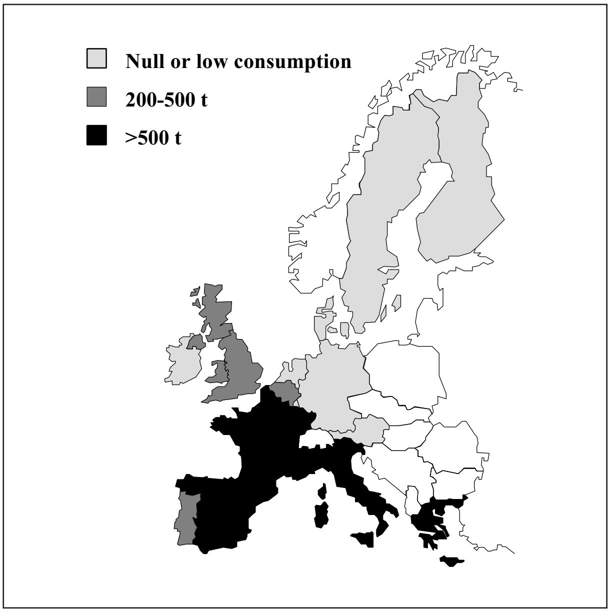

Figure 1. MB consumption in the EU

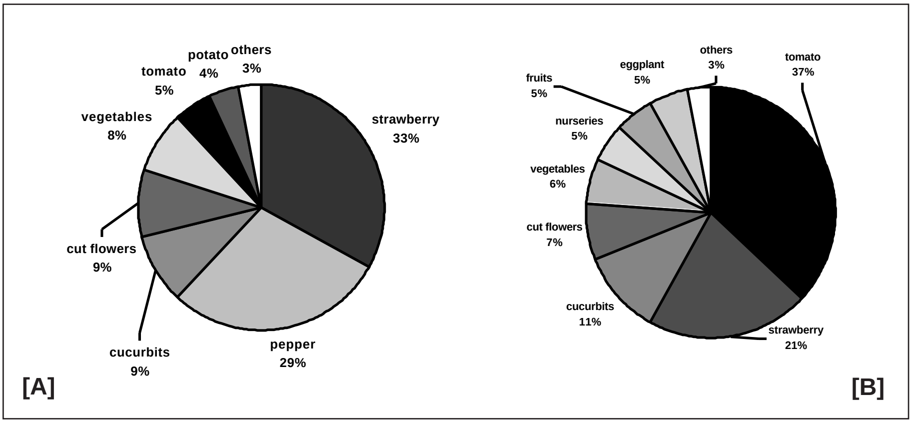

Figure 2. MB crops consumption in Spain [A] and EU [B]

The development of biofumigation and integrated crop management techniques began with the study of the effectiveness of biofumigation in vegetable crops in El Perelló at La Albufera (Valencia). The technique was optimized for tomato and banana crops in the Canary Islands, for the traditional systems of organic matter management in the crops of Castilla-La Mancha (grapes and melon), for citrus and other fruit crops in Valencia, for the sand-covered soils of Lanzarote, Almería and Cádiz (Bello *et al.*, 1996a, 1997c; Bello, 1998), for pepper crops in Murcia, Valencia and Castilla-La Mancha (Bello *et al.*, 1997a), and for cucumber crops in Madrid (Sanz *et al.*, 1998).

VEGETABLE CROPS IN EL PERELLÓ (LA ALBUFERA, VALENCIA)

Among the pathogenic organisms, parasitic plant nematodes (*Meloidogyne incognita)* have a great economic repercussion. By limiting the cultivation of certain plants they make the application of nematicides necessary. It has been determined that the nematode population starts to increase in April-May, continuing this trend until the temperature begins to drop in October-November (Fig. 3). Nematode population growth is intensified during the summer months, resulting from a rupture produced in the resistance of the cultivars with the *Mi* gene by temperatures higher than 27°C.

The dynamics of *M. incognita* was studied in 10 tunnels (835 m^2 each). Since August 7, 1995, samples were taken in tunnel T3 once a month at 6 spots at three depths (0-15, 15-30 and > 30 cm), until July 31, 1996.

The evolution of the populations of *M. incognita* in the T3 tunnel is shown in Fig. 3, with an average initial population of 325 J_2 / 100 cc. After the application of sheep manure (4 t / 835 m^2) with a C/N proportion 19.3, the initial population is rapidly reduced to 21.9 J_2 / 100 cc. After flooding, the population is further reduced to 0.5 J_2 / 100 cc. This is because the initial populations were controlled during the months of September and October by the application of manure (biofumigation). Low populations were maintained from October until the month of April (six months), through the trap effect of the consecutive fast crops: chrysanthemum, yellow flower (Flowering cabbage, *Brassica parachinensis*) and white flower (Chinese kale, *B. parachinensis*). Nematode populations do not increase in these conditions for two reasons as follows: firsty, nematode life cycles exeed the two month time span for crop rotation; secondly, the temperature remains below 20°C (fig. 3), limiting reproduction.

At the end of cropping during the first week of August, five rows of CV Nikita tomato plants were sampled at random, after eliminating the two side rows, by collecting four plants per row from the beginning, center and end of the tunnel, resulting in 20 plants with a rate of 0. This confirmed our results on the value of the CV Nikita as being resistant to nematodes and not having a break in resistance due to high temperatures or selection of new aggressive races.

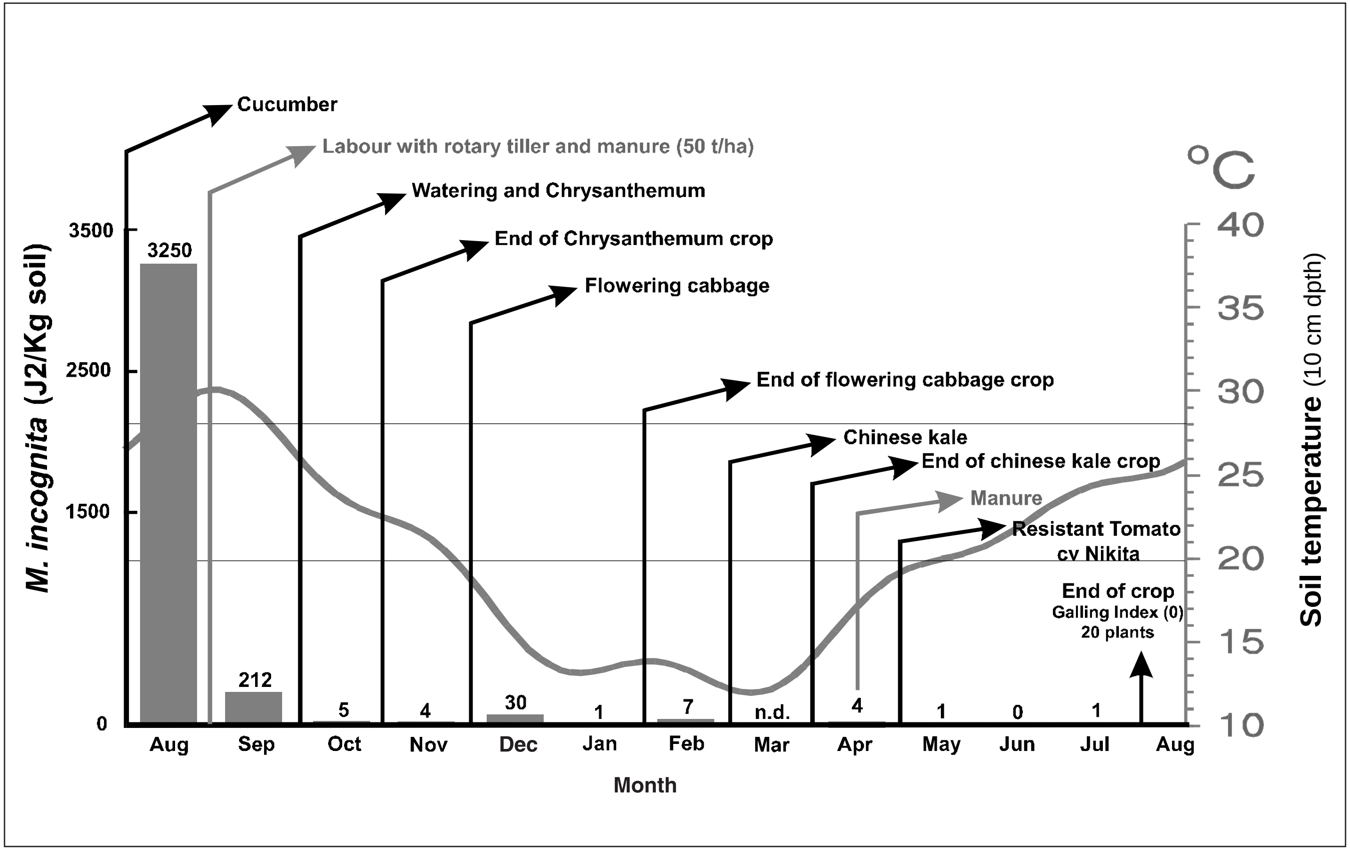

Figure 3. Population of *M. incognita*, crops, tillage and soil temperatures in Tunnel 3, El Perelló (Bello *et al.*, 1996a)

Table 1. Biofumigation results in vegetable crops at El Perelló, Valencia

	Rotations[1]				
Tunnel	**1993-94**	**1994-95**	**1995-96**	**1996-97**	**1997-98**
T1	YF-EC-RC-YF-CU	SP-YF-WFB-CH-CU	CE-YF-EC-NT	CH-WF-CU	CH-WF-PM
T2	PL	YF-SP-CU	WF-RC-EC-NT	WFB-RC-CU	WF-YF-PL
T3	PL	EC-YF-CU	CR-YF-WF-NT	WFB-YF-CU	YF-CH-NT
T4	EC-YF-CH-CHCU	YF-GF-YF-CU	YF-CH-YF-NT	SP-YF-CU	EC-YF-GT
T5	YF-GC-SP-YF-CU	LC-YF-GC-CU	YF-EC-GC-CU	YF-CH-RC-CU	WF-DT-+N
T6	SP-YF-CU	EC-RC-NT	EC-WF-NT	YF-SP-YF-NT	WFB-CU
T7	CH-EC-YF-VT	YF-CH-YA-EC-NT	SP-EC-CU	EC-YF-NT	WFB-EC-CU
MA1	WFB-WF-CSP	WFB-YF-NT	RC-YF-CH-CU	RC-EC-YF-NT	EC-YF-WF-CU
MA2	RC-YF-EC-CSP	RC-SP-NT	WFB-EC-CU	RC-GC-CH-NT	CE-YF-CU
T8	CE-RC-BM	CE-CH-NT	GC-WFB-CU	GC-YF-EC-NT	SP-EC-GC-CU

Treatment and root-knot index[4]

Tunnel	1993-94	1994-95	1995-96		1996-97		1997-98	
T1	—-	ethoprophos	Sanimul (May 1) [2]	0	Biofumigation	0.3	Biofumigation	1.9
T2	—-	"	Sanimul (May 1)	0	"	1.0	"	1.6
T3	MB	"	Manure (April 15) [3]	0	"	0.7	"	0
T4	—-	"	Sanimul (March 15)	1	"	0.4	"	0
T5	—-	"	Sanimul (March 15)	2	"	0	"	0
T6	—-	"	Sanimul (April 15)	0	"	0	"	0
T7	—-	"	Manure (March 15)	1	"	0	"	0
MA1	—-	"	Sanimul (April 15)	1	"	0	"	0
MA2	—-	"	Sanimul (April 15)	1	"	0	"	0
T8	—-	"	Manure (May 1)	1	"	0	"	0.2

(1) BM: bitter melon (*Momordica charantia)*; CE: celery (*Apium graveolens*), CH: chrysanthemum, CHCU: Chinese cucumber (*Benincasa hispida)*; CSP: Ceylon spinach (*Brassica rubra CV. alba);* CU: cucumber, DT+N: Durita tomato with *Mi* gen, EC: English chard (*Brassica chinensis)*, GC: green chard (*B. chinensis*), GT: Gabriela tomato, NT: Nikita tomato, LC: Long cabbage (*B.juncea*), PL: pepper var Lipari, PM: pepper var.Mariner, RC: round cabbage (*B. juncea*), SP: spinach, WF: white flower (*B. parachinensis*), WFB: white flower buds, YF: yellow flower (*B. parachinensis*); (2) 6 kg/835 m^2; (3) 4 t/835 m^2; mainly mushroom compost, (4) Bridges & Pages (1980).

In the remaining tunnels nematode populations were surveyed each month (Table 1). At the end of cropping 20 plants in 5 rows were sampled, distributed at random, 4 per row, after eliminating the side rows. Rates of pathogenicity were applied from 1 to 10, which have been establish by Bridge & Page (1980). A rate of 0 was found in all the tunnels of CV Nikita tomatoes (T1, T2, T3, T4 and T6). Tunnels where cucumbers were grown (T7, MA1, MA2, T8), demonstrated a rate of 1, with the exception of T5, that demonstrated a rate of 2, where the cucumber crop was repeated from the previous year. The problems with *M. incognita* that showed up in cucumbers were localized in a focus at the edge of the tunnel, not surpassing a rate of 3, depending on the orientation of the tunnel.

Biofumigation alone was applied during the 1996-97 and 1997-98 crop seasons, with no phytopathological problem appearing throughout the year. At the end of cultivation in the month of July, an index of only 1 showed up in the tunnels with cucumber crops. In the remaining tunnels where the Nikita variety of tomato was grown, the index was 0, even in the T5 tunnel (1996-97 season) where cucumber was grown for four consecutive years. Table 2 shows biofumigation effects on vegetable yields by type of crop and by crop season, as well as the soil pesticide costs. Production increased by about two-fold in tomato and cucurbit production and the consumption of oil pesticides was null.

Table 2. Yield of vegetable crops at El Perelló, Valencia (kg m^{-2})

Crops	1993-94	1994-95	1995-96 (1)	1996-97 (1)	1997-98 (1)
Chinese vegetable	2.7	2.6	2.5	2.5	2.2
Tomato	3.9	3.7	5.3	5.2	9.8
Cucurbits (2)	5.2	6.6	8.0	10.5	8.4
Pepper var.Lipari	4.4	—	—	—	5.2
Pepper var Mariner	—	—	—	—	2.0
Soil pesticides Cost (ptas)	14030 (3)	21974 (4)	15853 (5)	0	0

(1) Biofumigation; (2) mainly cucumber; (3) MB in tunnel 3; (4) ethoprophos in all tunnels; (5) ethoprophos in seven tunnels.

PEPPER CROPS IN MURCIA, VALENCIA AND CASTILLA-LA MANCHA

World consumption of MB for pepper crops is about 5,104 t, which composes 10% of the total consumption. Peppers follow closely behind cucurbits (11%), strawberries (20%), tomatoes (35%). MB consumption in Spain has reached about 1,206 t (21.5% of total world consumption) The highest users are Murcia (683 t), Alicante (311 t) and Almería (208 t). According to data from the MAPA memorandum (1997) 2,300 ha of pepper crops in greenhouses are fumigated with MB, which is 30% of the cultivated surface, 1,400 ha at Almería, and 800 ha in Murcia. In Almería, peppers are cultivated in rotation with melon crops and in the “Campo de Cartagena” in Murcia they are grown as a monoculture (Varés, 1998). Concerning the use of MB, pepper crops have been included among the horticultural crops. Even in the alternatives of MBTOC (1997), it is included with tomato, since both are solanaceous plants, making it difficult to know what alternatives correspond to pepper crops.

The dynamics of the populations of *M.incognita* with respect to biofumigation techniques involving the application of organic matter, are studied at San Javier (Murcia), on the outskirts of La Albufera (Valencia), and at Castilla-La Mancha. The study has pointed out interesting biofumigation based on the application of organic matter as an alternative to MB for soil fumigation. In addition, our laboratory has received results on the fumigant action of pepper residues on *M.incognita.* Previously, Marull *et al.* (1997) reported the effectiveness of the composted urban residues from Barcelona, at 33% and 66% doses and olive pomace at 1% and 2 % doses in decreasing *M.javanica* populations in pepper crops from Bajo Llobregat (Barcelona). The control of nematodes appears to be related to the esterase activity, which is lower in MB fumigated soils. Kim *et al.* (1996 a, b) used compost as soil amendment in the control of *Phythophtora* pepper stem rot in greenhouses.

Campo de Cartagena (Murcia). Five greenhouses with peppers were studied in the locality of San Javier. A sampling was carried out on August 4th in five greenhouses (I, IV, V, VI and D-IV) at three different depths (0-20, 20-40 and >40 cm). A serious infestation of *M.incognita* was found in all of them, with populations reaching 156,600 J_2 kg^{-1} soil. To control the nematodes, greenhouse IV was ploughed in early June and 10 kg m^{-2} of manure without plastic or irrigation were applied, and one sample at each of the depths were taken on September 29, 1997. In greenhouse VI manure was applied at the dose of 6 kg m^{-2}, covering it with a plastic sheet and watering it on the 25th of August 1997. Samples were taken on 9-29-97 in the same way as in the greenhouse IV. Greenhouse D-IV was irrigated and covered with a plastic sheet on

8-30-97 and, samples were also taken on 9-29-97 at one point at each depth level. Samples in the three greenhouses did not reveal the presence of *Meloidogyne* spp. In greenhouse I manure was applied at 10 kg m $^{-2}$ and covered with a plastic sheet without watering. Although in the sampling done on 9-29-97, the soil was wet, an average of 14 J_2 kg^{-1} soil was found.

In greenhouse V four treatments were done, and in the sampling on 9-20-97 the average of *Meloidogyne* juveniles was low (19 J_2 kg^{-1} soil) where manure, irrigated and covered with a plastic sheet have been applied. There was no difference between it and the plot where pepper residues had been added, in which the average nematode population at a depth of 0-20 cm was only 4 J_2 kg^{-1} soil. The following treatment was with crop residues, with an average of 28 J_2 kg_{-1} soil, and the final treatment was with manure that was irrigated which had 54 J_2 kg^{-1} soil. In all of these treatments, results are far from the 61,350 J_2 kg^{-1} soil of the August, 4 1997 samplings. A new sampling was taken the 11-22-97, two months later, to follow the evolution of the *Meloidogyme* population. Only one sample reached 68 J_2 kg^{-1} soil, where uncovered manure was applied. Some 100 g of that sample was used to cultivate tomato var. *Marmande,* sensitive to *M.incognita, o*n a 500 g pot. The number of knots was determined after 44 days, proving that the highest efficacy is with the combination of manure with pepper crop residues (index 2.2), followed by soil with pepper crop residues (3.7). In two other treatments there are similar results (4.2), but neither treatment reaches an index of 5. The lower indices correspond to the samples taken in levels deeper than 40 cm. Most of the nematodes in all the treatments appear parasitized by *Pasteuria penetrans*.

La Albufera (Valencia). Three experiments were designed in pepper crop. In the first one the residues of crop pepper were used in two tunnels irrigated and covered with plastic. In tunnel II the reduction of *M.incognita* was total, while in tunnel I biofumigation was efficient at three points, with an average of 2,007 J_2 kg^{-1} soil being the maximum population level in the samples deeper than 40 cm, a fact that allows us to demonstrate the inefficiency of solarization to control nematodes of the *Meloidogyne* genus, because they move to deeper horizons. In the second experiment 7 kg m^{-2} of sheep manure was mixed with spent *Pleurotus* sp mushroom compost. The biofumigation effect was total also in the control of *M.incognita* either with or without covering the soil with plastic. The yield was 4.3 kg m^{-2} of red pepper and 6.4 3 kg m^{-2} of green pepper. In the third experiment 6 kg of sheep and chicken manure at 1:1 proportion were applied. Biofumigation did not work in only one point 4A (1,420 J_2 kg-1 of soil).

Castilla-La Mancha. Pepper crops for fresh consumption has a long tradition in the Autonomous Community of Castilla – La Mancha. The total cultivated surface is 2,157 ha. Ciudad Real is the province with the greatest surface area: 832 ha. The average yield is 17,500 kg ha^{-1}. Toledo has the highest yield with 22,629 kg ha^{-1}. Traditionally pepper crops are grown in rotation followed by melon and cereals. Seedbed sowing is done at the end of February or beginning of March to transplant in mid-May. The basic fertilization is done with a mixture of sheep and chicken manure at a 1:1 proportion and at a dose of 20 t ha^{-1},spread over the entire surface, which is 15 t ha^{-1} if it is applied in deep furrows. The result of this procedure is not only fertilization, but biofumigation as well (Sanz *et al*., 1998). As basic mineral fertilization, 400 kg of the compound 9-18-27 were applied during the growing cycle. Five hundred to six hundred kg of ammonium nitrate was also applied in addition to 300-400 kg of potassium nitrate and 150 kg of magnesium sulfate. Harvest starts in August and finishes at the end of October depending on climatic conditions.

On the other hand, looking for an alternative crop to corn, a trial of one ha was planted with paprika pepper in Fuensanta (Albacete). An area in the middle of a corn field was infested by *M.incognita,* and 100 t ha^{-1} of sheep manure was used for its control. Irrigation and fertilization were done at the same time as for the corn. The transplant was been done on May 27 and harvest in the mid-October. Yield was 25,000 kg ha^{-1}, but in the biofumigated area production was higher than in the rest of the plot, the highest nematode infection level was index 2 (Wridge & Page, 1980) at the end of harvest.

