A Summary Report of Useful Information on Soil Disinfestation Gathered for UK Growers

7th International Symposium on Chemical and Non-chemical Soil and Substrate Disinfestation
Leuven, Belgium
13-18 September 2009

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Background and purpose of this summary report

As well as commissioning near market research and development projects, HDC aims to provide growers with information on best practice and new information from sources outside of the HDC. The 2009 International Soil Disinfestation Symposium (SD2009) offered a further source of information that could be useful to UK growers who disinfest soil or substrates.

Introduction

The 2009 International Soil Disinfestation Symposium was organised by the Katholieke University, Leuven, Belgium and the Agricultural Research Organisation, Israel under the auspices of the International Society of Horticultural Sciences (ISHS) and the Benelux Society for Horticultural Science. All presentations and posters will be published in a special volume of *Acta Horticulturae* in 2010. This was the seventh international symposium on soil and substrate disinfestation; the first was held at Leuven in 1973 and the eighth will be held in 2014 at a venue to be decided. The objective of the conference was to provide a forum for international researchers, crop consultants, fumigation contractors and other professionals to meet, exchange research results, market information, ideas and debate the latest advances in soil disinfestation.

The symposium consisted of a special session on new developments and expectations since the previous symposium (Corfu, 2004), reports on progress in the global phase-out of methyl bromide (MB), and six technical sessions on soil and substrate disinfestation. There were also posters relating to each technical session, and a round table discussion on application practice.

The main business of the conference was conducted through oral presentation sessions that were held from 14-18 September 2009, with a break on 16 September for a technical visit to the vegetable research station and auction at Mechelen, near to Antwerp. The conference programme is provided as an Appendix of this report.

Attendance

Around 110 delegates attended from 27 countries including Australia, USA, Japan and Europe. The largest numbers of delegates were from Belgium (27) and Israel (16). Delegates were drawn from a range of sectors of the horticultural industry; the largest proportion was made up of researchers, others being the commercial supply sector, consultants, extension workers and regulators. There were three UK representatives (report author, Custodian Fumigation and Dow Agrosciences).

Key topics

Key topics of relevance to UK growers covered in the conference were:

- Progress in MB phase-out
- Emerging and re-emerging disease problems

- Chemical fumigants
  - Availability of existing fumigants in the UK
  - Registration of new products
  - Improving efficacy
  - New developments in application
  - Reducing emissions
  - Loss of efficacy through accelerated degradation
- Physical methods
  - Steaming and heat treatment
  - Anaerobic Soil Disinfestation
- Biological methods
  - Organic amendments
  - Biofumigation
- Soilless culture
- Assessment tools

These are each discussed below.

Progress in methyl bromide phase-out

Global use of methyl bromide (MB) for soil disinfestation had declined from 65,000 tonnes in 2005 to 12,000 tonnes in 2008. Use in Europe has ceased; the last Critical Use Extensions (CUEs) were for strawberry production in Spain and Poland. Continuing major users of methyl bromide are USA, Australia, Canada and Japan. The crop sectors still using it are cucurbit, melon, pepper, aubergine, strawberry, cut flowers and orchard replant. Pre-plant use in Turkey ceased in 2008; use in Japan is due to cease by 2013

An EU project (www.alterbromide.org) on adoption of alternatives in France, Italy and Spain found that the major alternatives being used since 2003 were:

1,3-D + chloropicrin	31%
Metam sodium	16%
Dazomet	9%
Solarisation	8%
1,3-D	8%
Grafting onto resistant rootstock	7%
Metam sodium + chloropicrin	4%
Chloropicrin	3%
Biofumigation	1%

Internationally, there is increasing pressure to further restrict the use of all soil fumigants, where judged necessary for environmental, operator, bystander or other protection, by tighter regulation.

Emerging and re-emerging disease problems

During the last five years there have been many reports of new and re-emerging diseases caused by soilborne pathogens. They are believed to be a consequence of profound changes in soil disinfestation methods, increased globalisation, climate change and restrictions on the use of chemicals. Some diseases of potential relevance to UK growers are shown in Table 1 below.

Table 1: Emerging and re-emerging soil-borne diseases

Crop	Disease	Pathogen	Example country(ies) affected
Chrysanthemum	Fusarium wilt	*F. oxysporum*	Italy
Lambs lettuce	Fusarium wilt	*F. oxysporum*	Italy
Lettuce	Big vein disease	Virus transmitted by *Olpidium sp.*	France
	Fusarium wilt	*F. lactucae*	Italy, USA
Pepper	Root rot	*Phytophthora capsici*	Italy
Rocket	Fusarium wilt	*F. oxysporum* f.sp. *raphani* and *F. oxysporum* f.sp. *conglutinans*	Japan (1967); Italy (2002), Portugal (2004)
Strawberry	Fusarium wilt	*F. oxysporum*	Spain, Australia, USA,
	Charcoal rot	*Macrophomina phaseolina*	USA
	Pythium root rot	*Pythium* spp.	
Tomato	Corky root rot	*Pyrenochaeta lycopersici*	Switzerland
	Root rot	*Phytophthora nicotianae*	Italy
	Black dot	*Colletotrichum coccodes*	Italy

Chemical fumigants

Availability of existing fumigants in the UK

At present, no soil fumigant has been approved in the EU review of pesticides (EU Directive 91/414). All of those assessed are considered to have a very high risk profile due to ecotoxicological impact and by-stander risk. Product impurities are also a problem due to the high application rates, while some products cannot be stated as safe as unidentified impurities are present. The current (October 2009) status of applications for Annex 1 listing under Directive 91/414 is detailed below, and the approval status of soil fumigants in the UK is shown in Table 2.

<u>1,3 dichloropropene (1,3-D) (e.g. Telone)</u>
A first submission was not approved due to a high level of impurities. Use in the UK was revoked. A new dossier has been submitted and a decision on this is expected in December 2009. Some countries (not the UK) have obtained a rolling 120 day CUE until a final decision is made.

<u>Chloropicrin (CP) (e.g. Chlorofume)</u>
The original dossier submitted to the EC was voluntarily withdrawn. A new dossier was submitted in June 2009 and evaluation is on-going. The existing approval is valid until

December 2010, although product can be stored and used until December 2011. Should the submission be unsuccessful, a good case can be made for Critical Use Exemption, which, if successful, would allow the product to be used beyond 2011.

