Safe and high efficient method for application of liquid ethyl formate (Fumate™) to replace methyl bromide for treatment of imported nursery plants

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Abstract

There have been significantly increased reports of finding invasive quarantine pests with increasing import plants into Korea. Moreover, the efficacy and work safety issues have been reported regarding use of methyl bromide (MeBr) for fumigation of imported nursery plants. For replacement of MeBr use on imported plants, a new technology of using liquid ethyl formate has been registered in South Korea as Fumate™. The technology involved to mix ethyl format with nitrogen gas to form non-flamable ethyl format formulation. It has been evaluated on various imported plants. The Fumate™ is recently developed and commercialized in Republic of Korea and Australia for quarantine treatments on fresh fruits, grains etc. Fumigation with Fumate™ offers environmental-friendly and practically safe use of liquid ethyl formate. We have extended the use of liquid EF application technology to quarantine treatment of imported nursery plants.

Keywords: Quarantine fumigation, Ethyl formate, FumateTM, Nursery plantsIntroduction

1. Introduction

Methyl bromide (MeBr) had long been planned for its phasing out and recommended for reduction of its usage by the International Plant Protection Convention (IPPC). Therefore, for protecting the ozone policy and work safe applications, MeBr needs to be urgently replaced. Ethyl formate (EF) offers great potential to replace MeBr for fresh fruit fumigation. The Animal and Plant Quarantine Agency (APQA) of the Korean Government, is under progress for developing new alternative fumigants and fumigation technology to replace MeBr. However, intially, the cylinderized liquid EF with carbon dioxide formulation faced with challenges from higher costs, work safety issues and phytotoxicity of furits and vegetables (Ryan et al., 2003; Simpson et al., 2004). Recently, the cost-effective and practically safe use of liquid EF with nitrogen gas has been developed by cooperative research between Murdoch University in Australia and APQA in Korea. An innovative application of EF (Fumate™) with nitrogen is replacing cylinderized formulation because new EF application technology benefits to reduce operation costs of fumigation, provide safety for workers, handling heavy cylinders as well as reduction of green house gas (Yang et al., 2016). Here, we report the phytotoxicity of EF on imported nursery plants.

2. Materials and Methods

2-1. Preparation of samples

In this preliminary test, 12 different variety of imported nursery plants were used as listed below:

Alocasia amazonica, Cactaceae spp, Sansevieria trifasciata, Codiaeum variegatum, Peperomia obtusifolia, Peperomia puteolata, Hoya carnosa, Viburnum odoratissimum, Spathiphyllum wallisii, Rhapis excalsa, Hedera helix, Fatsia japonica and Sansevieria stuckyi.

2-2. Fumigant

Fumate™ (Ethyl formate, 99%) was supplied from Safefume Inc., Korea. EF was vaporized with heated nitrogen gas through a nitrogen heater, which was fitted in vaporizer (SFM-1) and discharged into the fumigation chamber.

2-3. Preliminary test of phytotoxicity to nursery plants

Phytotoxic tests were performed at Gyeongsang National University (GNU) site. A fumigation chamber (0.55m x 0.50m x 1m) was used and the loading ratio of plants was 5 to 15%. After loading the nursery plants, we calculated the required dosage of EF (70 g m^{-3}) that was injected into the chamber for fumigation for 4 hours. The air temperature in fumigation room was controlled with an air conditioner at 20±2°C. After fumigation, the chamber was ventilated for more than 1 hour, and phytotoxicity on nursery plant was investigated after 1st and 7th day after treatment. Assessment for recovery of post-fumigated plants was undertaken after 4 weeks after treatment.

2-4. Measurement of fumigant concentration

For monitoring concentration of EF in the chamber, gas samples were drawn with an electric pump at timed intervals and stored in Tedlar gas sampling bags (1 liter, SKC Inc.) before analysis. The concentration of EF was determined by using an Agilent Technology 7890N gas chromatography (GC) equipped with a flame ionization detector (FID) after isothermal separation on a 30 m × 0.32 mm I.D. HP-5 (0.25 µm film)-fused silica capillary column (Restek Co. Ltd.). The GC oven, injector and detector temperature were 150, 200 and 200°C, respectively. Helium was used as the carrier gas at a rate of 2 mL/min. The peak areas were calibrated periodically using a standard (inject the known volume of ethanedinitrile in 1 L Tedlar gas sampling bags).

