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甲酸乙酯与二氧化碳混合熏蒸可食用鲜切花（中英文）

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摘　要：西花蓟马（缨翅目）是蓟马类中一种具有代表性的植物害虫，是一种能够对作物生产造成不利影响的多食性物种。因此，在欧盟，这些蓟马物种被作为检疫生物进行管理。西花蓟马以易感植物为食，并会传播几种导致严重植物疾病的病毒，从而对这些植物造成非常大的损害。以色列的供应占欧洲新鲜草本市场的 50%，被认为是可食用鲜切花的主要供应市场。然而，在过去的十年中，由于没有可选的处理方法来控制检疫害虫而导致植物检疫失败，大大减少了出口量。目前尚无有效的采后杀虫处理方法。众所周知，熏蒸剂甲基溴（MB）具有植物毒性，尤其是对叶类产品和叶片，且与臭氧层的损耗有关。目前甲基溴仅能用作检疫和装运前熏蒸。甲酸乙酯（EF）被建议作为甲基溴的替代品，药效快、价格低廉、哺乳动物无毒性、环境无害、分解迅速，残留量极少或无残留。在以色列进行的 30 g/m^3 甲酸乙酯与二氧化碳（1∶1.6）混合处理不同花种的实验中，在 10 和 15 ℃条件下分别处理 1 和 1.5 h，对西花蓟马各虫态均有较好的防治效果。在 15 ℃暴露 2 h，可杀死全部害虫，对花或其保质期没有不良影响。因此甲酸乙酯熏蒸可作为一种检疫处理方法，也是甲基溴（MB）的可行替代方法。

关键词：食用鲜切花；甲酸乙酯；甲基溴代替品；检疫处理
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Fumigation of Edible Cut Flowers with Ethyl Formate Mixed with CO_2 (Chinese and English versions)

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Abstract: The Western flower thrips, *Frankliniella occidentalis* (order Thysanoptera) is a thrips species that

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本专栏背景及第一作者、译者介绍详见 PC8-15，本文英文原文详见 P35-39

represents major plant pests. It is a polyphagous species capable of adversely affecting crop production. As such, in the European Union, these thrips species are regulated as quarantine organisms. *F. occidentalis* can cause considerable damage to susceptible plants by feeding on them and transmitting several viruses responsible for serious plant diseases. Israel is responsible for 50% of the fresh herbs market in Europe, among them is considered the edible cut flowers market. However, phytosanitary failures due to quarantine pests with no optional treatment to control them, in the past decade, reduced significantly export volumes. Up to today, there is no effective disinfestation post-harvest treatment. Due to its association with the depletion of the ozone layer, the fumigant methyl bromide (MB) has been phased out and today is serving as a Quarantine and Pre-Shipment fumigant. However, MB is known for its phytotoxic character, especially on leafy products and foliage. Ethyl formate (EF) was suggested as an alternative to MB due to its rapid action, low mammalian toxicity, benign to the environment, and rapid breakdown with minimum or no residues. Trials conducted in Israel on various flower species treated with 30 g/m^3 EF mixed with CO_2 (1：6 ratio) at 1, and 1.5 h in 10 and 15 ℃ obtained high efficacy in controlling all life stages of *F. occidentalis*. In 2 h exposure time at 15 ℃ resulted in complete mortality with no adverse effects on the flowers or their shelf lives. Ethyl formate fumigation was found as a suitable treatment for quarantine purposes and as an appropriate alternative to Methyl bromide.