Dazomet (Basamid)
As for chloropicrin

Metam sodium (MS) (e.g. Discovery)
In July 2009 it was decided that metam sodium should not be approved due to impurities. Approval for use in the UK was revoked in September 2009. Specific uses are permitted in the UK until 31 December 2014, approved under CUEs. These include pre-plant soil use before soft fruit, tree fruit, vegetables, ornamentals and forestry.

Methyl bromide (MB)
Not approved for soil disinfestation as it is an ozone depleter. Although it is currently permitted for Quarantine Pre-Shipment (QPS) use, this also is due to be banned from March 2010.

Table 2: Approval status of soil fumigants in the UK (October 2009)

Active ingredient	**Example product**	**Status of application for EU approval (Annex 1 listing)**	**Status of UK approval**
1,3 dichloropropene (1, 3 – D)	Telone II	Not approved	Revoked
Chloropicrin (CP)	Chlorofume	Evaluation on-going	Existing approval valid to 31.12.10. Use up by 31.12.11*
Dazomet	Basamid	Evaluation on-going	Existing approval valid to 31.12.10
Metam sodium (MS)	Sistan	Not approved	Revoked. CUEs until 31.12.14
Methyl bromide (MB)	Methyl bromide	Not approved	Revoked. CUE for Quarantine Pre-Shipment use until 31.3.10

* This reflects the current legal situation, and may change if the current evaluation for Annex I listing is successful

Registration of new products

No new active ingredients for soil disinfestation have been submitted for approval in Europe in the last five years. Outside of the EU, two new chemicals have been approved, or are being considered for approval.

Methyl iodide (MI) + chloropicrin (e.g. Midas)
Registered for use in much of the USA (47 states; not California). Applications for registration are being considered in Colombia, Morocco, New Zealand, Turkey and elsewhere. The product is being developed by Arysta LifeScience (www.arystalifescience.com). In the USA, methyl-iodide ($12/kg) is currently sold at a premium to methyl bromide ($8/kg). It has broad spectrum activity, similar to methyl bromide, with the advantage that it is not an ozone depleting chemical. Development work with different crops and soils to define rates that are effective and not phytotoxic is on-going. Its vapour pressure, although less than MB, is significantly greater than that of CP, MITC and 1,3-D (i.e. it has a real fumigant effect).

Dimethyl disulphide (DMDS)
An application for registration in the USA is being assessed; the outcome is due November 2009. If successful, an application will be made in Europe. The smell of DMDS is an issue; work is in progress to develop a masking agent or scent to use with it. DMDS was reported to give good control of root knot nematode at low doses, but high doses were needed to reduce fungal populations. In Spain, DMDS at 30 ml/m^2 greatly reduced fusarium wilt in carnation; in Italy, DMDS at 80 ml/m^2 reduced verticillium wilt in aubergine whereas 40 ml/m^2 was ineffective.

New pesticide regulations
From May 2011, new regulations on Plant Protection Products (PPP Regulations) will apply in Europe and replace those of EC Directive 91/414. The PPP Regulations aim to protect human and animal health and the environment, safeguard EU competitiveness and speed up decision making.

Key aspects are:

- Registration by geographic zone (there are 3 zones), to enhance availability of products to farmers
- More stringent criteria for approval
- Provision for substitution of active ingredients with safer alternatives
- Lists of approved synergists, safeners and co-formulants
- Simplified procedures for low risk substances

Improving efficacy

Improvements in the efficacy of existing fumigants are being sought, notably by the use of mixtures, better application and combination with non-fumigant methods (especially soil solarisation).

Mixtures
Outside the UK, chloropicrin (CP) is commonly used in mixture with 1,3-D to permit reduced dose application and extend the spectrum of activity (this formulated mixture is not approved in the UK).

In Spain, adjuvants are being tested to increase the evaporative capacity of 1,3-D + CP at low temperatures and so allow winter treatment of soil.

In Belgium, various combinations of fumigants were evaluated in the laboratory and field for control of *Rhizoctonia solani, Sclerotinia sclerotiorum* and root knot nematode (*Meloidogyne*) spp. (RKN) in lettuce. Synergism was reported between 1,3-D and dazomet, and DMDS and dazomet. No field treatments, including MB, MI and MI + CP, reduced *Rhizoctonia* basal rot in a field trial; it was suggested that soil treatments that kill bacteria but fail to eliminate *Rhizoctonia* from within soil particles allow rapid re-colonisation by the surviving *Rhizoctonia.*

In Israel, potato powdery scab (*Spongospora subterranea*) was reduced by 86% and 94% using 1,3-D + CP at 400 kg/ha, and 500 kg/ha respectively. The disease was reduced by 71% using MS (800 L/ha) and by 98% using MB (500 kg/ha). Fluazinam and fludioxonil fungicide seed treatments gave limited reductions.

In Spain, a range of treatments applied by drip irrigation were evaluated for control of fusarium wilt (*F. oxysporum* f. sp. *dianthi*) in carnation on heavily infested soil. DMDS gave control equivalent to 1,3-D + CP (Table 3).

Table 3: Effect of pre-plant soil treatments on control of fusarium wilt in two-year crops of carnation (Spain)

Treatment	**Mean % plants dead**	**Mean harvest of stems/m²**
Exp 1 (2006-08)		
Untreated	100	84
Sodium azide (65 mL/m²)	44	248
DMDS + CP (30 + 10 mL/m²)	23	309
1,3-D + CP (40 + 10 mL/m²)	14	343
Exp 2 (2008-09)		
Untreated	47	68
Sodium azide (65 mL/m²)	18	160
DMDS (80 mL/m²)	0.1	192
DMDS (53 mL/m²) + solarisation (4 wks)	0.2	226
1,3-D + CP (40 + 10 mL/m²)	0	198

In Italy, CP (400 kg/ha) combined with 1,3-D (240 kg/ha) applied by shank injection significantly reduced peach tree replant disease caused by honey fungus (*Armillaria mellea*) in heavily infested fields and increased plant development and yield. Previously MB was used to control this disease.

Better application

In Spain, emulsifiable formulations of DMDS applied by drip irrigation, alone or in mixture with CP, were evaluated for pepper production. DMDS alone at a high rate (105 g/m^2) gave good weed control. Fungicidal activity was improved by the mixture. Yields were equal to those achieved with MB and 1,3-D + CP.

In Turkey, DMDS applied by drip application at 300 L/ha under VIF or 450 L/ha under low density polyethylene film (LDPE) gave good control of RKN in greenhouse vegetable crops.

