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Effects of Electron Beam Irradiation on *Myzus persicae* (SULZER) (Homoptera : Aphididae)

Toshiyuki DOHINO, Ikuko MATSUOKA, Toshitatsu TAKANO and Toru HAYASHI*

Research Division, Yokohama Plant Protection Station, Naka-ku, Yokohama 231-0801, Japan
*National Food Research Institute, Tsukuba, Ibaraki 305-8642, Japan

Abstract: The survival rate, fecundity and feeding behavior of the green peach aphid, *Myzus persicae* were studied after electron beam irradiation (2.5 MeV) with doses 0, 200, 400 and 600 Gy. The survival rate of irradiated aphids significantly decreased with dose increased when aphids were treated with doses of 400-600 Gy. The descendants from irradiated females could not develop to adult stage, which suggested that the females irradiated at 200 Gy or higher were sterilized. The irradiation affected the feeding behavior but could not inhibit it even at 600 Gy.

Key words: radiation, Aphididae, *Myzus persicae*, sterility, feeding behavior, commodity treatment

Introduction

A total number of the cut flowers including cut foliage imported into Japan reached 1,008 million stalks in 1995. Of that amount 12.3% of imported cut flowers were subjected to methyl bromide or hydrogen cyanide fumigation to kill insect and arthropod pests such as thrips, aphids and mites (Yokohama Plant Protection Station, MAFF, 1996).

As methyl bromide was regarded as an ozone depleting substance in the 4th Meeting of Montreal Protcol in November 1992, it is urgently required to develop the alternatives to methyl bromide for disinfestation of quarantine pests (KAWAKAMI, 1997).

Some papers have reported that gamma irradiation was an effective quarantine treatment (CHIU, 1986 ; BURDITT and HUNGATE, 1989 ; GOODWIN and WELLHAM, 1990). As electron beam irradiation with an electron accelerator has many advantages in comparison with gamma irradiation, e.g. more safety, good cost performance, ability to treat more in less time and little damage to the environment (FURUTA, *et al*., 1987), we have studied the efficacy of electron beam irradiation for cut flowers as a quarantine treatment (DOHINO and TANABE, 1993, 1994 ; TANABE and DOHINO, 1993, 1995 ; TANABE *et al*., 1994 ; DOHINO and MASAKI, 1995 ; KUMAGAI and DOHINO, 1995; DOHINO *et al.,* 1996ab). It found that higher-dose irradiation which kills the pests during the treatment induces severe damage to the cut flowers and a dose of 400 Gy sterilizes the pests without deterioration of the cut flowers.

A few papers have reported on the effects of irradiation on survival, development and fecundity of aphids (WIT and van de VRIE, 1985 ; HALFHILL, 1988 ; WIENDL *et al*., 1994). As PHATAK *et al*. (1994) described plant viruses were much tolerant to irradiation, feeding behavior of aphids after irradiation should also be studied because aphids work as virus vectors. In this study, we investigated the effects of electron beam irradiation on the feeding behavior of green peach aphid, *Myzus persicae* as well as the survival and fecundity.

Materials and Methods

Test insects

Myzus persicae was obtained from Yokohama Research Center, Mitsubishi Chemical Corporation. The aphids were reared with leaves of potted Chinese cabbages in a cage (29×44×30 cm) which was covered with Bemberg® nets (Asahi Chemical Industry Co. Ltd.) under 25±1°C and 60-80% RH and a photoperiod of 16L : 8D. Two adult females were allowed to lay nymphs for 24 hours on an uninfested Chinese cabbage leaf of which the base was covered with moistened cotton and aluminium foil in a plastic petri-dish (2 cm in height, 9 cm in diameter). The nymphs on the leaf in the petri-dish were kept in an environmental chamber set at 25°C with the photoperiod of 16L : 8D until irradiation.

