Strawberry Nurseries: Summaries of Alternatives and Trials in Different Geographic Regions

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Abstract

Worldwide, only a limited number of trials have been conducted in the strawberry nursery industry to investigate alternatives to methyl bromide (MB) for soil disinfestation, in contrast to the large number conducted in the strawberry fruit industry. Moreover, the development of alternatives for nurseries is proving more difficult than for the fruit industry because of the higher levels of pathogen, weed and nematode control that are required. Consequently, many strawberry nursery industries from around the world have applied for, and been granted, critical use exemptions (CUE) from the MB phase-out, on grounds that there are no technical alternatives to soil fumigation with MB for runner production.

The physical properties of alternative fumigants generally make application more difficult. The most promising, commercially-available alternatives have difficulty in achieving acceptable efficacy against pests, and in matching yields, plant-back times, and propensity to cause crop phytotoxicity. Despite this, in three key regions, 1,3-D/Pic and Pic alone have resulted in significant reductions in pathogen populations and disease incidence equivalent to that with MB/Pic. Furthermore, preliminary results in Australia with cyanogen and methyl iodide/Pic indicate that these products may offer better results than previous alternatives evaluated because their physical properties are more similar to MB.

In several regions of the world e.g. northern Europe, plug plants (containerised transplants produced in soilless media) have gained acceptance for many short season strawberry crops. Plug plants decrease growers' reliance on soil fumigants because they reduce or eliminate the need for production in soil. However, the broad-scale adoption of plugs for long season production is proving difficult, owing to a lack of knowledge of the altered physiology of plug plants and their higher cost.

In spite of the variable results obtained with alternatives, use of virtually impermeable films (VIFs) has halved the amount of 1,3-D/Pic required for effective soil disinfestation in Spain, and also offers a means to reduce the amount of MB/Pic required for soil fumigation and global emissions of MB.

INTRODUCTION

Worldwide, most strawberry nursery plants are produced under phytosanitary controls or 'certification', where regulations generally require that soils be disinfested. Effective soil disinfestation is extremely critical for the strawberry nursery industry as it ensures the production of 'certified' transplants that minimise the spread of diseases to the strawberry fruit industry. Methyl bromide/chloropicrin mixtures have been adopted throughout the world because of their broad-spectrum control of pathogens and weeds, their ability to induce an 'increased growth response' in crops, and their ease of use. The most, prominent pathogens controlled include those that cause major loss in the fruit industry viz. *Phytophthora* spp., *Verticillium dahliae, Pythium* spp., *Rhizoctonia* spp., *Cylindrocarpon* spp., and *Fusarium* spp. (Duniway, 2002).

Finding alternatives to MB for the strawberry nursery industry worldwide is proving more difficult than for the strawberry fruit industry because of the complex number of factors that needs to he taken into account when adopting an alternative. The volatile nature of formulations of methyl bromide/chloropicrin (MB/Pic) mixtures provides growers with an easy and reliable method of fumigation in a wide range of climatic conditions, soil types and cropping conditions, and this has ensured that strawberry nursery and fruit industries have remained highly productive. Most alternative fumigants have higher boiling points and lower vapour pressures than MB, and therefore do not move through soil profiles as readily as MB. This factor is often exacerbated in regions where strawberry nursery transplants are grown because of the climatic conditions that are required for their production i.e. high elevations and/or low temperatures, and high soil moisture. This paper discusses some of the issues that need to be overcome to increase the rate of ado tion of alternatives in strawberry nursery industries.

INDUSTRY REQUIREMENT FOR METHYL BROMIDE

The strawberry nursery industry relies on rigorous screening of varieties for high health, which includes virus testing of nuclear material and routine soil disinfestation. At present, three of the four generations (nuclear-foundation-mother-runners) are grown in disinfested soils to ensure that disease does not increase progressively through the multiplication process. In spite of this, nursery plants have been shown to contain low levels of specific diseases such as P *cactorum* even with the use of MB/Pic mixtures (DeCal et al., 2004). Most of the nuclear stock is produced in hydroponic substrate systems, and in some countries with smaller crop production there is potential for the next generation foundation stock to also be produced in hydroponics. To date, only a small proportion of mother stock and runners (<2%) has been produced in substrates in the major strawberry production regions of the world i.e. USA, Spain, Italy.