2-5. Assessmenet of post-fumigation phytotoxicity

The market qualities on nursery plants post-fumigation was assessed by three different ways. The external damage was measured by researchers and numbered as index ranged from 0 (none) to 4 (severe). Chrolophyll contents were measured with chrolophyll meter. Color changes of leaf was measured with colorimeter. Unfumigated nursery plants were used as controls for these assessments.

3. Results

Phytotoxicity of EF to nursery plants

The cumulative concentation X time products (Ct) of EF were 74.9 to 143.4 g h m^{-3}. The Ct products decreased with the increase of loading ratio of plants. Even though there were small damages in terms of reducion of chlorphyll and changes in colors in post-fumigated nursery plants within the first week, there were no serious damages found in terms of recoveries at 4 weeks post-fumigation. This is the time (4 weeks), at which, usually post-quarantine plants are distributed in markets in Korea. However, there was no recoveries in *Spathiphyllum wallisii* and *Peperomia puteolata* plants (Table 1)

Tab. 1 One week end point damage of nursery plants after 4 hr EF fumigation (20°C)

Nursery plants	Filling ratio (%)	CT value (mg h/L)	Damage index[a] (Mean ± SE)		Chlorophyll			Hue[b]			recovery
			Control	Treatment	Control	Treatment (Damaged leaf)	Treatment (Undamaged leaf)	Control	Treatment (Damaged leaf)	Treatment (Undamaged leaf)	
Alocasia amazonica	5	141.7	0.0 ± 0.0	3.0 ± 0.0	37.9 ± 0.6	-	-	8.3 ± 4.2	-	-	O
Cactaceae spp	10	143.4	0.0 ± 0.0	0.0 ± 0.0	-	-	-	-	-	-	-
Sansevieria trifasciata	15	110.6	0.0 ± 0.0	1.0 ± 0.0	56.4 ± 2.7	-	35.8 ± 5.2	17.3 ± 8.6	-	10.3 ± 5.2	-
Codiaeum variegatum	5	141.7	0.0 ± 0.0	1.7 ± 0.3	78.3 ± 1.4	32.5 ± 2.7	75.1 ± 0.0	6.2 ± 3.1	-	11.8 ± 6.2	O
Peperomia obtusifolia	8	104.1	0.0 ± 0.0	2.7 ± 0.3	41.6 ± 1.5	19.4 ± 2.7	34.6 ± 1.0	6.9 ± 3.5	19.4 ± 2.7	13.2 ± 0.6	O
Peperomia puteolata	15	80.1	0.0 ± 0.0	1.3 ± 0.3	41.9 ± 0.9	-	39.6 ± 0.3	8.6 ± 4.3	-	18.2 ± 0.6	X
Hoya camosa	8	104.1	0.0 ± 0.0	2.7 ± 0.3	58.5 ± 0.8	25.6 ± 5.8	65.8 ± 3.0	6.5 ± 3.2	18.2 ± 2.1	9.3 ± 0.7	O
Vibumum odoratissimum	5	141.7	0.0 ± 0.0	3.0 ± 0.0	59.0 ± 0.5	33.4 ± 5.7	22.5 ± 4.6	7.0 ± 3.5	16.4 ± 2.6	17.0 ± 0.6	O
Spathiphyllum wallisii	5	141.7	0.0 ± 0.0	4.0 ± 0.0	55.4 ± 0.2	36.4 ± 2.6	58.3 ± 6.6	7.3 ± 3.7	11.1 ± 0.2	15.5 ± 1.4	X
Rhapis excalsa	8	104.1	0.0 ± 0.0	4.0 ± 0.0	-	-	-	-	-	-	O
Hedera helix	8	104.1	0.0 ± 0.0	4.0 ± 0.0	47.7 ± 0.4	18.9 ± 2.6	57.8 ± 1.2	8.2 ± 4.1	19.2 ± 1.9	11.6 ± 0.2	O
Fatsia japonica	8	104.1	0.0 ± 0.0	4.0 ± 0.0	52.4 ± 0.4	41.9 ± 1.0	-	5.8 ± 2.8	8.5 ± 4.2	-	O
Sansevieria stuckyi	10	74.9	0.0 ± 0.0	0.0 ± 0.0	-	-	-	-	-	-	-

a: Damage score : 0 (0%), 1 (<5% affected shoot), 2 (0-25% affected shoot), 3 (25-50% affected shoot), 4 (>50% affected shoot)
b: [Color L x 2 + Color a x 2 + Color b x 2]/2
- : Impossible to check