In Israel, drip application of DMDS was improved by using VIF rather than LDPE. VIF resulted in more uniform distribution in the soil profile, greater concentrations and an extended retention period. DMDS moves mainly in the water with little lateral movement. Soil fungi vary in sensitivity to DMDS but *Fusarium* spp. appear to be very sensitive.

<u>Combinations with non-fumigant methods</u>
In protected crops in northern Italy, soil fumigants applied by drip irrigation under Virtually Impermeable Film (VIF) were evaluated alone and in combination with grafted plants for control of tomato root rot caused by *Colletotrichum coccodes* and aubergine wilt caused by *Verticillium dahliae*. On tomato, at high disease pressure, the best disease control was obtained by combining grafted plants (Beaufort, He-man, Maxifort) with use of MS at 192 g/m^2 or DMDS at 40-80 g/m^2. CP at 20 g/m^2 and rootstocks alone did not give effective control. On aubergine, DMDS + CP (20 + 20 g/m^2) gave better control than 1,3-D + CP (20 + 20 g/m^2); DMDS alone showed good activity only at high doses (80 g/m^2). In the absence of soil fumigation and at medium-high disease pressure, the proportion of roots visibly affected by black dot was 42%, 58% and 60% on Beaufort, He-Man and Maxifort respectively.

In Israel, a combination of solarisation (2 weeks) and reduced dose DMDS gave effective control of a range of fungi and nematodes. *Fusarium* species appeared to be susceptible to DMDS whereas a *Macrophomina* sp*.* was highly tolerant. The lateral movement of DMDS was limited.

New developments in application

<u>Shank injection</u>
- Reduced spacing between shanks from 60 cm (MB) to 30 cm (e.g. with MI, MS, CP), to get better distribution of the MB alternatives with lower fumigant activity.
- Two-layers of shanks for separate application at different levels in the soil of two fumigants that do not mix (e.g. MS + CP, MS + MI). Used in strawberry to apply CP at 30 cm for fungal pathogens and MS at 10 cm for weed control.
- MS applied by shank injection or overhead irrigation lines and sealed in with water (1.3 cm).

<u>Drip line application</u>
- Two bands of Basamid applied at 30 cm depth and activated by CP applied through drip lines beneath VIF plastic. Instant activation of Basamid gave excellent weed control (California). In Turkey, layers of Basamid applied in the soil, covered by VIF, and irrigated by drip line gave good results.
- Drip application of CP followed by MS after 7 days. This is reported to improve treatment efficacy and reduce risk of accelerated degradation (AD).
- Midas 33 and Midas 50 work well by drip application, better than shank injection for strawberry. MI helps to move CP through the soil (as did MB in MB/CP mixes).

- Potential problems with drip application are degradation of PVC pipework by CP (need special equipment), requirement for large volumes of water to move product to depth ('against its will') for pathogen control; the maximum treatment depth is around 30 cm.
- Drip application of CP is best done with a constant concentration in the water (e.g. 500-1500 ppm in 85-90% of the applied water). Application at a high concentration in a low water volume, followed by washing it down with water is not recommended as it results in CP coming out of emulsion.
- Drip application allows soil to be prepared to optimum conditions beforehand.
- Under VIF or LDPE, consider wetting the soil for 2-3 days before fumigant application to prevent cracks in the soil and loss of gas.

Other

- Use of a patented adjuvant (FA245) with MI to increase its vapour pressure from 400 to 1400 millibar (i.e. similar to MB). It was reported that there is potential to increase the vapour pressure of CP from 18 to around 400 by use of an adjuvant, but this is not yet developed.
- MS applied by a rotary spader gave good results at a low dose (300 L/ha) but is a slow method (impractical if >8 ha).
- It is not possible to generalise on application methods for MB alternatives. Acceptable methods will depend on product, soil and legislation (e.g. groundwater issues, air quality, buffer zones).

Solarisation

- The sequence of treatments is important when low dose fumigants (e.g. MS at 15 mL/m2) are combined with short solarisation (8 days). Information on the soil temperatures achieved was not reported. Better results are achieved if the soil is solarised before treatment (increased susceptibility of pathogens; greater toxicity of fumigant; greater distribution of MITC). Apply fumigant by drip, or side-shank injection when the bed is already covered.
- When combining a fumigant with solarisation, an MITC generator is much better than MI, CP or 1,3-D; the latter three all degrade rapidly by hydrolysis at high temperatures whereas MITC degrades slowly, by biological action.

Reducing emissions

Volatile Organic Compounds (VOCs)

In California, new regulations on VOCs, in order to reduce smog formation, require fumigant emission reductions in agricultural areas. A project on emissions reductions, using sorbent tubes to monitor VOCs around treated strawberry fields, reported good results with potassium thiosulphate applied by sprinklers to seal the soil and degrade volatiles as they are released. Results were improved when soil was also sealed with VIF or Totally Impermeable Film (TIF). Other methods being used to reduce emissions are:

- improved application methods (e.g. drip beneath VIF; deep shank injection);
- lower application rates (CP maximum permitted rate in California is just 135 kg/ha, compared with 400 L/ha in the UK);

- non-fumigant soil disinfestation (e.g. steam);
- field production in substrates in troughs (used in buffer zones).

<u>Nutrients and pesticides</u>
The EU Water Framework Directive (WFD) aims to restrict emissions of nutrients and pesticides from both field and protected crops to virtually zero. Each member state has submitted to the EC a national plan on how this will be achieved.

In the Netherlands, the target is excellent chemical and ecological quality of surface waters by 2015 and near zero emissions by 2027. For glasshouse crops, a new project is registering emissions of VOCs, pesticides and nutrients in discharged irrigation water and in waste water (from glasshouse cleaning, filter changes etc). Production in soilless systems is expected to increase for both protected and open-field crops. Experiments in open-field production of lettuce, leek, strawberry and trees in closed substrate systems are in progress.

Loss of efficacy through accelerated degradation

Accelerated degradation (AD) of methyl-isothiocyantate (MITC), the active ingredient of MS, has been reported in the Netherlands, Australia and Israel. The problem develops in certain soils (e.g. high pH, high K) following application of MS. It results in a reduced concentration and duration of MITC in the soil and a loss of disease control (e.g. *Fusarium* wilt, *Pythium* root rot). Studies in Israel and Australia on affected soils have identified various bacteria (e.g. *Naxibacter* spp.) that rapidly degrade MITC. Autoclaving soil eliminated the AD problem; re-inoculation with the bacteria re-introduced the problem. There is evidence that some soils are suppressive to the development of AD even when MITC-degrading bacteria are added.

