ECO$_2$FUME® fumigation protocols for effective quarantine and pre-shipment treatment of export cut flowers in Turkey

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Abstract

Cut flowers such as carnation, gerbera and roses are major export of Turkey destined mostly to European and Middle East countries. Export cut flowers are infested with Thrips (*Frankliniella occidentalis*) and mites (*Tetranychus cinnabarinus*) and treatment before shipment is needed to avoid rejection by the importing countries. An alternative fumigation treatment for export cut flowers using ECO$_2$FUME® phosphine fumigant was developed by establishing fumigation protocols for 100% mortality of thrips and mites. ECO$_2$FUME® is a non-flammable cylinderized formulation of 2% phosphine and 98% CO_2 by weight which is commercially used globally for safe, effective and user-friendly fumigation of stored products. Efficacy trials of different phosphine concentration and exposure time were conducted following the Probit 9 standard. Test insects of thrips and mites were collected from infested cut flowers in the Antalya Turkey region. The treatments used were of 500 ppm, 750 ppm, 1000 ppm and 1250 ppm of phosphine concentrations for 24 hours at 4°C and 250 ppm, 400 ppm, 500 ppm and 750 ppm of phosphine concentrations for 72 hours at 4°C. Results of the study showed that 100% mortality of all stages of thrips and mites was achieved at minimum of 1000 ppm (70 g ECO$_2$FUME®/m^3) for 24 hours at 4°C and minimum of 500 ppm (35 g ECO$_2$FUME®/m^3) for 72 hours at 4°C. The 24 hours protocol using 70 g ECO$_2$FUME®/m^3 at 4°C is applicable to fixed cold chambers while the 72 hours protocol using 35 g ECO$_2$FUME®/m^3 at 4°C can be used for in-transit refrigerated container. The two protocols will provide operation flexibility for the export cut flower industry in Turkey.

Keywords: ECO$_2$FUME®, export cut flower, quarantine and pre-shipment

1. Introduction

The world ornamental-plant production is a multibillion-dollar industry. The international trade of ornamental-plants in past 50 years has increased from \$3 billion to \$40 billion (Woodward, 2012). Of this, cut flowers have a share of ca. \$15 billion (AIPH and UF, 2009). The total cut flower production area in the world is around 652.000 ha, and most of the production is concentrated in Asia (72%), Latin America (13%), and Europe (9%) (AIPH and UF, 2013) (Table1).

Turkey is one of the growing ornamental plants exporting countries of the world. Ornamental plants export made by Turkey reached ca. \$77 million in 2013. Of this figure, ca. \$28 million related to cut flower exports (Anonymous, 2013). Commercial cut flower production in Turkey dates back to 1940s in the Yalova region, because of its proximity to Istanbul, the main consumption center, and then spread to other provinces (Baris and Uslu, 2009; Babadogan 2009). First high quality cut flower exports from Turkey were made from Antalya region in 1985. Cut flower production areas in Turkey have since increased year by year and reached 1332 ha in 2009, which is 0.2% of the world producing area (SERKA, 2012). In 2009, 73% of cut flower production in Turkey was produced in plastic greenhouses, while 4% was produced in glass greenhouses and 23% in open fields. Carnations represent half of the cut flowers produced in Turkey. They also account for 90% of cut flowers destined for export. Amongst other flowers, rose (18%), *Narcissus* (14%), *Gerbera* (11), *Chrysanthemum* (4%), and *Gypsophilla* (3%) are important items for the Turkish cut flower sector (SERKA, 2012).

Table 1 Worldwide cut flower production area. (AIPH and UF, 2013)

Region	Production area (ha)	Percentage (%)
Europe	61.500	9,43
Middle East	4.100	0,63
Africa	18.200	2,79
Asia/Pacific	468.000	71,78
North America	17.000	2,61
Middle/South Americas	83.000	12,73
Total	652.000	100.00