Key words: edible cut flowers; ethyl formate; methyl bromide alternative; quarantine treatment

新鲜木本植物包括食用花卉，以色列的供应约 7 000 t，30 多种占欧洲市场的 50%以上，特别是出口到欧洲和美国，每年还以 10%的速率增长[1]。然而，检疫性害虫导致以色列的切花和新鲜草药出口量下降，对国际贸易形成了障碍。

西花蓟马以北美西部为发源地，在 70 年代末开始广泛传播，随着全球花卉和园艺产品贸易增加，已成为全球最重要的农业害虫之一[2]。此外，20 世纪七八十年代，由于在加利福尼亚的温室作物中广泛使用杀虫剂，导致出现了一种高抗品系[3]，并在北美、欧洲、亚洲、南美、非洲和澳大利亚的许多国家传播和定殖[2]。由于西花蓟马具有杂食性，从而增加其在新地区找到合适宿主的可能性[4]。众所周知，西花蓟马以来自 60 多个植物科的 250 多种不同作物为食[3,5]，是几乎所有作物的重要害虫，包括结果蔬菜、多叶蔬菜、观赏植物、果树、水果和棉花[6]。

摄食损伤常常发生在组织发育的过程中，直到花或果实成熟才被发现[7-8]。大量摄食也可能导致落花落果[9]，并对观赏和果实作物的美观造成相当大的损害[10]。雌性产卵还会对发育中的果实造成另一种损害，它们的锯状卵器将卵插入植物表皮之下，在一些植物中引起生理伤口反应，导致果实产生斑点。到目前为止，西花蓟马最大的威胁是具有传播番茄斑萎病毒（TSWV）的能力。西花蓟马是 5 种病毒的载体，其中番茄斑萎病毒和凤仙花坏死斑病毒（INSV）出现在美国。84 科植物种类中超过 1 000 种植物对番茄斑萎病毒敏感[11]，使其成为所有植物病原体中最广泛的宿主范围之一。病毒传播在其 2 龄时发生非常迅速，仅需 5 min[12]。传播所需的时间很短，导致杀虫剂对限制番茄斑萎病毒传播方面无效，同时该物种的趋触性限制了接解性杀虫剂的使用。随着国际贸易往来，西花蓟马可以通过气流远距离传播[13]，且多食性和人类活动进一步加快了传播范围和速度。此外，微小体型（<1 mm）和幼虫及成虫的趋触性行为等特性使其难于被检测发现。由于卵产在植物组织中很难被检测到，使西花蓟马成为通过人类活动传播的理想入侵物种，一种重要的检疫害虫。

国际贸易要求农业商品无虫害，但检疫性害虫的侵扰给国际贸易规则带来了障碍。尽管甲基溴已被逐步淘汰[14]，但其有效性和多功能性，目前仍在豁免用于检疫和装运前（QPS）处理。然而，由于其具有植物毒性，因此不适用于所有新鲜农产品的熏蒸[15]。

熏蒸剂甲酸乙酯被认为是甲基溴的候选替代品[16]，对哺乳动物的毒性低，残留物能迅速分解，溶于水，天然存在于食品中，环境无害[17-18]，以及具有快速杀灭活性[16]。然而，由于甲酸乙酯在2.8%~16.5%(v/v)的浓度下是易燃的，为了将易燃性降至最低，Jones[19]明确了甲酸乙酯在二氧化碳中的非易燃混合物比例为 1∶6（按体积计）。Haritos 等[20]发现，二氧化碳（5%~20%）与甲酸乙酯的组合显著增强了熏蒸剂的分布和对几种常见储藏物非隐蔽性昆虫和虫态的防治效果。因此，本研究旨在检测二氧化碳与甲酸乙酯混合物对食用花卉的杀虫效果，研究不影响花卉生长的情况下防治西花蓟马的最佳施用方法。

1 材料与方法

鲜花由一位以色列出口商提供，包括西葫芦、万寿菊、三色堇、金鱼草、菊花。在每次实验中，鲜花均在早上采摘，带到包装间，放在工厂的盒子里，每盒 200 g，并在 3 ℃下储存。

利用冷藏室内的低渗透性熏蒸立方体（氧气透过率（OTR）<2mL O_2m^2/天，100 μm 壁厚）进行熏蒸。每次熏蒸前，在 6 mm 水负压下进行压力半衰期测试，以确保熏蒸空间的气密性。按照表 1 所示进行熏蒸。