In discussion, it was stated that:
i) AD can also occur following use of dazomet;
ii) AD can involve the conversion of MS and dazomet to MITC as well as MITC to breakdown products;
iii) alternation of MS and dazomet with unrelated fumigants or soil steaming may control the microorganisms responsible for AD of MITC.

Physical methods

Steaming and heat treatments

Steaming continues to be used for high value crops, mostly under protection (e.g. cut flowers, herbs, salads) and occasionally in the field (e.g. bulbs, weed control in salad crops). Sheet steaming and negative pressure steaming predominate in glasshouses in Europe. Treatment is effective, predictable and crop-safe. The main problems are high cost, physical labour requirement, a slow treatment rate and risk to operators. Points of interest noted were:

- Use of cheap bubble foil over a steaming sheet saves 15% of energy requirement.

- Sheet-steaming of used sleeved rockwool slabs is ineffective due to poor heat penetration. But steaming unsleeved palleted slabs in a container for 3 minutes at 100ºC was effective (10 minutes required if *V. dahliae* or *Cucumber Green Mottle Mosaic Virus* is present in roots).
- Spading and steaming of field soil using a mobile boiler is slow (100-125 h/ha) and expensive ($18,000/ha). A small boiler to treat beds is being tested in Poland.
- A plate/hood steamer which treats soil to 10 cm can be used for weed control (previously tested at Warwick HRI).
- A steaming plate with 16 cm spikes is being used in Italy for high value crops (Ferrari sterilisation).
- Pasteurisation (30 mins at 70-80ºC) is preferred to full sterilisation because of the preservation of some antagonists and the risk of manganese toxicity if soil is heated to more than 85ºC.
- In Japan, soils are treated with hot water (70-95ºC), applied by a hot water sprayer or via heat-resistant tubes.
- The Cultivit hot air treatment was developed in Israel; air at > 700°C is blown into soil as it is moved by a rotary spader. With a low energy use (0.1-0.2 L oil/m^2) it is suitable for field treatment. Although experiments revealed it gave no control of three soil-borne fungi or RKN, it resulted in large increases in yields of squash.
- The Agritron radiation treatment developed in the Netherlands has not progressed beyond prototype stage due to poor results in trials. Work is continuing.

Anaerobic Soil Disinfestation (ASD)

Also known as Biological Soil Disinfestation (BSD), a green manure crop (usually grass) at around 40 t/ha is incorporated into the soil, lightly compacted, irrigated, and covered with VIF. Anaerobic conditions and toxic fermentation products are formed that reduce levels of pathogens, nematodes and weeds. In the Netherlands, ASD is used on around 70 ha for asparagus, strawberry runner production and tree nurseries. It is not used more widely due to high cost (€4,000/ha), and problems with gluing VIF sheets together.

A similar technique is used in glasshouses in Japan. Wheat or rice bran is incorporated into soil, mixed with water to create a slurry and left for 3 weeks at >20°C.

The sustainability of ASD was questioned. If nitrous oxide is released in significant quantities, this will be a problem as it is both an ozone depleter and a climate change gas.

A new three-year project (2009-11) at Lelystad, the Netherlands, is comparing defined, standardised vegetable by-products with the aim of identifying the most suitable soil amendments, reducing treatment time (from 6 to 2 weeks), quantifying gas production and better understanding the mechanism of ASD.

Biological methods

Organic amendments

It was predicted that the use of organic amendments to disinfest soil/improve crop growth will increase greatly in the next five years. There will be challenges in availability, quality and bulk handling.

In Belgium, lignin by-products (flax shives and dust, fibreboard dust), incorporated at 5% w/w or pure pine lignin incorporated at 0.5-1% to 10 cm reduced viability of *R. solani* sclerotia and/or rhizoctonia basal rot in a lettuce crop. Results varied with soil type. Soils showed significant increases in populations of bacteria, fungi and actinomycetes and a decreased pH. It was suggested that lignin products stimulate lignin-degrading microorganisms which make sclerotia more susceptible to microbial antagonists (e.g. *Trichoderma* spp.)

In Switzerland, organic amendments were evaluated for control of corky root rot (*Pyrenochaeta lycopersici*) in tomato. Agrobiosal (chitin containing pellets produced by a *Penicillium* sp.) gave no control on a heavily infested site and no improvement in yield. A liquid formation of Biofence (mustard seed meal) applied to the crop via irrigation water is being tested at a low disease pressure site.

Biofumigation

Biofumigation has increased greatly in recent years. Brassica species produce glucosinolates that, upon degradation, release a mixture of volatile toxic isothiocycanates (similar to MITC).

In Italy, a brassica (*B. juncea* ISC120) green manure (2 kg/m^2) and brassica pellets (*B. carinata*) at 2-4 g/L were evaluated against verticillium wilt of aubergine and fusarium wilt of lettuce and basil respectively. Biofumigation with the green manure gave partial control of verticillium wilt, improved when combined with a resistant rootstock. Biofumigation with the brassica pellets partially reduced fusarium wilt of lettuce and basil. Brassica pellets combined with solarisation (2 weeks) gave good control of fusarium wilt.

In the USA, biofumigation using an endophytic fungus (*Muscodor albus*), which produces toxic volatile organic compounds, has shown some control of a range of pathogens including species of *Fusarium, Verticillium* and *Phytophthora*. Treatment is not phytotoxic and has no activity on weeds. The method is also known as mycofumigation. In field trials in Montana, *M. albus* grown on colonised barley seeds applied in-furrow at 224-448 kg/ha reduced scab, *Rhizoctonia, Verticillium* and black dot of potato. AgraQuest is seeking product registration in USA. The fungus is strongly aerobic and survives on grain for less than 6 months. Field experiments with the same fungus in Spain were unsuccessful – possibly due to strain differences, method of production on grain or soil conditions (wetter soil).

Soilless culture

In California, a raised bed trough system is being tested for strawberry production in a 'Farming Without Fumigants Initiative'. Two V-shaped grooves are made in a raised bed, lined with nylon fabric, and filled with a soilless medium.

In Japan, a water permeable/root impermeable production system is being tested for greenhouse pepper production.

In the Netherlands, work at Wageningen University is seeking to develop closed soilless systems for a greater range of protected crops, and some open-field fruit and vegetable crops, in order to achieve reduced emissions to the environment. Water treatments commonly used to eliminate pathogens from recycled water are UV (high pressure lamps), heat (95°C for 30 seconds) and slow sand filters (SSF). SSF are only suitable for relatively small nurseries due to the large surface area of sand (or other substrate) required.

