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Chemical Fumigants as Alternatives Methyl Bromide for Soil Disinfestation of Plant Integrated Pest Management

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Abstract Methyl bromide (MB) is an soil fumigants provide excellent, reliable disease and pest control, increase yields, high quality produce, extended crop seasons and dependable economic returns, but also to increase contamination of soil, water, and air as well as the main of a stratospheric ozone-depleting compounds. So, alternatives of methyl bromide has effective on wide range of fungi, weed , nematodes and pest , biodegradable and non ozone depleting, including fumigants chemicals, such as, 1,3-D, methyl isothiocyanate (MITC), chloropicrin, dichloropropene , methyl iodide (MI), dimethyl disulfide (DMDS), propargyl bromide, sodium azide, propylene oxide. Combination of fumigants is highly effective against nematodes, fungi, weeds and soil insects can provide and yield increases i.e., dichloropropene (1,3D) / chloropicrin (Pic), 1,3D and methyl isothiocyanate (MITC),MITC and PIC,,MITC, 1,3-D and Pic. Ozone has potential to be an effective general soil fumigant also is very effective at destroying bacteria, viruses and odors . Application of gaseous ozone to soil sterilization change of soil physical, chemical and biological properties.

Keyword: Chemical fumigants, methyl bromidealternative, Soil disinfestation, fungi, bacteria, weed, insect, pest

Introduction

Methyl bromide (MB) is an odorless,colorless gas that has been used as a fumigant of agriculture in France , 1930s to control plant pests *i.e.,* insects, nematodes, weeds, pathogens, and rodents (Gilreath *et al.*, 2005). as well as for fumigation of commodity and quarantine treatment. Methyl bromide dissipates rapidly to atmosphere, at high is most dangerous of human central nervous system, respiratory system failure, and severe deleterious actions on the lungs, eyes and skin (Wagner, 1981). Methyl bromide contributes to stratospheric ozone depletion (Bulter and Rodriguez, 1996).So, that methyl bromide phased out obligations under the Montreal protocol, 2005 expect for emergency and critical use exemption. Alternatives of methyl bromide has effective on wide range of fungi, weed , nematodes and pest , biodegradable and non ozone depleting

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(Kokalis-Burelle, 2003, Rodriguez-Kabana *et al.*, 2003 ,Gilreath and Santos , 2004 and Gilreath *et al*., 2005). Alternative chemical fumigants can be applied effectively for soilborne pest control properties, including weeds and fungi through drip irrigation systems is receiving increasing attention as a method to improve the uniformity of fumigant application (López-Aranda, 2014), and have potential for use in the floriculture industry. Drip applied fumigants on efficacy equivalent to shank-applied fumigants (Samtani *et al*., 2011). Good irrigation distribution uniformity and safety are critical issues for drip fumigation (Thomas *et al*., 2003) .The main advantage of applying fumigants via drip irrigation is the improved distribution of the fumigants in soil. Subsurface drip irrigation and plastic mulch are also used to improve distribution and minimize fumigant volatilization (Schneider *et al.*, 2003, Papiernik *et al*., 2004, Duniway, 2005 and López-Aranda, 2014).

Methyl isothiocyanate (MITC)

Generating materialsof 1,3-D, methyl isothiocyanate (MITC) include metam sodium and metam potassium ascommericalliquid formulation of (Vapam and K-Pam) and dazomet (Basamid) as granular.

Dazomet

Dazomet is a granular MITC generator. it is easier to apply than most other fumigants including (MB).It is a suitable replacement for use in small-scale applications It is requires mechanical means of soil tratment and adequate soil moisture for good movement and efficacy for control weeds, nematodes, and fungi were obtained in Argentina, Australia, Europe, USA and Japan (Gilreath *et al*., 2005).

Metam sodium

Metam sodium was introduced a pre-bed spray (935 liters/ha) with rotovation to 15-20 cm prior to final bed preparation combined with pebulate at 4.5 Kg/ha. This treatment resulted in *Fusarium* crown rot and nutsedge control that were equivalent to methyl bromide (McGovern *et al*., 1998). The combination of metam sodium (320 Kg/ha) combined with pebulate (4.5 Kg/ha) provided control of nutsedge that was equivalent to methyl bromide (98:2, at 400 Kg/ha) at the begining and at the end of the season. Metam sodium are used for soil fumigation of agricultural land, good fumigant distribution within sandy loam soil ,under medium water application amount (50 mm) with slow to intermediate drip application rates (1.9-5.0 L h m) Nelson *et al*., 2013.