表 1 西葫芦、万寿菊、三色堇、金鱼草和菊花的甲酸乙酯熏蒸条件

Table 1 Fumigation conditions of Zucchini, Tagetes spp., Viola tricolor, Antirrhinum spp. and Chrysanthemum spp. with EF

实验编号	1.0	2.0	2.1	3.0	3.1	3.2	4**	5**	6**
花卉种类	西葫芦	西葫芦			万寿菊 三色堇 金鱼草 菊花		西葫芦 三色堇	西葫芦	西葫芦
温度/℃	15	10	15	15	15	15	15	15	15
暴露时间/h	2	2	1	2	1.5	1.5	1.5	2	2
剂量/(g/m^3)	30	60	60	30	30	30	30	30	30
盒子编号	14	2	2	1*	1*	1*	4*	12	6

注：*每个花卉品种的盒子数量，**增加一台循环风机。

Note: * No. of boxes from each flower species, ** Addition of a circulating fan.

在加压钢瓶中将食品级甲酸乙酯与液体二氧化碳 1∶6 混合。通过加热线圈将钢瓶与熏蒸立方体连接起来，使甲酸乙酯汽化，将钢瓶放在天平上测量所需混合物的量。

实验用花均自然感染了西花蓟马和烟草蓟马。熏蒸后，通过模拟装运条件测试花的植物毒性和保质期；在 3 ℃下储存 6 d，到达目的国家时检查和测试其质量是否完好。

2 结果与分析

在实验 1.0 中，西花蓟马和烟草蓟马均完全死亡，而对照组中的幼虫和成虫死亡率分别为4.7%和 27.2%。熏蒸和 3 ℃储存 6 天后两个实验组试花均未显示不良作用。

在实验 2.0 中，通过降低温度提高剂量至 60 g/m^3 可获得 100%死亡率，但在 3 ℃下储存 6 d 后显示一些植物毒性问题。这可能与熏蒸期间断电，使得平均温度为 11 ℃、气体扩散近一个小时造成的。在实验 2.1 中，通过增加剂量缩短暴露时间获得了相同的防治效果，但没有植物毒性问题。其中，气体扩散时间约占暴露时间的三分之一。在两个实验中，后续培养观察处理组均达到 100%死亡率，而对照中幼虫和成虫死亡率分别为 13.7%和 16.2%。

在实验 3.0~3.2 中，对万寿菊、三色堇、金鱼草和菊花进行了测试。所有花种质量均完好，也无植物毒性反应。暴露于二氧化碳与甲酸乙酯混合物中 2 h 后，西花蓟马和烟草蓟马均完全死亡。然而，实验 3.1 中，在每盒 40 头试虫的金鱼草属中发现有一只成虫存活。

在 4.0 实验中，通过在熏蒸立方体底部安装三个计时风扇，以使气体循环和均匀分布，从而将暴露时间缩短至 1.5 h。实验发现，气体在 5 min 内就能均匀分布在 1 m^3 的熏蒸立方体中。然而，在 1.5 h 的暴露时间内，在每盒 1~7 头试虫的样品中仍发现有一头西花蓟马成虫存活。

因此，在实验 5 和 6 中，保留环流循环功能，暴露时间增至 2 h。防治重感染西葫芦花（平均每箱 125 个）时，两害虫死亡率为 100%，对鲜切花质量和货架期没有不良影响。

3 讨论

利用磷化氢防治西花蓟马研究较多，但只有一项研究是对切花的。在 5 ℃条件下，利用 1.66 mg/m^3 磷化氢和 12%二氧化碳混合物或 2.29 mg/m^3 磷化氢（不含二氧化碳）熏蒸 16 h，2 天可 100%控制最耐受虫态（3 日龄卵期）[21]。此外，研究还发现，在实验室条件下暴露于 500 mg/m^3 磷化氢 18 h 后可完全控制感染莴苣的西花蓟马[22]。在商业规模处理中也获得了相同的结果。为了完全致死害虫，磷化氢处理最适环境温度应在 20 ℃以上，处理莴苣的温度需从 4.5 ℃升至 7.2 ℃。从熏蒸 2 周后对莴苣质量评估的结果来看，没有显著的负面影响[23]。Kostyukovsky 等[24]使用 2 g/m^3 磷化氢对浸染甜椒的蓟马混合虫态（成虫和若虫）进行了 24 h 的完全致死实验。并在相同实验室条件下测试了甲酸乙酯液体的药效，结果显示在 20 μL/L 剂量下 24 h 获得 100%死亡率。