ALTERNATIVES THAT AVOID THE NEED FOR FUMIGATION

Soilless Culture/Hydroponics - Plug Plants

Strawberry plug plants (containerised transplants produced in soilless media) offer: the best opportunity for the nursery industry to reduce its reliance on chemical fumigation. Plugs have the advantage that they can be 'certified' disease-free, and can yield frui 2 to 3 weeks earlier than bare-rooted runners produced in soil (Sances, 2001). At present, plugs generally only compete for early or short season markets. In 2001, 3 million plants of the varieties Camarosa and Ventura were produced for planting in central and': southern California. Future expansion in the subsequent years was affected by widespread outbreaks of *Colletotrichum acutatum*, which spread because strict hygiene protocols`: were not maintained (Ajwa et al., 2004; C. Winterbottom, pers. commun., 2003). The cost: of plug plants compared with a standard bare-rooted runner plant in the USA in 2001 was US$ 0.17 - 0.21 and $0.08, respectively. Plugs have the disadvantage compared with bare-rooted runners, that they require extra handling, are difficult to transport, and the:: yield performance of plugs is not yet fully understood (F. Sances, pers. commun.).

Attempts in these regions to replace MB using plug plants grown in substrate cut ture has failed, with less than 2% of plants produced in substrates. Plugs were found to economical for short season production where market windows offset the production cost. Further effort should be directed to the development of successful plug plant systems replace or offset the need for MB, as these systems can offer further advantages in crop production such as short production cycles, mechanised transplanting, reduced water requirement, improved plant survival, early production (Durner et al., 2002).

Non-chemical Alternatives

Other non-chemical methods of soil disinfestation are presently considered impractical in the environments where runners are grown. The physiological requirement chilling prevents solarization being suitable in nurseries because of the cool climatic zones where nurseries are located worldwide. Biofumigant crops (Brassicas) have been shown to be beneficial in rotation with strawberries, but do not provide sufficient eradication of pathogens (Mattner et al., 2005). Other possible non-chemical options are steaming for small scale areas, or runner production on virgin soils (previously non-cropped soil) combined with a range of integrated pest management treatments and manual or chemical weed cultivation.

ALTERNATIVE FUMIGANTS

The strawberry nursery industry's need for complete elimination of diseases i.e. eradication of pathogens, and weeds, means that in the short term, large-scale production is likely to continue to rely on chemical disinfestation. The most promising chemical alternative in strawberry fruit production, 1,3-D/Pic, has not been as effective for strawberry runner production because it has given variable yields and has not controlled weeds as effectively as MB/Pic mixtures (Porter et al., 2004). For example, in a 3-year trial in the USA, Gordon et al. (1999) found that MB (MB/Pic 67:33, 390 kg/ha), chloropicrin (280 kg/ha) and 1,3-D/Pic (65:35, 448 kg/ha) were equally effective in controlling *Verticillium dahliae* in nursery beds. Fumigation reduced *V dahliae* microsclerotia populations from 20 ms/g soil to <1 ms/g soil, and the incidence of Verticillium wilt in strawberry runners (varieties 'Selva' and `Camarosa') from 87% to 0%. Strawberries grown in 1,3-D/Pic and chloropicrin-treated plots produced 23% fewer runners than plants in MB-treated plots. Similarly in Spain, Lopez-Aranda (1999) found that fumigation with MB (MB/Pie 67:33, 400 kg/ha), 1,3-D/Pic (83:17, 400 kg/ha), 1,3-D/Pie (65:35, 350 kg/ha) and chloropicrin (400 kg/ha) effectively controlled *Phytophthora cactorum* in nursery beds. Fumigation with MB and 1,3-D/Pic (83:17) increased yields of 'Camarosa ' strawberries by up to 300% compared with untreated plots. However, 1,3-D/Pic (65:35) and chloropicrin were less effective, increasing yields by up to 195%. In Australia, Mattner et al. (2004) found that fumigation of nursery beds with MB (MB/Pic 70:30, 500 kg/ha) controlled 99.5% of all weeds (mostly *Poa annua* and *Spergula arvensis).* In comparison, l,3-D/Pic (65:35, 500kg/ha) controlled only 73.3% of weeds. In a separate study, fumigation with 1,3-D/Pic stimulated the germination of the weed, *Chenopodium murales,* in runner beds, by breaking its dormancy (Donohoe et al., 2001). Over a 6 year period in Australia, 1,3-D/Pic, Pic alone, and metham followed by Pic have given variable yield results (Table 1) but good disease control (Fig. 1; Mattner et al., 2004) compared with MB for runner production.

One reason for the variable results of alternatives in the nursery industry is that most alternatives have higher boiling points and lower vapour pressures than MB, and therefore do not move through soil profiles as readily as MB. This factor is often exacerbated in regions where strawberry nursery transplants are grown because of the climatic conditions that are required for their production. For example, in Australia this has led to increased plant-back requirements for some alternatives in the nursery industry and incidences of crop phytotoxicity (Mattner et al., 2003). Preliminary results in Australia with cyanogen, together with a number of trials in the USA with methyl iodide/Pic, indicate that these products may offer better results than previous alternatives evaluated because their physical properties are more similar to MB (Mattner et al., 2004).