In Australia, persistence of *Fusarium* spp. on polystyrene trays used in a flood culture system was reduced by improved hygiene practices (tray handling and storage), pressure washing of used trays, heat disinfestation with aerated steam (1 h at a maximum of 80°C) and solarisation by wrapping in LDPE and storing in a tunnel for 6 weeks (maximum temperatures 75°C). Dipping trays in sodium hypochlorite or a QAC disinfectant reduced pathogen populations on trays but sometimes caused phytotoxicity in transplants. Pressure washing combined with steam or solarisation were effective alternatives to MB.

Assessment tools

Several presentations highlighted the need for improved soil assessment tools, including:

- Improved diagnostic tools
- A standard test to measure soil suppressiveness
- Correlations between propagule density in soil and disease incidence and yield.

Remote sensing

In Israel, remote (eg satellite or aircraft) and proximal (e.g. tractor mounted) sensing in different parts of the electromagnetic spectrum is being evaluated to map soil and plants affected by soil-borne diseases. The aim is to optimise soil disinfestation and reduce fumigant use by site-specific application. Soil type, crop species and pathogen can all affect the signal and will necessitate calibration before use. Although costly at present, the technology is developing rapidly, prices are reducing and the use of hyper-spectral images (i.e. using many narrow-band wavelengths) is reported to offer good potential for greater specificity.

GIS

GIS and crop data were used to examine the factors affecting control of soilborne *Streptomyces scabies* (cause of peanut pod wart disease) by formalin pre-plant soil treatment. The major factors influencing treatment efficacy were irrigation method (linear better than rotating sprinklers), soil type (greater disease on sandy soils), soil preparation (rotovating prior to application improved control) and soil infestation level.

Pyrosequencing using the CPN60 gene marker

In Canada, a new molecular method (pyrosequencing) is being used to examine comprehensively the microbial communities associated with roots. The method is based on rapid sequencing of a small gene tag present between two conserved regions of a chaperonin gene (used to produce proteins that stabilise membranes) present in all organisms. The gene tag between the conserved regions of DNA is unique for each organism. A reference database is required to identify microorganisms detected; this is being assembled. The method generates microbial fingerprints (i.e. information on identity and relative quantity of each microorganism). It offers great potential to compare healthy crops with those affected by root disease and determine why some ecosystems remain healthy. In an initial study, the number of bacterial groups detected on potato roots was less than in bulk soil from around the crop. A large number of unusual bacteria were identified.

Monitoring MITC in the environment

After treatment with MS or dazomet, soil needs to be checked for residual MITC prior to planting as the gas is phytotoxic at levels above around 20 mg/m^3. Options are shown in Table 4.

Table 4: Parameters of tests for MITC

Method	Test duration	Sensitivity	Comment
1. Cress test	2-3 days	25-50 ppm	Cheap
2. MITC gas detection tube	3 minutes	2 ppm	Developed by BASF
3. Quartz micro balance	45 minutes	5-10 ppm	Known as 'electronic nose'
4. Photo-ionisation detection (PID)	Seconds	Very sensitive	Costs around €5,000

The cress test remains the most popular method used by growers.

Conclusions drawn from the symposium

Why soil disinfestation?

1. Soil disinfestation is a very effective tool for improving crop health in pathogen-infested soils with replant problems. It may also improve crop yield in non-infested soils.

2. Soil disinfestation is very important in intensive agriculture and this need will likely increase with the rapidly rising global population and improved diets.

3. Soil disinfestation by itself is not a solution – it needs to be part of a holistic approach. The use of healthy plants is critical. Additional measures to control soil-borne diseases are pathogen-free water, resistant varieties and rootstocks and optimum soil conditions.

Life after methyl bromide

4. Life without methyl bromide is possible – it was last used in the Netherlands in 1992 yet Dutch horticulture is large and remains very competitive, despite limited availability of land.

5. Crop production without methyl bromide is associated with the appearance of new and re-emerging diseases, most notably fusarium wilts (e.g. lettuce, strawberry).

Threats in a world without methyl bromide

6. Legislation is restricting the use of alternative fumigants.

7. There will be increased requirements to reduce emissions to air and water.

8. Alternatives to MB are generally less effective (60-90% at high rates) yet quality requirements remain high and there is fierce competition for growers.

Chemical fumigants

9. Only one new chemical fumigant (methyl iodide) has been registered in the last 5 years and only in the USA (so far). It was predicted that the next 5 years will see an increase in use of organic amendments, solarisation and integrated control. The performance of existing fumigants (e.g. CP, MS, 1,3-D, dazomet) will be improved by greater use of mixtures, adjuvants, gas impermeable films, drip fumigation, deep shank injection and good product stewardship.

Biological methods

11. Biological control at present is mainly through the use of *Brassica* spp. cover crops. In addition to soil disinfestation, such crops can improve soil fertility and lock-up CO_2 (increase soil organic matter).

12. Other soil amendments show promise such as herb residues, *Medicago* meal and agricultural waste and other by-products (e.g. lignin, manure). Pellet and liquid formulations should improve grower acceptability.

13. Modification of the original soil microbial population, by organic amendment or crop rotation for example, is considered more likely to succeed than inundative application of biological control organisms.

14. A greater understanding of soil biology is required to explain why most plants remain unaffected by soil-borne diseases for so long.

15. Resistant varieties and rootstocks can provide very effective control of soil-borne diseases; their potential use is often overlooked.

16. Mycofumigation using endophytic fungi grown on grain is a novel biological approach.

Physical methods

17. Steaming is a good method but expensive and not for large areas.

18. Increased yield following a hot air treatment (>700°C) of soil that does not kill pests or pathogens requires explanation.

19. Anaerobic soil disinfestation is used successfully for long-term and high-value crops on certain soils in the Netherlands; research has started to investigate how it works, optimise effect and check it does not produce significant quantities of ozone-depleting or global-warming gases.

20. Solarisation is widely accepted in warmer countries, often in combination with chemicals or organic amendments.

Soilless culture

21. Soilless culture offers prospects of more efficient use of water, fertilisers and crop protection products, and reduced emissions to ground and surface water.

22. Soilless culture of open-field crops is possible; work in this area is on-going.

23. Re-used irrigation water will likely require disinfestation to prevent dispersal of root-infecting pathogens; UV, heat and slow sand filters are commonly used to treat recycled water.