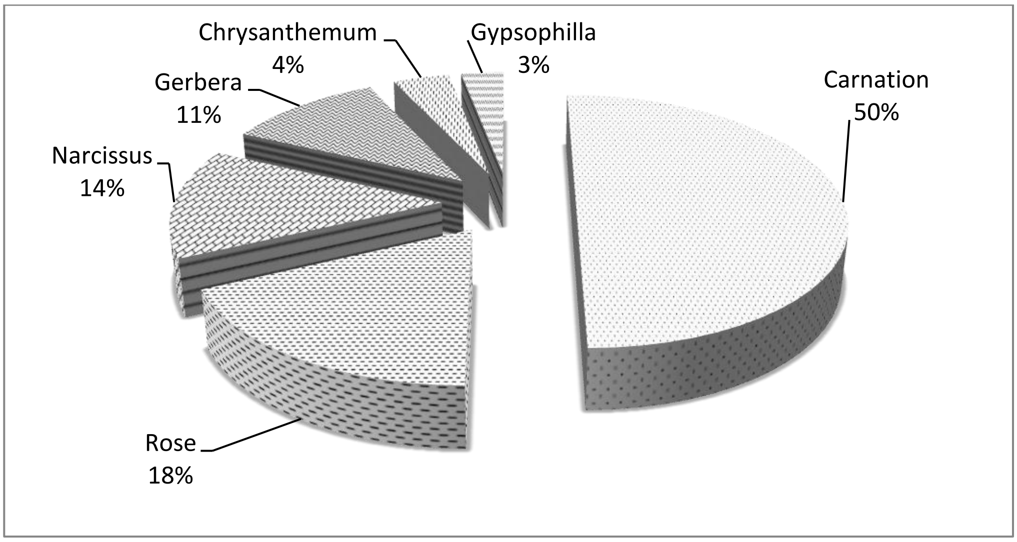

Figure 1 Cut flower production in Turkey (SERKA, 2012).

The presence of arthropod pests in consignments of cut flowers is one of the major problems negatively affecting the international trade of cut flowers. This is particularly the case for countries whose quarantine regulations are very strict (Seaton and Joyce, 2010). Postharvest treatment of cut flowers for insect control is therefore an important part of cut flower production for export.

Currently, there are various postharvest disinfestation methods of cut flowers; each has its own advantages or disadvantages. Conventional chemical postharvest treatments include spraying with aerosols, fumigation applications, dipping in insecticide solution, use of slow-release insecticides (Seaton and Joyce, 2010). Unfortunately most of the time they do not ensure the flower quality or the level of pest mortality required by international quarantine regulations or authorities. Therefore, the principal management strategy used to deal with cut flower pests in most countries involves the use of residual pesticides in the field. However, the sole reliance on pesticides to control arthropod pest populations causes severe problems such as rapid development of insecticide resistance (Dagli and Tunç, 2007), pest resurgence & secondary pest outbreaks, and human & environmental risks (Stimamiglio et al., 1998).

Physical and mechanical methods cover manual removal of insects, irradiation applications and use of extreme temperatures (Seaton and Joyce, 2010). Rose varieties received 0.75 and 1 kGy of electron beam irradiation showed unacceptable quality and dosages higher than 1 kGy caused necrosis on petals and decreased vase life at 20°C (Chang et al., 1997). *Gerbera* sp. was found not resistant to gamma irradiation and resistant to electron-beam irradiation up to 300 Gy (Kikuchi, 2003). While flowers such as chrysanthemums, carnations, gladiolus, lilium and some tropical flowers have been shown to have a good resistance to irradiation of up to 500 Gy (Osouli et al., 2014), the dose rates which cause immediate mortality in mites lie in the range of 1–3 KGy, which seriously damage and shorten the vase life of flowers and thus cannot be used as a quarantine application (Sulaiman et al., 2004).

Besides individual methods, combined control measures can also be used to increase the killing effects of the treatments. They may help increase the efficacy, improve safety and reduce phytotoxicity more than any single treatment. Since cold storage is a routine part of postharvest handling process of cut flowers, it is more convenient to include cold storage into combined treatments. Low temperature plus carbon dioxide and fumigation followed by low temperature can be given as combined treatments (Seaton and Joyce, 2010). Although modified atmosphere applications, for example against western flower thrips, result in complete adult mortality, they failed to give complete kill of 2nd stage nymphs after 1 h application at a temperature range between 0°C and 36°C (Carpenter et al., 1994).

Globally, phosphine is the most widely used and cheapest fumigant in controlling postharvest pests (Cavasin et al., 2010). Besides durable products, it can also be used against pests of perishable crops (Liu, 2008). For treatment of exported cut flowers and foliages in New Zealand, a fast fumigation procedure lasting 4 hours at 15°C of temperature has been developed for commercial use with ECO_2FUME (2% phosphine and 98% CO_2 w/w) under 70 mm Hg vacuum condition (Zhang, 2004).

Since cut flowers are highly perishable, they are mostly transported via air cargo. Therefore, during postharvest handling, they must be disinfested in the shortest possible time and without any loss of quality. Thus, this communication aims at using ECO_2FUME at low temperatures for developing a QPS fumigation protocol for export cut flowers against thrips and mites.