FUTURE CHALLENGES

Whilst the commercially available alternatives discussed above have given promising results in terms of pathogen control, more work is required to confirm that alternatives provide the same consistent control that has been provided by MB/Pic. Only a limited number of studies have benchmarked the comparative performance of alternatives against MB for the major target pathogens of strawberries and weeds. Further comparative studies on specific pathogen control with depth between MB/Pic and alternative fumigants are required for the wide range of root pathogens that affect strawberry plants. Studies are also required to confirm their performance for control of the most common Weeds in nursery production regions and to determine consistent effects of alternatives on the yields of different varieties. Also, no studies have determined if runners produced under different fumigant regimes have different disease threshold levels in the fruiting generation.

In several regions of the world e.g. northern Europe, plug plants have gained acceptance for many short season crops, but broad-scale adoption for long season crops is proving difficult owing to their increased costs and lack of studies establishing how to get consistent yields from plug plants. As this system offers a sustainable means of producing disease-free plants, further studies are required.

In spite of the variable results obtained with alternatives, use of barrier films e.g.VIF has halved the amount of I,3-D/Pic and MB required for effectiveness in Spain (DeCal et al., 2004; Lopez Aranda et al., 2004), and also offers a means to reduce amounts of MB/Pic required and global emissions of MB. Problems in laying barrier films have occurred in Australia, but further studies are anticipated with new films. Future studies verifying the advantages of impermeable barrier films are required.

The strawberry nursery industry should not be complacent and rely on exemptions for 'Critical Use' being available for substantial periods after 2005. Even though some CUEs have been granted, future markets are forever demanding more 'environmentally friendly' production practices, and no industry will be truly sustainable until such practices are implemented. The strawberry nursery industry has two options. It can switch to the next best fumigant alternative or invest in the development of soilless production systems that promote environmental sustainability.

Further comparative studies in the strawberry nursery industry on alternative fumigants for soil disinfestation are required to determine;

(a) effective control with depth for the full range of root pathogens and weeds that affect strawberry plants,
(b) effects of alternatives on the yields of different strawberry varieties,
(c) the impact of alternatives on disease threshold levels of nursery plants and the fruit-yielding potential of transplants
(d) issues relating to the scale-up and long-term use of alternatives e.g. enhanced bio-degradation of fumigants, etc.

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Tables

Table 1. Relative effect of alternatives compared with methyl bromide on strawberry nursery yield (numbers of runners per metre of row) in Australia.

Treatment	MB/Pic	Unt	TC35	Pic	MS and Pic	MI	EDN
No of studies	8	6	8	8	2	1	1
Range	100	59-103	75**-105	62-109	82-101	122	107
Average	100	73	91	89	91	122	107

**- TC35 was phytotoxic

MB/Pic = Methyl bromide/chloropicrin (70:30); TC35 = 1,3-D/chloropicrin (65:35); Pic = chloropicrin; MS/Pic = Metham sodium followed by chloropicrin; MI = Methyl iodide/chloropicrin (30:70); EDN = ethanedinitrile

Figures

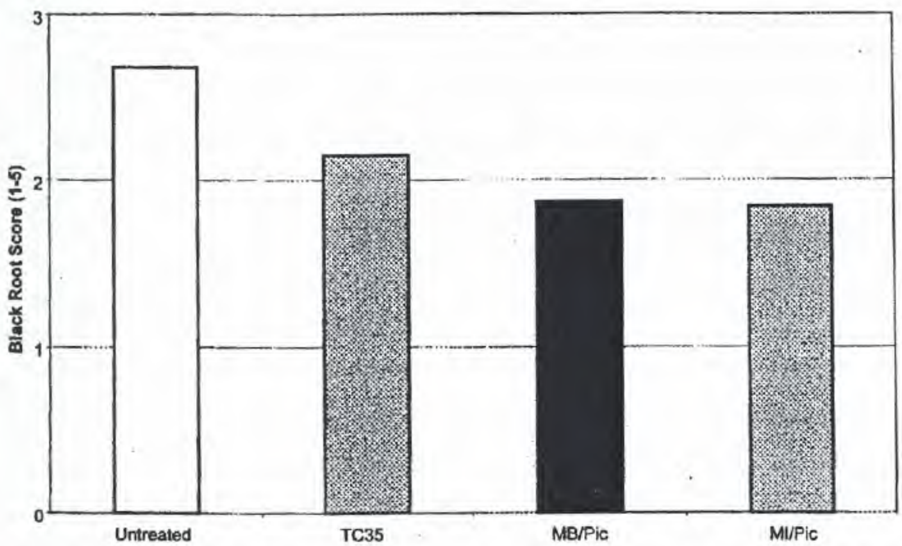

Fig. 1. Relative effect of methyl bromide and alternatives for control of black root rot in a strawberry nursery trial in Australia.