Assessment tools

24. New molecular tools allow a step-change in the study of microbial populations associated with roots.

25. Use of these tools to study identity and levels of soil microorganisms (including non-culturable ones) will allow investigation of why some soils remain 'healthy'.

26. Quantitative PCR may provide improved quantification of specific soil microorganisms in soil pre-planting better to predict disease risk.

27. Remote sensing and GIS have potential to map soil infestation and allow more precisely targeted soil treatment.

What is needed?

28. For the future, we need to:

- move further from chemical to biological control;
- improve diagnostic tools and their practical implementation;
- develop tests for soil suppressiveness;
- determine correlations between propagule density in soil, disease incidence and yield;
- better understand the mechanisms of biological control, organic amendments, ASD;
- a better understanding of soil population dynamics with crop rotation;
- transfer technology to less developed countries.

Specific recommendations for future research and development in the UK

1. Commission a study visit to the Netherlands to discuss the latest research on ASD (Lelystadt Research Station), soilless production systems and emissions reductions, (Wageningen University), their applicability to the UK sectors and opportunities for collaborative work.

2. Evaluate some Midas and DMDS treatments on UK nurseries for control of *Fusarium oxysporum* and *Verticillium dahliae* and crop-safety to strawberry and commercially important flower species (e.g. chrysanthemum, stock).

3. Use novel molecular diagnostic and population monitoring techniques to determine the effect of current and new soil disinfestation treatments on pathogen populations and the soil microflora.

4. Determine the potential of some soil solarisation treatments alone and separately combined with low-dose chemical fumigants and organic amendments for control of soil-borne diseases in glasshouse, tunnel and field crops.

5. Investigate any cases of significantly poor results with MS and dazomet on UK nurseries for possible accelerated degradation.

6. Monitor unexpected and unusual crop problems for the possible emergence of new diseases, especially fusarium wilt and charcoal rot of strawberry and fusarium wilt of lettuce, rocket and cut flowers.

Appendix

SYMPOSIUM PROGRAMME

Sunday, 13 September 2009

1500-2000 Registration at Collegium De Valk

1800-2000 Opening reception at Collegium De Valk

Monday, 14 September 2009

0900-1000 Opening session

0900-0920 Welcome and introduction: *Prof. Josef. Coosemans (Belgium)*
Introduction to the scientific program *Dr. Abraham Gamliel (Israel)*

0920 Keynote lecture: Soil and crop health following soil disinfestation *Jaacov Katan (Israel) and Alfons Vanachter (Belgium)*

1000–1200 Special session
New developments and expectations since the Sixth Symposium - Corfu 2004. Needs, possibilities, legal changes, expectations
Chairperson: Ian Porter (Australia)

1000 Invited lecture:
Emerging new pests and diseases and new trends in their management - Angelo Garibaldi (Italy)

1030 New developments and expectations: Vision from the scientific world – Abraham Gamliel (Israel)

1045 New developments and expectations: Vision and expectations from *horticultural and agricultural* sector- Marta Pizano (Colombia)

1100-11.30 COFFE BREAK

1130 New developments and expectations: Vision from *industry and fumigators* - Husein Ajwa (USA)

1145 New developments and expectations: Vision from *decision makers* - Francesca Arena (EC)

1200 Discussion

1215-1330 Session 1
MBr Alternatives
Chairperson – Marta Pizano (Colombia)

1215 Progress in the global phase out of methyl bromide and the relative effectiveness of soil disinfestation products to replace fumigation for pre-plant soil uses - Ian.Porter, M. Pizano, M. Besri, S. Mattner, and P. Fraser

1230 Is There a Future for 1,3-Dichloropropene and Other Chemical Soil Fumigants in European Agriculture? – Andrew Leader, Busacca, J; Dawson, J; Lyall, T and Eelen, H.

1245 Adoption of Methyl Bromide Alternatives and a Profile of Turkish Cut flower sector – Suat Yılmaz, M. A. Çelikyurt and B. Sayın

1300 Japan big effort to phase out of methyl bromide by 2013 – Akio Tateya

13.30 14.30 LUNCH BREAK AND POSTER VIEWING

1430-1630 Special Session
Methyl bromide alternatives : ALTERBROMIDE (EC) project
Chairperson: Gael Du Fretay

1430 Invited lecture
ALTERBROMIDE, dissemination of sustainable alternatives to Methyl Bromide in soil disinfestation and in post harvest - Gael Du Fratey, J Dasque J Auger; J Coosemans; P Colla; F Pauwels; and J Fritsch.

1500 Current status of chemical and non-chemical soil disinfestations solutions in France – Jerome Fritsch

1515 Mechanical or manual applications of soil solarization for the control of soilborne pathogens in plastic house or open field in Greece – Polymnia Antoniou, Sotiris Tjamos and E. C. Tjamos

1530 Soil disinfestation treatments with 1.3-dichloropropene and chloropicrin under low temperature conditions for strawberry mother plants – Vicent Cebolla, and Serrano. Fernando

1545 Greenhouse grafting cucumber crop – methyl bromide alternative in Romania – Marian Bogoescu, Madalina Doltu, D.Sora, and Niculina Tanasa

1600 Soil and substrate microbiologizing: a promising approach for sustainable horticulture' – Frans Pauwels

1615 Discussions

1630-1700 COFFE BREAK

17.00 -1800 Special Session:
Methyl bromide alternatives: ALTMET (B) project
Chairperson: Henry Maraite – Belgium)

1700 Efficacy of chemical alternatives for Methyl bromide in lettuce production: field experiment - Ann Ceustermans, E. Van Wambeke and J. Coosemans

1715 Combinations of chemical soil fumigants for broad spectrum soil disinfestation- Etienne Van Wambeke, A. Ceustermans A. De Landtsheer, K. Gybels and J. Coosemans.