Irradiation

Aphids were irradiated at 3rd-instar nymph to adult stage. Five to six aphids left on the leaf in a petri-dish were irradiated with electron beams under 20°C and 50-60% RH in a Van de Graaff electron accelerator (Nissin High Voltage Co. Ltd., 2.5 MeV, 1.5×10^6 Gy/hr) at National Food Research Institute (Tsukuba, Ibaraki, Japan). The absorbed dose was controlled by changing the beam current at a conveyer speed of 3.0 m/min. Doses were measured with a radiochromic film (RCF) dosimeter (FWT-60-00, Far West Technology Inc.) (HAYASHI *et al.*, 1992). Beam currents were 29.4, 58.8 and 88.2 μA for 200, 400 and 600 Gy, respectively.

All newly nymphs from reproductive females observed after irradiation were removed from the leaf immediately for the following examination on fecundity of irradiated aphids. All honeydew droplets which were excreted by aphids and adhered to the internal surface of petri-dish were wiped up, after irradiation, with wet JKwiper® (Kimberly-Clark Co.) for the examination on feeding of irradiated aphids.

Examination of survival rate, fecundity and feeding

Rearing conditions of the irradiated aphids were the same as the test insects. To obtain survival rate and fecundity of the irradiated aphids, the number of survivors and newly born nymphs from the adult female (nymphs/an adult female) were counted. In order to observe the subsequent development of newly born nymphs, 5 newly born nymphs were selected randomly from each replication and transferred to a fresh leaf (the other nymphs were discarded) when the number of nymphs per replication was over 5. Otherwise, all of the nymphs were examined.

RAPUSAS and HEINRICHS (1990) reported that honeydew droplets were being excreted by the leafhopper, *Nephotettix virescens* during ingestion. In our preliminary test, no honeydew droplets were observed on the internal surface of petri-dish while aphids were kept starved (without leaf) in petri-dish for 24 hours although honeydew droplets were observed while aphids were kept with the leaf. Thus, the number of honeydews (drops/an aphid) adhered to the internal surface of petri-dish were used as an index of degree of ingestion. After being counted the number, all of the honeydews were wiped out to get prepared for next counting.

Five petri-dishes were subjected to one replication and all tests were replicated 4 times. These examinations were conducted everyday for 14 days after irradiation.

Results and Discussion

Effect of irradiation on development and survival rate

The number of daily exuviae of aphids provided the daily age construction of colony in a petri-dish. Fig. 1 shows the daily change of age construction of aphids irradiated with different doses. The days in this figure are the days after irradiation. All individuals in the control grew up into adults in 3 days after irradiation. However, 10.1, 8.3 and 29.1% of those irradiated at 200, 400 and 600 Gy respectively, did not reached the adult stage in the same period. The percentages stayed the same even on the 4th day. The development of 600 Gy-irradiated aphids was delayed or inhibited to a larger extent as compared to those irradiated at 200 Gy and 400 Gy.

The survival rate of irradiated aphids was decreased as irradiation dose increased (Fig. 2). All 600 Gy-irradiated aphids (117 in total) died within 10 days after the treatment. Almost all 400 Gy-irradiated aphids (119 out of 120) died within 14 days after irradiation. On the other hand, there was no significant difference between the survival rate of control aphids (91.5±3.2% (n=117)) and that of 200 Gy-irradiated aphids (92.4±1.6% (n=119)) at 14 days after irradiation.

