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EVALUATION OF SOIL-APPLIED SYSTEMIC INSECTICIDES AGAINST CABBAGE APHID, BREVICORYNE BRASSICAE (L.), AND RESULTANT SURVIVAL OF THE PRIMARY PARASITOID, DIAERETIELLA RAPAE (MCINTOSH), ON CABBAGE[1]

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ABSTRACT

Three soil-applied systemic insecticides, phosphamidon, carbofuran and aldicarb, were tested in cabbage field plots and individual potted plants against cabbage aphid, *Brevicoryne brassicae* (L.) and its primary parasitoid, *Diaeretiella rapae* (McIntosh). The results indicated that single soil incorporation of aldicarb at 1-3 kg ha^{-1} proctected the cabbage from aphids for the entire growing season. Phosphamidon and carbofuran in field plots did not provide similar suppression of cabbage aphid and this was ascribed to either inadequate doses or slower uptake by the plants as all tested doses of the toxicants in potted plants gave significant ($P<0.05$) aphid suppression with reasonable apparent persistence. Both plot and pot experiments showed selectivity towards parasitoid survival, measured in terms of percentage parasitism and percentage of adult parasitoid emergence from aphid mummies.

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ارزیابی اثرسموم سیستمیک اضافه شده بخاک برعلیه شته کلم *Brevicoryne brassicae* (L.)
ونتیجه آن برروی زنبورپارازیت اولیه آن *Diaeretiella rapae* (McIntosh)

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خلاصه

اثر سموم فسفامیدن، کاربوفوران و آلدیکارب در قطعات آزمایشی مزرعه کلم و در گلدانهائیکه در آنها کلم کاشته شده بود و از طریق افزوده شدن بخاک برروی شته کلم و پارازیت اولیه شته مزبور مورد آزمایش قرار گرفت. نتایج بدست آمده نشان داد که یکبار اضافه کردن سم آلدیکارب بمیزان ۳-۱ کیلوگرم در هکتار کافی است که شته کلم را در تمام فصل کنترل کند. فسفامیدن و کاربوفوران در قطعات آزمایشی باندازه سم آلدیکارب برعلیه شته کلم موثر نبودند. این امر میتواند بعلت غلظت های ناکافی این سموم و یا جذب کندتر آنها توسط گیاه باشد. تمام غلظت های آزمایش شده در گلدانها باعث تقلیل جمعیت شته ها گردید و ظاهرا" دارای دوام نسبی هم بودند. آزمایشهای صحرائی و گلدانی نشان داد که پارازیت اولیه شته کلم میتواند به حیات خود تحت شرائط مصرف سموم فوق ادامه دهد و این موضوع با محاسبه درصد پارازیت شدن شته های ماده (مادر) و تعداد زنبورهای پارازیت خارج شده از این شته ها اندازه گیری گردید. با بررسی اکولوژیکی بیشتر درباره تطابق زمانی جمعیت های شته و پارازیت، و همچنین انتخاب فیزیولوژیکی سموم سیستمیک، میتوان یک مبارزه تلفیقی موثر برعلیه شته کلم انجام داد.

INTRODUCTION

Cabbage aphid, *Brevicoryne brassicae* (L.) (Homoptera : Aphididae), a cosmopolitan pest of brassica vegetables, often remains in high numbers on its cruciferous hosts in Iran (5). Besides being vector of several viruses, the aphid may cause wilting, distortion and stunting of the host plant and finally degradation of the marketable product (4).

The parasitoid, *Diaeretiella rapae* (McIntosh) (Hymenoptera : Braconidae), oviposits in the adipose tissues of both alate and apterous aphids of usually early or middle instars (6). There are 4 larval instars. The final instar larva kills the aphid and consumes the remaining body tissues. The larva then cuts a slit in the ventral surface of the aphid's skin and uses a secretion from a silk gland to cement it to the leaf (6). At this stage the swollen, brownish dead aphid is referred to as a "mummy". After pupation, the adult parasitoid cuts a circular hole at the posterior end of the mummy and emerges (6). The parasitization rate depends upon environmental and host phenological attributes and under favorable conditions ranges from 26.5 to 80% (3).