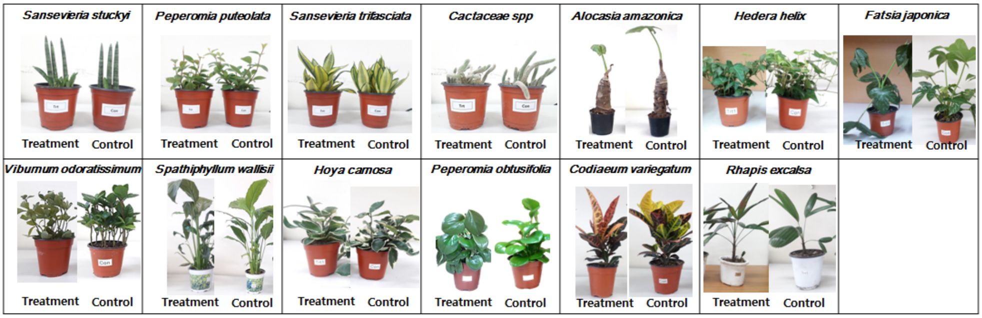

Fig. 1 Comparison of untreated and EF treated nursery plants

4. Discussion

Although EF fumigation caused decrease of chrolophyll contents on leaf and withering from some imported plants after one week of fumigation, this research showed that ethyl formate (EF) fumigation could be potentially used on imported nursery plants in terms of recoveries, 2 weeks post-fumigation, which is more than the period required in Korea to distribute the plants to consumers. The imported nursery plants in Korea might be grown in remote nusery sites for several months depending on plants for satisfication of market values and to certify disease-free, and during this period the damaged plant can be recoverred. The degree of phytotoxic damages with EF fumigation could be various depending on species, ages and physical conditions of plants when imported in Korea. It is known that MeBr fumigation can cause serious and unrecoverable damage on imported nursery plants as well as chronic inhalation damages to fumigator and related workers in post-fumgation process (Kim et al., 2016). Ethyl formate fumigation of nursery plants could be provide better options than current MeBr application in tems of work safety and less phytotoxic to commodities as well as classification of definatly non-ozone depletion chemical.

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A new concept for controlling tiny-scale insect pest in green house – noval technology to apply liquid ethyl formate

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Abstract

As increased agricultural insecticide uses and trends in insecticide resistance, increased labor cost to apply insecticide and limited its application to fertility season in green house. There is a need of a safe, labor-saving and confined space application concept to manage control tiny-scale insect pest such as thrips and whitefly. Fumigation with ethyl formate (EF), which is considered as effective to various insect pest and safely use in quarantine treatment, was evaluated in the confined space (glass house) and semi-confined space (vinyl house). The new application technology for application of liquid EF could be the one of the key options for control of tiny flying insects in greenhouses that would save labor and operation costs. It could be connected to smart-farm technologies in the near future.

Keywords: Ethyl formate, Inert gas application, green houses, future smart-farm technology

1. Introduction

Fumigants, like methyl bromide (MeBr) and phosphine, are widely used for quarantine and pre-shipment (QPS) fumigations and restriced use in preplant soil disinfestation because physically fumigants have less residues than solid/liquid active ingredients. Its use has advantages for better efficacies because it can penetrate into deep and easy in application even in tiny small space without addtional labor work. This means that fumigants have a potential to replace liquid/solid pesticides in plant cultivation in case they are grown in sealed or semi-sealed enviroments. Even though we know the benefits, usage of fumigant in agricultural purpose especially in sealed system is limited because most fumigants are expensive to apply and normally higher toxic to mammals and human being in terms of acute inhalation toxicity. Ethyl formate (EF), a MeBr alternative which was re-evaluated and commercialized in recent years, is less toxic than other fumigants and has less risk on environments (Muthu et al, 1984). Use of EF on plant cultivation could solve the issue like emerging and increasing pesticide resistant insects (PSI) and residues on harvest. Moreover, in case of application in a sealed system, workers do not need to be exposed to pesticide solution directly which is hazardous and there will be decreased labor-cost. EF fumigation in greenhouse was considered as higher operation costs than pesticide and concerns of leaked out environments. In recent report, liquid EF (Fumate™) with inert gas application was cost-effective and safer protocols than formulated in gas cylinder to apply various imported and exported fruits (Kim et al, 2017, Yang et al, 2016, 2017a, 2017b). In the preliminary studies, efficacies of EF on tiny small insect pest in cucumber green house was reported by Kim et al (2016). In this research, we reported liquid EF with nitrogen applied in the confined space (glass house) and semi-confined space (vinyl house) model and was evaluated for the accumulative Ct product in two system and monitoring of ethyl formate level in spaces after fumigations and aerations for accessment of worker safety.