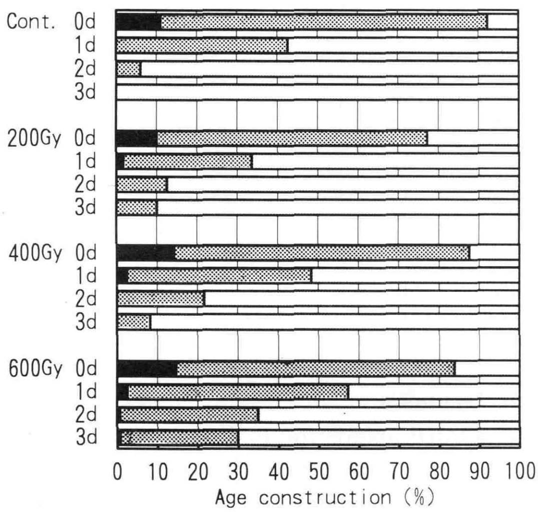

Fig. 1. Development of *M. persicae* irradiated with electron beams
Age constructions were shown in each absorbed dose on (0 d) and 1-3 days (1-3 d) after irradiation.
■ 3rd instar ▨ 4th instar □ Adult

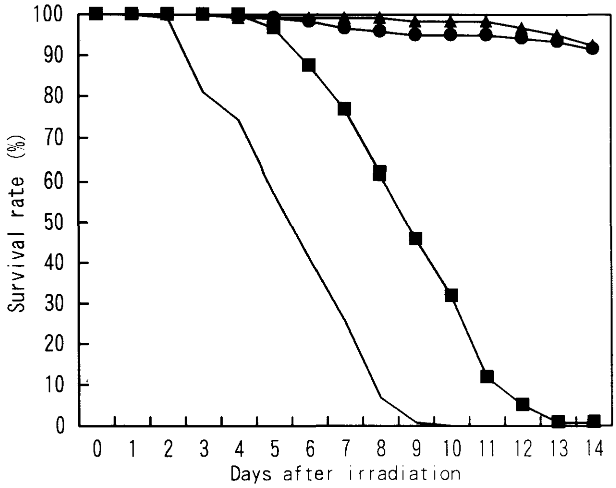

Fig. 2. Survival rate of *M. persicae* irradiated with electron beams
—●— Control —▲— 200 Gy —■— 400 Gy ——— 600 Gy

Table 1. Fecundity of *M. persicae* irradiated with electron beams

Days after irradiation	No. of newly nymphs from an irradiated aphid (nymphs/an adult female)			
	Control	200 Gy	400 Gy	600 Gy
1	3.0±2.2	2.5±1.5	0.7±1.0	1.8±1.3
2	1.9±0.4	1.3±0.2	0.4±0.4	0.5±0.3
3	2.0±0.4	0.5±0.2	0.1±0.1	0.1±0.1
4	2.0±0.4	0.1±0.1	0	0.1±0.1
5	1.4±0.2	0	0	0
6	1.8±0.2	0.1±0.1	0	0
7	1.5±0.2	0	0	0
8	1.6±0.2	0	0	0
9	1.3±0.2	0	0	0
10	1.2±0.1	0	0	—
11	1.5±0.3	0	0	—
12	1.1±0.2	0	0	—
13	1.4±0.4	0	0	—
14	1.1±0.1	0	0	—

Effect of irradiation on fecundity

The fecundity of irradiated aphids for 14 days is shown in Table 1. The irradiated females stopped laying nymphs within 6 days after irradiation, although untreated females continuously laid nymphs even on the 14th day. The reproductive ability of F_1 progeny from irradiated aphids in each dose is shown in Table 2. The reproductive ability of all F_1 from the treated aphids was calculated at zero while that of control was 2.8-5.4. The nymphs from 200 Gy-irradiated females attained to 2nd-instar although the nymphs from

Table 2. Reproductive ability of nymphs from irradiated *M. persicae*

Dose (Gy)	Days after irradiation	No. of nymphs[1)] tested (A)	Population after[2)] 10 days (B)	Reproductive ability (B/A)
Control	1	15	45	3.0
	2	20	72	3.6
	3	20	83	4.2
	4	20	55	2.8
	5	20	78	3.9
	6	20	108	5.4
200	1	16	0	0
	2	20	0	0
	3	20	0	0
	4	3	0	0
	5	—	—	—
	6	3	0	0
400	1	8	0	0
	2	13	0	0
	3	9	0	0
	4	—	—	—
	5	—	—	—
	6	—	—	—
600	1	15	0	0
	2	15	0	0
	3	3	0	0
	4	1	0	0
	5	—	—	—
	6	—	—	—