Chemical control in the form of foliage sprays is often ineffective on sheltered aphid colonies and detrimental to their predators and parasitoids and other non-target beneficial pollinators (7). Predators feeding on cabbage aphid sprayed with demeton or schradan suffered a higher mortality than those feeding on aphids killed by a soil-incorporated systemic insecticide (1). Previously, chemical and biological control measures against cabbage aphid have been employed in many parts of the world (2, 8, 11, 13). However, a detailed study on the selectivity of systemic insecticides on the aphid-parasitoid relationships, with particular reference to parasitoid survival, is lacking.

This paper reports our field and laboratory studies to determine the relative selectivity of three doses of soil-applied systemic insecticides which caused mortality of the aphids while allowing the survival and emergence of the parasitoid.

MATERIALS AND METHODS

Soil Type and Cabbage Culture

The study was conducted in 1979-80 at the College of Agriculture, Shiraz University, Shiraz, Iran. The mechanical-chemical analyses of the soil of experimental field plots gave sand=15.56%, silt=48.00%, and clay=36.44% in 0-15 cm depth of Ap-horizon, pH(paste)=8.05, N=0.12%, P=13 ppm, K=83 ppm and E.C.=0.32 mmhos cm^{-1}. After the analyses, N and P were applied at the rates of 50 and 60 kg ha^{-1}, respectively.

Five week old seedlings of cabbage, *Brassica oleracea* (Capitata group), locally known as Kalam-Roomi-e-Sabz, were transplanted on 1 October by hand into the experimental plots. Each plot (8x2.5 m) consisted of 52 plants in four rows. Both rows and plants were spaced 50 cm apart. The distance between parallel plots was 1 m. Seedlings were also transplanted into 20 cm diameter (ca. 3.5 l capacity) clay pots filled with soil from experimental plots. Each pot had three seedlings initially which were thinned to one after establishment. Aphid infestations were allowed to develop before treatments were applied.

Insecticidal Application

Fifteen days after transplanting, three insecticides, phosphamidon [Dimecron 100 E.C., Ciba-Geigy, 2-chloro-2-(diethylcarbamoyl)-1-methylvinyl dimethyl phosphate], carbofuran (Furadan 5G, F.M.C., 2, 3-dihydro-2, 2-dimethyl benzofuran-7-yl methylcarbamate), and aldicarb [Temik 10G, Union Carbide, 2-methyl-2-(methylthio) propionaldehyde-0-methylcarbamoyl oxime] at the rates given in Table 1 were added to the soil 1-1.5 cm deep in a band alongside the rows 5-6 cm away from the plants. Phosphamidon was applied as soil drench. Aldicarb and carbofuran granules were placed in bands and earthed up. Plants in the pots were treated with the insecticides at doses given in Table 3. Later, 40 pots used in the experiment were placed around the perimeter of the field plots. Insecticides were applied when the average population of aphids exceeded 25 and 15 per plant in plots and pots, respectively. The experimental design was randomized complete blocks with four replications. Plots were kept weed free manually and irrigated with an isolated siphon network.

Population Counts

Sampling and counting of live and parasitized aphids (mummies) started two days after treatment on 18 October and continued until the maturity of the crop (21 December). During a sampling occasion 12 plants were chosen at random in each treatment and one leaf was removed from each plant. The number of leaves removed from top, middle and bottom positions were equal. The leaves were taken to the laboratory in plastic bags. Mummies were isolated from the leaves for counts and subsequent rearing. Aphids were brushed from leaves into 70% ethanol in petri dishes for counts. Only total number of aphids, regardless of instars, were recorded.

In pots, *in situ* counts were made for aphids on three leaves/treatment and only unopened intact mummies were removed from them. All sampled plants (in pots and plots) were tagged to avoid repetition of counts on future occasions. In the laboratory, mummies were transferred to 12x5 mm glass vials held at 21±1°C, 70±5% R.H. and a 16 hr photoperiod for adult parasitoid emergence. Rate of parasitism was measured by relating the number of unopened mummies to the total number of aphids (6, 10).

The formula used for this purpose was as follows:

$$\text{Percentage of parasitism} = \frac{m}{m + a} \times 100$$

where:

m = No. of intact unopened mummies

a = No. of live aphids

For statistical analyses, ANOVA was performed on transformed ($\sqrt{X+0.5}$) data. Percentages were transformed by angular (arcsine) method for comparisons. Means were separated by Duncan's MRT.