Chloropicrin (Pic)

Chloropicrin (trichloronitromethane) is a liquid fumigant (boiling point: 112°C) was injected into soil under plastic. It has been shown to have some nematicidal activity of pepper and cucumber (Duniway , 2002 and Gilreath *et al.,* 2004). New formulations of chloropicrin allow the use of different application methods that are more effective, less costly, and friendlier to the environment. Chloropicrin can be applied directly by injection or by drip application. Emulsifiable concentrate (EC) formulations are now considered to be potential replacements for MB in California, particularly where fungal pathogens are concerned (López-Aranda, 2014).

Dichloropropene

Dichloropropene (1,3-D) is a liquid fumigant (boiling point: 104-112°C) is highly effective for controlling nematodes by rates of 35-50 g – m^2 and provides effective control of insects and suppresses some weeds and pathogenic fungi (Gerik and Hanson, 2011).The most commercial formulations of 1.3- dichloropropene*i.e.,*Telone II (100% 1,3-D), Telone C-17 (73% 1, 3-D and 17% chloropicrin) and Telone C-35 (65% 1,3-D and 35% chloropicrin) Over the bed top at plastic laying (Noling and Gilreath, 2002 and Gilreath *et al*., 2004). The best available formula was applied with strawberry is Telone C-35 (1,3-dichloropropene + 35% chloropicrin), when applied in-bed at 331 liters per treated ha, 3-5 weeks before transplanting. Florida strawberry production has been identified as the best available alternative, strawberry growers are still concerned about the increased vegetative growth that is associated with high concentrations of chloropicrin (Noling and Gilreath, 2002).

Methyl iodide (MI)

Methyl iodide, (MI) or iodomethane is a liquid chemical (boiling point of 42°C) was originally developed by researchers in California, USA (Duniway, 2002). Methyl iodide (MI) as a drop-in replacement for methyl bromide. It is an attractive replacement due to its soil mobility and broad-spectrum of activity. It is not associated with ozone depletion and rapidly breaks down when exposed to UV light. Methyl iodide was registrated by trade name (Midas®). In California, it has been tested in carrot, peach, cut-flower, and strawberry production systems (Schneider *et al.,* 2003). Efficay of (MI) equivalent to methyl bromide on yields of bell pepper and tomatoes when combined with chloropicrin (420 Kg/ha and 84 Kg/ha MI and pic) (Ohr, 1996 and Gilreath *et al*., 2005). Several reports, show that methyl iodide (iodomethane) provides similar efficacies to methyl bromide in trials (López-Aranda, 2014).

Propargyl bromide

Propargyl bromide was patented as a soil fumigant by Dow Chemical Co. in 1957. In Florida, trials evaluating application rates of propargyl bromide ranging from 45-224 Kg/ha identified rates between 45-112 Kg/ha as effective in controlling all tested pests, including root-knot nematode, *Fusariumo xysporum* f. sp. *lycopersici* race 3 *Phytophthoracapsici* and yellow nutsedge) (Noling *et al*., 2001 and 2002).

Dimethyl disulfide (DMDS)

Dimethyl disulfide (DMDS) one of the volatile compounds produced in soil amended with cabbage and solarized, it is an alternative to methyl bromide, highly reduction of fungal plant pathogens and nematodes (Gamliel *et al*., 2000 and 2005). This material has zero ozone depletion potential (ODP) and good control of several soilborne fungal plant pathogens and pathogenic nematodes was achieved in trials in France, Italy , Spain and USA as an alternative to MB for control of a number of soilborne fungi (*Verticillium dahliae, Sclerotinia. sclerotiorum, R. solani, S. rolfsii* and *F. oxysporum lycopersici, F. oxysporum radices lycopersici, F. oxysporum melonis*) and nematode species (*Meloidogyne incognita* and *javanica* and *Heterodera schachtii*) as a result of application as soil injection and drip application (Fritsch, 2005, Minuto *et al.,* 2006 and Abou Zeid and Noher, 2014). DMDS provided controlled Pythium root rot and root-knot nematode (*Meloidogyne* spp.) juveniles in soil at a level comparable to methyl bromide. Most importantly, DMDS did seem to reduce vegetative growth of cockscomb, marketable yields were equivalent to methyl bromide treatments (Church *et al*., 2004).