1730 Microbial mechanisms involved in the suppression of *Rhizoctonia solani* AG1-1B by lignin incorporation in soil – Sarah Van Beneden, Dries Roobroeck, Soraya C. França, Stefaan De Neve, Pascal Boeckx and Monica Höfte

1745 Use of oxamyl in the post methyl bromide era – Johan Desaeger and J. Wiles

18.00 Guided city tour

Tuesday, 15 September 2009

0830-1100: Session 2
Chemical Soil Disinfestation
Chairperson Husein Ajwa (USA)

0830 Shank application of chloropicrin as an alternative to methyl bromide for peach tree replant – S. Foschi, C. Spotti, A. Minuto, G. Minuto

0845 The emulsifiable formulations of Dimethyldisulfide (DMDS) and its mixtures with chloropicrin as alternatives to methyl bromide - Vicent Cebolla, Daniel Llobel, Antonio Oliver, Luís Miguel Valero, Francisco Torró, Andrés Hernández

0900 Evaluation of the efficacy of DMDS using drip application for the control of root knot nematodes (Meloidogyne spp.) in Turkey – J. J. Heller, E. Korkmaz, P. Charles

0915 Multi-tactic Approaches to Manage Soilborne Pathogens of Specialty Crops in North Carolina – Frank Louws, R.M. Welker, J.G. Driver and C.L. Rivard

0930 Powdery scab occurrence and control in Israel - Lea Tsror (Lahkim) O. Erlich, M. Hazanovsky and U. Zig

0945 Soil chemical treatments for the control of Fusarium wilt of Carnation in Spain - M. J. Basallote Ureba, M. D. Vela Delgado, F. J. Macías, C. J. López Herrera, and J. M. Melero Vara

1000 Effectiveness of fumigants alone and in combination with grafting to control Verticillium wilt and root-knot nematode in eggplant and tomato brown rot caused by Colletotrichum coccode – Giovanna Gilardi, Baudino M.,Gullino M. L. and Garibaldi A

1015 Top applications of fungicides for the control of melon sudden wilt caused by Monosporascus cannonballus - Shimon Pivonia, A. Maduel, R. Levita, and R. Cohen

1030 Accelerated degradation of metam-sodium in soil: Isolation and characterization of the involved microorganism - Shachaf Triky-Dotan, M. Austerweil, B. Steiner, D. Minz, J. Katan and A. Gamliel

1045 Discussion

1100-11.30 COFFEE BREAK

1130-1330 Session 3
Assessment tools for soil infestation and disinfestation
Chairperson – George Lazarovits

1130 Invited lecture:
Assessing the spatial distribution of soil infestation by means of remote sensing and GIS as the "first-aid" for soil disinfestation -Yafit Cohen (Israel)

1200 Distribution and control of pod wart disease of peanuts as analyzed using spatial means –Harel Caduri, A. Gamliel, Y. Cohen

1215 Unraveling Soil Communities Using the CPN60 Genomic Marker and Pyrosequencing. George Lazarovits, R. Ramarathnam, and S.M.Hemmingsen

1230 A knowledge based system to Predict Plot infestation with *Verticillium dahliae* and the success of disinfestation in Potato production systems - Goldstein E. Cohen Y, Hetzroni A., Tsror, L., Zig U., Lensky, I

1245 Methods to monitor MITC for phytotoxicity and in the environment - Etienne Van Wambeke

1300 Discussions

1330 - 1430 LUNCH BREAK AND POSTER VIEWING

1430- 1500 Poster viewing

1500- 1530 Poster Session discussion

Chairperson – Alfons Vanachter (Belgium)

1530-1630 Session 4

Integrated Control

Chairperson Maria Lodovica Gullino (Italy)

1530 invited lecture:

Biological control of plant-parasitic nematodes: from fantasy to reality - Yitzhak Spiegel (Israel)

1600 Evaluation of some pre-plant soil treatments and chemical disinfectants for control of Fusarium wilt diseases in cut flowers - Timothy. O'Neill and K.R. Green

1615 TrichoNema: a Trichoderma-based project to develop a commercial biocontrol agent product against phytonematodes - Edna Sharon, M. Mor, M. Bar-Eyal, Y. Oka, S. Van Kerckhove, A. Vanachter, I. Chet and Y. Spiegel

1630-1700 COFFE BREAK

17.00 -1900 **Roundtable discussion**

Application of soil disinfestation: bottlenecks, challenges and improvement possibilities:

- Application of fumigants (drip or shank) alone and in combination - Husein Ajwa
- Application of fumigants with other methods (solarization) - Abraham Gamliel
- Application of non-fumigant treatments (soft chemicals) - Steve Fennimore
- Application of soil disinfestation with biocontrol agents

Wednesday, 16 September 2009

Technical Visit to the Vegetable Production in the region of Mechelen and Antwerp

Thursday, 17 September 2009

0830-1100: Session 5

Physical methods of soil disinfestation and solarization

Chairperson - Eleftherios Tjamos (Greece)

0830 invited lecture:
Physical methods for soil disinfestation in intensive agriculture: Old methods and new approaches - Willemien Runia, L.P.G. Molendijk (the Netherlands

0900 Combining Effects of Soil Solarization and Grafting on Plant Yield and soilborne pathogens in cucumber – Suat Yilmaz and I. Celik

0915 Nitrate leaching after organic amendment under soil solarization in two different soils and its effects on yield and health of escarole and pepper - Vicent Cebolla, Josep Roselló, Carlos Ramos, Fernando Pomares

0930 The Effect of Pre-wetting on Thermal Inactivation of Soilborne Pathogens in Connection with Structural Solarization of Greenhouses - E. Shlevin, P. Di-Primo, and J. Katan

0945 Perspectives of anaerobic soil disinfestation - Willemien Runia, L.P. G. Molendijk, P. O. Bleeker

1000 - 1315 Session 6

Organic amendments

Chairperson José Melero-Vara (Spain)

1000 Effect of Biofumigation with Brassica Cover Crops on Weed Populations, Soil microbial Activity, and Fruit Rot in Pickling Cucumber Production - Mathieu Ngouajio and J. W. Counts

1015 Green manures and organic amendments to control corky root of tomato - Vincent Michel and L. Lazzeri

1030 Effect of Brassica green manure and Brassica pellets in combination with grafting and soil solarization against Verticillum wilt of eggplant and Fusarium wilt of lettuce and basil - Giovanna Gilardi L. Lazzeri, L. Malaguti, F. Clematis, A. Minuto and M.L.Gullino

1045 Use of pelleted medicago sativa meal for the control of root-knot and cyst nematodes - Trifone D'addabbo P. Avato, V. Radicci and A. Tava

1100-11.30 COFFE BREAK

1130 Kakawate (Gliricidia sepium) as a Soil Amendment and Biological Control of Soil-borne Pathogens: The Philippines Experience - Gina Pangga

1145 Combined Effects of Bio control Agent and Residues on Root Rot Mortality in Indian Mesquite (Prosopis cineraria) – Satish Lodha and L.N. Harsh

1200 Additional benefits to the efficacy in containing soilborne pest and pathogens of buifumigant plant and materials – Lucca Lazzeri, Onofrio Leoni, , Lorena Malaguti, Lorenzo D’Avino