磷化氢可作为检疫处理控制食用花卉害虫替代方式。但由于花保质期短，需尽可能缩短检疫处理时间。Rigby[25]评价了 Vapormate®（16.7%甲酸乙酯与二氧化碳混合）的效果，结果表明可将 16 种澳大利亚野花的昆虫数量降至无检出水平，且对花质量损害最小。在植株实验中，评价不同剂量的甲酸乙酯（90 g/m^3 和 60 g/m^3 处理 1 和 2 h，30 g/m^3 处理 1 h）的影响，结果表明对大多数野花物种，高剂量产生了不可接受的植物毒性效应，最低剂量和缩短处理时间（60 和 30 g/$m^3$1 h）时植物毒性效应可降到无检出水平，但昆虫死亡率低。本实验结果与 Rigby 的一致。在实验 2 中，60 g/m^3 甲酸乙酯熏蒸对西葫芦花有一定的植物毒性作用。模拟在 3 ℃储存 6 天处理条件下后，可见植物毒性效应。本研究中，将暴露时间减少到 1.5 h 时，对一些西花蓟马防治效果差（实验编号 3.1 和 4）。增加循环风扇可加快气体扩散，获得 100%死亡率，即使模拟在 3 ℃储存 6 d 处理条件下，对花质量也没有不利影响。

甲酸乙酯是一种食品添加剂，是美国食品和药物管理局（FDA）认定的安全化学品[26]。本研究首次用作可食用切花的熏蒸剂，可作为控制西花蓟马的甲基溴替代品。

4 结论

甲酸乙酯与液体二氧化碳混合物是一种有效的检疫处理方法。15 ℃，利用 30 g/m^3 的甲酸乙酯与液体二氧化碳混合物处理 2 h，可 100%控制西花蓟马，对鲜切花质量和保质期没有不良影响，是一种潜在的甲基溴替代品。

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Fumigation of Edible Cut Flowers with Ethyl Formate Mixed with CO_2 (英文原文)

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Abstract: The Western flower thrips, *Frankliniella occidentalis* (order Thysanoptera) is a thrips species that represents major plant pests. It is a polyphagous species capable of adversely affecting crop production. As such, in the European Union, these thrips species are regulated as quarantine organisms. *F. occidentalis* can cause considerable damage to susceptible plants by feeding on them and transmitting several viruses responsible for serious plant diseases. Israel is responsible for 50% of the fresh herbs market in Europe, among them is considered the edible cut flowers market. However, phytosanitary failures due to quarantine pests with no optional treatment to control them, in the past decade, reduced significantly export volumes. Up to today, there is no effective disinfestation post-harvest treatment. Due to its association with the depletion of the ozone layer, the fumigant methyl bromide (MB) has been phased out and today is serving as a quarantine and pre-shipment fumigant. However, MB is known for its phytotoxic character, especially on leafy products and foliage. Ethyl formate (EF) was suggested as an alternative to MB due to its rapid action, low mammalian toxicity, benign to the environment, and rapid breakdown with minimum or no residues. Trials conducted in Israel on various flower species treated with 30 g/m^3 EF mixed with CO_2 (1∶6 ratio) at 1, and 1.5 h in 10 and 15 ℃ obtained high efficacy in controlling all life stages of *F. occidentalis*. In 2 h exposure time at 15 ℃ resulted in complete mortality with no adverse effects on the flowers or their shelf lives. Ethyl formate fumigation was found as a suitable treatment for quarantine purposes and as an appropriate alternative to Methyl bromide.