Sodium azide

Sodium azide is another material that has been investigated as an alternative to methyl bromide. This material has been reported to have a wide range of activity, including control nematodes, fungi, and weeds in a variety of crops. Hard-to-kill weeds, such as nutsedges required high rates of sodium azide. combiation sodium azide with herbicides, s-metholachlor and halosulfuron-methyl, demonstrated good weed control at the lower rates effective on nematodes and fungi (Rodriguez Kabana and Akridge, 2003, Rodriguez Kabana *et al.*, 2003).

Propylene oxide

Propylene oxide has been used for more than 40 years as a stored-product treatment is currently under development for soil applications under

the trade name PROPOZONE. It consists of 100% propylene oxide and is shanked or drip applied at rates ranging from 374-935 L/ha., and high rates(748-935 L/ha) were control nutsedge, meanwhile, lower rates were effective in controlling nematodes and fungal plant pathogens Gilreath *et al.*,2004.

Ozone

Ozone (O3) is an extremely reactive gas naturally produced in upper atmosphere. This reactivity makes it a very effective biocide and it is approved for use as a post-harvest fumigant. Ozone (O3) is the strongest commercially available disinfectant and also is very effective at destroying bacteria, viruses and odors. It has a very short half-life in water and soil. The use of ozone as a soil fumigant was investigated in tomato and carrot fields in Southern California and strawberry fields in Northern California. The studies demonstrated that reduction in Verticillium wilt was comparable to the MB treatment. Application of gaseous ozone to soil sterilization change of soil physical, chemical properties in the process of ozone treatment, plant growth, biological phenomena and DNA genome of bacteria and viruses (Ebihara *et al*., 2013)

Combinations of chemical fumigants alternatives of methyl bromide

Researchers has demonstrated that mixtures of fumigants or sequential applications of these chemicals of integration with or without other non chemicalof IPM techniques can provide pest control and yield increases which are equivalent to those obtained with MB (Gilreath and Santos, 2004, Gilreath *et al.,* 2005 and Minuto *et al.,* 2006).

Dichloropropene (1,3D) / chloropicrin (Pic)

Formulation of dichloropropene1,3 /Pic is a key alternative to MB, which has been widely accepted commercially for control soil nematodes and fungal diseases. A large number of studies and a recent review internationally have shown that these formulations consistently gave yields equivalent to MB (Duniway, 2005 and López-Aranda, 2014). Formulations of 1,3-D and chloropicrin (Pic) has expanded rapidly for certain crops such as strawberry fruit, melons and ornamental crops, such as carnations. 1,3-D/Pic with or without a follow-up treatment of metham sodium has proven effective for strawberries in several countries (Ajwa *et al.,* 2004, Duniway, 2005 and López-Aranda, 2014).

Dichloropropene (1,3D) and Methyl isothiocyanate (MITC)

Combinations of 1, 3-D and MITC are used in Europe, Canada and other countries (Thomson, 1992). Combination of 1,3-D and metam sodium or methyl isothiocyanate) were increase weed and pest control (Csinos *et al.,* 2002 and López-Aranda, 2014). Ajwa *et al.,* (2004) have demonstrated that sequential application of metam sodium after reduced rates of 1,3-D/Pic

or chloropicrin controlled soil pests and produced strawberry yields equivalent to standard MB/ Pic fumigation, without negative effects **.**

Methyl isothiocyanate (MITC) and chloropicrin (Pic)

The combination of chloropicrin and metham, applied sequentially, has gained new interest, particularly in regions where use of 1,3-D is limited by regulatory restrictions. Research has shown that sequential application of metam sodium after reduced rates of 1,3-D/Pic (InLine) or chloropicrin controlled soil pests in strawberry fruit and produced fruit yields equivalent to standard MB/Pic fumigation (Ajwa *et al.,* 2004). Demonstration trials confirmed earlier research that metham can be used to reduce application rates of InLine and Pic without a loss in yield in strawberry fruit in California, USA, even though pathogen pressure was severe (Ajwa *et al.,* 2004).