1) Total number of nymphs tested in 4 replicates. Maximum 5 nymphs per replication were transferred to a leaf in a petri-dish.
2) Total number of aphids in 4 replicates 10 days after inoculation of nymphs.

females irradiated at 400 Gy or higher died in 1st-instar. In short, the nymphs from irradiated aphids did not develop up to adult stage and did not produce the next generation. Sterile effect of irradiation is exhibited when the irradiated insect cannot produce the progeny or produce the progeny without reproductive ability due to the inherited genetic damage. Therefore, it was concluded that electron beam irradiation with doses of 200 Gy or higher sterilized *M. persicae*.

Effect of irradiation on feeding

The amount of ingestion of irradiated females was decreased rapidly with age and with an increase of irradiation dose, i.e. number of honeydew droplets excreted by irradiated females decreased with dose increase (Fig. 3). On the other hand, the droplets decreased slowly with age in case of unirradiated females.

One day after irradiation, the number of honeydew droplets per aphid of control, 200

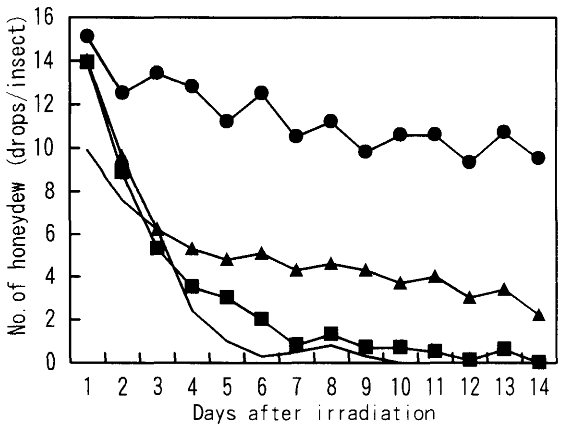

Fig. 3. Food consumption of *M. persicae* irradiated with electron beams
—●— Control —▲— 200 Gy —■— 400 Gy ——— 600 Gy

Gy and 400 Gy were 15.1±1.0 (n=117), 14.0±1.5 (n=119) and 13.9±1.6 (n=120), respectively, and there was no significant difference among them. However, 3 days after irradiation, significant difference between control and irradiated group was observed with the values 13.4±1.3 (n=117), 6.2±1.6 (n=119), 5.3±0.6 (n=120) and 6.2±1.7 (n=95) for Control, 200, 400 and 600 Gy, respectively (t-test, $P < 0.01$). These results indicate that the sterilized aphids can still feed which means that they would be able to work as the virus vectors.

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和 文 摘 要

モモアカアブラムシ *Myzus persicae* (SULZER) (Homoptera : Aphididae)に対する電子線照射の効果

土肥野 利 幸・松 岡 郁 子
高 野 利 達・林 徹*
横浜植物防疫所調査研究部
*食品総合研究所流通保全部

モモアカアブラムシ *Myzus persicae* の3齢幼虫から成虫までを含むコロニーに，200 Gy，400 Gy 及び 600 Gy の電子線 (2.5 MeV) を照射し，その効果を調べた。

1) モモアカアブラムシの発育は照射によって遅延又は抑制された。
2) 照射後の生存率は，線量が高くなるにつれて低下したが，対照区と 200 Gy 照射区の間では有意差は認められなかった。
3) 照射個体は次世代を産んだが，その次世代は発育の過程で全て死亡し子孫を残すことができなかった。そのため，200 Gy 以上の照射でモモアカアブラムシを不妊化できると考えられた。
4) 照射個体の摂食能力を排泄物(甘露)数で評価した。線量増加に伴い摂食は抑制されたが，本試験最高線量の 600 Gy でも完全に摂食を阻止できなかった。