Experimental study of biofumigant effect of pepper crop residues. A sample of Campo de Cartagena soil with a high population of *M.incognita* was used. Ten g of fresh pepper leaves and 10 g of pepper fruit were added to 500 g of soil, which was mixed, introduced into a plastic bag, and moistened. The plastic bag was closed and placed in a chamber at 30 ºC for a week. The population was reduced by 99%. As a control five repetitions were made with five other bags of 500 g soil without crop residues.

The second experiment was completed out with soil from Mareny de Barraquetes (Valencia), with an average *M.incognita* population of 15,047 J_2 kg^{-1} . Ten pots were prepared with 500 g soil in each, with five pots used as a control and five pots of soil were mixed with 20 g of green minced pepper plants. Sensitive tomato CV Marmende was planted in all pots on 12-12-96. The plants were uprooted after two months (2-5-97). In the biofumigated pots the root-knot index was 4, while in the control it was 8.2.

CUCUMBER IN VILLA DEL PRADO (MADRID)

The studies on cucumbers were done in a greenhouse where the rotated crops were Swiss chard (autumn-winter) and cucumbers (spring-summer), where treatment with MB had not been done, and where there was a substantial *Meloidogyne incognita* infestation. Studies started with Swiss Chard the winter crop. In order to determine the state of the plot, the roots of Swiss chard plants were examined one by one at the time of their removal and the indices of infestation were established for *M. incognita* based on those on Bridge & Page (1980) for tomato. Once the crop residues of the Swiss chard were plowed under, the customary treatments of the area were carried out in the entire greenhouse, meaning the addition of 5 kg m^{-2} of overdone cow manure was later well-mixed with the soil. Then 12 plots were chosen of 52 m^2 and three repetitions were carried out with each one of the following alternatives: 60 g m^{-2} of MB, 0.09 l m^{-2} of metam sodium and 5 kg m^{-2} of mushroom compost on the corresponding plots (three plots per treatment). The plots were covered for twenty days with a sheet of polyethylene (220 µm thick). Later cucumber seedlings were planted (CV *Serena*).

The production of each plot was measured from the beginning, from May to the beginning of August, to compare the possible differences in the effectiveness of each treatment. It was observed that in the early stages of cultivation, the differences were minimal but they increased in the later stages of the crop. A failure occurred in the watering of two plots, one control and one compost plot, so that of the three repetitions only two were analyzed. Results are shown on Fig. 4.

Upon crop removal, the roots were likewise examined, following the indexes established by Bridge & Page (1980) and taking plants at random from each plot. It was observed that the highest indexes were found at the border of the greenhouse and more so at the northern border, but the differences among the various plots were not significant.

STRAWBERRY CROPS IN HUELVA

Spain supplies more than 10% of the total world production of strawberry and it is the source of nearly all EU strawberry production during the first months of the year. Huelva is the main strawberry producing area in Europe with more than 6,000 ha in monoculture. During 1994, the production was 282,183 t on a surface of 9,000 ha, of which about 1,000 ha were dedicated to nurseries (Romero, 1999). The use of MB

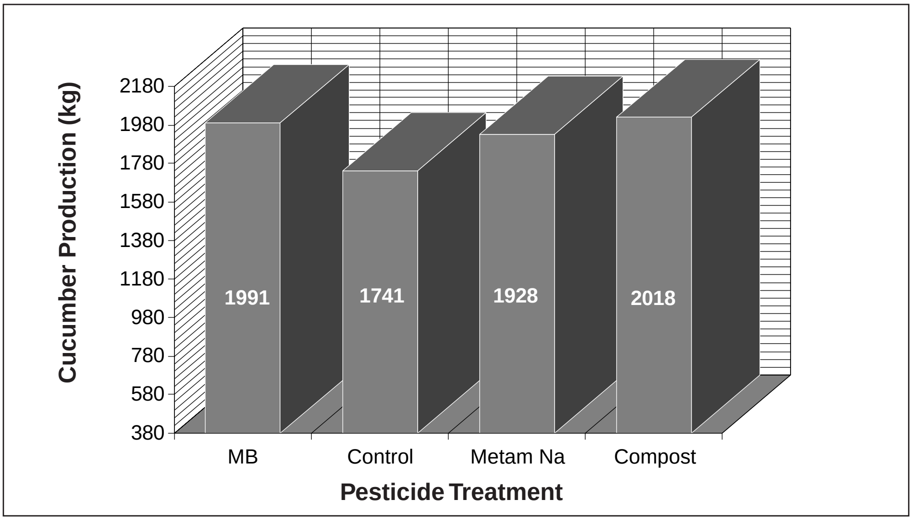

Figure 4. Average cucumber production (kg) (Sanz *et al.*, 1998)

in strawberry was 1,399 t (33% of the total consumption in Spain), including 431 t in nurseries, mainly in Castilla y León. Huelva is the province with the highest consumption (897 t) followed by Barcelona (52 t) and Valencia.

An experiment was begun combining biofumigation (using 5 kg m^{-2} of mushroom compost) plus one month of solarization in August 1997, in a field treated with MB in the previous years which have low populations of *M.hapla*. From six samples taken on 7-15-97 at two depths (0-20 cm and 20-40 cm) four were positive with an average of one to two J_2 100 cc^{-1}. Lateron (7-25-97) from three samples taken at a depth of 0-20 cm only one was positive with 26 J_2 100 cc^{-1}. On September 27, after biofumigation, another sampling was taken from which 10 out of 18 samples were positive with populations not higher than 28 J_2 100 cc^{-1}. Averages at the 0-20 cm depth were 20 J_2 100 cc^{-1}, and 2 J_2 100 cc^{-1} at a depth of 20-40 cm (Table 3). In the experimental test with sensitive tomato CV Marmande, only five samples were positive, with indices of 1-2 (Bridge & Page, 1980). Low populations were also found of the endoparasitic nematode, *Pratylenchus penetrans*, that may be important to the development of a disease complex produced by fungi and other pathogenic organisms in strawberry. Two virus vector nematodes (Trichodorids) were also found and very low populations of saprophagous, predators and omnivorous organisms. Nematode analyses at the end of the harvest (6-10-98) showed a population increase with an average of 43 J_2 100 cc^{-1} soil at a depth of 0-20 cm and 9 J_2 100 cc^{-1} soil at a depth of

Table 3. Results of biofumigation in strawberry. Cartaya (Huelva) (indiv./100 cc) (25 September 1997)

Sample	*Meloidogyne* J_2	Index. experiment	*Pratylenchus*	Rabditids	Dorilaimids	*Tylenchus*	Mononch.	Trichodorids	Enquitre.
0 -20 cm									
F1.A1(20606)	10	2	0	106	2	20	0	2	12
F1.A2(20608)	28	2	0	44	0	0	0	6	4
F1.A3(20610)	0	1	0	32	10	4	0	6	0
F2.A1(20612)	0	0	2	42	10	6	0	10	14
F2.A2(20614)	20	0	0	0	6	10	0	0	4
F2.A3(20616)	6	0	0	44	10	0	0	17	0
F3.A1(20618)	0	0	0	30	0	0	0	0	4
F3.A2(20620)	28	0	0	48	14	0	4	0	0
F3.A3(20622)	0	0	0	20	4	0	0	0	0
Average	**10**	**0.6**	**0.2**	**41**	**6**	**4**	**0.4**	**5**	**4**
20-40 cm									
F1.B1(20607)	6	2	0	58	4	0	2	0	0
F1.B2(20609)	2	2	0	0	4	0	0	0	2
F1.B3(20611)	4	0	0	60	4	0	0	0	0
F2.B1(20613)	0	0	2	40	18	0	0	1	10
F2.B2(20615)	8	0	2	48	6	0	0	6	0
F2.B3(20617)	0	0	0	38	0	0	2	15	0
F3.B1(20619)	0	0	0	12	2	0	0	2	12
F3.B2(20621)	0	0	0	22	4	0	0	0	0
F3.B3(20623)	2	0	0	2	0	0	0	0	0
Average	**2**	**0.5**	**0.4**	**31**	**5**	**0**	**0.4**	**2.5**	**3**

Table 4. Results of strawberry biofumigation with mushroom compost (5kg m^{-2}) to control *Meloidogyne hapla* in Cartaya, Huelva (J_2 / 100 cc)

Plots	Initial population (15-7-97)		Final population (10-6-98)		one plant
	0-20cm	20-40cm	0-20cm	20-40cm	
F1	3	0	98	22	134
F2	1	3	24	6	93
F3	1	0	6	0	16
Total	5	3	128	28	243
Average	**2**	**1**	**43**	**9**	**81**

20-40 cm, the highest populations (134 J_2 100 cc^{-1} soil) being around the root system (Table 4). It may be concluded that when MB is phased out, root-knot nematode populations will increase.

In order to determine the future risks of infestations by *M.hapla*, a temperate species which is able to develop in the winter, an experimental test was carried out to determine its life cycle at 17 ºC. It was found that Huelva populations complete their life cycle in three months, so it can be concluded that in normal temperature conditions, only two generations can be completed from November to April. Problems can appear in May which is when the harvest concludes. Therefore, the importance of biofumigation to reduce nematode populations at the time of planting should be emphasized. Also, the last crop of the year should be picked in June, taking care to eliminate crop residues, mainly roots. This technique will contribute to an inoculum reduction, avoiding the passage of juveniles from the roots to the soil and consequently the fulfillment of their life cycle. Any increase in the duration of the harvest may influence the crop yield, especially in the final months of the crop, and over all for the following year's production for biannual crops.

To avoid the transportation cost for compost, an experimental test with local chicken manure was conducted. The results of a dose of 5 kg m^{-2} (10 g 500 g^{-1}) are shown in Table 5, where we can observe a 89% decrease in population with a 48% increase of saprophagous nematodes, not affecting dorilaimids. To confirm this result and determine the phytotoxic effect of chicken manure on the crop, a sensitive tomato *CV* Marmande was cultivated on 400 g of the rest of the biofumigated soil, with four replicates and two controls. It was found that one replicate with biofumigated soil

Table 5. Results of five days experimental biofumigation with chicken manure (10 g/ 500 g soil) on strawberry soil to control *M. hapla* (J_2 / *100 cc)*

Replicates	M.hapla	Rhabditids	Dorilaimids
Control			
1	42	22	18
2	10	18	24
3	62	28	6
4	32	28	10
Total	146	96	58
Average	**36**	**24**	**14**
Biofumigated			
1	4	70	14
2	4	34	4
3	6	28	8
4	4	54	20
Total	18	186	46
Average	**4**	**46**	**11**
Observations	89%controlled	48% increase	no effect

presented index of 5 and the other three, an index of 4. In one of the controls, the plants died and the other indicated an index of 9. It may be concluded that chicken manure has a biofumigant effect although its effectiveness could be increased with the mixture of another kind of organic amendments.

Finally, in order to determine the sanitary conditions of strawberry nurseries in Castilla y León, a sampling was taken on 8-5-98. Seventeen samples of six fields were studied and no phytoparasitic nematodes were found. Saprophagous populations were very low, only four of them surpassing 200 individuals $100cc^{-1}$. No dorilaimids were found.

TOMATO CROPS IN THE CANARY ISLANDS

The Canaries represent the principal area for tomato production in winter in the EU. With some 4830 ha cultivated and a production of 413014 t in 1994, it is one of the regions of Spain with the highest yield in crops under cover (96 t ha^{-1}) (MAPA, 1996). The Canaries have an average temperature of over 20 ºC for more than 7 months a year, which permits up to 7 generations of the thermophile species of the *Meloidogyne* genus to develop. Therefore, the Canary Islands is possibly one of the areas of greatest risk for these nematodes in the world.

During the study of the agricultural techniques used by the Canarian farmers in tomato crops, we found that one of the principal factors was the planting of crops during the autumn-winter period with a prolonged fallow in spring-summer, together with the adjustment of planting time in relation to the altitude. Planting begins in the month of August in the highest area (400 m), continuing through the areas at 250 m later in September, and in the coastal areas between October and November. By means of this tomato planting time- schedule, reduction of the periods of optimum temperature for the development of the thermophile species of the genus *Meloidogyne* during cultivation is achieved, decreasing the number of generations and therefore their negative effects on production and reducing the risk of a break in resistance due to the effect of high temperature. A second component of the system is the use of chemical fumigants before planting such as 1,3-D and metam sodium as an alternative to MB, followed in some cases by applications of conventional pesticides during cropping, principally nematicides. Other practices are the exploitation of the fumigant action of organic amendments, which have verified as effective for the control of nematodes.

On July 1, 1996, 100 t ha^{-1} of manure was applied in the field. A portion of the treated area was covered with 200 gauge plastic sheets, another maintained without plastic and the third was left untreated but covered with plastic as a control group. Samples were taken on July 14th at four depths: A (0-15 cm), B (15-30 cm), C (30-40 cm), and D (> 40 cm). The controlling effect of biofumigation at 15 days on root-knot nematodes at depth levels A and B (up to 30 cm) is 100% when a plastic covering is used, reaching 62% at depth C (30-40 cm) and 58% at depth D (> 40 cm). Where plastic was not used, an effectiveness of 100% was observed on the A horizon (0-15 cm), while on B (15-30 cm) it is of 95%, and at C (30-40 cm) and D (> 40 cm) the effectiveness is superior to 87%.

The next step, once the biofumigant effect was confirmed, was to determine the quantity of manure and the time the plastic must remain in place. On November 15, 1996, an experiment commenced with doses of 90, 60 and 40 t/ha of manure. Samples were taken at 0-20, 20-40, and >40 cm, and at 90 t ha-1. There was 100% effectiveness to 20 cm in depth, and 99.6% at over 40 cm; at 60 t/ha results were 100% positive to 20 cm; and superior to 98% for over 20 cm; for 40 t ha^{-1} effectiveness was

99.4% to 20 cm; 98.6% between 20-40 cm; and 96.2 % over 40 cm. Final evaluation was made on May 2nd at the end of cultivation, with the Bridge & Page (1980) root-knot index scale and the results obtained are shown on Table 6. According to Table 6 an effective dosages is around 50 t ha^{-1}, and its biofumigant effect can be optimized by using plastic coverings and even by making applications on the ridges where planting will be done, by which means the dosages can be reduced by more than half (25 t ha^{-1}).

Table 6. Effectiveness of doses of manure and the means of application

		Root-knot indices	
Doses of manure	**No. of plants**	**Maximum**	**Average**
100 t ha^{-1}, with plastic	55	5	2.5
100 t ha^{-1}, with plastic *	64	4	1.9
100 t ha^{-1} without plastic	59	7	3.8
90 t ha^{-1} with plastic	70	6	3.5
60 t ha-1 with plastic	59	6	3.6
40 t ha-1 with plastic	76	7	4.5

(*) 30 days, the rest 15 days.

The use of varieties that incorporate the *Mi* gene and which confer resistance to nematodes are only resistant under 27 ºC in the soil. Nevertheless, we have observed that in crops planted on substrates based on volcanic ash (pumice or “jables”), breaks in resistance are not observed due to its low thermal conductivity. Among biological control agents, the actinomycete *Pasteuria penetrans* stands out, which parasitizes root-knot nematodes, suppressing their reproduction. We have found this hyperparasite in tomato crops in southern Tenerife, parasitizing *M. incognita* and *M. javanica* females, which may be contributing to the suppression of problems caused by nematodes.

BANANA IN THE CANARY ISLANDS

In the last few years, with plants obtained “in vitro,” the banana plant can be replaced for each crop, leaving an alley between the rows where fallow is practiced. At the end of cropping the entire biomass from the previous crop is buried and mixed with the organic matter, and the new crop is established in the alleys.

This study is centered on the analysis of the suppressing effect of the organic matter and of the remains from the previous crop on phytoparasitic nematodes, based on its use as a biofumigant. A farm was selected where the organic matter and the waste from the previous crop had been buried in the month of December and planting was done in February. Sampling was done on March 25, 1996 (one month after planting) and on June 3, 1996 (five months later).

In the March samples (3-25-96), the root-knot nematode populations (*Meloidogyne javanica*) were 0, proving biofumigation to be more effective than the most potent nematicide. In the June samples (four months later) the biofumigant effect of the organic matter was still maintained. The biofumigant action, since the organic matter is not uniformly applied, presents only very localized phytonematological problems in focal points such as in sample number 17761 with 38 J_2 / 100cc. Two species were present, *M. incognita* and *M. javanica*.

The biofumigant effect ought to be maintained over a period of time by the regulation of soil temperature with coverings of pine needles or of vegetable waste from the banana plants themselves. The dynamics of temperature have been studied throughout the year, temperature in wintertime being found higher in the covered soils, and the reverse in springtime and summer. The bearing of fruit begins in June, when the suppressing effect on the pathogens also takes place. Since the roots are not functional and sugars are being accumulated in the fruit, the plant exercises suppressive effects on the nematodes.

There was an abundance of *Pasteuria penetrans*, an actinomycete that is of interest for biological control of root-knot nematodes, which are pests that appear consistently in old banana orchards. At first the possible influence on this antagonist of the purified municipal waste water used for watering was considered, and of the agrochemicals applied to the soil, as well as its frequency of occurrence in the land. The organism is widely distributed from Arico to Santiago del Teide (Tenerife), in banana plants as well as in tomatoes. A noteworthy function in the biological control of nematodes is that it does not seem to be affected by the action of fertilizers, biocides applied to the soil, or the use of purified municipal waste water.

BIOFUMIGATION IN FRUIT AND CITRUS TREES (VALENCIA)

MB is applied in fruit and citrus trees to solve replant problems, which represents one of the lowest percentages of MB consumption in the world (5%). In

Spain only 127 t MB (3% of the Spanish consumption) was used for citrus replants, tobacco and raspberry (Bello, 1997). In the Mediterranean region 1447 t is consumed for fruit trees (5.9%), 909 t for vineyards (3.8%), 740 t for nurseries (3.1%), and 40 t. for citrus trees (0.2%). California USA is in the lead with 1197 t for fruit trees and 909 t for vineyards (Bello & Tello, 1997).

An experiment with soil biofumigation in recently uprooted orange trees in the vicinity of Alcira (Valencia) was established, by applying 25 t ha^{-1} of solid urban waste +600 kg urea and covering it with plastic for 74 days. The nematodes collected in the May samples at the end of biofumigation were immobile and twisted, with an almost total elimination of the *T. semipenetrans* juveniles being observed in the December surveys. In some spots the presence of nematodes exists, which is explained by the low quantity of compost used (25 t ha^{-1}) and above all by the low effectiveness of urban waste as a biofumigant. Similar biofumigation experiments were conducted in soils from peach orchards affected by *Meloidogyne incognita*, with highly positive results obtained in relation to the solution of replant problems (Escuer *et al.*,1998).

In this area, citrus are frequently in long-term rotation with fruit trees (*Prunus* spp.) and vegetables, which is considered to be an effective practice for solving nematode problems. Those caused to citrus by the citrus nematode (*T. semipenetrans*) do not affect fruit trees or vegetables, while the root-knot nematodes affecting fruit trees and vegetables do not harm citrus trees.

CROPS IN SAND-COVERED SOIL

This type of technique is used for vegetable crops on the island of Lanzarote (Canary Islands), Almería, Murcia and Cádiz. It is based on placing a layer of manure which acts as a biofumigant, and a layer of sand that was previously solarized, which acts as a support for the crop. In these systems MB is not being used, although its effectiveness varies with the thickness of the layer of sand and the quality of the manure used (Bello, 1998; Tello, 1998).

IMPROVEMENT OF BIOFUMIGATION

The use of organic matter is a very complex item, and much experience and technological help to farmers is necessary due to its variability. The use of organic amendments as biofumigants depends on the composition and the organisms involved in their biodegradation. They can accumulate contaminant compounds such as heavy metals or plant pathogen inocula and also they may produce phytotoxic effects. Another side effect is the environmental impact of the plastic used to trap the gasses produced in their decomposition. Conversely, their use is limited by availability and transportation cost. It is necessary to design methodologies for phytosanitary and agronomic characterization of the materials to be used, as well as to develop the correct techniques for their application in the field.

To solve the problems that have appeared due to the use of biofumigation different species of brassicas have been used as bioindicators of its effectiveness. Much data exists on the value of these plants in biofumigation (Gamliel & Stapleton, 1993; Kirkegaard *et al.*, 1993; Angus *et al.*, 1994; Ramírez-Villapudua & Munnecke, 1984). The principal reasons for selecting these plants are: the cost of seed is low, sowing has no technical problems, except the need for abundant irrigation, germination is produced in a few days, they are good indicators of the organic matter's phytotoxic substances, they grow fast, and they are very sensitive to root-knot nematodes so they may act as traps and increase the biodiversity when brassicas are incorporated to soil.

In laboratory experiments their great sensibility to root-knot nematodes (*Meloigogyne*) and their biofumigant effect was proved. They also increased saprophagous nematode populations, without affecting dorilaimids, which are sensitive to phytotoxic substances (Table 7). In field experiments in the Valencia Region the effectiveness of this technique has been confirmed which is available to technicians and farmers, allowing them to know the dynamics of the pathogenic nematode populations and the effectiveness of biofumigation without the need of specialized laboratories or sophisticated techniques.