Methyl isothiocyanate (MITC), Dichloropropene (1,3D) and chloropicrin (Pic)

Vorlex, is a trade name of a mixture formula of MITC and 1,3-D and chloropicrin, it is highly effective against nematodes, fungi, weeds and soil insects (Thomson, 1992).Vorlex is highly active even at low soil temperatures (40ºC) but it can be phytotoxic and has long plant back periods (Porter *et al.,* 1999 and López-Aranda, 2014).Application of emulsified formulations of 1,3-D/Pic (InLine) through the drip irrigation system was shown to be effective and safe (Peretz-Alon and Ucko, 2005 and López-Aranda, 2014). Drip irrigation of 1,3-D/Pic has been adopted as a key alternative to MB for strawberry and vegetable production over five years (López-Aranda, 2014).

Conclusion

Since 1994, researchers from governmental, academic and private institutions, as well as extension agents and users, have gathered together to share information on a variety of laboratory, field, and on-farm research and technology transfer topics on chemical replacements for methyl bromide, due to the urgency driven by the protocol, there is a need to be visionary in the development of more sustainable production systems for methyl bromide-dependent crops. An integrated approach that utilizes new fumigantes, no ozone deplation and friendly environment can be combined with novel application technology and procedures to improve their spectrum of pest control.

References

Abou, Z. N. M. and Noher, A. M. (2014). Efficacy of dmds as methyl bromide alternative in controlling soil borne diseases, root-knot nematode and weeds on pepper, cucumber and tomato in Egypt. Acta Horticulturae 1044:411-414.

Ajwa, H. A., Fennimore, S., Kabin, Z., Martin, F., Duniway, J., Browne, G., Trout, T., Khan, A. and Daugovish, O. (2004). Strawberry yield with chloropicrin and Inline in combination with Metham Sodium and VIF. In: Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions, Orlando, Florida. pp. 38.

Butler, J. H. and Rodriguez, J. M. (1996). Methyl Bromide in the Atmosphere. The Methyl Bromide Issue. John Wiley & Sons, Ltd.

Church, G., Rosskopf, E. and Holzinger, J. (2004). Evaluation of DMDS for production of ornamental cockscomb (*Celosia argentea*). Proc. Annual Int. Res. Conference on Methyl Bromide Alternatives and Emissions Reductions. MBAO. pp. 87-1:87-5.

Csinos, A., Webster, T., Sumner, D., Johnson, A., Dowler, C. and Seebold, K. (2002). Application and crop safety parameters for soil fumigants. Crop Protection 21:973-982.

Duniway, J. M. (2002). Status of chemical alternatives to methyl bromide for pre-plant fumigation of soil. Phytopathology 92:1337-1343.

Duniway, J. M. (2005). Alternatives to methyl bromide for strawberry production in california, USA. Acta Horticulturae 698:27-32.

Ebihara, K., Mitsugi, F., Ikegami, T., Nakamura, N., Hashimoto, Y., Yamashita, Y. and Sung, T.-L. (2013). Ozone-mist spray sterilization for pest control in agricultural management. The European Physical Journal Applied Physics 61: 24318.

Fritsch, J. (2005). Dimethyl disulfide as a new chemical potential alternative to methyl bromide in soil disinfestation in FRANCE. Acta Horticulturae 698:71-76.

Gamliel, A., Austerweil, M. and Kritzman, G. (2000). Non-chemical approach to soilborne pest management – organic amendments. Crop Protection 19:847-853.

Gamliel, A., Triky, S., Austerweil, M., Peretz-Alon, Y. and Ucko, O. (2005). Combined soil fumigants: Synergistic performance and improved yield. Acta Horticulturae, 698:135-140.

Gerik, J. S. and Hanson, B. D. (2011). Drip application of methyl bromide alternative chemicals for control of soilborne pathogens and weeds. Pest Management Science, n/a–n/a.

Gilreath, J. P. and Santos B. M. (2004). Methyl bromide alternatives for weed and soilborne disease management in tomato (*Lycopersicon esculentum*). Crop Protection 23:1193-1198.

Gilreath, J. P., Noling, J. W. and Santos, B. M. (2004). Methyl bromide alternatives for bell pepper (*Capsicum annuum*) and cucumber (*Cucumis sativus*) rotations. Crop Protection 23:347-351.

Gilreath, J. P., Santos, B. M., Motis, T. N., Noling, J. W. and Mirusso, J. M. (2005). Methyl bromide alternatives for nematode and Cyperus control in bell pepper (*Capsicum annuum*). Crop Protection 24:903-908.

Kokalis-Burelle, N. (2003). Plant and Soil 256:273-280.

