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Effects of electron beam irradiation on six insect pests in different sections of flower boxes for export

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ABSTRACT

We explored effects of electron beam irradiation on disinfestation of six floriculture insect pests (*Liriomyza trifolii*, *Spodoptera litura*, *Myzus persicae*, *Tetranychus urticae*, *Bemisia tabaci*, and *Frankliniella intonsa*) placed at top, middle, or bottom section in boxes of roses and chrysanthemums. After irradiation with an electron beam of 200 Gy, eggs of *T. urticae*, *B. tabaci*, and *F. intonsa* were prevented from hatching at every position in the boxes, whereas some eggs of *L. trifolii* and *S. litura* hatched at the bottom of the boxes. The pupation and emergence of *L. trifolii* and *S. litura* larvae and *B. tabaci* nymphs were inhibited at every position in the boxes. However, the emergence of *T. urticae* and *M. persicae* nymphs was not inhibited, even at the top of the boxes. When pupae were irradiated, the emergence of *L. trifolii* was inhibited at every section in the boxes, whereas *S. litura* was not inhibited completely, even at the top section. When adult *T. urticae* were irradiated, the hatching of the F_1 generation was completely inhibited at the middle section in rose boxes but not completely in chrysanthemum boxes. The insect pests that were not inhibited completely at 200 Gy were completely inhibited at 300 Gy, except for *T. urticae*. Therefore, the doses of electron beam irradiation required might depend on the types of flowers, the species of insect pests, and the insect pest sections within the boxes.

Introduction

Roses (*Rosa hybrida*), chrysanthemums (*Chrysanthemum morifolium*), and lilies are important cut flower exports of Republic of Korea (Seo et al., 2012). In 2012, rose exports amounted to $27.14 million and chrysanthemum exports reached $9.76 million (KITA, 2013). Nine cases of disinfection and 27 cases of waste disposal were found in Korean-exported roses among the 6026 quarantined cases over the last 10 years. For exported chrysanthemums, there were 15 cases of disinfection and 20 cases of waste disposal (APQA, 2013). If any insect pest is found in cut flowers, the flowers are often discarded due to their shortened life, although they are usually fumigated with methyl bromide (MB) and hydrocyanic acid gas (HCN). Furthermore, import suspension measures may be taken, although these measures often differ between countries (Son et al., 1998). In order to avoid economic losses due to the impedimentation of flower exports and increased prevention costs, it is necessary to develop more effective disinfection techniques to replace the fumigation processing that is used to sterilize cut flowers (Kang et al., 2007).

Electron beam irradiation can be used as an alternative disinfection method to chemical fumigants, such as MB (Kikuchi, 2003a). Technologies used for ionizing irradiation include gamma-ray, X-ray, and electron beam irradiation (Hallman, 2004). Ionizing irradiation can be used effectively in the quarantine processing of cut flowers and agricultural products because irradiation requires a shorter processing time than fumigation and leave no residues (Osouli et al., 2013). Electron beams are produced using electrical energy, and adjusting the irradiation dose is simple. Electron beams have been widely used in medical treatments, the semi-conductor industry, food processing, and the quarantine of some agricultural products (Taniguchi, 2005; Park et al., 2006; Moon et al., 2010). We have conducted several studies on insect pests using electron beams in Korea. Moon et al. (2010) investigated the electron beam sensitivity of *Tetranychus urticae* Koch (Acari: Tetranychidae), *Myzus persicae* Sulzer (Hemiptera: Aphididae) and *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae). In addition, Koo et al. (2011, 2012) studied the extent of electron beam sensitivity in *Plutella xylostella* Linnaeus (Lepidoptera: Plutellidae), *Liriomyza trifolii* Burgess (Diptera: Agromyzidae), and *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae) (Yun et al., 2014) and reported that electron beam irradiation caused DNA damage, which induced abnormal development and reproduction.

The susceptibility of various insect pests to electron beam radiation has been studied. However, the effects of electron beam irradiation on

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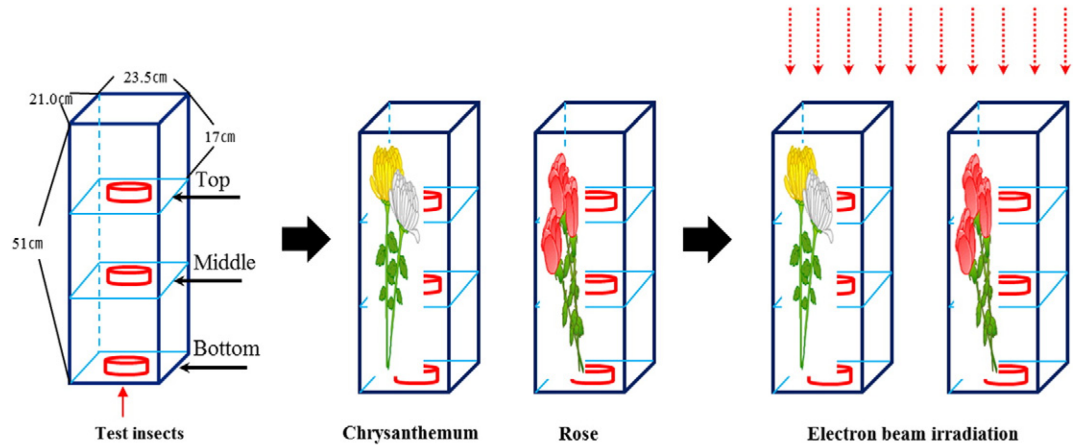

Fig. 1. Diagram of the electron beam irradiation on insect pests in rose and chrysanthemum boxes used for exportation.

insect pests in different sections of exporting flower box have not yet been studied. Therefore, the present work will aid in the development for disinfestation techniques using electron beam in Korea.