Problems caused by using plastic to trap the gasses released by the biodegradation of organic matter in the soil will be solved by not using plastics which are high in cost and detrimental to the environment. Instead, a roller will go over the field and the soil will be kept wet while biofumigation occurs. This alternative will be especially efficient in clay soils. Problems related to the quality of organic matter for biofumigation depend mainly on an adequate mixture that reaches a C/N relationship of 8 to 20. Farmers may easily determine the biofumigant quality of a by-product by its strong odor of ammonia.

Table 7. Results of 23 days biofumigation with turnip leaves in laboratory (10 g/ 500 g soil), indiv./100 cc

Samples	*M.incognita* (J_2)			Rhabditids	Dorilaimids
	Dead	Alive	Index(1)		
Biofumigation					
1	72	0	2	94	0
2	16	2	1	172	6
3	14	0	2	50	4
4	34	0	3	208	0
Total	136	2	8	520	10
Average	**34**	**0.5**	**2**	**130**	**2.5**
Control					
1	8	52	6	16	4
2	4	72	6	22	6
3	6	38	6	32	4
4	4	24	6	26	0
Total	22	186	24	96	14
Average	**5.5**	**46.5**	**6**	**24**	**3.5**

(1) Bridge & Page (1980).

COST EVALUATION OF BIOFUMIGATION

The cost of biofumigation for one ha has been estimated, taking the experiment in vegetables in El Perelló as model and adding the cost field labor for using brassica as bioindicators. In Table 8 a comparison between the cost of biofumigation (60 t organic matter) and MB application (600 kg ha^{-1}) is made, establishing the difference in 201 US $ in favor of MB in this case.

It must be considered that the cost of organic matter in this experiment was high because of the cost of transportation (2 ptas/kg), since spent mushroom substrate

(0.6 ptas /kg) was produced in Castilla-La Mancha, 150 km from the location of the experiment. To this the cost of other organic matter and the cost of preparing the mixture must be added to industrial benefits, to reach a total price of 4.5 ptas/kg at the location of the farm organic benefits.

Table 8. Cost of biofumigation (60 t ha^{-1}) and MB (600 kg ha^{-1}) in US $

Item	Biofumigation	MB
Product cost	1800	1705
Plastic	1136	1136
Field labor	584	478
Total	3520	3319

Expenses related to organic matter may be greatly reduced by using agrarian or urban residues closer to the place of application. Secondly, plastic is not necessary in most cases; and with experience, the expense of using brassica as a bioindicator may be eliminated. With all this in mind, biofumigation costs can be reduced to a minimum, and in most cases, they will decrease since the traditional addition of organic matter is necessary for most crops. The only innovation is the selection of organic matter and its method of application. Therefore, in the cucumber experiments at Villa del Prado, Madrid, the present cost of sheep manure is 3 ptas/kg, which reduces the cost of the product to 1000 US $, and makes it cheaper than the application of MB.

CONCLUSIONS

- Biofumigation uses volatile substances from the biodegradation of organic amendments and by-product residues as fumigants for the control of soilborne pathogens, which furthermore solves serious environmental problems that these products can originate. Its effectiveness is increased when it is incorporated in an integrated crop management system, prolonging its effect in time through crop rotation and fallow, the use of resistant and tolerant varieties, grafting, solarization, and, in general, such cultural practices as the time and mode of planting, ploughing, water management, mulching, sanitation, use of natural and artificial substrates, biological control and a low dose of chemicals.

- The function of organic matter in the regulation of soilborne pathogens, through its processes of biodegradation, is an alternative based on the same principles as fumigants such as MB, the only difference being that the gasses released are the result of the decomposition of organic matter through the effect of soil organisms or of those which are found associated with organic amendments.

- The possibilities for the development of biofumigation techniques are as diverse as the types of by-products available for the preparation of amendments. Biofumigation depends on the composition of organic matter and on the microorganisms implicated in their decomposition. The addition of great quantities of organic matter to the soil (> 50 t ha^{-1}) is necessary. Its use is limited by the availability of organic matter and the costs of transportation. Biofumigation is similar in effectiveness to conventional phytosanitary products. The incorporation of organic matter into the soil may be done in combination with plastic coverings or any other appropriate system for the purpose of trapping solar energy as well as retaining the gasses generated during the process.

- Biofumigation stimulates microbial activity in the soil. When organic matter is added to the soil, a sequence of microbiological changes is produced, with an initial microbiological proliferation that depends on the sources of energy added. The decomposers are a source of nourishment at the same time as they increase the nematophagous fungi and free-living nematodes, which in turn increase the number of predator nematodes and microarthropods, omnivorous nematodes, fungi, protozoans, algae and other organisms. The increase of the microbiological activity produces the rise of enzyme levels in the soil.

- Biofumigation has no negative effects on the environment or consumers' health. It has no limitation to its use in integrated production or ecological agriculture. It will have high competitive prices due to its use of agricultural by-products. The greatest problem is the high variability of organic amendments. Some organic corrections have the potential of accumulating harmful compounds and of increasing the level of the inoculum of some pathogens. It is necessary to design methodologies for the phytosanitary and agronomic characterization of the materials to be used, as well as to develop the correct techniques for their application in the field.

- To solve the problems that may have appeared from the use of biofumigation different species of brassicas have been used as bioindicators of the effectiveness of biofumigation. Many experiences also exist on the value of these plants in biofumigation. The principal reasons for selecting these plants are the low cost of seed, the lack of technical problems in sowing, the production of germination in a few days, their good indications of the phytotoxic substances of organic matter, fast crops, and high sensitivity to root-knot nematodes, which makes them act as trap plants, and the biodiversity increase when brassicas are incorporated into soil.

- Problems that arise from the gasses released during the biodegradation of organic matter which is trapped in the soil; and from the negative environmental impact and high cost of the use of plastic can be eliminated by substituting plastic covering with the passage of a roller and the maintenance of the soil in a wet condition during biofumigation. This method will be especially efficient in clay soils. Problems related to the biofumigant quality of organic matter, depends mainly on adequate mixtures to reach a C/N ratio of 8 to 20.

- The expenses related to organic matter may be greately reduced by using agrarian or urban residues closer to the place of application. Secondly, the plastic is not necessary in most cases and with some experience, the expenses of using brassica as bioindicators may be eliminated. Taking all these factors into account, biofumigation costs can be reduced to a minimum. In most cases, costs will decrease as the addition of organic matter already in practice and is necessary for most crops. The only change will be the selection of organic matter for pest control and its method of application.

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Chapter 15

SOIL-LESS CULTURE FOR GREENHOUSE CROPS IN THE MEDITERRANEAN COUNTRIES

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SUMMARY

The paper reports an analysis of why and how soil-less cultures are becoming more common for the greenhouse industry throughout the world. The advantages and disadvantages of hydroponics are highlighted with particular emphasis on the environmental aspects. Finally, the trend in developing soil-less growing techniques for the low-technology greenhouses of Mediterranean countries is presented.

INTRODUCTION

Despite the large, but nevertheless increasing number of greenhouses crops, the employment of soil-less growing techniques are currently limited in the Mediterranean regions where protected crops are mostly grown in low-technology structures and facilities. Growers' interest in hydroponics, however, is rapidly increasing, and these techniques play a pivotal role in the process of technological updating of Mediterranean industry. This process is necessary to enable the greenhouse industry to face the increasing competition due to the globalization of production and marketing and the consequent need to reduce production costs and improve yield quality; the enhanced awareness of environmental pollution provoked by agriculture, and the resultant legal constraints to crop production; and finally, the shortage of resources such as energy, labour and, above all, water.

SPREAD OF SOILLESS SYSTEMS

The total area of greenhouses in the world is around 300.000 ha. In 1996 the area equipped with hydroponic systems was around 12.000 ha and at the beginning of the next millennium it might be over 25.000, as reported by M. Schwarz in the first announcement at an International Symposium on soil-less culture to be held in Israel in 2000. After the use of soil-less culture was initiated in Northern Europe in early '70, the technique is rapidly expanding in other countries, in particular the Mediterranean basin and East Asia. Various techniques can be adopted for soil-less culture, each having their own advantages and disadvantages (Table 1); however soil-less techniques currently adopted in the Mediterranean regions are based almost completely on open-loop (free-drainage) substrate cultivation. Adverse climatic factors (namely high air and root temperature) and the poor quality of supply water due to high hardiness and salinity (mainly due to sodium chloride) represent some of the major agronomic constraints for the diffusion of soil-less cultivation systems for the greenhouse industry in the Mediterranean basin.

In Italy soil-less cultures have been employed since '70; however, Italian growers' interest in hydroponics is quite recent. In 1990 there was less than 50 ha of soil-less cultures, which grew to more than 400 ha in 1997; rose, tomato, gerbera and strawberry are the most important crops grown with open-loop substrate culture on perlite, rockwoll or the cheaper pumice. In Italy, soil-less culture was initially considered too sophisticated a technology which would cause an excessive increase in production costs with no relevant effects in term of yield quantity and quality. More recently, the opposite thought has developed, and now many growers are looking at hydroponics as the remedy to any problems. This enthusiasm is often fed by people who aim to make money with hydroponics. On the contrary, the diffusion of these growing techniques for greenhouse crops should be based on a precise analysis of costs and benefits. In general, a change from soil towards soil-less production systems is feasible for crops with a few (less than 10) plants per m^2 (tomato, cucumber, pepper, eggplant, strawberry gerbera, rosa, etc.), by which an increase in both yield and quality can be expected; this change is more difficult for high-density crops, such as leafy vegetable or some flower crops such as chrysanthemum. Nutrient film technique may be used for growing leafy vegetables since the short cultivation cycle reduced the risks associated with the spread of pathogens and the lack of buffer capacity of the solid substrate which make the system much less suitable for long-season crops.

GROWING PLANTS WITH HYDROPONICS

In principle, soil-less culture offers many advantages, as it contributes to increased crop yield, improves the quality of produce quality, conserves energy and water, and reduces the needs of hand-labour as well as the use of chemicals. Saving water represents one of the most important benefits of hydroponics, since water resources and quality are rapidly depleting, mostly due to the progressive salinization which affects many regions all over the world.

Soil-less culture also represents an effective tool to control soil-borne pests and diseases, and in this sense it represents a valid alternative to other non-chemical methods such as solarization, grafting, crop rotation, and cultivation of resistant cultivars. Nevertheless, the development of soil-less culture has not resulted in the disappearance of root diseases. Most root pathogens affect hydroponically-grown plants, in particular those who are easily transmitted in recirculating water, such as *Pythium* or *Phythophtora*. Moreover, some pathogens like *Fusarium oxysporum f. sp. radicis-lycopersici*, seem more virulent in soil-less culture than in soil. To avoid the risks of root diseases it is fundamental to sterilize the nutrient solution by heating, iodination, ozonization, ultraviolet radiation or slow sand filtration. The disinfection equipments, however, increase the installation and management costs of hydroponic plants.

CLOSED- VS OPEN- SYSTEMS

Open-loop soil-less culture may exploit saline water as there are no risks of progressive salt accumulation in the root zone provided an adequate drainage is maintained. Open systems waste water and fertilizers, thus increasing production costs and causing severe environmental pollution due to the contamination of deep water. The use of closed systems (i.e. with recirculating nutrient solution) with proper management of the nutrient solution supply can reduce substantially these disadvantages.

When low-salinity irrigation water is available, closed systems can be easily adopted.

The management of closed systems is much more difficult with respect to the open ones. Crop plants grown with closed-loop hydroponics may undergo salt stress due to the accumulation of non-essential ions in the recirculating nutrient solutions when supply water of poor quality is used. Therefore there is need to know how the plant responds to progressive salinization, is typical in transient conditions. Current scientific literature provides many papers on crop response to salinity, but less attention has been paid to the effect of transient salinity or salinization due to nutrient excess.

In closed-loop hydroponics the differential ion uptake by the crop and the use of irrigation water containing non-essential ions (mostly, sodium and chloride) cause nutritional imbalances and salt accumulation in the recirculating nutrient solution. The nutrient solution must therefore be continuously analyzed and adjusted for pH and ion concentration (see Table 2 for the range of element concentration in the nutrient solution employed for different kind of soil-less cultures), and renewed more or less frequently depending on the salt tolerance of the crop and the quality of irrigation water.

The accumulation of nutrients and other ions in the root zone depends on complex interactions among different plant and cultural factors such plant size, growth rate, development stage, water uptake, soil-less system (NFT, substrate cultivation, aeroponics), type of substrate and container, irrigation scheduling and, of course, quality of supply water. If the salt accumulation in the root zone can be described and predicted by modelling, it will be possible to develop more efficient systems where the re nutrient solution is recirculated for a longer period and periodically renewed when its nutrient content is negligible and safe from the environmental standpoint.

Another approach to reduce the waste of water and chemicals associated with free drainage is the development of a drain nutrient solution reuse system, which is based on the cultivation of plants with successively higher salt tolerance, as proposed also for the disposal of saline drainage waters in open-field crops. In these systems salt-tolerant crops would be cultivated with salt-enriched nutrient solutions flushed out of growing systems with less tolerant species. The drainage nutrient solution becomes progressively more saline as each successive species is grown, and it is finally discarded when the salinity is too high for cropping, but the nutrient concentration (in particular that of nitrate and phosphorus) is low and therefore environmentally-safe.

FUTURE DEVELOPMENTS

An ideal soil-less growing system should be flexible and sustainable. Growers have to be able to change substrate and/or crop without new investment costs; in addition, the system must be cheap, in particular in the Mediterranean regions, durable and environmental safe. In this regards, the employment of closed system with recirculation of drainage nutrient solution should be encouraged. Finally, the diffusion of soil-less systems have to be supported by the development of an adequate technical assistance (consultants and laboratory services) in order to make the growers less dependent on *instant* experts who may be responsible for crop disasters.

Table 1. Characteristics of various hydroponic techniques.

	substrate + trickle irrigat.	ebb-and-flow	nutrient film technique	aeroponics	floating system
diffusion	++++	++	++	+	+
type of crops	fruit veget. cut flowers	pot plants	leafy veget.	vegetables	leafy veget. herbs
substrate	yes	yes	no	no	no
recirculating nut. sol.	yes/no	yes	yes	yes	stagnant n.s.
investment costs	++	+++	+++	+++	++
management costs	++	++	+++	+++	+
buffer capacity	+++	+++	+	+	+
risks of root diseases	+	++	++	+	++
risks of root hypoxia	+	++	+++	+	+++
yield and quality	++++	++++	++++	+++	+++
growing risks	++	++	+++	++++	+++

Table 2. Concentrations of elements in the nutrient solution for different types of soil-less culture.

		vegetables	strawberry & flower crops
N	mM	15.0 ÷ 20.0	8.0 ÷ 10.0
P	mM	1.5 ÷2.0	1.0 ÷ 1.5
K	mM	8.0 ÷10.0	5.0 ÷ 6.0
Ca	mM	4.0 ÷5.0	3.0 ÷ 4.0
Mg	mM	1.0 ÷1.5	1.0 ÷ 1.5
S	mM	1.5 ÷3.0	1.5 ÷ 2.0
Fe	µM	15.0 ÷ 20.0	15.0 ÷ 25.0
B	µM	20.0 ÷ 25.0	15.0 ÷ 20.0
Zn	µM	4.0 ÷ 6.0	4.0 ÷ 6.0
Cu	µM	1.0 ÷ 2.0	1.0 ÷ 2.0

Chapter 16

ALTERNATIVES FOR METHYL BROMIDE FUMIGATION OF TOBACCO SEED BEDS, PEPPER AND TOMATO SEEDLINGS

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INTRODUCTION

Tobacco, pepper and tomato seedlings are not currently produced for market in soil beds without Methyl Bromide. This study investigates the use of alternative materials for Methyl Bromide. Tobacco and pepper, and to a lesser degree tomato, require a long pest-free period to develop into healthy transplants. Alternatives that are being evaluated include chloropicrin, Telone C- 17 and Vapam (Metam Sodium).

MATERIALS AND METHODS

The plot area used was planted with vegetables in 1996. The land was turned, disc harrowed and beds formed prior to test initiation. All treatments except Methyl Bromide were put in on 10/30/96. Plastic covers were applied over the area immediately after treating. Methyl Bromide was injected under 3 mil plastic on 10/31/96. Vinyl pouches with isolates of Pythium and Rhizoctonia were placed in each plot and covered by 2-3 inches of soil. Telone II (10 gal/A), Telone C-17 (10 gal/A) and Chloropicrin (6 gal/A) were applied by chisel injection at a depth of 6-9 inches. Metam Sodium (37.3 gal/A) was applied by spraying on the soil surface and incorporating with a power rototiller. Combinations of Metam Sodium + Telone II, Metam Sodium + Chloropicrin and Metam Sodium + Telone C- 17 were applied by a power rototiller also. On 12/3/96 the pouches with Rhizoctonia and Pythium were removed by cutting the plastic. On 12/4/96 all the plastic was pulled from the plots. 7-14-7 fertilizer was broadcast at 1 lb/sq yard on 12/11/96. Enide 90W 3 oz/1000 sq ft was sprayed on that date also. On 12/12/96 the beds were tilled and shaped for seeding. The beds were seeded on 12/16/96 with K-326 tobacco (22 seed/ft) and pepper (14 seed/ft).

On 1/21/97 stand counts were taken on tobacco and pepper (2 meter section of 1 row). On 2/18/97 the covers were pulled. On 2/21/97 the beds were recovered. The covers on the beds were pulled the final time on 3/2/97. On 3/4/97 Orthene 75S 1 lb/A was applied. On 3/10/97 and 3/11/97 the tobacco plants were pulled and measured (1 meter/row). Vigor ratings were also made on these 2 dates. On 3/12/97 pepper and tomatoes were seeded. On 3/28/97 stand counts were made on tomatoes (1 meter section). Vigor ratings were done on tomatoes on 4/16/97 and 4125197.

RESULTS

The combination of soil fumigants Metam Sodium plus Chloropicrin, Telone C-17 and Telone C-35 tended to be the best for reducing populations of fungi in the soil (Table 1). Most materials except Enide and Chloropicrin eliminated Pythium from the toothpick cultures (Table 2).

Vigor ratings conducted at different times and by different evaluators suggested that plants in plots with mixtures of fumigants and Methyl Bromide had the highest vigor rating (Table 3). Stand counts of tobacco and height measurements suggested that the combination fumigants were superior to some of the fumigants alone, and in some instances superior to Methyl Bromide (Table 4). Nematode sampling during the study indicated that populations at the time of this study were low and seldom did we have differences among treatments (Table 5). Weed pressure in this test site was low (Table 6). All materials except for Chloropicrin alone and Enide did a good job in controlling weeds encountered in the test area (Table 7). Stand counts and vigor ratings for tomatoes suggested very little difference among treatments (Table 8). Peppers were very erratic in performance. Stand counts and vigor ratings tended to be best in treatments where mixtures of fumigants were used (Table 9).

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Table 1. Fungi in soil 4 December, 1996 after soil fumigation 30 October, 1996.

Treatment	Rate/A	*Rhizoctonia solani* AG-4 Oat kernels %	*Rhizoctonia solani* AG-4 Soil cfu/[1] 100g	*Pythium* spp. cfu/g	*Fusarium solani* cfu/g	Total *Fusarium* spp. cfu/g	*Trichoderma* spp. cfu/g	Total fungi cfu/g
Chloropicrin 6 gal/A	6.0 gal.	13.3 cde	2.0 b[2]	16.7 b	2,161 a	3,279 a	37,430 a	68,200 a
Metam Sodium 37.3 gal/A (42%)	37.3 gal.	6.7 de	4.9 b[2]	ND c	ND c	189 c	870 cd	16,800 a
Telone C-17 10 gal/A	10.0 gal.	26.7 bcd	ND b[3]	ND c	44 b	667 b	89,080 a	92,000 a
Telone C-35 10 gal/A	10.0 gal.	36.7 abc	ND b	0.7 c	29 bc	363 b	60,060 a	70,800 a
Methyl bromide 580 lb/A, 12 lb/100 yd	580.0 lb	10.0 de	ND b	ND c	ND c	116 c	7,830 bcd	7,300 a
Chloropicrin 6 gal/A + Metam Sodium 37.3 gal/A	6.0 gal. 37.3 gal.	0 e	1.0 b	ND c	15 bc	44 c	ND d	1,700 b
Telone C-35 10 gal/A + Metam Sodium 37.3 gal/A	10.0 gal. 37.3 gal.	0 e	ND b	ND c	ND c	ND c	ND d	4,600 b
Telone C-17 10 gal/A + Metam Sodium 37.3 gal/A	10.0 gal. 37.3 gal.	0 e	ND b	ND c	15 bc	44 c	ND d	2,300 b
Untreated (weed control)								
Enide 90W 8 lb/A	8.0 lb	38.3 ab	23.5 a	66.7	1,175 a	3,699 a	15,380 b	83,300 a
Untreated	-	61.7 a	22.5 a	86.3 a	696 a	3,162 a	1,740 b	64,100 a

[1] Cfu = colony forming units per 100 g of oven-dry soil in R. *solani* AG-4, and per gram of soil with other fungi.

[2] Numbers followed by the same letter are not significantly different, P = 0.05.

[3] ND = not detectable. Detection levels were: 1.0 cfu/100 g for R. *solani* AG-4; 0.7 cfu/g for *Pythium* spp.; 15 cfu/g for *F. solani* and *Fusarium* spp.; and 290 cfu/g for all other fungi.