2. Materials and Methods

Experiments were performed at the premises of Flash Tarim Ltd. (Antalya, Turkey) in May 2013. Carnations heavily infested by *Tetranychus cinnabarinus* and *Frankliniella occidentalis* were collected from the plastic greenhouse early in the morning and placed in carton boxes of size 100X40X20 cm., which are the same ones used for export. Experimental fumigation units were prepared by stacking the boxes of infested carnation bunches, and each experimental fumigation unit was then sealed by two-fold plastic sheet in order to ensure gas tightness. Carton boxes containing gerberas were also put into each fumigation unit to check the phytotoxicity and vase life determinations. Phosphine gas was delivered to each experimental block via PVC tubing (6 mm diameter) attached to the ECO_2FUME cylinder. Phosphine concentrations were determined using ATI PortaSense II by means of PVC tubes inserted into carton boxes that placed at the bottom, center and upper level of the fumigation unit. Tested PH_3 concentrations were 250, 400, 500, 750, 1000 and 1250 ppm, which are equivalent to 17.4 g/m^3, 27.84 g/m^3, 34,8 g/m^3, 52.2 g/m^3, 69.6 g/m^3, and 87 g/m^3 ECO_2FUME, respectively. Each experimental unit was fumigated for different exposure times of up to 72 hours. Experiments were performed at a controlled room temperature adjusted at 4°C. Temperature of the room was continuously recorded during the experiments.

After the end of fumigation, flower bunches randomly sampled from each fumigation unit were taken to the inspection room and checked for insect and mite mortality. Visual inspection to scout for nymphs and adults was made by shaking open flowers over a white sheet of paper. Selected flowers were also examined under a stereoscopic binocular microscope. Additionally, randomly selected carnation and gerberas were put into 1 liter of glass vases for 20 days to determine any adverse effect on vase life of the flowers according to petal wilting and pedicel bending, and on pest development following the fumigation.

3. Results and Discussion

Results of the study showed that 100% mortality of all stages of thrips and mites was achieved at minimum of 1000 ppm (70 g ECO_2FUME/m^3) for 24 hours at 4°C and minimum of 500 ppm (35 g ECO_2FUME/m^3) for 72 hours at 4°C (Table 2). Similar results on the toxicity of phosphine against insect and mite pests of perishable products were found in the literature review. Liu (2008) reported that a complete kill of the western flower thrips was achieved in ≥18-h fumigation treatments with ≥250 ppm phosphine. Similarly, fumigation of vacuum-cooled commercial iceberg lettuce at 3°C with 484±17 ppm phosphine for 18 h under storage at 20°C resulted with a complete control of western flower thrips (Liu, 2011). Overall mortality ratios of mixed stages of *Tetranychus urticae* exposed to 1 gm^{-3} phosphine for 5 and 15 h at 13-21°C of temperature varied from 19.3% to 98.3% and from 90.7% to 100%, respectively (Weller and Van S. Graver, 1998).

Table 2 The effects of various phosphine levels applied at 4°C for different exposure periods on pest mortality and flower quality.

Flower	PH_3 concentration (ppm)	Exposure Periods (h)	Pest mortality (%)		Pest development after fumigation	Flower Quality & Vase life
			Tetranychus cinnabarinus	*Frankliniella occidentalis*		
Carnation and Gerbera	500	24	Live individuals	Live individuals	-	Not affected
	750	24	Live individuals	Live individuals	-	Not affected
	1000	24	100	100	No development	Not affected
	1250	24	100	100	No development	Not affected
Carnation and Gerbera	250	72	Live individuals	Live individuals	-	Not affected
	400	72	Live individuals	Live individuals	-	Not affected
	500	72	100	100	No development	Not affected
	750	72	100	100	No development	Not affected

Carnation and Gerbera varieties showed good tolerance to PH_3 fumigation, as they could endure 24 h exposure with dosages as high as 1250 ppm at 4°C and 3 d with 750 ppm at 4°C. No visible adverse effects on flower quality and vase life were observed. Similarly, carnations treated with phosphine for 6 h with dosages as high as 12.2 mgL^{-1} at 24 °C or 3.04 mgL^{-1} at 2°C were reported to produce no negative effects on flower color, diameter, vase life, and other damage indices (Zang et al., 2013). Phosphine was found to be the least phytotoxic fumigant to cut flowers (Weller and Van S. Graver, 1998)

Due to its high efficacy and low phytotoxicity, phosphine fumigations can be used for QPS purposes against insect and mite pests of cut flowers. Therefore, at the temperature of 4°C, ECO_2FUME doses at either 70 g $ECO_2FUME*m^{-3}$ (=1000 ppm PH_3) for 24 h or 35 g $ECO_2FUME*m^{-3}$ (=500 ppm PH_3) for 72 h can be proposed against cut flower pests in Turkey. Phosphine can also be integrated into a pest management system with other treatments such as pre-harvest pest control, insecticidal dipping, and fogging with insecticides (Weller and Van S. Graver, 1998).

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