López-Aranda, J. M. (2014). Methyl bromide alternatives (chemical and non-chemical) for strawberry cultivation in conventional areas of production. Acta Horticulturae, 1049:77-88.

McGovern, R. J., Vavrina, C. S., Noling, J. W., Datnoff, L. A. and Yonce, H. D. (1998). Evaluation of application methods of metam sodium for management of fusarium crown and root rot in tomato in Southwest Florida. Plant Disease 82:919-923.

Minuto, A., Gullino, M. L., Lamberti, F., D'Addabbo, T., Tescari, E., Ajwa, H. and Garibaldi, A. (2006). Application of an emulsifiable mixture of 1,3-dichloropropene and chloropicrin against root knot Nematodes and Soil borne Fungi for Greenhouse Tomatoes in Italy. Crop Protection 25:1244-1252.

Nelson, S. D., Ajwa, H. A., Trout, T., Stromberger, M., Yates, S. R. and Sharma, S. (2013). Water and methyl isothiocyanate distribution in soil after drip fumigation. Journal of Environment Quality 42:1555.

Noling, J. W. and Gilreath, J. P. (2002). Field scale demonstration/ validation studies of alternatives for methyl bromide in plastic mulch culture in Florida. Citrus and Vegetable Magazine 65:19-31.

Noling, J. W., Gilreath, J. P. and Rosskopf, E. N. (2001). Alternatives to methyl bromide field research effort for nematode control in Florida. Proc. Annual Int. Research Conf. on Methyl Bromide Alternative Reductions and Emissions Reductions, MBAO. pp. 141-143.

Noling, J. W., Rosskopf, E. N. and Chellemi, D. O. (2002). Impacts of alternative fumigants on soil pest control and tomato yield. Proc. Annual Int. Research Conf. on Methyl Bromide Alternative Reductions and Emissions Reductions, MBAO, pp. 301-303.

Ohr, H. D. (1996). Methyl Iodide, an Ozone-Safe Alternative to Methyl Bromide as a Soil Fumigant. Plant Disease 80:731.

Papiernik, S. K., Dungan, R. S., Zheng, W., Guo, M., Lesch, S. M. and Yates, S. R. (2004). Effect of application variables on emissions and distribution of fumigants applied via subsurface drip irrigation. Environment Science Technology 38:5489-5496.

Peretz-Alon, I. and Ucko, O. (2005). Combined soil fumigants: synergistic performance and improved yield. Acta Horticulturae:135-140.

Porter, I. J., Brett, R. W. and Wiseman, B. M. (1999). Alternatives to methyl bromide: chemical fumigants or integrated pest management systems?. Australasian Plant Pathology 28: 65.

Rodriguez-Kabana, R. and Akridge, J. R. (2003). Sodium azide (SEP-100) for control of nematodes and weed problems in green pepper production. Proc. Annual Int. Research Conf. on Methyl Bromide Alternative Reductions and Emissions Reductions, MBAO. pp. 461:468.

Rodriguez-Kabana, R., Akridge, J. R. and Burkett, J. E. (2003). Sodium azide (SEP-100) for control of nutsedge, root-knot nematode and Fusarium crown rot in tomato production. Proc. Annual Int. Research Conf. on Methyl Bromide Alternative Reductions and Emissions Reductions, MBAO, pp. 2101-2112.

Samtani, J. B., Ajwa, H. A., Weber, J. B., Browne, G. T., Klose, S., Hunzie, J. and Fennimore, S. A. (2011). Evaluation of non-fumigant alternatives to methyl bromide for weed control and crop yield in California strawberries (*Fragariaan anassa* L.). Crop Protection 30:45-51.

Schneider, S. M., Rosskop, E. N., Leesch, J. G., Chellemi, D. O., Bull, C. T. and Mazzola, M. (2003). United States Department of Agriculture? Agricultural Research Service research on alternatives to methyl bromide: pre-plant and post-harvest. Pest Management Science 59:814-826.

Thomas, J. T. and Husein, A. A. (2003). Application of soil fumigants through micro-irrigation systems. Las Vegas, NV.

Thomson, W. T. (1992). Agricultural Chemicals. Book III..Thomson Publications, Fresno, Ca., U.S.A. 206 pp.

Wanger, S. L. (1981). The Fumigants. In *Clinical Toxicology of Agricultural Chemicals. Oregon* State University, Environmental Health Sciences Center : Corvallis. pp. 284-290.

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