Table 2. *Pythium sp.* survivability in fumigated plots - 1996-97

Treatment	Survivability (%)[1] 24 hrs.	120 hrs.
Chloropicrin 6 gal/A+	16.6	16.6
Metam Sodium 37.3 gal/A (42%)	0	0
Telone C- 17 10 gal/A	0	0
Telone C-35 10 gal/A	0	0
Methyl Bromide 580 lb/A, (12 lb/100 yd)	0	0
Chloropicrin 6 gal/A+ Metam Sodium 37.3 gal/A	0	0
Telone C-35 10 gal/A+ Metam Sodium 37.3 gal/A	0	0
Telone C-17 10 gal/A + Metam Sodium 37.3 gal/A	0	0
Enide 90W 8 lb/A (weed control)	33.3	100
Untreated	66.6	100

’ Culture grown on toothpicks, placed in polymesh bags and buried in plots at time of fumigation. Cultures retrieved after fumigation at time of aeration and tested for viability.

Table 3. Fall seed bed fumigation vigor ratings

Early vigor Treatment’	Late vigor ratings[1]	Late vigor ratings[2A]	ratings[2B]
Chloropicrin 6 gal/A	4 0 bc[3]	3 0 bc	4.5 abc
Metam Sodium 37.3 gal/A (42%)	6.3 a	5.0 a	6.7 a
Telone C-17 10 gal/A	4.0 bc	3.7 abc	5.0 abc
Telone C-35 10 gal/A	5.5 ab	3.8 abc	5.3 ab
Methyl Bromide 580 lb/A	5.2 ab	4.7 ab	6.5 a
Chloropicrin 6 gal/A + Metam Sodium 37.3 gal/A	6.0 a	4.7 ab	6.8 a
Telone C-35 10 gal/A + Metam Sodium 37.3 gal/A	5.3 ab	5.3 a	6.3 a
Telone C-17 10 gal/A + Metam Sodium 37.3 gal/A	6.0 a	5.4 a	6.8 a
Enide 90W 8 lb/A	2.8 c	2.1 c	2.7 c
Untreated	3.1 c	2.3 c	3.2 bc

’ Tobacco plants are Coker-371 Gold. Plots were fumigated 31 Oct. 1996. Methyl bromide injected 1 Nov. 1996, plastic removed 4 Dec. 1996 and seeded 16 Dec. 1996.

[2] Vigor ratings are based on a scale of 1 - 10, where 1 = poor and 10 = excellent on 19 Feb. And two ratings on 10 March 1997 by two different people (A & B).

[3] Means with the same letter are not significantly different according to Duncan’s Multiple Range Test (P = 0.05).

Table 4. Fall seed bed fumigation, stand counts and height measurements, 1996-1997

Treatment[1]	Stand Counts[2]	Height Measurements[3] (cm)
Chloropicrin 6 gal/A +	48.0 b[4]	12.1 bcd
Metam Sodium 37.3 gaUA (42%)	59.0 ab	20.1 a
Telone C-17 10 gal/A	51.8 b	15.5 abcd
Telone C-35 10 gal/A	54.7 ab	15.8 abc
Methyl Bromide 580 lb/A	49.2 b	19.8 a
Chloropicrin 6 gal/A + Metam Sodium 37.3 gal/A	55.0 ab	20.7 a
Telone C-35 10 gal/A + Metam Sodium 37.3 gal/A	60.0 ab	18.5 abc
Telone C-17 10 gal/A Metam Sodium 37.3 gal/A	75.2 a	19.1 ab
Enide 90W 8 IB/A	24.0 c	8.4 d
Untreated	40.8 bc	11.5 cd

‘ Plots were fumigated 31 Oct. 1996, methyl bromide injected under plastic 1 Nov. 1996, plastic removed 4 Dec. 1996 and Coker-371 Gold tobacco seeded 16 Dec. 1996.

[2] Numbers are total of plants from 2 meters of row, 1 meter from each of the 2 center rows, on 21 Jan. 1997.

[3] 1 meter of row of plants was uprooted and length of plants from soil surface to tip of longest leaf was measured in cm on 1 May 1997.

[4] Means with the same letter are not significantly different according to Duncan's Multiple Range Test ($\underline{P}$=0.05)

Table 5. Nematode (no/150 cc soil) in fumigated plots - 1996-97

	Root Knot Larvae (No./150 cc soil)				Sting Nematode (No./150 cc soil)			
Treatment[2]	**11/06/96**	**12/02/97**	**02/19/97**	**03/14/97**	**11/06/96**	**12/02/96**	**02/19/97**	**03/14/97**
Chloropicrin 6 gal/A	213.33 a[1]	1.67 b	5.00 a	0.00 b	0.00 a	1.67 a	0.00 a	0.00 a
Metam Sodium 37.3 gal/A (42%)	111.67 a	3.33 b	5.00 a	0.00 b	3.33 a	0.00 a	0.00 a	0.00 a
Telone C-17 10 gal/A	275.00 a	11.67 ab	8.33 a	6.67 b	1.67 a	0.00 a	0.00 a	0.00 a
Telone C-35 10 gal/A	191.67 a	13.33 ab	1.67 a	1.67 b	1.67 a	0.00 a	0.00 a	0.00 a
Methyl bromide 580 lb/A, 12 lb/100 yd	116.67 a	16.67 ab	6.67 b	1.67 b	3.33 a	3.33 a	0.00 a	0.00 a
Chloropicrin 6 gal/A Metam Sodium 37.3 gal/A	233.33 a	56.67 ab	3.33 a	0.00 b	8.33 a	0.00 a	0.00 a	0.00 a
Telone C-35 10 gal/A + Metam Sodium 37.3 gal/A	213.33 a	11.67 ab	1.67 a	3.33 b	0.00 a	1.67 a	0.00 a	0.00 a
Telone C-17 10 gal/A + Metam Sodium 37.3 gal/A	278.33 a	20.00 ab	6.67 a	3.33 b	0.00 a	0.00 a	0.00 a	0.00 a
Untreated (weed control) Enide 90W 8lb/A	220.00 a	60.00 a	15.00 a	10.00 ab	3.33 a	0.00a	0.00 a	0.00 a
Untreated	223.33 a	26.67 ab	13.33 a	20.00 a	0.00 a	3.33 a	0.00 a	0.00 a

[1] Means followed by the same letter are not significantly different according to Duncan's Multiple Range Test (P=0.05).

[2] Tobacco cultivar was Coker-371 Gold; plots were fumigated 31 Oct. 1996, methyl bromide injected under plastic 1 Nov. 1996, plastic removed 4 Dec. 1996, tobacco seeded on 16 Dec. 1996.

Table 6. Nematode (no/150 cc soil) and root knot index on roots in-fumigated plots - 1996-97

Treatment[2]	Stubby Root (No./50 cc soil) 11/6/96	12/2/96	2/19/97	3/14/97	Tobacco 5/22/97	Root Knot Index Pepper 5/22/97	Tomatoes[3] 5/22/97
Chloropicrin 6 gaVA + Metam Sodium 37.3 gaVA	1.67 a'	0.00 a	0.00 a	0.00 a	2.78 bcd	2.23 ab	3.07 abc
Metam Sodium 37.3 gaVA	8.33 a	0.00 a	0.00 a	0.00 a	3.97 ab	1.80 bc	4.38 ab
Telone C-17 10 gaVA	3.33 a	0.00 a	0.00 a	0.00 a	2.07 de	1.27 c	1.77 cd
Telone C-35 10 gal/A	0.00 a	0.00 a	0.00 a	0.00 a	2.55 cd	1.40 bc	2.65 cd
Methyl bromide 580 Ib/A, 12 Ib/100 yd	5.00 a	0.00 a	0.00 a	0.00 a	1.25 e	1.45 bc	1.56 d
Chloropicrin 6 gaVA + Metam Sodium 37.3 gaVA	3.33 a	0.00 a	0.00 a	0.00 a	4.25 a	1.42 bc	3.13 abc
Telone C-35 10 gal/A + Metam Sodiurn 37.3 gal/A	0.00 a	0.00 a	0.00 a	0.00 a	3.33 abcd	1.65 bc	2.78 cd
Telone C-17 10 gaVA + Metam Sodium 37.3 gaVA	3.33 a	0.00 a	0.00 a	0.00 a	2.78 bcd	1.53 bc	3.02 bc
Untreated (weed control) Enide 90W 8 Ib/A	0.00 a	0.00 a	0.00 a	0.00 a	4.10 a	2.88 a	4.28 ab
Untreated	8.33 a	1.67a	0.00 a	0.00 a	3.65 abc	1.04c	4.43 a

' Means followed by the same letter are not significantly different according to Duncan's Multiple Range Test (P = 0.05).

[2] Tobacco cultivar was Coker-371 Gold; plots were fumigated 31 Oct. 1996, methyl bromide injected under plastic I Nov. 1996, plastic removed 4 Dec. 1996, tobacco seeded on 16 Dec. 1996

[3] Tomato cultivar was Rutgers.

Table 7. Tobacco fall seedbed fumigation, weed control efficacy ratings, 1996-1997

Treatment[1]	Corn Spurrey[2] 5 Dec. 96	Cutleaf-Evening Primrose 5 Dec. 96	Yellow Nutsedge 5 Dec. 96	Corn Spurrey 20 Feb. 97	Cutleaf-Evening Primrose 20 Feb. 97	Henbit 20 Feb. 97	Cutleaf-Evening Primrose 11 Mar. 97	Corn Spurrey 11 Mar. 97	Annual Sedge 11 Mar. 97	Cutleaf-Evening Primrose 11 Mar. 97	Yellow Nutsedge 8 Apr. 97
Chloropicrin 6 gal/A	79.2 b[3]	84.2 b	61.7 b	76.2 b	80.8 b	84.2 b	87.5 b	82.0 b	89.0 c	58.3 b	81.7 b
Metam Sodium 37.3 gal/A 42%	95.0 a	95.0 a	95.0 a	92.8 a	94.5 a	95.0 a	94.5 a	93.8 a	90.5 bc	90.8 a	90.0 ab
Telone C-17 10 gal/A	95.0 a	95.0 a	95.0 a	92.8 a	95.0 a	95.0 a	92.8 a	94.0 a	94.0 a	90.8 a	93.3 a
Telone C-35 10 gal/A	95.0 a	95.0 a	94.2 a	92.3 a	95.0 a	95.0 a	92.8 a	92.8 a	92.3 abc	92.5 a	91.2 a
Methyl Bromide 580 lb/A	95.0 a	95.0 a	95.0 a	92.0 a	93.3 a	93.3 a	95.0 a	94.0 a	92.7 ab	95.0 a	95.0 a
Chloropicrin 6 gal/A + Metam Sodium 37.3 gal/A	95.0 a	95.0 a	95.0 a	93.7 a	93.3 a	94.2 a	95.0 a	92.8 a	91.5 abc	95.0 a	95.0 a
Telone C-35 10 gal/A + Metam Sodium 37.3 gal/A	95.0 a	95.0 a	95.0 a	94.0 a	94.5 a	94.2 a	95.0 a	94.5 a	90.0 bc	95.0 a	94.2 a
Telone C-17 10 gal/A + Metam Sodium 37.3 gal/A	95.0 a	0.0 a	95.0 a	93.5 a	94.0 a	94.0 a	95.0 a	95.0 a	91.0 abc	94.2 a	94.2 a
Enide 90W 8 lb/A	0.0 c	0.0 c	0.0 c	93.3 a	92.2 a	94.2 a	93.3 a	93.8 a	93.2 ab	92.5 a	68.3 d
Unnntreated	0.0 c	0.0 c	0.0 c	0.0 c	0.0 c	0.0 c	0.0 c	0.0 c	0.0 d	0.0 c	0.0 d

1 Tobacco cultivar was Coker-371 Gold; plots were fumigated on 31 Oct. 96, methyl bromide injected under plastic I Nov. 96, plastic removed on 4 Dec. 96, tobacco seeded on 16 Dec. 96.

2 Numbers are % control as compared to nontreated control. Weeds evaluated were Annual Sedge *(Cyperus compressus L.)*, Corn Spurrey *(Spurrey arvensis L.)*, Cutleaf Evening Primrose *(Oenthera laciniata Hill)*, Henbit *(Lamium amplexicaule L.)*, and Yellow Nutsedge *(Cyperus esculentus L.)*.

3 Means followed by the same letter are not significantly different according to Duncan's Multiple Range Test (P=00.05).

Table 8. Stand counts and vigor ratings of tomato, Fall fumigation - 1996-97

	Stand Counts'	Vigor Rating[2]	Vigor Rating
Chloropicrin	11.33 b[3]	5.67 abc	6.67 ab
Metam Sodium	14.50 ab	6.50 ab	7.50 a
Telone C-17	14.83 ab	6.17 ab	7.67 a
Telone C-35	15.17 ab	6.50 ab	7.33 a
Methyl Bromide	13.67 ab	6.83 a	7.67 a
Chloropicrin + Metam Sodium	16.50 ab	6.33 ab	6.83 ab
Telone C-35 + Metam Sodium	18.17 a	6.33 ab	6.83 ab
Telone C-17 + Metam Sodium	15.83 ab	5.67 abc	6.17 ab
Enide (weed control)	12.67 ab	4.83 bc	5.33 b
Untreated	11.33 b	5.67 abc	6.67 ab

' Stand counts made on lm section of row. Plots were fumigated 31 Oct. 1996. Tomatoes were seeded 12 Mar. 1997.

[2] Vigor rating based on a scale of 1-10 (1=poor, 10=excellent).

[3] Means followed by the same letter are not significantly different from each other according to Duncan's Multiple Range Test (P=0.05).

Table 9. Stand counts and vigor ratings of pepper, Fall fumigation - 1996-97

Treatment	Stand Counts' 1/21/97	Stand Counts 4/11/97	Vigor Rating[2] 2/19/97
Chloropicrin	6.83 b[3]	6.17 bc	2.00 ab
Metam Sodium	8.17 ab	9.00 abc	2.17 ab
Telone C-17	9.67 ab	11.33 a	2.08 ab
Telone C-35	11.50 ab	12.50 a	2.50 a
Methyl Bromide	9.50 ab	11.00 ab	2.50 a
Chloropicrin + Metam Sodium	8.83 ab	11.83 a	2.33 a
Telone C-35 + Metam Sodium	10.67 ab	12.33 a	2.67 a
Telone C-17 + Metam Sodium	13.00 a	10.67 ab	2.50 a
Enide (weed control)	7.33 b	9.33 abc	1.58 bc
Untreated	6.83 b	5.17 c	1.25 c

' Stand counts made on 2m section of row.

[2] Vigor rating made on 2-1-97, based on a scale of 1-10 (l=poor, 10=excellent).

[3] Means followed by the same letter are not significantly different from each other according to Duncan's Multiple Range Test (P=0.05).

Table 10. Insect damage to plots fumigated with alternative chemicals for methyl bromide, 1996-97

Treatment	Mole cricket' tunnels per plot	Slug damaged plants per plot
Chloropicrin	0.7 b[2]	5.0 a
Metam Sodium	0.7 b	4.0 a
Telone C-17	0.3 b	2.7 a
Telone C-35	0.0 b	7.8 a
Methyl Bromide	0.2 b	0.8 a
Chloropicrin + Metam Sodium	0.3 b	3.2 a
Telone C-35 + Metam Sodium	0.2 b	3.2 a
Telone C-17 + Metam Sodium	0.2 b	1.7 a
Enide (weed control)	1.8 a	2.2 a
Untreated	1.5 a	5.4a

[1] All plots visually rated for the number of mole cricket (scapteriscus spp.) tunnels and slug (several spp.) damaged plants (leaf rasping and small holes) on 26 February 1997.

[2] Means followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($\underline{P}$ = 0.05).

Chapter 17
TOMATO PRODUCTION IN SPAIN WITHOUT METHYL BROMIDE

J. Tello [1]

SUMMARY

Crop management systems without methyl bromide (MB) for tomato in Spain are analyzed. It is discovered that the principal alternatives are hybrid varieties with resistance to pathogens and soil fumigation with other conventional fumigants. Problems have recently arisen with relation to the Meloidogyne *genus, since the new "long life" varieties lack resistance to those pathogens. These problems have been solved with the recent appearance of "long life" varieties possessing the* Mi *gene. The so-called "Mediterranean system" of management is described for the production of tomato for fresh consumption. It is much more effective in the control of diseases and yields better quality than the "Dutch system," based primarily on cultivation on substrates.*

Keywords: *fungi, nematodes, soilborne, fumigants, crop management*

INTRODUCTION

In order to understand the reasons why tomato crops in Spain do not generally use methyl bromide (MB) for soil disinfestation, a preliminary analysis is necessary of cultural techniques and of the crop innovations that have been introduced in the last thirty years. This analysis should be done for crops produced for fresh consumption as well as for crops for industrialization. Both subsectors are defined as different activities, because of their production techniques as well as their geographic distribution. While tomato for canning is an extensive, seasonal crop confined to Mediterranean countries, that tomato crops destined for fresh consumption have an intensive production and extend throughout the EU territory.

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Both subsectors of tomato crops have followed different technological paths. Nevertheless, in both cases, technical change has sought an increase in output per surface unit and crop adaptation to less favorable climatic conditions. Developments have included out-of-season and greenhouse crops. This change has been accompanied by new criteria in consumer conduct, which is concern for a healthy diet. Among Europeans, disquiet exists over the degree of safety in foods, an uneasiness which carries implicit criticism of intensive production methods and their contaminating effects (Aldanondo Ochoa, 1995). Regulation of the maximum limit of residues for phytosanitary products, well reflects this state of opinion, a concern that reaches as far as to the deterioration of our surroundings, even though they may be as distant as the stratospheric ozone layer. The growing interest of the large distribution chains to establish commercial trademarks for more natural products (organic, ecological, etc.), is a phenomenon that is influencing the tomato-producing areas of Spain, starting with the advantage of the scarce or null use of MB in its crops (Bello & Tello, 1997).

PRODUCTION TECHNIQUES IN THE PAST THIRTY YEARS

In the three years from 1990-1992, the EU produced a total of 13,118 thousand tons of tomato. Twenty-two percent of that figure corresponded to Spanish production (Aldanondo Ochoa, 1995). This analysis of the changes in production techniques will be centered on tomato for fresh consumption, since the cultivation of tomato for canning in Spain does not normally use MB.

There are two models for tomato production in the EU, i.e., in Holland, Belgium, the United Kingdom, Denmark and Germany. The surface area adjusts itself to the “Dutch system,” a system in which cultivation is done under glass greenhouses, on substrates (principally of rock wool), with a central hot water heating system and computerized control of environmental constants and of the watering system. Generalization of soilless cultivation—partly compelled by the strict prohibition against using MB—varietal improvements, innovations in the design of greenhouses and the perfection of agricultural practices, has permitted output to reach spectacular levels (400 t/ha, triple the production of Spanish greenhouses). This system is especially expensive in energy (heat, fertilizers, etc.) and in production per unit (from 20-30% above that of Spain’s). Also, the system is particularly contaminating. It is calculated that substrate crops require two to three times more fertilizer than field crops. The degradation problem surrounding agricultural areas in Holland, where production is particularly intensive, has propitiated governmental plans to minimize them. Among other modifications are the savings in energy consumption, the decrease in the use of fertilizers and pesticides and, particularly, a closed circuit of recycling of the water used for irrigation. In this way they endeavour to put a stop to one of the major sources of contamination: the filtration of pesticides and fertilizers into the waterbeds. The advantages of the system are as certain as its remarkable rise in production costs (Aldanondo Ochoa, 1995).

The "Dutch system" has been considered the archetype of efficiency. Nevertheless, the growing preoccupation of consumers about the environment and the safety of foods has motivated their rejection of the Dutch tomato, which they consider "artificial and insipid." In fact, between 1991 and 1992 the mean price fell about 28%.

Taking Spain as an example, since 30% of its production is in fresh tomato and 20% is exported, the "Mediterranean system", is different from the "Dutch system" in its more natural in cultural practices, favored by more propitious climatological conditions. The Spanish tomato production system has a certain technological dependence on the "Dutch system" and a great heterogeneity in productive structures. The basic elements of the Spanish system are: field cultivation, or cultivation in soil under plastic or mesh-covered greenhouses without temperature or atmospheric control. Varieties exist such as cultivation in sand-covered soils. Soil-less cultivation is done on a small scale.

Mediterranean production in the last few years has undergone an important modernization process. Outstanding changes are the adaptation of plastic greenhouses, the introduction of the localized irrigation system, the utilization of soluble fertilizers, varietal reconversion (Aldanondo Ochoa, 1995; Díez Niclos, 1995), automatization of the packaging line, and the incipient automatization of the irrigation system. A great part of these innovations were generated in the EU, especially in Holland.

One of the most important changes was created by hybrid varieties (Díez Niclos, 1995). Their part in the non-utilization of MB well deserves a brief commentary. Holland maintained a monopoly on the production of the most-acceptable hybrids commercially, which were carriers of a resistance to the crop's gravest pathogens. This monopoly has gone on to be the patrimony of the "long-life" varieties, an Israeli patent, which presents advantages over the Dutch varieties. They contribute a remarkable improvement in quality, firmness and homogeneity, although not so in flavor. It could be said that Israel has broken the seed market monopoly and has placed a new starting point in research. The qualities of these hybrids favor production areas at a distance from the market. It must be added that these "long-life" varieties at their commercial birth have been deficient against pathogens, especially root-knot nematodes (*Meloidogyne* spp) (Díez Niclos, 1995; Tello & del Moral, 1995).