Key words: edible cut flowers; ethyl formate; methyl bromide alternative; quarantine treatment

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1 INTRODUCTION

The Israeli market used to supply more than 50% of the European fresh herbs market among them are edible flowers. Approximately, 7,000 tonnes, consisting of more than 30 species, are being exported annually, especially to Europe and the USA, with an annual increase of 10%[1]. However, the presence of quarantine pests poses a barrier to international trade which has led to a decrease in Israel's cut flower and fresh herbs exported volumes.

The western flower thrips, *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae), have become one of the most important agricultural pests worldwide. It is oriented in western North America and began its widespread in the late 70s[2] probably due to increased global trade in floricultural and horticultural products. Moreover, extensive use of insecticides in greenhouse crops in the 1970s and 1980s in California, greenhouse populations resulted in a highly insecticide-resistant strain[3] which has contributed to its spread and establishment throughout North America, and many countries in Europe, Asia, South America, Africa, and Australia[2]. The polyphagous nature of Western flower thrips increases the number of crops on which it may be exported from a country, and then enhances the probability of introduced individuals finding suitable hosts in new areas[4]. Western flower thrips are known to feed on over 250 different crop plants from more than 60 plant families[3,5]. It is a significant pest of virtually all crops, including fruiting vegetables, leafy vegetables, ornamentals, tree fruits, small fruits, and cotton[6].

Feeding damage is often inflicted on developing tissue, which then goes undetected until flowers or fruits mature[7-8]. Extensive feeding can also result in flower and fruitlet abortion[9], and considerable aesthetic damage to ornamental and fruiting crops[10]. Female oviposition causes another type of damage to developing fruits; they insert eggs under the plant epidermis with their saw-like ovipositor that elicits a physiological wound response in some plants that produces spots on fruits. By far the greatest damage caused by Western flower thrips is its ability to transmit *Tospoviruses*. Western flower thrips are known to vector 5 *Tospovirus* species, 2 of which, *Tomato spotted wilt virus* (TSWV) and Impatiens necrotic spot virus occur in the United States. Over 1,000 species of plants in 84 families are susceptible to TSWV[11], giving it one of the broadest host ranges of any plant pathogen. Transmission can occur by the second instar quite rapidly, in as little as 5 min of feeding[12]. The short time needed for transmission contributes to the ineffectiveness of insecticides to limit the spread of TSWV along with the thigmotactic nature of this species that limits its direct exposure to contact insecticides. Along with its human-assisted movement through international trade, Western flower thrips can move long distances on wind currents[13], and its spread is further enhanced by its polyphagy and the ability of small founder populations to succeed. Moreover, their small size (<1 mm) and the thigmotactic behavior of larvae and adults make detection difficult. In addition, because eggs are deposited within plant tissue, they are even less readily detected, making it an ideal invasive species to be spread by human activity thus making it a quarantine-significant pest.

The requirement for international trade of agricultural commodities to be free from insect infestation, especially quarantine pests, poses a barrier to international trade. Although Methyl Bromide has been phase-out[14], is still in use for Quarantine and Pre-Shipment (QPS) treatments due to its effectiveness and versatile traits. However, due to its phytotoxic characteristics, it is not suitable for all fresh produce fumigation[15].

The rising fumigant EF was suggested as a candidate alternative to MB[16]. Ethyl formate was found to be a successful alternative fumigant due to its low mammalian toxicity, rapid loss of residues, solubility in water, natural presence in foodstuffs, benign to the environment[17-18], and due to its rapid activity[16]. However, since EF is flammable at levels of 2.8%~16.5% (v/v), to minimize potential flammability in air, Jones[19] established the specific non-flammable mixture range of EF in CO_2 as 1:6 by volume to avoid dangerous explosions. Haritos et al. [20], found that the combination of CO_2 (5%~20%) with EF significantly enhances both distribution and efficacy of the fumigant against external living stages of several common stored product insects. Therefore, this work aims to test the efficacy of a mixture of EF with CO_2 on edible flowers and to determine the best application method to control Western flower thrips with no adverse effects on the flowers.