RESULTS AND DISCUSSION

Aphid Suppression by Insecticides

The highest suppression of cabbage aphid was observed in plots treated with 2-3 kg ha^{-1} of aldicarb. Phosphamidon and carbofuran at the concentrations tested failed to suppress the aphid populations (Table 1). The loss in aphicidal action was ascribed to either lower doses or slower uptake of the insecticides by the cabbage plants in field plots.

In pots, seasonal aphid population means per leaf for the three toxicant doses given in Table 3, were respectively 1.9, 3.4 and 2.9 for phosphamidon, 3.0, 3.1 and 1.6 for carbofuran and 0.9, 1.7 and 1.6 for aldicarb, compared with 8.3 for untreated plants. Significant suppression ($P<0.05$) of aphids in pot treatment suggested that phosphamidon and carbofuran, if used in higher concentrations, may maintain adequate aphid control in field situations. Factors such as higher soil moisture in pots may have induced rapid translocation of toxicants and enhanced rate of decline in aphid population. Suett

Table 1. Effect of single applications of systemic insecticides against cabbage aphid in cabbage field plots.

Treatment kg a.i. ha^{-1}	Mean No. aphids/leaf* Days after treatment 2	5	8	11	15	22	29	36	50	64	Seasonal mean
Phosphamidon											
1.0	111.6a	67.0c	70.3d	70.6c	28.0b	10.3ab	4.6abc	9.0b	3.6bc	2.3cd	37.7c
0.6	77.1a	19.3abc	23.0abcd	24.6abc	12.3ab	9.6ab	7.0bcd	7.6b	3.3bc	2.3cd	18.6bc
0.3	93.0a	49.6bc	52.3bcd	46.3bc	36.0b	17.3b	12.3cd	10.6b	4.6cd	2.0cd	32.4c
Carbofuran											
1.70	98.3a	70.0c	60.3bcd	52.6bc	49.6b	15.6ab	2.3ab	1.0a	0.3a	0.3ab	35.0c
1.25	76.0a	18.3abc	18.0abc	25.3abc	22.3b	17.0b	16.3cd	9.0b	0.3a	0.3ab	20.2bc
0.75	86.6a	28.6abc	24.0abc	21.0ab	12.3ab	9.3ab	11.0cd	10.3b	2.3b	2.3cd	20.7bc
Aldicarb											
3.0	80.6a	13.6ab	4.0a	2.3a	0.3a	0.3a	0a	0.3a	0a	0a	10.1a
2.0	73.0a	8.3a	5.6a	1.3a	0a	1.3a	1.6ab	1.6ab	1.6a	0.6a	9.3a
1.0	92.6a	17.0abc	10.0ab	6.3ab	11.0ab	4.3ab	6.6bcd	8.3b	2.6b	1.3bc	16.0ab
Untreated (control)	83.0a	49.0bc	53.6dc	38.0bc	35.0b	21.0b	14.3d	18.0b	6.0d	3.3d	32.1c

*Means within a column followed by a common letter are not significantly different ($P<0.05$) using Duncan's multiple range test.

and Padbury (12) reported that the uptake of systemic chemicals was greater in plants grown in peat blocks than in those grown in the field. More persistent aphid suppression observed in aldicarb treated plots or pots was consistent with the results obtained by other workers on higher potency of aldicarb compared with dimethoate and ethiofencarb applied to the root systems of citrus trees (9). No signs of phytotoxicity were observed in any treatment in plots or in pots. No significant difference in the final head weight or marketability was found between harvested heads in treated and untreated plots.

Parasitism and Parasitoid Survival

Table 2 shows the densities of parasitized aphids (mummies) recorded in various treatments. No toxicant, at tested concentrations, was detrimental to the parasitization of aphids as the mean numbers of mummies recorded in treated plots were not significantly different ($P<0.05$) from those in untreated plots. Similar results were obtained in pot treatments.

The estimates of parasitism obtained from counts of mummified aphids excluding an unknown proportion of aphid population which was parasitized but did not show any mummy like symptom, might have underestimated the actual level of parasitism. Furthermore, as the mummies remained stuck to the leaf, the data on parasitism might reflect the cumulative results of the activity of parasitoids on a given leaf. However, the principal objective of the study was essentially a comparison of the trends in parasitism in various treatments instead of measuring their absolute values.

Parasitism did not appear to be suppressed by the direct action of the toxicant, i.e. mortality and dislodgement of the poisoned aphids from the plant or in response to any induced changes in the aphid densities. As a result, percentage parasitism was also not affected by the toxicants (Table 3). From the mummies reared, only *D. rapae* was emerged. The adult parasitoid emergence from mummies treated and untreated

Table 2. Densities of parasitized cabbage aphids (mummies) on cabbage plants in field plots treated with systemic insecticides.