This brief analysis clearly intends what could be expressed in the following manner: the temptation to continue a technological strategy similar to that of the northern EU. Intensifying production systems to reduce unit costs may be inconvenient in the long run. The Mediterranean area enjoys relative prestige in the market place due to the naturalness of its crops (Tello, 1984; Tello & Lacasa, 1990; Tello & del Moral, 1995).

TOMATO PRODUCTION IN SPAIN

Tomato is a basic product in Spanish horticulture. It occupies 14% of the horticultural surface cultivated and contributes to 23% of the value of the sector's production. Spanish tomatoes satisfy the interior demand and have a strong exportation sector. Twenty-five percent of the fresh production and 50% of the industrial transformations are exported. The details of production are found on Table 1, where data indicates an increase in unitary output, especially in fresh tomato, corresponding to a decrease in the surface area cultivated (Aldanondo Ochoa, 1995; Rodríguez del Rincón, 1995).

Table 1. Tomato production in Spain, 1983-1993 (Aldanondo Ochoa, 1995)

Type	Year	10^3ha	t/ha	Total Production
Tomato for fresh consumption	1983	43.1	39.2	1688.7
	1993	35.5	50.9	1805.9
Tomato for industrial transformation	1983	18.7	39.4	740.8
	1993	21.2	42.1	893.5

Spain's production areas are centered in the Southeast of the peninsula (Valencia, Alicante, Murcia and Almería), the Ebro River Valley (Navarra, Rioja and Saragossa), Extremadura and the Canaries, which are areas in which 73% of the national production is concentrated (Fig. 1).

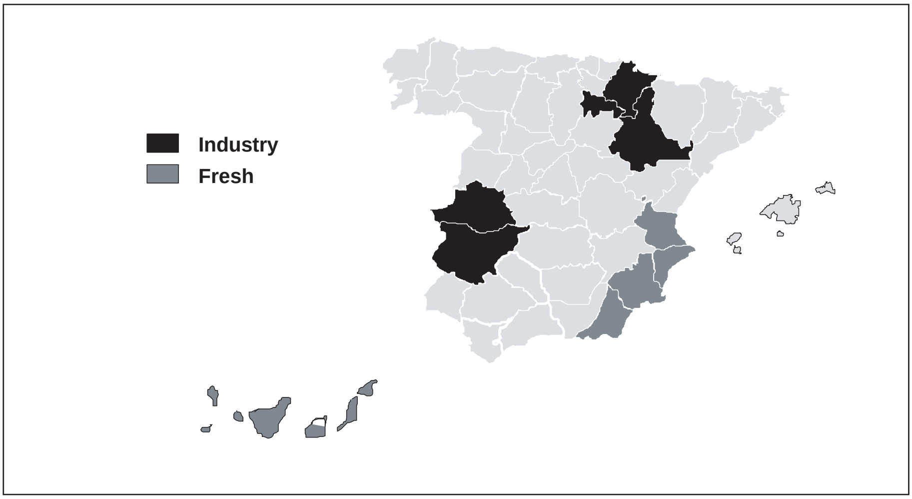

Figure 1. Tomato production sectors in Spain

Nevertheless, crop systems are different. Extremadura and the Ebro River Valley are dedicated to production for industrial transformation (canned tomatoes, sauce, paste, etc.). In this crop system, rotation every three years is habitual, a rotation that maintains bearable disease levels, and where the use of MB has never been necessary**.** For this reason these areas will not be considered in this paper (Aldanondo Ochoa, 1995; Tello & del Moral, 1995).

Southeastern Spain and the Canary Islands dedicate their fields to the production of fresh tomato. The crop system has been described in a previous paragraph on the “Mediterranean system.” It will be commented on later from the point of view of pathosystems and soil disinfestation.

DISEASES IN SPANISH TOMATO CROPS

Diseases in tomato have undergone an important increase in the world. They have almost tripled in the last few years (Messiaen *et al.*, 1991). A review of the papers published 20 years ago to prove that there were no more than thirty disease outbreaks.

Today the figure is around 124 outbreaks, as is shown on Table 2, distributed among mycosis, bacteriosis, virosis, phytoplasmosis and non-parasitic diseases (Tello, 1984; Tello & Lacasa, 1990; Jordá Gutíerrez, 1995; Tello & del Moral, 1995; Jordá & Llácer, 1996; López & Montesinos, 1996).

Table 2. Parasitic and non-parasitic diseases described in tomato crops

Groups of pathogenic agents	Total	Present in Spain
Fungi	30	18
Bacteriae	7	6
Viruses	33	10
Phytoplasms	6	2
Nematodes	26	2
Parasitic plants	2	1
Non-parasitic alterations	20	15
Total	124	54

Many of these new diseases have been described when the techniques for diagnosing them have improved, as is the case in virosis (Jordá, 1995; Jordá & Llácer, 1996). Others have appeared with the modification of cultural techniques (Tello & dell Moral, 1995). An exponent of this statement is constituted by the mycosis caused by *Spongospora subterrana* and *Calytella campanula* (Messiaen *et al.*, 1991). Nevertheless, non-parasitic diseases reveal that new developments in crop management affect the appeareance of new pathologies. Non-parasitic diseases are confused with others caused by mycrobes which put harmless, if not counter-productive, phytosanitary provisions into action (Tello & del Moral, 1995).

After years of observation, experience has demonstrated that MB is not effective in the soil for controlling bacteria, phytoplasms and virus, except when limiting the populations of the latter's vector agents, such as nematodes or fungi. Nor has it been recommended to control parasitic plants, since they have no relevance to Spanish tomato crops (Messiaen *et al.*, 1991). Therefore, the study of fungi and root-knot nematodes explains why the use of MB is insignificant in Spanish tomato crops.

FUNGI AND NEMATODES DISEASES: THEIR IMPORTANCE AND CONTROL

Table 3 outlines the inventory of fungi and nematodes described as tomato crop parasites. Of a total of 30 described, the presence of eighteen are registered in Spain, whose presence does not indicate that they constitute a cause of appreciable losses (Tello & del Moral, 1995).

Limiting ourselves to the pathogens that cause diseases in the aerial part of the plant, the following observations must be made. *Erysiphe* spp and *Fulvia fulva* appeared superficially, without becoming extended with the passing of the years. On the other hand, *Alternaria dauci* fsp *solani, Botryotinia fuckeliana, Leveillula taurica* and *Phytophthora infestans* are responsible for important losses, regularly or sporadically, in spite of repeated and intense treatments with fungicides.

Soilborne fungi present in Spain deserve a lengthier commentary, since they are what motivate disinfection practices with MB. As is deduced from Table 3, *Fusarium oxysporum* fsp *lycopersici, Verticillium dahliae* and *Meloidogyne* spp are what have or have had a relevant incidence in production. Fortunately, the appearance of *Fusarium oxysporum* fsp *radicis-lycopersici* over ten years ago produced an unjustifiable alarm "a posteriori" since this pathogen does not seem to have become extended (Tello & del Moral, 1995).

At present, *Fusarium oxysporum* fsp *lycopersici* has two strains described in Spain (strain 0 and strain 1). Before hybrid cultivars with resistance to pathogens were introduced, it was one of the most important diseases, and compelled long cultural rotations (from 3-4 years) and soil disinfection. Resistant tomato hybrids permitted the escalation of fixed installations for production (irrigation, greenhouses, etc.), eliminating rotation. The combination of soil disinfection, generally based on metam sodium, and varieties with the resistant *gene I,* made the maintenance of an almost total control of mycosis possible for five years. The apparition of a new strain (strain 0) and its escalation compelled the introduction of varieties with *gene* I_2, resistant to that pathogen. For the 13 years since that time, the system has remained stable, in spite of continued crop intensification, with the consequent disappearance of traditional cultural tasks (Tello & Lacasa, 1990; Tello & del Moral, 1995).

Verticillium dahliae has shown a similar recent trend to that of *F.oxysporum fsp lycopersici.,* except for one important factor.The *Ve gene* introduced in the hybrid varieties, has remained stable for more than 20 years, without new fungi pathotypes being detected. It would be interesting to understand why new strains of *F.oxysporum* fsp *lycopersici* and *V. dahliae* have not appeared. The answer would permit a better understanding of the system and consequently, the extension of its use. In an empirical way, how some cultural techniques influence this, can be known by intuition.

In root-knot nematodes of the genus *Meloidogyne*, the species most widely extended in Spanish crops is *M. incognita* and *M.javanica*, where the situation has

Table 3. Pathogenic fungi and nematodes in tomato crops, their importance in Spain

Species	**Presence in Spain**	**Present Importance**
Alternaria dauci fsp *solani*	+	1
A. tomato	-	-
A. alternata fsp *lycopersici*	-	-
Botryotinia fuckeliana	+	2
Calyptella campanula	-	-
Cercospora fuliginea	-	-
Colletotrichum atramentarium	+	-
C. gloeosporioides	-	-
C. acutatum	-	-
Didymella lycopersici	+	-
Erysiphe spp	+	-
Fulvia fulva	+	-
Fusarium oxysporum fsp *lycopersici*	+	2
F. oxysporum fsp *radicis-lycopersici*	+	-
F. solani	+	-
Leveillula taurica	+	2
Phoma destructiva	-	-
Phytophthora infestans	+	1
P. nicotianae var parasitica	+	-
Pyrenochaeta lycopersici	+	-
Pythium spp	+	-
Rhizoctonia solani	+	-
Sclerotium rolfsii	+	-
Sclerotinia sclerotiorum	+	-
Septoria lycopersici	-	-
Spongospora subterranea	-	-
Stemphyllium solani	-	-
St. botryosum fsp *lycopersici*	-	-
St. vesicarium	-	-
Verticillium dahliae	+	2
Meloidogyne spp	+	2

(+) present; (-)no present; (1) acceptable control with phytosanitary products; (2) control with pesticides is difficult, making resistant varieties necessary.

developed in a different way. The fragility of the hypersensibility *Mi* gene (chromosome 6) which loses its effectiveness at 32^0 C when in homocygosis and at 27^0 when in heterocygosis, provides insufficient protection during some seasons of the year (Messiaen *et al.*, 1991; Tello & del Moral, 1995). This circumstance makes soil disinfection treatments necessary. Nevertheless, recent experience acquired in Spain shows quite well that for such disinfections it is not necessary to recur to MB. Biofumigation and its combination with solarization, and even nematicides, have been shown to be sufficiently effective, on the condition that the time and the technique for application is well known (Bello *et al.,* 1998).

Nevertheless, recent concern about nematodes in tomato crops in some Spanish areas is not precisely over the lack of effectiveness of the *Mi* gene, but rather over the fact that this gene is absent in present "long life" varieties. See this effect on Table 4.

Table 4 compiles the most extended varieties at the present time. A survey done during the summer of 1997 among 59 farmers from Almeria, dedicated for more than 10 years to tomato monoculture farming in greenhouses, and who use the above-indicated cultivars, showed that 77% of their operations experienced difficulties with *Meloidogyne* spp.

Table 4. Resistance to soil pathogens in "long life" tomato for fresh consumption cultivated in Spain

Cultivar	***Meloidogyne***	***V. dahliae***	**Tomato Mosaic**	**F.o. fsp *lycopersici***	
Virus (ToMV)	***strain 0***	***strain 1***			
CLX-3759 F1	-	+	+		+
Daniela F1	-	+	+	+	+
Durinta F1	-	+	+	+	+
E-873 F1	-	+	+	+	+
E-875 F1	-	+	+	+	+
Gabriela	+	+	+	+	+

(+) resistance incorporated; (-) without resistance.

One interpretation of this data is the following: the escalation of the "long life" varieties of tomato lacking the *Mi* gene resistant to *Meloidogyne* spp, have incurred problems in the soil that have remained at bearable levels with resistant varieties. When those cultivars incorporate the *Mi* gene, as in the case of the Gabriela variety, as indicated by Table 4, the situation will again be restored that was reached with hybrids without the "long life" gene.

CONCLUSIONS

Three conclusions made to explain the reason why MB is not used for tomato production in Spain:

There is a small number of pathogens that cause relevant losses in Spanish tomato crops. The reason must be looked for in the "more natural" form of producing tomato, if compared with other countries of the European Union. The superior quality of the Mediterranean tomato is a reputation well-earned by Spain in the European markets. This quality is a consequence of a "more natural" form of production.

The absence of MB in practically all of Spain's tomato crops could be explained in the following manner: the stability of the genes resistant to *Fusarium oxysporum* fsp *lycopersici, Verticillium dahliae* and *Meloidogyne* spp has been verified in the last 20 years. The durability of the effectiveness of the resistant genes has been influenced by crop management, both because an important part of the surface area applies Almeria's type of "sand-covered soils", and because of soil disinfectants, essentially based on methyl-isothiocyanate.

"Long life" hybrid varieties are susceptible to *Meloidogyne* spp due to their lack of the *Mi* gene. Alternative control techniques based on biofumigation, alone or combined with solarization, and the use of nematicides developed in Spain, have demonstrated their utility when practicing correct application. In any case, the introduction of the *Mi* gene in "long life" hybrids has begun. Varieties with that property are offered on the seed market. This circumstance will predictably restore the situation to that generated by previous hybrid cultivars.

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Chapter 18

PRODUCTION OF MARKET GARDEN CROPS IN GREECE WITHOUT METHYL BROMIDE

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ABSTRACT

Methyl bromide in the earth's atmosphere arising from natural and man-made sources is one of the substances contributing to the depletion of the ozone layer. For this reason the countries that signed the Montreal Protocol decided progressively to ban its production and use. The phase-out of this substance in Greece will have a profoundly adverse affect on the economic viability of indoor market garden crops, and will lead to a diversification of farming practices. Greece uses 1100 tonnes of methyl bromide a year and is one of the ten leading non-producer countries. The Greek government has the political will and the social responsibility to abide by the Montreal Protocol, and has already started developing strategies for phasing out and for replacing methyl bromide. For the moment however, farmers in Greece do not have access to any effective new methods. Accordingly it is necessary, if vegetable production is to continue, to provide economic support for research programmes into the development of alternatives to methyl bromide and for disseminating the knowledge obtained.

MARKET GARDEN CROPS IN GREECE

Indoor production of vegetables is of considerable economic importance to Greece, and in 1996 accounted for a total area of 6111.9 ha. Such market garden crops are grown in hothouses, coldhouses and tunnels. In Greece, plastic coldhouses predominate, covering an area of 3751.5 ha. The main crop is tomatoes, covering an area of 2381.7 ha, with an output of 232,017 tonnes, followed by melons and cucumbers (Table 1).

METHYL BROMIDE AND ITS CONTRIBUTION TO OZONE DEPLETION. THE SITUATION IN GREECE.

Methyl bromide, also known as methylic bromide, methane monobromide, monobromomethane and methyl monobromide, is one of the most commonly used pesticides. Three industries are responsible for all production, two of them in the United States and the third in Israel. Over the period 1984-1996, world sales reached a maximum of 73,731 tonnes in 1994. In 1996, sales fell by 6.8% from 1994 levels. Sales in North America in 1996 accounted for 43.38% of the total. In Europe, in the same year, sales accounted for 23.37% (Table 2). Methyl bromide is a highly toxic biocide that is extremely hazardous to man. A dose of 1000 ppm by volume in air can be lethal in 30 minutes(1). Safe and tolerance limits are taken to be 17 and 20 mg/l respectively for an exposure of 7 h a day. The effective depth of the substance, in the conditions found in Crete, does not exceed 30 cm(2).

Methyl bromide causes substantial perturbation of the soil microfauna and microflora, producing a biological void in the ecosystem and the "boomerang" phenomenon(3). When soil has been fumigated with methyl bromide, it is possible to observe substantial reductions in animal organisms, fungi, mycorhizomes and nitrifying bacteria. On the other hand certain fungal species such as *Aspergillus alutaceus Paecilomyces lilacinus, Penicillium chrysogenum, P. funiculosum, P. herquei, Trichodema harzianum, T. viride, Verticillium dahliae*(4) and the weed *Malva* sp. appear to be tolerant of methyl bromide. Ammonia-generating bacteria also show complete resistance and even improve their production of ammonia. This group of bacteria can become dangerous to the crop either through a build-up of plant-toxic ammonia or through incidental phytopathogenesis. The reconstitution of mycoflora synthesis is relatively slow. In fact one month after treatment, the saprophytic mycoflora cover only 32.12% of the reference material at a depth of 10-20 cm(5).

Most of the methyl bromide applied to the soil is emitted into the atmosphere. In fact it has been shown that 87% of the methyl bromide escapes into the air in the 7 days following application when the surface of the soil covered for 95 hours(6). Covering the soil with ordinary plastic tunnels reduces the emission into the atmosphere of the methyl bromide by 40%. Other research has shown that 30% of the product is emitted in 24 hours and 63% in 18 days(7),(8). Part of the methyl bromide may be absorbed into the soil or broken down by hydrolysis or methylation. This decomposition depends on the depth of the soil, the quantity of organic matter, the anaerobic activity of the bacteria and the moisture content of the soil(9),(10).

It is well known that bromine and chlorine present in the atmosphere react chemically with ozone and destroy it, depleting its layer in the stratosphere. This layer, known as the ozonosphere, contains 90% of atmospheric ozone and acts as a barrier to UV radiation, particularly the UV-B radiation which is hazardous to man, animals and plants. An atom of bromine destroys 60 times more ozone than an atom of chlorine. The methyl bromide in the atmosphere can come either from natural sources (the seas) or man-made sources (agriculture, biomass fires or motor vehicles)[11] (Table 3).

According to the Montreal Protocol, methyl bromide is characterised as a substance that threatens the ozone layer. Its lifetime in the atmosphere has been calculated to be 1.7 years. Its ozone depletion potential (ODP) with respect to CFC-11 varies between 0.6 and 0.7. This potential rises with the concentration of chlorine in the atmosphere. It is classified in category I[12][13]. The production and use of substances in this category must be phased out in stages.

Table 1: Protected vegetable crops in Greece

Crops	Hothouses				Coldhouses				Total	
	Glass		plastic		glass		plastic		ha	tonnes
	Ha	tonnes	ha	tonnes	ha	tonnes	ha	tonnes		
Aubergine	0.8	75	7.6	580	0.1	4	138.1	11761	172.6	13394
a.field	0.8	75	7.6	580	0.1	4	138.1	11761	146.6	12420
b.in tunnels									3.1	124
									22.9	850
Cucumber	7	1491	143.6	19631	0.5	50	597.4	72029	1096.7	132054
a.field	7	1491	143.6	19631	0.5	50	597.4	72029	748.5	93201
b.in tunnels									343.2	38503
									5	350
Courgette	7.4	459	7.4	459	1	5	1221	6995	413.7	15180
a.field	7.4	459	7.4	459	1	5	1221	6995	129.6	7459
b.in tunnels									39.1	2131
									245.0	5590
Strawberry							110	3540	135.5	4600
a.field							110	3540	110	3540
b.in tunnels									35.5	1060

Green beans			19.1	460			22.7	671	187.3	3841
a.field			19.1	460			22.7	671	41.8	1131
b.in tunnels									119.5	1735
									26.0	975
Lettuce			2.9	231			7.1	508	74.4	2421
a.field			2.9	231			7.1	508	10.0	739
b.in tunnels									64.4	1682
Melon			6.3	105			6.3	236	1261.3	39874
a.field			6.3	105			6.3	236	12.6	341
b.in tunnels									196.2	8286
									1052.5	31220
Pepper	0.4	13	63.8	3632	0.1	4	287.2	18796	388.7	23433
a.field	0.4	13	63.8	3632	0.1	4	287.2	18796	351.5	22445
b.in tunnels									14	213
									23.2	775
Tomato	10.7	1599	681.9	64949	5.5	799	1361.7	139713	2381.7	232017
a.field	10.7	1599	681.9	64949	5.5	799	1361.7	139713	2059.8	207060
b.in tunnels									283.7	23017
									38.2	1940
TOTAL	26.3		932.6		7.2		3751.5		6111.9	
a.field	26.3		932.6		7.2		3751.5		3610.4	
b.in tunnels									1063.2	
									1448.3	

Source: Ministry for Agriculture, 1996

Table 2: World sales of methyl bromide by region (1984-1996)

Year	North America	Europe	Asia	Subtotal	Other regions*	Total sales
1984	19659	11364	10678	41701	3871	45572
1985	20062	14414	9743	44219	4054	48273
1986	20410	13870	11278	45558	4897	50455
1987	23004	15339	12816	51159	4531	55690
1988	24848	17478	13555	55881	4729	60610
1989	26083	16952	14,86	57421	5149	62570
1990	28101	19119	14605	61825	4074	66644
1991	31924	18020	17396	67340	6260	73600
1992	29466	18521	16944	64931	6654	71585
1993	30723	18286	17185	66195	6463	72658
1994	31981	18052	17427	67460	6271	73731
1995	28965	16350	15784	61098	5680	66778
1996	29679	16753	16173	62604	5820	68424

Sources: UNEP 1995, ICF 1996 and 1997.

* Africa, South America and Australia.

Table 3: The main sources of methyl bromide emissions into the atmosphere.