1215 Mycofumigation using Muscodor albus for control of soilborne plant pathogens - Barry Jacobson, Grimme E. and Strobel, G

1230 Induced soil suppressiveness to root diseases by herb amendments and solarization Eyal klein, J. katan, and A. gamliel

1245 Plant metabolites derived from brassica spp. tissues as biofumigant to control soil borne fungi pathogens- Eva romero luna C. Barrau and F. Romero

1300 **Discussion**

13.15 14.30 LUNCH BREAK

1430 - 1630 session 3 Soilless culture.
Chairperson Vicent Cebolla (Spain)

1430 I nvited lecture
Disease control in soil-less systems **-** Erik Van Os (the Netherlands)

1500 Disinfestation of Polystyrene Seedling Trays for Substrate-based Float Systems in Australia - Scott Mattner, D.A. Wite, G.G. Baxter, R.C. Mann, R.J Holmes, and I.J. Porter

1515 Effect of commercially available composts on plant health – Oliver Gurnett, Maaike Perneel, and Stefaan Vandaele)

1530 Effect of ozone treatment on suppressivity of composted sewage sludge on Meloidogyne incognita - N. Sasanelli, Trifone. D'Addabbo, L. Mancini and F. Ciccarese

1545 **Discussions**

1600–1630 Coffee break

1630 -1800 Closing Session
– Concluding remarks – Monica Hofte (Belgium)
– General discussion and next meeting – Scientific Committee

2000 Conference Dinner

Posters

MB alternatives

1. Economic Evaluation of Chemical and Non-Chemical Soil Disinfestation - B. Sayin[1], M. A. Çelikyurt[1] Suat Yilmaz[1] and İ. Çelik[1]
2. Maintaining Biosecurity and Market Access in the Australian Strawberry Industry Following Methyl Bromide Phase-out – Scott W. Mattner, I.J Porter, R.K. Gounder, R.C. Mann, B. Guijarro
3. Pests and diseases of sweet basil after methyl bromide phase out: the Northern Italian experience - Anedrea Minuto, N. Vovlas, A. Troccoli, C. Bruzzone, M. Scortichini, G. Minuto

Chemical disinfestation

4. Effect of soil fumigants on fungal communities in protected pepper crops in Southeast Spain - Maria Angeles Martínez M.A. Martínez, M.C.Martínez, J. Torres, C. Ros, M.M. Guerrero, A. Lacasa
5. Efficacy of DMDS as a soil treatment against Meloidogyne chitwoodii in the Netherlands - Charles Patrick and Jan Jacque Heller

6. Evaluation of DMDS as Soil Fumigant Application, Distribution and Pest control - A. Gamliel1, Miriam Austerweil[1], Bracha Steiner[1], Yehodit Riven[1], Marina Benichis[1], Sagi Gal[2]).
7. *Roni Alon*

Integrated control

8. The physiological sudden collapse of grafted melon as a result of a not appropriate growing procedure - A. Minuto, G. Causarano, C. Bruzzone, G. La Lota, S. Longombardo, G. Minuto,
9. Evaluation of Steam, Biofumigants, and Fungicides for Strawberry Production in Field Soils - S. Fennimore, J. Weber, J. Samtani, and C. Gilbert
10. A comparison of four pre-plant soil treatments for control of Verticillium wilt in field-grown trees - T.M. O'Neill, T. Locke and C.J. Dyer
11. Chemical and biological alternatives for soil disinfestation in strawberry production - M. Thoelen, F. Meurrens, K. Stevens, J. Kellers, J. Coosemans and S. Clemens

Physical methods of soil Disinfestation and solarization

12. Soil Solarization as Alternative to Methyl Bromide for the Control of Protected Vegetable Soil Borne Pathogens in Morocco - Mohamed Besri

Organic amendments

13. Non-Chemical Options for Managing Soil Borne Plant Pathogens in Indian Arid Zone - Satish Lodha, R.Mawar and V.Singh
14. Effect of biosolarisation using pellets of Brassica carinata on soil-borne pathogens in protected pepper crops - M.M. Guerrero, M.A. Martínez, C. Ros, C.M. Lacasa, V. Martínez, A. Lacasa, P. Fernández
15. Efficacy of biosolarisation with sugar beet vinasses for soil disinfestation in pepper greenhouses - C. M. Lacasa, M.M. Guerrero, C. Ros, M.A. Martínez, V. Martínez, A. Lacasa, P. Fernández
16. Integration of Non-chemical Methods of Controlling Fusarium Wilt of Carnation - R. A. Nava-Juárez and J.M. Melero-Vara
17. Application of organic amendments followed by plastic mulching for the control of Phytophthora root rot of pepper in northern Spain - *Mireia*. Núñez-Zofío, C. Garbisu and S. Larregla*)*
18. Effect of meal of Aster caucasicus and A. sedifolius on the control of root-knot nematodes in glasshouse - *Mauro Di Vito* M. Di Vito, P. Pecchia, F. Catalano, M. Cammareri, C. Conicella
19. Effects of Soil Organic Amendments and Incubation Temperature on the Control of *Fusarium oxysporum f. sp. Asparagi* - A. Borrego-Benjumea, J. M. Melero-Vara and M. J. Basallote-Ureba
20. Effects of Several Soil Amendments on Allelopathy and Tolerance to Violet Root Rot in Mycorrhizal Asparagus Plants. A. S. M. Nahiyan, Y. Yagi, T. Okada and Y. Matsubara

Soilless culture

21. Effects of Zeolite-Peat Mixtures on Yield and Some Quality Parameters of - S. Kazaz1 and S. Yilmaz

Biological control

22. Biocontrol of Eggplant Bacterial Wilt with Combination of Avirulent Bacteriocin Producing Strain of Ralstonia solanacearum and Rhizosphere Bacteria - Triwidodo Arwiyanto1 and Suhartiningsih Dwi Nurcahyanti[2]
23. Determination of Deoxynivalenol in corn crop at Ardabil province in Iran and realated Fusarim species in 2007-2008 - Z.Aliakbari[1], H. Aminian[1], M. Mirabolfathi[2] and R. Karami-Osboo[2]
24. Evaluation of Trichoderma Isolates for Biological Control of Crown and Root rot in wheat (Bipolaris spicifera(Bainer)Subram) - H. R. Etebarian and M. Mohammadifar
25. Tolerance to Allelopathy and Fusarium Disease in Mycorrhizal Asparagus Plants Raised in Decline Soil - Y. Matsubara, T. Okada and A. S. M. Nahiyan