2 MATERIALS AND METHODS

Flowers were supplied by an Israeli exporter. In each trial, the flowers including Zucchini, Tagetes spp., Antirrhinum spp., Viola tricolor, Chrysanthemun spp. were picked in the morning, brought to the packing house and stored at 3 ℃ The flowers were placed in factory boxes containing each 200 g.

Fumigation was carried out in the packing house in one of the refrigerated rooms under a low permeability fumigation cube (OTR <2 mL O_2 m^{-2} per day, 100 μm thickness). Before each fumigation, a half-time pressure decay test was carried out by applying a negative pressure of 6 mm H_2O to ensure the gas tightness of the fumigation cube. Fumigations were carried out as represented in Table 1.

A food-grade EF was mixed with liquid CO_2 at a 1∶6 ratio in a pressurized cylinder. The cylinder was connected to the fumigation cube through a heating coil to enable the vaporization of EF while it was placed on a scale to measure the amount of gas mixture to be delivered.

The flowers were naturally infested with Western flower thrips *F. occidentalis* and the tobacco thrips *Thrips tabacci*. After each fumigation, the flowers were tested for phytotoxicity and their shelf life by simulating the conditions of a shipment; storing them at 3 ℃ for 6 d, and checking upon arrival to the destination country in the packing house to test if their quality was preserved.

Table 1 Fumigation conditions of Zucchini, Tagetes spp., Viola tricolor, Antirrhinum spp. and Chrysanthemum spp. with EF

Trial no	1.0	2.0	2.1	3.0	3.1	3.2	4**	5**	6**
Flower species	Zucchini	Zucchini		Tagetes spp., Viola tricolor, Antirrhinum spp., Chrysanthemun spp.			Zucchini and Viola tricolor	Zucchini	Zucchini
Temperature (℃)	15	10	15	15	15	15	15	15	15
Exposure time (h)	2	2	1	2	1.5	1.5	1.5	2	2
Dosage ($g \cdot m^{-3}$)	30	60	60	30	30	30	30	30	30
No. of boxes	14	2	2	1*	1*	1*	4*	12	6

* No. of boxes from each flower species
** Addition of a circulating fan

3 RESULTS

In trial no. 1.0, complete mortality was achieved for both Western flower thrips and tobacco thrips while the mortality in the control was 4.7% for larvae and 27.2% for the adult stage from a mixed-species culture. No adverse effect was shown after fumigation and neither after 6 days of storage at 3 ℃.

In trial no. 2.0, reducing the temperature while increasing the dosage to 60 g/m^3 obtained complete mortality but showed some phytotoxicity issues after 6 d of storage at 3 ℃. Moreover, due to power failure during fumigation, the average temperature obtained was 11 ℃. Gas distribution took nearly an hour. Also in trial no. 2.1, reduced exposure time by multiplying dosage gave similar results with no phytotoxicity issues. However, gas distribution took approximately a third of the exposure time. In both trials, complete mortality was achieved in mixed cultures of both species. The control for these trials was 13.7% for larvae and 16.2% for the adult stage from a mixed-species culture.

In trials 3.0~3.2, other flower species were tested. Tagetes spp., Viola tricolor, Antirrhinum spp. and Chrysanthemun spp. After exposure time the flowers were packed in their final package for 6 d at 3 ℃. None of the flower species showed any adverse effects and no phytotoxicity was obtained. The 2 h exposure time obtained complete mortality of both Western flower thrips and tobacco thrips. However, in trial no. 3.1, one adult survived the treatment on Antirrhinum spp. The average number of individuals in each box was forty.