Sources of emission	Quantity in thousands of tonnes
Oceans	26 - 100
Soil fumigation	16 - 47.3
Biomass burning	10 - 50
Motor vehicles	0.5 - 2
Other	2

In Greece, methyl bromide plays an essential role in expanding production of protected market garden crops. In Crete for example, the increase in the output of and areas under tomatoes and cucumbers in coldhouses is largely due to the use of methyl bromide for soil disinfection.

The product is active against the main species of parasitic nematodes as well as fungi, insects and weeds. It is authorised for use as a pressurised liquid (Table 4).

Methyl bromide is used at present as a fumigant for disinfecting the soil used for protected crops and seedbeds, and for products in storage and quarantine. In 1997 total consumption (al imported) was 1100 tonnes. In 1991, Greece was sixth in the world amongst the countries not producing methyl bromide, with a consumption of 800 tonnes. A quantity of 950 tonnes of the product was used for soil disinfection. The product is supplied only to persons who have obtained a special permit from the Ministry of Agriculture. Soil fumigation uses 12.63% of special agents.

Table 4: Commercial methyl bromide specialities in Greece.

Commercial specialities	in the form of	concentration of active material	Marketed by
Bromide compounds	GA	100%	Filokrop
Sobrom AX	GA	99.5%	Rhône Poulenc Agrochimika Hellas
Sobron	GA	98% + 2% Chloropicrin	Rhône Poulenc Agrochimika Hellas
Methyl bromide Mebron	GA	98% + Chloropicrin 2%	Intrachem Hellas

Source: P. Balagiannis,1994.

The product can also be applied by farmers who have received special training. In Crete, 59.1% of the total is so applied. Cucumber production accounts for 40% of the total used (Tables 5 and 6). The average dose applied is 75 g/m^2. As regards protected market garden crops, soil disinfection is applied only to 24% of the total area.

Table 5: Methyl bromide consumption in the regions of Greece

Regions	Quantity (tonnes)	%
Crete	650	59.09
Peloponnese	200	18.18
Macedonia	150	13.64
Other regions	100	9.09
Total	1100	100.00

The total cost of applying the product in Crete is $3359.7 and 5838.4 per hectare for the areas covered by plastic or the whole area respectively.

Table 6: Use of methyl bromide in Greece for different crops

Crop	Quantity (tonnes)	%
Cucumber	380	40
Tomato	332.5	35
Other	237.5	25
Total	950	100

PROPOSED STRATEGIES FOR OVERCOMING THE AGRICULTURAL PROBLEM OF THE BAN ON METHYL BROMIDE

In Greece, protected crops have high value and make a substantial contribution to total agricultural incomes. Methyl bromide plays a crucial role in the economies of these crops. It is a multipurpose product which can simultaneously control soil diseases, pests and weeds.

In accordance with the Montreal Protocol, a search is under way for alternatives or ways and means of reducing methyl bromide emissions into the atmosphere.

Emissions of the product into the atmosphere can be reduced by:

- Additional irrigation which enhances breakdown of methyl bromide in the soil.
- Deep injection of the product.
- Incorporation of organic matter before disinfecting the soil. It is possible that this technique will make the product less effective.
- Using plastic sheeting that is highly impermeable to methyl bromide. New VIF plastics have been tested in Israel. In Crete, the polyamide plastic Kritifil PA 1051 known as "Orgafum" is being investigated: this is 400 times more impermeable compared with 50 µm polyethylene at a temperature of 20°C (Table 7). The use of this plastic will make it possible to reduce the dose of methyl bromide used by of the order of 50 to 70%. The application cost would be reduced by 13-15%.
- Use of specialities with a low content of methyl bromide and a high content of Chloropicrin.
- Treating the soil in profitable zones.

The methyl bromide dose applied can be reduced to about 20 g/m^2 by using the product in combination with the physio-biological method of soil insolation. The Greek government has also decided to reduce the amounts imported by 25% in 1999.

Table 7: Permeability to methyl bromide of certain plastics used in Greece.

Plastic	**Permeability in $g/m^2/h$**
Polyethylene 50 µm (thickness)	40
Polyethylene 75 µm	25
Special polyethylene 30 µm	40
Orgafum 40 µm	<0.1

So far no single product has been found that is alone capable of replacing methyl bromide, there being rather a range of solutions.

To begin with, it must be accepted that the diseases and damage caused by parasites and weeds are the result of the combined effects of the various biotic and abiotic factors. It is therefore necessary to investigate these factors in order to develop and then select the most appropriate method of control

With regards to replacing methyl bromide, alternatives of chemical, physical, species, and biological origin are being sought

Other fumigating substances are being investigated and are in use in hothouses for integrated control of diseases, pests and weeds for market garden crops. We may mention:

- Chloropicrin, which controls nematodes, insects and many soil fungi such as *Fusarium, Pythium, Rhizoctonia, Sclerotinia, Verticillium, and Colletotrichum.*
- Biocides based upon methyl isothiocyanate to control fungi, parasitic insects in the soil, and weeds (Basamid, dichloropropene+dichloropropane, metam sodium).
- Calcium cyanamide together with soil insolation for 3 weeks.
- Selective fungicides, insecticides, nematicides and herbicides applied separately or in combination. Combinations of 1,3 dichloropropene+chloropicrin+pebulate; 1,3 dichloropropene+pebulate; 1,3 dichloropropene + metam sodium; oxamyl+chloropicrin+glyphosate+pebulate have given satisfactory results [15]
- Methyl iodide, with an atmospheric lifetime of one week, can play an outstanding role in controlling soil parasites and weeds.
- Interesting results also demonstrate Ultradyn C which contains iodine, citric acid and Yuga extract.
- Enzymes that inhibit the growth of plant parasites and weeds in the form of inorganic azides. These products are very promising.

Cropping methods such as mixed crops, rotation, and leaving the land fallow based upon the use of the phenomenon of allellopathy can in certain cases control plant parasites in the soil and weeds.

Flooding the earth for six weeks at a temperature of 200°C depletes the hydrophilic weeds and nematodes.

Soil improvement with compost or organic matter that suppress disease, particularly in organic agriculture, have been used and are effective. The composts contain appropriate micro-organisms which have an overall or particular suppressive action. They also stimulate the self-protection mechanisms in the plants.

Hydroponics and non-soil crops have few protection problems.

Organic production which is based on prohibiting the use of multipurpose and highly toxic chemicals.

The use of micro-organisms to control plant parasites in the soil for market garden crops is beginning to spread. A range of organic products is now sold around the world. For example, Kodiak-Gus 2000 (*Bacillus subtilis* GBO3), Epic-Gus 376 (*Bacillus subtilis* MBI 600), Soilgard (*Gliocladium virens* Gl-21), Diterra (*Myrothecium verrucaria*), Victus (*Pseudomonas fluorescens* NCIB 12089), Deny (*Burkholderia cepacia*), Mycostop (*Streptomyces griseoviridis* K61), Biotrec (*Trichoderma harzianum* T-22), Promot (*Trichoderma koningii, T. harzianum*). In Greece too few of these products have been authorised (15).

Natural and artificial disease-resistant soils are an attractive field for research.

Pasteurising the soil using steam or water from geothermal sources reduces pathogenic microflora, leaving useful organisms unharmed.

In certain conditions heating the soil electrically can effectively control pathogenic agents.

Insolation of the soil either on its own or in combination with chemicals (metam sodium, calcium cyanamide, ammonium sulphate) or biological substances can in certain cases replace methyl bromide. The cost of using this technique is 5 or 6 times lower than methyl bromide.

The use of cultivars and graft supports that resist plant parasites in the soil can resolve certain problems of protection.

DISCUSSION

It has clearly been shown that methyl bromide is an active substance that threatens the stratospheric ozone layer. It is also a fact that the use of this product is critical to protected vegetable production in Greece.

As a result, the ban on its production and use for the protection of market garden crops, without practicable alternatives, will have a considerable adverse effect on economic viability and necessitate diversification of farming practices for these crops.

Greece has the political will and social responsibility to abide by the Montreal

Protocol. It has already started to develop strategies for phasing out or replacing methyl bromide. For the moment however, the country lacks new effective methods. It is therefore necessary, if vegetable production is to continue, to provide economic support for research programmes aimed at developing alternatives to methyl bromide and for disseminating the knowledge obtained.

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Chapter 19
SOLARIZATION OF STRAWBERRY CROPS IN HUELVA, SPAIN

F. Romero (1)

SUMMARY

Spain supplies more than 10% of the world production of strawberries and provides nearly all strawberries of the European Community during the first months of the year. Huelva's coast is the main strawberry area in Europe, with more than 6.000 ha in monoculture which are mostly dedicated to export. The use of methyl bromide (MB) in the province of Huelva in 1995 was 1,188 t, including 497 t in nurseries, which corresponds to more than 40% of the Spanish consumption. The discovery of the destructive capacity of the ozone layer by MB requires the urgent substitution of this product. The practice of soil solarization for strawberry cultivation is being adopted by some farmers in the province of Huelva, and it is possible that solarization, together with other techniques such as the biofumigation or low doses of chemicals, will become important alternatives to MB.

Keywords: *Methyl bromide, fungi, soilborne, fumigants, crop management*

INTRODUCTION

The cultivation of strawberry in Spain has undergone enormous transformation and progression in the last 20 years. During 1994, production was 282,183 t, from a registered surface of 9,000 ha, from which about 1,000 ha were dedicated to seedling nurseries. Spain supplies more than 10% of the world strawberry production and provides nearly all the strawberries of the European Community during the first months of the year.

Huelva's coast is the main strawberry area in Europe, with more than 6,000

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ha in monoculture, which is mostly dedicated to export, 80% to fresh consumption, 18% to industry transformation and 2% to other purposes. Information regarding the last seasons show clearly the economic and social importance of the crop in Huelva's province. During the 96/97 campaign, the production value (250,629 t) was more than 58,000 million pesetas (~ 400 million US $) generating a gross income for farmers of 36,350 million and salaries of 3,873 million. The benefits are divided among a number of small farms as 95% of them are smaller than 15 ha and accumulate 75% of the total cultivated surface (7,391 ha in the 95/96 season, period to which this information corresponds).

The particularity of Huelva's strawberry crop compared to other European countries, allows Spain to supply the European market during winter, is due to cultivation development in two different soils and climates. The first cultivation is in summer in the cold Spanish regions, mainly in Castilla y León, and even in Navarra and La Rioja (Fig.1). At the beginning of autumn, before the typical frost of septentrional areas, the adult plants in summer are rooted, classified and refrigerated before they are transported to the province of Huelva, where the climate is milder and where they will be definitively planted. The result is an extra-early production which permits its commercialization in the European markets in favourable conditions. In 1997, there was a registered surface of strawberry cultivation of 7,000 ha. The nursery area was about 1,000 ha, with a production of 15.5 million of mother-plants, which provided 450 million plants.

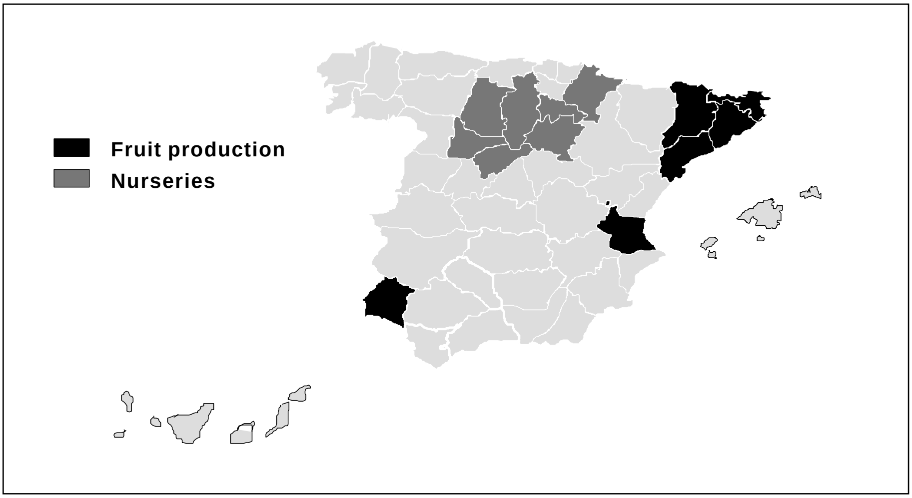

Figure 1. Strawberry production areas in Spain

METHYL BROMIDE USE IN STRAWBERRY

In Spain, two formulations of MB are commercialized: 98% MB + 2% chloropicrin and 67% MB + 33% chloropicrin. Since 1996, the doses of MB has been reduced as many farmers used the formulation 67/33. On the other hand, the soil disinfection is localized to the soil where the planting is done, obtaining a reduction of more than 50% of the MB dose.

The use of MB in the province of Huelva in 1995 was 1,188 t, including 497t in nurseries, which corresponds to more than 40% of the Spanish consumption. The discovery of the destructive capacity of the ozone layer by MB instigated, at the 1992 meeting of the Parties to the Montreal Protocol of Copenhagen, a recommendation for the urgent substitution of this product.

Since 1997, a macroproject in Spain, with the participation of researchers from all regions where MB is used (Andalucía, Valencia, Murcia and Castilla y León), has been developed. The fundamental objective is to search for alternatives to MB. Among the alternative treatments to MB in strawberry crops we may emphasize the following appraisal:

- solarization
- biofumigation
- solarization + biofumigation
- solarization + chemical treatments

SOIL SOLARIZATION

In the province of Huelva, the soil is mostly sandy. When the soil is to be solarized, it is tilled to obtain a surface as homogeneous as possible to avoid the formation of air bags and as a consequence, a disminution of the temperature. The soils are then watered until saturation and they are later covered with transparent polyethylene of 40 µm thick. Polythylene sheets 6 m wide and from 50 to 100 m long are used, depending on the plot size. Between sheets, a soil surface is left without covering, which allows extension of the polyethylene. The chosen months for the solarization are July, August and in some cases, September when the temperatures reach the highest point and the soil is not cultivated.

The camellons are covered at the same time with drip irrigation and black polyethylene. The objective of this method is to avoid weeds and the direct contact of fruits with the soil. The polyethylene of the camellons of soil is pierced. In each of these holes, a seedling is planted, the density is between 70,000 and 80,000 plants/ha. In order to force the crop, two systems are used: the small tunnels, which covers one camellon, and the macrotunnel which covers 6 camellons. Each one has its advantages and disadvantages. This technique has been practiced for 5 years in an experimental farm of our Research Center in Huelva, where soil disinfectants have never been used and there has never been a phytopathological problem with soil plant pathogens.

The knowledge of the cultivation system used allows us to understand better the phytopathologic problems which affect the strawberry in Spain and more specially in Huelva. This problem is not as complex as it should be after 35 years of the initiation of this crop.

Table 1. Pathogens on strawberry in Spain

High incidence	Low incidence
Botrytis cinerea (Sclerotinia fuckeliana)	*Sphaerotheca macularis*
Colletotrichum acutatum	*Verticillium dahliae*
Phytophthora cactorum (nurseries)	*Rhizopus stolonifer* assotiated to
Rhizoctonia fragariae	*Frankiniella occidentalis*

The pathogens which affect the strawberry cultivation in Spain may be observed on the Table 1. From all of them, those which produce more losses in the yield are *Botrytis cinerea* (Gray mold) and *Colletotrichum acutatum* (Crown rot). The first one depends greatly on the cultivation conditions and on the fruit handling by the people who manage the crop. *Colletotrichum* is considered by some authors as a soil pathogen, but not by others (Eastburn & Gubler, 1990, 1992). We have verified that in the Spanish conditions and more specially in the province of Huelva, this fungus does not survive from one year to the next; for this reason, we do not consider it as a soil-borne plant pathogen. The rest of the pathogens has a lower incidence on the cause of production losses.

To determine the solarization efficiency in the control of soilborne plant pathogens and in the yield increase, we have used randomized blocks, four replicates of elemental plots of 25 X 6 m^2, in four different fields, with the same soil preparation system and the above mentioned polyethylene sheets.

In each of the elemental plots, we took soil samples between 0 and 20 cm depth, before covering them with polyethylene-mulched, as well as after the solarization period. These samples were analyzed to estimate the number of pathogens inocula: *Sclerotinia fuckeliana, P.cactorum, Rhizoctonia fragariae* and *Verticillium dahliae* (Table 2). To compare the effect of the polyethylene mulches and MB on yield of strawberry fruits we used randomized blocks and four replicates (Table 3).

The practice of soil solarization for the strawberry crop is being adopted by some farmers in the province of Huelva and we do hope that, together with other techniques such as the biofumigation or low dose of chemicals, they become in a few years an important alternative to MB consumption.

Table 2. Effect of solarization on soil inoculum density in strawberry crops

Pathogen	**Inoculum/ g soil**							
	Premulching (1)				**Postmulching** (2)			
	1 (3)	2	3	4	1	2	3	4
S.fuckeliana	60	90	80	110	5	10	8	10
P.cactorum	3	—	5	4	0	0	8	0
R.fragariae	7	2	8	1	0	0	0	0
V.dahliae	5	2	2	3	0	0	0	0

(1) Ten soil samples were collected from depths 0-20 cm. In each elemental plot (25 X 6 m^2), the inoculum determined by *S.fuckeliana:* sclerotia; *P.cactorum:* oospore; *R.fragariae:* sclerotia; *V.dahliae:* microsclerotia; (2) transparent polyethylene tarps 40 µm thick were placed on soil on 1st July and removed 14th August, strawberry plants were planted on 20th October; (3) field number.

Table 3. Effect of solarization and MB on strawberry yield in Huelva

Soil treatment	Yield (kg/ha)							
	First year				Second year			
	March	April	May	Total	March	April	May	Total
Nontreated	6,763	16,063	12,498	35,324	11,511	16,596	19,484	47,591
Solarized	8,696	18,688	13,921	41,305	13,116	20,079	22,585	55,780
MB (20g/m^2)	8,999	19,030	14,124	42,153	13,651	22,153	22,256	58,060
MB (40g/m^2)	9,866	20,107	15,531	45,504	15,022	23,167	23,257	61,446
LSD (P=0.05)	—	2,496	1,914	5,324	1,514	3,118	—	5,094

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Chapter 20

ANALYSIS OF ALTERNATIVES TO SOIL FUMIGATION WITH METHYL BROMIDE IN PORTUGAL

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ABSTRACT

Methods and technologies experienced in recent years in Portugal for the control of soilborne plant pathogens and pests related to intensive land use, and which are potential alternatives to methyl bromide use, include soil solarization, soil amendments with Tagetes minuta, *vegetable cultivars resistant to* Meloidogyne *spp., steam heating and soiless cultures. The results of experimentation accomplished in these areas are presented and discussed. Considering the wide range of vegetable crops and cut flowers produced and the variety of soil types where they are grown in Portugal, the need for more data of the performance of each measure in the control of specific crops problems is stressed.*

INTRODUCTION

Since the beginning of agriculture, humans have attempted to increase the production of food and other farm commodities and in the process, have changed the plant cropping system. The self-sufficient, sustainable agriculture of early times was substituted by the intensive land use of present time. Many agrochemicals has been produced in the last fifty years for the control of plant pests and diseases associated with intensive crop production. Arsenical compounds (insecticides such as Paris green, lead arsenate), mercuric compounds (fungicides like mercurous chloride), organochlorine compounds (insecticides such as DDT, BHC, Aldrin, Dieldrin, and nematicides like DBCP), and organophosphorous compounds (insecticides such as Parathion, Malathion) were used during the last few decades. However, the production of most of those agrochemicals was discontinued because of undesirable health and environmental risks associated with their use. Similarly methyl bromide (MBr), a gas used in agriculture throughout the world since the early 1960's mainly as a soil fumigant but also as a postharvest treatment and plant quarantine pest control treatment, was found to contribute to the depletion of the ozone layer. The Parties to the Montreal Protocol of 1991, at a meeting held in Vienna in December 1995, agreed that developed countries would stop producing MBr by 2010. A wide spectrum of pests, plant pathogens and weeds are controlled by MBr. There is no single alternative to MBr in all of its wide range of uses. However , chemical and non-chemical alternatives do already exist for a number of specific applications. In our presentation we examine measures and technologies used in recent years in Portugal for controlling specific soil borne plant pathogens (SPP) that are potential alternatives to MBr use.

SOIL SOLARIZATION

Soil solarization is based on pasteurization of the soil by means of solar radiation. It is achieved by continuous mulching covering the whole soil to be treated with thin transparent polyethylene sheets, usually 50-100 m thick. The thickness of the plastic and its physical properties can influence greatly the results of solarization. In greenhouses the soil can also be successfully solarized.

In Portugal, owing to its geographical location in Southern Europe, the monthly average daily global solar radiation reaching the land in the hottest months (June, July, August) varies between 22.9 MJm^{-2} and 28.8 $MJ\ m^{-2}$. The experience with soil solarization technology, applied either in greenhouses or in the open field to control SPP and weeds in several crops, is encouraging. Nevertheless, in the Atlantic littoral and coastal uplands, soil temperatures are not high enough to control SPP efficiently, so solarization should be combined with other technologies.

The control of several *formae speciales* of *Fusarium oxysporum*, of *Pyrenochaeta lycopersici* as well as the root-knot nematodes (*Meloidogyne arenaria, M. hapla, M. incognita* and *M. javanica*), the carrot cyst nematode (*Heterodera carotae*), spiral nematodes (*Helicotylenchus* spp., *Rotylenchus robustus*), and root-lesion nematodes (*Pratylenchus* spp.) vary from good to very good (Reis, 1997). In general, the control of annual weeds is achieved for a residual period of 7-9 months. A few perennials such as yellow nutsedge (*Cyperus esculentus*), yellow sorrel (*Oxalis pes-caprae*) and field bindweed (*Convolvulus arvensis*) are not controlled.