Materials and methods

Test insects

Insecticide-susceptible strains of *T. urticae* and *M. persicae* were obtained from the Korean Research Institute of Chemical Technology (Daejeon, Korea). The *T. urticae* and *M. persicae* strains were reared on kidney beans (*Phaseolus vulgaris* L.) and 2-week-old Chinese cabbage (*Brassica rapa* L. cv. Chunchujeonguk), respectively. Furthermore, we used tomatoes as food for *B. tabaci*, which were collected in Cheongju, Korea. *L. trifolii* were reared on kidney beans. *S. litura* larvae were collected from cucumber leaves in the Gurye area, Korea. In addition, we used kidney beans as host plants for *F. intonsa*, which were collected in Cheongju. The insects used in these experiments were reared in the laboratory under the following conditions: 23 °C to 27 °C, 16 L:8D h photoperiod, and 50% to 60% relative humidity (RH).

Preparation of experimental insects

Twenty female *T. urticae* adults were placed in a Petri dish (6.0 cm in diameter by 1.5 cm in height) with kidney bean leaf discs (3.5 cm in diameter) on 1.6% agar. Females were allowed to lay eggs for 12 h and were then removed. Twenty 1st instar nymphs were placed in a Petri dish under the same conditions as those used for the eggs. Twenty adults (24 h after emergence) were placed in a Petri dish. Twenty 1st instar nymphs of *M. persicae* were placed in a Petri dish with Chinese cabbage leaf discs (3.5 cm in diameter) on 1.6% agar, and the dish was then sealed with Parafilm (Pechiney, Chicago, IL, USA). For *M. persicae* adults, we inoculated 20 adults each within 24 h after emergence onto Chinese cabbage leaf discs. We placed the eggs in tomato seedlings for 24 h and used tomato seedlings for the 3rd instar nymphs of *B. tabaci*. Twenty female and 20 male *B. tabaci* adults (24 h after emergence) were placed in a glass vial (2.5 cm in diameter by 7 cm in height). Twenty female and 20 male *L. trifolii* adults were placed in a plastic cage (30 cm^3) with a 2-week-old kidney bean plant. The females were allowed to lay eggs for 24 h, after which all adults were removed. Leaves with attached eggs (0–24 h) were exposed to an electron beam. One hundred *L. trifolii* larvae (2nd instar) and puparia (0–24 h after

Table 1
Effect of electron beam irradiation of 200 Gy on different stages of *T. urticae* according to the positions in flower box[1].

Stage	Flower box	Position	No. mites tested	Hatchability (%)	Emergence (%)	No. eggs/day	Hatchability (%) (F_1)
Egg	R[2]	Top	32–38	0.0 ± 0.0a	–	–	–
		Middle	36–55	0.0 ± 0.0a	–	–	–
		Bottom	34–56	0.0 ± 0.0a	–	–	–
	C[3]	Top	25–47	0.0 ± 0.0a	–	–	–
		Middle	20–52	0.0 ± 0.0a	–	–	–
		Bottom	23–55	0.0 ± 0.0a	–	–	–
	Control		35–74	92.6 ± 3.9b	–	–	–
Nymph	R	Top	60	–	83.7 ± 4.1a	0.0 ± 0.0a	–
		Middle	60	–	83.2 ± 5.1a	4.5 ± 5.7ab	1.0 ± 1.4a
		Bottom	60	–	89.7 ± 1.4a	17.2 ± 7.8bc	17.3 ± 6.5b
	C	Top	60	–	82.5 ± 0.8a	0.7 ± 2.1a	0.0 ± 0.0a
		Middle	60	–	88.6 ± 7.9a	1.4 ± 1.4a	0.8 ± 1.7a
		Bottom	60	–	89.3 ± 9.4a	19.9 ± 14.3c	21.0 ± 10.0b
	Control		60	–	94.7 ± 6.1a	52.7 ± 24.4d	84.6 ± 7.8c
Adult	R	Top	60	–	–	37.3 ± 6.5a	0.0 ± 0.0a
		Middle	60	–	–	33.1 ± 12.4a	9.7 ± 4.0bc
		Bottom	60	–	–	36.7 ± 9.0a	18.6 ± 4.8d
	C	Top	60	–	–	35.9 ± 12.9a	0.0 ± 0.0a
		Middle	60	–	–	31.1 ± 13.4a	7.6 ± 3.1ab
		Bottom	60	–	–	35.4 ± 8.8a	17.4 ± 6.9 cd
	Control		60			51.2 ± 2.3a	86.0 ± 3.6e

1 Means within each column followed by the same letter are not significantly different at $p = 0.05$ by Tukey's HSD test (SAS Institute, 2003).
2 Rose box.
3 Chrysanthemum box.