In trial no. 4.0 there was another attempt to reduce the exposure time to 1.5 h. Therefore, three computer fans were placed at the bottom of the fumigation cube to enable circulation of the gas and even distribution. An even distribution of the gas was achieved in 5 min in the 1 m^3 capacity fumigation cube. However, also here, in 1.5 h of exposure time, one adult of Western flower thrips survived the treatment. Since this trial was carried out during wintertime, the infestation was low and the number of individuals ranged between 1 to 7 per box.

Therefore, in trials 5 and 6, the exposure time was increased again to 2 h with circulation. Complete mortality was achieved with Zucchini flowers heavily infested with trips (average of 125 per box) with no adverse effects on the flowers and shelf life.

4 DISCUSSION

Several investigations have been carried out to control the Western flower thrips using phosphine. However, only one work was carried out on cut flowers. Phosphine fumigation achieved 100% mortality in the most tolerant stage, the 3-d-old egg stage by applying 1.66 mg/m^3 PH_3 and 12% CO_2 for 16 h, and 2.29 mg/ m^3 PH_3 without CO_2 gas for 2 d at 5 ℃[21]. Infested lettuce was also investigated which resulted in complete mortality after 18 h of exposure time at approximately 500 mg/m^3 of phosphine under laboratory conditions[22]. The same results were obtained in commercial-scale treatment. However, to obtain complete mortality of the pest, temperatures had to be increased to 20 ℃ which resulted in an increase in temperature within the lettuce from 4.5 ℃ to 7.2 ℃. Nevertheless, the fumigation had no significant negative impact on lettuce quality also after it was evaluated 2 weeks after fumigation[23]. Kostyukovsky et al.[24] obtained complete mortality on sweet pepper infested with a mixed population of adults and nymphs using 2 g/m^3 of phosphine for 24 h. They tested also, under laboratory conditions, the efficacy of liquid EF on sweet pepper infested with a mixed population of adults and nymphs of Western flower thrips. The results showed complete mortality at a dosage of 20 μl/L for 24 h.

The use of Phosphine as a quarantine treatment to control the pest from edible flowers could serve as an alternative treatment. However, for quarantine purposes, due to flowers' short shelf life, treatment should be shorter. Therefore, Rigby[25] tested the efficacy of Vapormate® (16.7% EF mixed in CO_2) in reducing insect loads to undetectable levels with minimal damage on 16 Australian wildflower species. The flowers were treated with varying doses of EF (90 g/m^3 and 60 g/m^3 for 1 and 2 h and 30 g/m^3 for 1 h). Trials resulted in unacceptable phytotoxic effects for the higher dosages for most wildflower species during their vase life trials. Phytotoxic effects were reduced to undetectable levels at the lowest doses and reduced treatment time (60 and 30 g/m^3 1 h), but insect mortality rates were unacceptable. Rigby's results are following the results obtained in this work. In trial no. 2, Zucchini flowers showed some phytotoxic effects after being fumigated with 60 g/m^3 of EF. The phytotoxic effect was visible after shipment simulation at 3 ^{o}C for 6 d storage, post-treatment. In this work, the reduction of exposure time to 1.5 h resulted in some Western flower thrip survivors (trials no. 3.1 and 4). The addition of circulating fans enhanced gas distribution resulting in complete mortality with no adverse effects on the flowers even after shipment simulation at 3 ℃ for 6 d.

Ethyl formate is a food additive chemical and is considered Generally Recognized As Safe by the FDA[26] that, for the first time, serves as an effective fumigant for edible cut flowers. Hence, it should be considered as an appropriate Methyl bromide alternative for the control of the Western flower thrips.

5 CONCLUSIONS

Ethyl formate mixed with liquid CO_2 was found as a very effective treatment for quarantine purposes. Complete control of Western flower thrips was achieved within 2 h of exposure time at 15 ℃ and 30 g/m^3 of EF mixed with liquid CO_2. This fumigation schedule was found as an appropriate methyl bromide alternative with no adverse effects on the flowers and their shelf life.

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See in its Chinese version P33-34. 完