Soil solarization is effective only where there is sufficient sunshine, soil conditions are favourable, technical assistance is available to farmers, and where costs of an unproductive period in the hottest months (4-6 weeks) can be accomodated. The unpredictability of the natural variation of the global radiation reaching the soil in the hottest months (last year in Portugal the summer months were cooler than in the preceeding years) suggest that to ensure a good control of SPP and weeds soil solarization should be combined with other measures *viz.* organic amendments, pesticides applied at reduced dosages, biocontrol agents and crop rotation. The plastic sheets used constitute a potential environmental problem. Measures should be taken to ensure that the used plastic is collected and disposed of by recycling. In strawberry culture and in tobacco seed beds, where MBr is applied to control SPP, an evaluation of the plant pathogens and weeds to be controlled must be made before substituting MBr for soil solarization. In addition, to avoid the recontamination of treated soils, the quality of the irrigation water should be assessed carefully.

SOIL AMENDMENTS WITH *TAGETES MINUTA*

The addition of organic matter to improve soil fertility and control plant pests and diseases is a practice as old as agriculture. A large variety of materials, including agricultural and industrial by-products, much of which are wastes, can control phytoparasitic nematodes when used as amendments (Castillo, 1985). The reduction in nematode population density due to organic soil amendments was considered by Sayre (1971) to be due to the direct toxicity of the products of decomposition, an increase in the number of natural enemies, and to the alteration of plant-nematode relationship. Other explanations for the nematicidal effect of amendments with organic materials include ammonification (Walker, 1969) and raising of soil temperature during decomposition (Sussman, 1982).

It has been known for a few decades that marigolds (*Tagetes* spp.) effectively control some species of phytoparasitic nematodes (Steiner, 1941; Oostenbrink, Kuiper & S'Jacob, 1957; Daulton & Curtis, 1963). The effect of one crop of *Tagetes* may approximate that of treatment with a nematicide (Oostenbrink *et al.*, *op. cit.*). Chemical substances strongly nematicidal were isolated from *Tagetes* roots (Uhlenbroek & Bijloo, 1958, 1959). Differences, however, exist between the various species of the genus *Tagetes* in their ability to effectively reduce nematode populations (Daulton & Curtis, *op. cit.*).

Due to the high degree of polyphagy exhibited by most of the root-knot nematodes (*Meloidogyne* spp.) occurring in Portugal, in preliminary experiments we investigated the host status of some *Tagetes* species (Reis, 1997). The African marigold *T. erecta* cv. Hawaii , the French marigolds *T. patula* cvs. Lilliput double nain Helen Chapman and nain double citronella, and *T. minuta* cv. Nemanon were found to be non-hosts of populations of *M. javanica* (no nematode reproduction occurred) in experiments conducted in three Portuguese localities far apart each other. *T. erecta* cv. Hawaii was found to be also a non-host for *M. arenaria*, *M. incognita* and *T. patula nana* cv. nain double citronella. On the other, hand *Terecta* cv. *Hawaii* was found to be a host (nematode reproduction occurred) for *M. incognita* and *M. arenaria*. Subsequently we studied the efficacy of an organic amendment with *T. minuta* cv. Nemanon for controlling the root-knot nematode *M. javanica* in a greenhouse. *T. minuta* cv. Nemanon planted in three 6 m^2 plots was incorporated into the soil at the initiation of flowering (7 kg m^{-2}). Three control plots were used. Afterwards, lettuce cv. Rainha de Maio was planted in all experimental plots. When the lettuce began flowering the root-knot index was determined. The results obtained (Reis, 1997) showed that the amendment with *T. minuta* cv. Nemanon conferred some degree of protection to the lettuce root systems. Nevertheless, more experimentation must be done, which will include other *Tagetes* species and various dosages of the amendment.

CULTIVARS RESISTANT TO ROOT-KNOT NEMATODES (*MELOIDOGYNE* SPP.)

The use of nematode-resistant cultivars, is a long-term, cost-effective and environmentally safe measure for nematode control, although its development and adoption in horticultural production has been hindered by the availability of effective nematicides. These cultivars can be used as an effective alternative to MBr for controlling specific nematodes in a wide range of crops. Resistant cultivars prevent the build up of nematode populations, do not require special application techniques or equipment, have a comparable cost to non-resistant cultivars and can be used associated with other plant pest or disease control measures.

Among the phytoparasitic nematodes occurring in Portugal, either in the open field or in greenhouses, root-knot-nematodes are the most important, causing invariably great crop losses, unless growers adopt appropriate control measures. Many root-knot nematode-resistant vegetable crop cultivars have been developed, but often they have not been chosen by growers for several reasons, *viz.,* unsuitable agronomic performances, fruit characteristics did not meet market requirements, etc. Since their resistance genes have usually been specific for a few *Meloidogyne* species, some of these cultivars can only be grown profitably where the species composition of the root-knot infested soil is known.

In greenhouse experiments we found that the tomato cultivars Royal Flush, Hybrid 9889 and Jackpot to have very good resistance against populations of *M. javanica* and we observed that the tomato cultivars Boa, Solstar, LM 309, Optima, Alpado and Indalo exhibited good resistance against a mixed population of *M. hapla* and *M. javanica* (Reis, 1997). Furthermore, in a greenhouse whose soil was heavily infested with *M. hapla* we noted that the yields of lettuce cv. Fleur and of pepper cv. Lido, was not affected. These cultivars were shown to be tolerant to nematode attack. Although their root systems were severelly galled, no nematode reproduction occurred in lettuce. In pepper the nematode reproduced abundantly, but the exceptional vigour of its root system apparently compensated for damage caused by the nematodes.

In order to enable growers to select the appropriate cultivars among the numerous vegetable seed varieties available in the market further research is needed. Of utmost importance is the implementation of a screening program aimed at evaluating the resistance/tolerance of each vegetable cultivar against specific root-knot nematodes.

STEAM HEATING

Although steam heating for soil treatment, when used alone, has the broad spectrum of activity and efficacy of MBr it is nonetheless the most energy intensive alternative. To effectivelly disinfest soils by steaming, soil temperatures of at least 70 ºC must be reached for 30 min. (Anon., 1997a). Steam sterilization has several advantages, *viz.*, it can be highly efficient for the control of SPP, plant pests and weeds, it precludes the need of tarps or fumigants, it leaves no toxic residues or fumes and so it is less harmful to other greenhouse crops, and no aeration time is needed in treated plots. However it should be stressed that steam heating presents some potential disadvantages, *viz.,* it is a non-selective control measure, killing pathogenic and non-pathogenic soil microorganisms, thus creating a ‘biological vacuum;’ it consumes very much time and labour; and above all, it is expensive, requiring large amounts of energy and capital investment. In addition, steam that is too hot (85-100 ºC) may increase soil aggregation and destroy soil structure.

Information about the results of soil steaming in portuguese soils is scarce We monitored nematode populations in two greenhouses where soil steam heating has been accomplished. In both cases active root-knot juveniles, (*Meloidogyne* sp.), root-lesion (*Pratylenchus* sp.) and spiral nematodes *(Helicotylenchus* sp., and *Rotylenchus robustus*) were recovered from soil samples collected a few days after the soil steaming treatment. Considering the variety of greenhouse soils where vegetable crops and cut flowers are grown throughout the country, there is a need to gather some performance data related specifically to duration of steaming x soil type x target organisms. Great care should be given to the quality of seeds, planting material and the irrigation water used after steam treatments so that the reinfestation of the steamed soils does not occur quickly.

SOILESS CULTURES

Hydroponics can be a viable alternative to MBr fumigation for several greenhouse grown crops such as vegetables and cut flowers. The absence of competing weeds, SPP and toxic residues, water conservation and the possibility of easily managing the hydropony system components to suit specific crops, various growth stages and environmental conditions are pointed out as advantages of the hydroponic technology. Furthermore, growers can space plants closer together, thus increasing the productivity per given area (Anon.,1997b). The high capital investment needed, however, to implant the hydroponic technology precludes its adoption by small-scale plant producers.

To avoid problems caused by SPP in areas of intensive vegetable production, an increasing number of growers are using hydroponic systems *viz.,* water culture or substrate culture (rockwool and sand cultures) for horticultural crop production. Tobacco growers in Portugal used to produce tobacco transplants in seed beds previously fumigated with MBr, but lately tobacco transplants are sucessfully produced in a float-system using direct-seeded expanded polystyrene trays filled with steam treated media. The system improves plant uniformity, enhances control over plant growth and decreases labour requirements and the costs of pulling. When producing transplants in this way, there is no need for MBr. The growing substrates can be disinfested by steam heating, solarization or with an appropriate pesticide.

In a few cases we found severe crop losses in rockwool cultures of melon and tomato, caused by root-knot nematodes that were introduced in the hydroponic system (Reis, 1993, 1997). It should be stressed that with these types of agricultural production technology the quality of the water to be used and the efficacy of the water filtering components are of utmost importance and should be carefully assessed. Effective and low cost water filtering systems should be developed.

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Chapter 21
TOBACCO SEEDLING PRODUCTION WITHOUT METHYL BROMIDE

by Inocencio Blanco

INTRODUCTION

The Spanish tobacco production is located in the Extremadura region (88%), and the rest in the South (province of Granada) and a few kg in the North. The tobacco production in Spain can oscillate a little bit from one season to other, depending, upon others factors climate and diseases, but follow closely the quota assigned by the european union. **Table 1.**

Table 1. Tobacco quotas for Spain

Variety	**Tm**
Virginia E	29.000
Burley E	2.470
Fermented burley	10.800
Kentucky	30
Total	**42.300**

Fermented burley tobacco production in Spain started in 1919. Burley tobacco is harvested when the whole plant is ripe. It is an air cured process inside of a barn. Once the curing process is finished, the leaves are stripped one by one and after a fermentation process, the manufacturers elaborate black cigarrettes. In 1978 the Virginia tobacco production started in Spain. It is harvested leaf by leaf when they are ripe, starting from the lower part of the plant. The curing process is a forced air ventilation system. After processing it is used to elaborate blond cigarrettes.

TOBACCO SEEDLING PRODUCTION

Obtainment of high quality seedling is the first step towards producing an excellent crop. The traditional seedbed begins with normal tillage and fertilization, after that the soil is fumigated with methyl bromide, to eliminate: nematodes, weeds, insects and fungi, to obtain bare roots seedlings.

In 1991, we started the experiments with the float tray system in the experimental farm of Cetarsa “La Cañalera”, located in the middle of the tobacco growing area of Extremadura Autonomous region. In order to obtain seedlings in trays.

Producing seedlings in trays, have the following advantages in relation with the bare root seedlings. **Table 2.**

Table 2. Advantages of seedling production in trays

- Save of required labour for seedling pulling that increases available labour for trasplant.
- These seedlings show better retaking speed and faster crop growing.
- It provides an uniform crop and, for this, lower production costs.

- The floating tray system is an easy and sure way to produce healthy, uniform and good tobacco seedlings, the seedlings grow in trays floating on a water bed from seeding to transplant.

- Several matherials can be used to build the pools: bricks, wood, metal. The soil should be carefully levelled, the water bed bottom needs one or better two black plastic coverings

- Good quality water is required, municipal. water is adecuate **table 3.**

- We add 100 p.p.m of nitrogen from a 20.10.20 fertilizer to the water. Excess nitrogen can make more sensible the seedlings to diseases.

- High density (32-35 g/l) polystyrene trays are required. If trays are going to be re-used, a ten percent solution of bleach, should be used to disinfect them.

- Media is the support for the root system that takes water and nutrients from the water pool. **table 4.**

- The cells of the trays are filled with the media, making a depression in the middle of the cell to place the seed. Cleaning the remaining media is necessary in

Table 3. Desirable characteristics for media used in float system tobacco

Blonde peat	50%
Vermiculite and/or perlite	50%
pH	5,8 to 6,3
Wetting agent	
Very little fertilized	
Humidity content	60%
Particle size	0,5 to 1,5 mm

Table 4. Desirable characteristics for water used in float system tobacco

Electrical conductivity	0,3 - 1 Mmhos/cm
Residual hardness (Eaton's index)[1]	60 - 100 ppm
Calcium	40 - 75 ppm
Magnesium	30 - 50 ppm
Total nitrogen	0 - 10 ppm
Phosporus	0 - 10 ppm
Potassium	0 - 10 ppm

[1] This is total alkalinity minus total hardness expressed as ppm of $CaCO3$.

order to avoid algae. Good quality pelleted seed must be used, with uniform size and germination power over 90%. The seeder will place one seed in each cell.

- To produce good quality seedling requires to start clipping when the plant height is 5 cm (bottom to top leaves). It is important, in order to control the collar rot, to realize preventive treatments against it with fungicide.

In 1992, we started the dissemination of the float system to the tobacco growers. At the begining on small scale and through the Cetarsa technicians, each one of them gives technical assistance to 35-40 growers. We carry on the difussion with courses, practices in grower´s farms, conferences, brochures, magazines, articles, technical demostrations and expositions that we celebrate yearly in March in Cetarsa´s experimental farm. We collaborate in European projects supported by the European Union. Some of them are comparison trials of different concentrations of aphicides and fungicides in the pool water in order to lessen pesticide residues in the tobacco leaves and the environment.

USE OF METHYL BROMIDE FOR TOBACCO SEEDBEDS IN CÁCERES (SPAIN)

The percentage of Virginia seedlings production in trays in Spain for the year 1998 was 92%. (Table 5). Burley seedlings percentage production in trays in Spain during the 1998 season was 44%.(table 6). The use of methyl bromide for tobacco seed-beds in Cáceres during the 1995 season was 46.410 kg. (Table 7). Table 8 shows the decreasing use of methyl bromide (Blanco 1997, del Moral, 1998).

CONCLUSION

The tobacco seedling production without methil bromide in Spain is possible by the development of a new alternative technique: float system, that supplys to the growers healthier, more uniform and better seedlings than from the traditional plant-bed.

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Chapter 22

INTEGRATED PEST MANAGEMENT IN COLOMBIAN FLORICULTURE

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Floriculture is a very important sector in Colombia, generating annual revenues of nearly $550 million dollars and providing more than 75,000 direct jobs and many more indirect ones. In only thirty years since its beginning, flowers have become the second agricultural export product after coffee, surpassing bananas which for many years held this place. At present, Colombia is also an example of development in floriculture which other Latin American countries such as Ecuador, Costa Rica and México are now following.

In spite of the technology required, of stringent quality requirements and the presence of phytosanitary problems associated with the soil, Colombian floriculture developed without methyl bromide. There are two main reasons to explain this: in the first place, the high organic matter content of Colombian soils (frequently surpassing 18%) seems to have led to the fixation of high quantities of bromine which are phytotoxic to plants; secondly thirty years ago methyl bromide was not readily available to Colombian flower growers and it was perceived as a costly product which was difficult to apply. Thus, they turned to alternative products and methodologies which today have become worth following.

This talk analyzes not only alternatives to methyl bromide used in Colombian floriculture but to alternatives to the general use of pesticides, within the concept of Integrated Pest Management. Even though it is impossible to produce export quality flowers without no pesticides at all due to quality requirements and phytosanitary barriers and quarantines existing in importing countries, rational or justified use of pesticides should be a commitment of every flower grower both for ecological and human hazard reasons.

All production processes should be framed within the IPM concept; pesticides needed should be correctly and safely applied; and less toxic alternatives or products - many times available - should always be preferred.

Pests and diseases should be detected as soon as possible, treating foci as soon as they appear and using otpions different to chemicals whenever feasible: physical and cultural controls, resistant varieties, biopesticides and others. Biocontrol, although not always easy to implement at the commercial level, is also an excellent option. In summary, IPM requires a grower to understand the life cycle of a pathogen, its epidemiology and ways of dissemination; surviving forms, alternate hosts, and others. The following table shows the main components of such a system, which are to be adapted to the particular situation of each pest and disease:

Table 1. RATIONAL USE OF PESTICIDES - INTEGRATED PEST MANAGEMENT

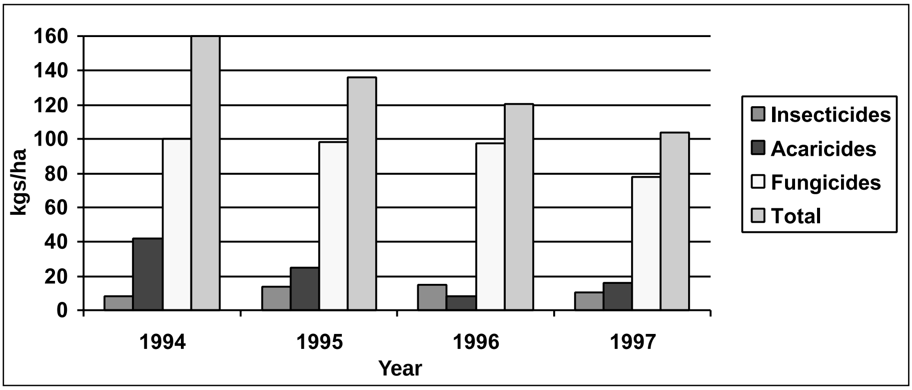
1. Monitoring (scouting)
- * Human resources - Trained personnel that can detect and identify problems in the field
- * Mapping - Identification of affected areas (foci) and pest or disease present
- * Collecting information - establishing of a damage threshold
- * Results and decisions - when and where to apply a pesticide

2. Greenhouse sanitation and maintenance
- * Avoiding weeds that act as alternate hosts
- * Good ventilation that reduces disease (caused by fungi for example)
- * Keeping greenhouse covers in good condition

3. Physical and chemical control
- * Insect traps (yellow, blue) to reduce and monitor populations
- * Screens and other barriers that restrict insect entrance
- * Aspirators or vacum cleaners that trap insects
- * Rouging diseased plants
- * Soil sterilization with steam
- * Restricting passage of workers and vehicles from diseased to healthy areas
- * Disinfestation of shoes, tools and others

4. Biological control
- * Biopesticides (many are now commercially available)
- * Biocontrol agents many times used at an experimental level but with good perspectives
- * Resistant varieties, available for many pests and diseases

Table 2. Kgs of active ingrdient per Ha and year in a carnation nursery using Integrated Pest Management.



Source: Carulla and Trujillo, 1997, 1998 Flexport de Colombia, Bogotá, Colombia

In its practical application IPM leads to excellent results not only by improving the efficiency of the business, but because over time, it represents siginificant savings both in natural resources and in money. This has been proven at the practical level in flower farms in Colombia and is evidenced in the following charts:

It is observed that between the first and second years the quantity of pesticides used was reduced by 15%; between the second and third by 12%; and between the third and fourth by 14% for an approximate total of 35% in four years. These data, however come from a flower company that has been using IPM for a long time, improving it and making it more efficient each year. If we compare this case with a traditional control system where insecticides for the control of thrips are applied every week (note that some manufacturers indicate applications as frequent as every five days) on the whole crop, not just foci and not taking a damage threshold in consideration, the following results would be obtained:

It can be observed that not only quantities of pesticides used are much higher in the traditional control system (almost 75% more) but that costs for IPM - contrary to what many would expect - costs almost 50% less! The experiences shown above are a clear demonstration that eco-efficiency and sustainable production are very feasible options in cut flower production.

Last but not least let us analyze 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*, the most limiting disease in carnation pro-

Table 3. Comparison between traditional pest control (spraying once a week) and IPM for thrips *(Frankliniella occidentalis*

A - Spraying program (dosis/Ha)		**Mode of Action**	**Dosis/Ha**
Thiocyclam (nereistoxin)		Contact - larvae	1.0 kg
Methiocarb (carbamate)		Contact - adults	1.0 kg
Lambda-cyhalothrin (pyridazinone)		Contact - adults	0.8 kg
B - Execution			
	Application	**kg /Ha/year**	**Cost**
TRADITIONAL	Weekly	43.7$	2145
IPM	Ind./Trap/Wk*	14.0	$1059**

* 0 - 5 individuals per trap per week: No spraying
5 - 10: One spray
10> : Two sprays
** Includes hand labour and materials such as traps

Source: Flexport de Colombia

duction. It should be noted that for steam to be a feasible option it should be used along with an integrated management program that includes points discussed above and summarized in Table 5. If not, disease incidence will probably be high and steam treatment costs will triplicate as it will become necessary to inject steam at a depth of at least 80 cm and more during very long periods of time. Likewise, 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.

In addition to costs, other benefits to steam sterilization are observed, mainly in relation to long waiting periods associated with soil fumigants - generally of at least thirty days - before replanting can occur. 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 this system also report more vigorous and productive plants; what is even better, they have been able to grow carnations in the same farm for over twenty years with losses of only 3% and even less, (Carulla y Trujillo 1996, personal communication); not many flower growers can tell this

Table 4. Comparison of general costs for sterilizing the soil with several fumigants and steam

Costs in US dollars. Data supplied by Jardines de los Andes and Flexport de Colombia, Bogotá, and Cultivos Miramonte, Medellín, Colombia

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

* includes general hand labour costs
** low disease incidence

story given the aggressiveness and virulence of this pathogen in Colombian soils, which have forced growers to change to a different crop.

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Table 5. IPM for fusarium wilt of carnations (*Fusarium oxysporum* f.sp.*dianthi*)

A. Monitoring	Disease scouts Special erradication measures. Mapping with all pertinent data Historic information for decision making
B. Cultural control	Crop sanitation Management of fertilisation (especially nitrogen sources) pH control (acid detracts the fungus) Restricted access to greenhouses
C. Physical and mechanical control	Soil steaming (especially if disease level is low) Destroying diseased plants
D. Biological control	Resistant varieties Antagonists-suppressive soils Allelopathy
E. Chemical control	Disinfestation when entering greenhouses Soil fumigants

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Appendix 1

WORKSHOP AGENDA

TUESDAY, 26 MAY

09:00-10:00 Registration

10:00-10:50 Welcome Remarks and Objectives of the Workshop

- Ministro dell'Ambiente, Sen. Edo Ronchi
- Gesellschaft für Technische Zusammenarbeit (GTZ), Peter Stoermer
- European Union (EU), Geoffrey Tierney
- United Nations Environment Programme (UNEP), Steve Gorman
- Food and Agricultural Organisation (FAO), Dr Nick van der Graff

10:50-11:15 Coffee break

Session I Methyl Bromide and the Montreal Protocol

Chair: Prof. M. L. Gullino

11:15-11:35 The Montreal Protocol and Implications for Article 5 as well as non-Article 5 Parties (Steve Gorman, UNEP)

11:35-11:55 The Methyl Bromide Technical Options Committee (MBTOC): How does it work? (Dr Rodrigo Rodriguez-Kabana, Co chair, UNEP MBTOC)

11:55-12:15 Economic Implications of moving to Methyl Bromide Alternatives (Dr Robert Van Slooten, Co Chair, UNEP Economic Options Committee)

12:15-13:00 Discussion (45 minutes)

13:00-14:00 Lunch

Session II	**Case study presentations on Alternatives to Methyl Bromide in Soil Fumigation**
Chairs:	**Dr Rodrigo Rodriguez-Kabana**
14:00-14:30	Vegetables production without methyl bromide in Italy (Prof.G. Cartia, University of Reggio Calabria and Prof. A. Minuto, Universita of Torino, Italy)
14:30-15:00	Case study from North African on tomato growing (Mr M. Ammati, University of Rabat, Morocco)
15:30-16:00	Soil solarisation and its application in the Mediterranean countries (Prof. Spiegel, Institute of Plant Protection, Israel)
16:00-16:20	Coffee break
16:20-16:50	Pepper varieties and resistance to soil-borne pathogens (Dr M. di Vito, Consiglio Nazionale delle Ricerche, Bari, Italy)
16:50-18:00	Discussion (1.10 hrs)
18:30	Reception

WEDNESDAY, 27 MAY

Session III	**Case Study Presentations on Alternatives to Methyl Bromide in Post Harvest Applications**
Chair:	**G. Mastino**
09:00- 9:30	Alternatives to methyl bromide in grain storage (Dr Robert Taylor, Natural Resources Institute, MBTOC)
Session IV	**Economic Competitiveness**
Chair:	**Dr Bob Van Slooten**
09:30-10:15	Making the right choices (Ms Edith Huang, Friends of the Earth, Spain) (Dr Abou Thiam, Pesticide Action Network, Senegal)
10:15-10:35	Coffee break
10:35-10:55	Eco-labelling in cut flower production (Dr J. Klijnstra, TNO Institute of Industrial Technology, The Netherlands)

Session V	**Future Challenges**
Chair:	**Steve Gorman**
11:15-11:35	Transferring lab results into viable demonstration projects (Mr C. Martin, Agriphyto, Perpignan, France)
11:35-13:00	Discussion (1.25mins)
13:00-14:00	Lunch
Session VI	**Future Legislative or Regulatory Approaches**
Chair:	**Prof. Guido Visconti**
14:00-14:20	The Netherlands (Dr Klijnstra, TNO Institute of Industrial Technology)
14:40-15:00	Tunisia (Mr Hassen Hannachi, Directeur du Controle à l'Agence Nationale de Protection de l'Envionment, Tunis)
15:00-15:20	The European Union (Mr G. Tierney, DG XI, European Commission, Brussels)
Session VII	**Sources of Financial Support for Methyl Bromide Phase out**
Chair:	**Geoffrey Tierney**
15:20-15:40	The Multilateral Fund for the Implementation of the Montreal Protocol (The Multilateral Fund Secretariat)
15:40-16:00	MEDA (EU Commission)
16:00-16:20	Coffee break
16:20-16:40	LIFE 2 EU Commission, Dr Volkmar Hasse
16:40-17:40	Discussion/recommendations on future actions to be taken to expedite methyl bromide phase out
17:40-18:00	Closing Remarks

THURSDAY, 28 MAY

Departure from Rome, FAO at 07:30 am

Arrival at Fondi Latina area at 09:00 am

09:00-10:00 Visit at the M.O.F. (general fruit and vegetable market)

Aim of the visit is to explain the importance of agricultural products in economic as well as commercial activities. During the visit participants will be informed about:

- the total amount of agricultural products sold; and
- geographic origin of the different products.

10:00-10:30 Alternatives to methyl bromide in the Bracciano area.
Short talk by Dott. Ciampi, Friends of the Earth, Italy.

11:00-1300 Field visit to two farms.

First field site

Main Crop Tomato

Fields where crops are grown using usually methyl bromide to control weeds, diseases and pests will be shown. It will be explained why other disinfestation systems such as soil solarization are not easy to apply in these fields.

Second field site

Main Crop Zucchini

Visit to a field where zucchini crops are grown without regular application of methyl bromide. The use of methyl bromide alternatives will be explained, i.e. such as soil solarization.

13:00-14:30 Lunch

15:00-17:00 Field visit to two farms

First field site

Main Crop Zucchini

Visit to a field where zucchini and tomato crops are grown without regular application of methyl bromide.

Second field site (if possible)

Main Production Cut Flowers

18:00 Return to Rome, FAO

FRIDAY 29, MAY

Scientific and Technical Update

Chair: **Prof. Rodrigo Kabana**

09:00-09:20	Status of methyl bromide alternatives for soil fumigation in southern Europe (Prof. M.L. Gullino, Universita di Torino, Italy)
09:20-09:40	Soil solarization and its application in southern Europe (Prof. E. C. Tjamos, University of Athens, Greece)
09:40-10:00	Biofumigation and organic amendments (Prof. A. Bello, CSIC, Madrid, Spain)
10:00-10:20	Soil-less culture in southern Europe (Prof. P. Tognoni, Universita di Pisa, Italy)
10:20-10:40	Coffee break
10:40-11:00	Dazomet – a methyl isothiocyanate generator with desirable properties (Dr H.J. Fritsch, BASF, Germany)
11:00-11:20	Combinations of 1,3-dichloropropene with chloropicrin and other chemicals as alternatives to methyl bromide for soil fumigation (Dr D. Sumner, University of Georgia, Tifton, GA, U.S.A.)
11:20-11:40	Tomato production without methyl bromide in Spain (Dr Javier Tello, University of Almeria)
12:10-12:30	Vegetable production without methyl bromide in Greece (Dr. Bourbos, National Agricultural Research Foundation,Greece)
12:30-13:30	Lunch
13:00-13:50	Solarization and control of soil-borne diseases in strawberry production in Huelva, Spain (Dr. F. Romero, Consejeria de Agricultura y Pesca, Junta de Andalucia, Spain)
13:50-14:10	Analysis of alternatives to soil fumigation with methyl bromide in Portugal (Dr. L.G. Reis, Estacao Agronomica Nacional, Quinta do Marques, Oeiras, Portugal)
14:10-14:30	Tobacco seedling production without methyl bromide (Ing. I. Blanco, CETARSA, Extremadura, Spain)

14:30-14:50	Integrated production of cut flower and ornamentals in Colombia (Ing. Marta Pizano, HortiTecnia, Santafe de Bogota, Colombia)
14:50-15:10	Coffee break
15:10-17:00	Discussion and recommendations on future actions in order to comply with the Montreal Amendment to the Montreal Protocol

Appendix 2

LIST OF PARTICIPANTS
REGIONAL WORKSHOP ON METHYL BROMIDE ALTERNATIVES FOR NORTH AFRICAN AND SOUTHERN EUROPEAN COUNTRIES

FAO, 26-29 May, 1998

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Appendix 3

WELCOME REMARKS ADDRESS TO THE REGIONAL WORKSHOP ON METHYL BROMIDE ALTERNATIVES FOR NORTH AFRICAN AND SOUTHERN EUROPEAN COUNTRIES

*Steve Gorman, **UNEP IE OzonAction Programme***

Rome, 26 May 1998

Ladies and Gentleman,

On behalf of the UNEP IE OzonAction Programme, I would like to welcome you to the Regional Workshop on Methyl Bromide Alternatives for North African and Southern European Countries. First, I would like to express our thanks and appreciation to the Italian Ministry of Environment and the European Commission for providing financial assistance to make this workshop possible and to GTZ for their cooperation and involvement in organizing the workshop.

This workshop presents an important opportunity for North African and Southern European countries to come together to learn about methyl bromide alternatives and identify ways to collaborate in promoting alternatives. There is much that countries from these two regions can learn from each other in identifying and implementing safe and effective alternatives. It is our hope that this workshop will mark the beginning of close cooperation between countries in these two regions in achieving the Montreal Protocol methyl bromide phase-out requirements.

Before we begin, I wanted to briefly outline the major objectives of the workshop and what we are hoping to achieve here. As you'll note from the agenda, one of the main purposes of the workshop is to provide information on the Montreal Protocol control measures for methyl bromide and to describe and demonstrate available alternatives to methyl bromide. There are many technical experts from both regions here today and we will benefit immensely from their expertise and experience in developing methyl bromide alternatives.

Another major focus of the workshop will be to exchange information on policy measures to meet the methyl bromide control measures and regional strategies, action plans and demonstration projects for phase out. Information on financing sources to assist with the methyl bromide phase out will also be discussed.

We hope that by the end of the workshop there is an increased awareness about the methyl bromide phase out and the alternatives technologies and substitutes that are available. Other expected outputs include the initiation of national action plans to implement alternatives, identification of further needs in the region to phase out methyl bromide and recommendations on strategies for the transfer of information to farmers on available alternative technologies.

I would to thank all of you for participating in this workshop. I look forward to working with you over the coming days and in the future to protect the ozone layer and phase out methyl bromide.

Thank you.

Steve Gorman

Appendix 4

WELCOME REMARKS ADDRESS TO THE REGIONAL WORKSHOP ON METHYL BROMIDE ALTERNATIVES FOR NORTH AFRICAN AND SOUTHERN EUROPEAN COUNTRIES

Peter Stoermer, GTZ

Rome-FAO, 26.05 - 29.05.98

Mr. Minister, Sir,

Dear participants,

Ladies and Gentlemen,

During the 10th anniversary celebrations of the Montreal Protocol and the 9th Meeting of the Parties in September 1997 in Montreal, the German Minister of Environment, Mrs.Angela Merkel announced that Germany is prepared to spend 20% of its MF contribution **bilaterally** to help A5Cs phase out ODSs. The decision was based on recognizing two facts:

1. that the MP is a success-story
2. that the earlier assumption of meeting the CFC freeze, in July 1999, which is just around the corner, seems to be unrealistic for a number of A5Cs. The total phase out in 2010 for CFCs and 2015 for MeBr seems to be far but past experience, as demonstrated in September 97 in Montreal, tells us that we are a lot slower with respect to the reduction of ODS as initially anticipated. Germany also offers **bilateral** help to meet the freeze and the later phase out. Being the third largest donor to the Fund, after the US and Japan, the German Government decided to charge the Ministry of Economic Cooperation and Development, BMZ through its executing agency GTZ and PROKLIMA to fulfil this task. PROKLIMA has so far concen-

trated on the phase out of CFCs in the refrigeration and foaming sectors. However, the focus will change.

The decision of the 9th Meeting of the Parties to fix the phase out of MeBr for A5Cs to 2015 is still fresh in our minds This decision has accelerated the MeBr strategy formulation of the ExCom and the Secretariat of the MP such that an expert meeting could prepare a strategy proposal in February which was approved in the 24th ExCom Meeting in March. In the Expert Group Meeting, GTZ had the chance to contribute out of practical experience with MeBr alternatives in the field.

The highlights of the agreed strategy can be summarized as follows:

1. Only A5Cs that have ratified the Copenhagen Amendment of the Protocol are eligible for funding.
2. The use of Methyl Bromide for quarantine and preshipment purposes is exempt from controls by the MP.
3. Priority should be given to crops and processes which represent significant global use and on which alternatives are most well understood. Including seed beds and nursery crops, these are flowers, tobacco, tomato, strawberries and cucurbits.
4. Projects will fall in three categories: a.) Demonstration projects, whose objective is to demonstrate alternatives that have proven effective in controlled settings. Those projects should facilitate broader scale implementation of investment projects. b.) Investment projects, whose prime objective is the reduction of methyl bromide consumption directly. c.) Non-Investment projects, which are aimed at creating and disseminating information and education of stakeholders.

As in the past, GTZ/PROKLIMA would like to cooperate with other donors and the Implementing agencies, now increasingly in the field of MeBr phase out but GTZ is also prepared to implement projects merely on a bilateral basis. This is of course under the assumption that a project proposal is accepted by the MP ExCom.

GTZ as a 100% German Government owned executing agency with her over 9000 staff world wide and 1400 staff at home is working in more than 2700 projects in more than 135 countries since over 40 years now. The track record of success has been recognized internationally as quite impressive. The basis for the success has been the steadily improved participative approach. The refinement of the partnership oriented philosophy in a broad multicultural setting is leading to better sustainability as experience shows.

We do think that Multilateral Fund projects of the Montreal Protocoll could be made even more successfull if the partnership oriented approach can be enhanced. We believe that countries not being in the position to establish their necessary country programs should be helped to be able to do so rather than being punished by banning any projects in those countries.That does not help anybody and the least the ozone layer. The concept of project ownership by the partner and the development of implementation strategies together with our partners coupled with monitoring and evaluation processes will also lead to success within the scope of MF projects.

The agenda for this workshop is fully packed. I do hope that enough room will be left in between presentations for discussions and exchange of experience.

I would like to welcome you to this workshop on behalf of the German Ministry of Economic Cooperation and GTZ. I would like to also extend our sincere thanks to the Italian hosts who have made it possible to meet in this wonderful, historical city of Rome and the EU for their generous contribution. A big THANK YOU to UNEP I.E. who have done much of the preparatory planning work. Much of the success of this workshop will however depend on the active participation of all of us.

The field visit on Thursday will not only give us the chance to observe the Italian efforts on alternatives to Methyl Bromide but will also allow us to look up from all the paper- and lecture work, up into the beautiful sky where the blue ozone layer protects all life on earth. Let us clear our brains that above all sophisticated scientifc research, all necessary administration and all national and cultural differences, there is one endangered protective shield which concerns us all.

I thank you.

Peter Stoermer, Ph.D.

Appendix 5
WELCOME REMARKS
ADDRESS TO THE REGIONAL WORKSHOP ON METHYL BROMIDE ALTERNATIVES FOR NORTH AFRICAN AND SOUTHERN EUROPEAN COUNTRIES

Geoffrey Tierney, European Commission

Rome, May 1998

Minister Ronchi, Ladies and Gentlemen,

On behalf of the European Commission and in particular the Commissioner for the Environment, Mrs Bjerregaard, I am pleased to be able to welcome you all to this important workshop on alternatives to methyl bromide. The European Commission is pleased to be able to help organise and co-finance this event. I should like to take this opportunity publicly to thank the other organisers, UNEP, GTZ and our hosts the Italian Ministry of Environment for their positive co-operation in helping to put together what I hope will be an interesting and productive workshop.

For some of us this is something of a reunion, for we first met around this time last year in Tenerife at the European Workshop on Alternatives to Methyl Bromide for Southern Member States. This was an important first step in helping the Commission and the Community Member States to understand the uses of methyl bromide in Mediterranean agriculture and the potential for changing to alternatives. Then as now we benefited from the presence of many international experts from the Methyl bromide Technical Options Committee, including Dr Rodrigo Rodriguez-Kabanna, who acted as Co-Chair of the Workshop. I am pleased to see that he is once again able to be with us. Last year, under his guidance, we were able to conclude that “the existence of many alternatives to the use of methyl bromide for soil fumigation was amply demonstrated. Many of the methods and technologies discussed are directly applicable to broad areas of the world, including Southern European Countries.” The report of that workshop is full of details about cost-effective alternatives which are in use or which have been shown to work. One of the questions we need to answer during this meeting is ‘what more is needed to persuade farmers (and their advisors) to use these alternatives rather than continuing to rely on methyl bromide?

I am particularly pleased that this year, with the encouragement of the Italian Government and through the participation of UNEP, we were able to widen the focus of the workshop to include North African countries. I should like to welcome the distinguished representatives of the North African countries and assure them of the continued interest of the European Commission in their activities, both to protect the environment and to promote agricultural trade. It is obvious that we share a number of common interests through our geographical proximity across the Mediterranean and through ever-closer trade links. The phase-out of methyl bromide will emphasis these links especially through the fact that, while North African countries may continue to use methyl bromide under the grace period, they will be trying to sell their products into a market where its use will have been phased out. The fact of these trade links creates a common interest in moving together to alternatives as soon as possible and the Commission looks forward to further work with our North African neighbours to bring this about.

Minister, Ladies and Gentlemen, we meet at a time of unprecedented ozone depletion. Current information shows us that severe ozone depletion is likely to last well into the next century with consequent increases in rates of skin cancer and damage to ecosystems. Farmers spending most of their time outside are perhaps at greater risk than most. Bromine is extremely good at destroying stratospheric ozone and methyl bromide use in agriculture is one of the major anthropogenic sources of bromine emissions to the atmosphere. The European Community is the world’s second largest consumer of methyl bromide and over 90% is used in the Southern Member States for a relatively small number of high-value crops. Not only does this methyl bromide destroy the ozone layer, it is also highly toxic and poses dangers to farm workers and those living near to fumigated areas. Its use has already been banned in a number of countries or regions because of contamination of ground water supplies. The European Commission believes that methyl bromide is an environmental hazard and should be phased out as soon as possible, without phasing out the farmers which currently depend on it. This requires alternatives to be identified and it to be demonstrated that they are technically and economically feasible. It further requires information about those alternatives and their trial results to be made available to farmers.

This workshop will help move this process forward in the European Community and North African, and I hope that we all find it interesting, challenging and ultimately helpful to our joint efforts to save the ozone layer.

Thank you.

Geoffrey Tierney

Appendix 6
ABOUT UNEP TIE OZONACTION PROGRAMME

Nations around the world are concerned about the emissions of man-made CFCs, halons, carbon tetrachloride, methyl chloroform, methyl bromide and other ozone-depleting substances (ODS) that have damaged the stratospheric ozone layer - a shield around the Earth which protects life from dangerous ultraviolet radiation from the Sun. Over 167 countries have committed themselves under the Montreal Protocol to phase out the use and production of these substances. Recognising the special needs of developing countries, the Parties to the Protocol also established a Multilateral Fund and appointed implementing agencies to provide technical and financial assistance to enable the developing countries to meet their commitments under the treaty. UNEP is one of the Fund's implementing agencies; the others are UNDP, UNIDO and the World Bank.

Since 1991, the UNEP TIE OzonAction Programme in Paris has been strengthening the capacity of governments (especially National Ozone Units) and industry in developing countries to make informed decisions on technology and policy options that will result in cost-effective ODS phase-out activities with minimal external intervention. The Programme accomplishes this by delivering a range of need-based services, including:

Information Exchange

to enable decision makers to take informed decisions on policies and investments. Information and management tools already provided for developing countries include the OzonAction Information Clearinghouse (OAIC) diskette and World Wide Web site, a quarterly newsletter, sector-specific technical publications for identifying and selecting alternative technologies, and policy guidelines.

Training and Networking

to provide platforms for exchanging experiences, developing skills, and tapping the expertise of peers and other experts in the global ozone protection community. Training and network workshops build skills for implementing and managing phase-out activities, and are conducted at the regional level (support is also extended to national activities). The Programme currently operates eight regional and sub-regional Networks of ODS Officers comprising 95 countries, which have resulted in member countries= taking early steps to implement the Montreal Protocol.

Country Programmes, Institutional Strengthening and Refrigerant Management Plans

to support the development of national ODS phase-out strategies and programmes, especially for low-volume ODS-consuming (LVC) countries. The Programme currently assists 79 countries in the development of their Country Programmes and implements Institutional-Strengthening projects for 67 countries. UNEP also assists LVC countries in the development of Refrigerant Management Plans, integrated national strategies to phase out ODS in the refrigeration sector.

For more information about these services please contact:

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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 TIE) located 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 TIE activities focus on raising awareness, improving the transfer of information, building capacity, fostering technology co-operation, partnerships and transfer, improving understanding of environmental impacts of trade issues, promoting integration of environmental considerations into economic policies, and catalysing global chemical safety.

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Appendix 6

Contacts for Implementing Agencies

The Multilateral Fund of the Montreal Protocol has been established to provide technical and financial assistance for developing countries to phase out ozone-depleting substances such as methyl bromide. For further information please contact the implementing agencies listed below.

Implementing agencies

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