Treatment kg a.i. ha^{-1}	Mean No. mummies/leaf* — Days after treatment: 2	5	8	11	15	22	29	36	50	64	Seasonal mean
Phosphamidon											
1.0	11.7	10.1ab	10.7ab	12.6ab	10.6	11.9	1.3	0.4a	0	0.1ab	6.9
0.6	9.1	12.1ab	14.8ab	15.9ab	12.6	7.8	2.1	0.2a	0.1	0	7.5
0.3	11.3	9.2ab	12.2ab	13.4ab	13.6	10.1	1.3	0.7ab	0.5	0.1ab	7.2
Carbofuran											
1.70	13.4	14.2ab	17.4ab	21.3ab	22.0	13.6	1.2	0.1a	0.2	0a	10.5
1.25	7.8	7.3a	8.5a	8.6a	12.4	5.2	0.6	0.2a	0.1	0.1ab	5.1
0.75	12.6	11.8ab	14.2ab	16.3ab	14.5	6.6	1.3	0.3a	0.1	0.1ab	7.8
Aldicarb											
3.0	16.1	23.8b	27.0b	28.1b	23.8	5.6	0	0.2a	0	0.1ab	11.1
2.0	7.6	7.8a	8.4a	9.1a	8.2	4.5	0.1	0.3a	0.1	0.1ab	4.6
1.0	18.3	17.2ab	20.7ab	25.4b	17.8	13.1	1.6	0.7ab	0.1	0.2ab	11.5
Untreated (control)	12.3	15.0ab	16.6ab	18.9ab	16.1	9.9	1.5	1.2b	0.7	0.4b	9.2

*Means in a column without any letter or followed by a common letter are not significantly different ($P<0.05$) using Duncan's multiple range test.

Table 3. Seasonal mean percentage (%) and angular transformation (AT) of parasitism of cabbage aphid and adult parasitoid emergence from laboratory reared mummies.

Treatment		Parasitism				Parasitoid emergence			
Plots	Pots	Plots		Pots		Plots		Pots	
kg a.i. ha^{-1}	mg a.i. pot^{-1}	%	AT	%	AT	%	AT	%	AT
Phosphamidon									
1.0	100	17.2	24.4	42.6	41.0	52.3	46.1	37.9	38.1
0.6	60	25.0	30.0	35.8	36.9	57.5	49.3	43.1	41.0
0.3	30	22.0	28.0	35.0	36.3	62.2	51.9	48.3	44.0
Carbofuran									
1.70	175	33.5	35.4	46.3	42.7	59.2	50.2	50.5	48.2
1.25	125	19.7	25.8	33.0	41.0	55.3	48.0	31.5	34.1
0.75	80	29.9	33.2	49.4	44.5	62.7	52.4	56.6	48.6
Aldicarb									
3.0	300	51.3	45.6	42.1	40.4	52.2	46.1	44.5	41.8
2.0	200	45.3	42.1	32.8	35.0	58.4	49.6	40.2	39.2
1.0	100	40.7	39.7	45.1	42.1	60.0	50.8	50.2	45.0
Untreated (control)		20.2	26.6	30.0	33.2	63.5	52.7	54.6	47.7
			N.S.		N.S.		N.S.		N.S.

N.S. Values in the column are not significantly different ($P<0.05$) using Duncan's multiple range test.

plots and pots (ranging 38-63%) shows that none of the concentrations had any apparent toxic effect on the larva, pupa or post pupal parasitoid within the mummy.

Parasitism varied from 17-51% and appeared to be capable of providing an appreciable level of aphid suppression throughout the season. This invites further studies on aphid-parasitoid seasonal equilibrium. The non-emergence of some parasitoids from the reared mummies is difficult to interpret. Possible factors such as hyperparasitization, overwintering, diapause or sudden change of environment from field to laboratory rearing conditions might have affected the emergence (3, 6).

CONCLUSION

In a low population season (winter), the soil-applied insecticides carry a potential for prolonged but less intensive protection (14). Thus a single post planting application in winter seems economical and sufficient to keep cabbage aphid-free. Considering the economic and environmental advantages of a single soil application of a systemic insecticide and the results of this study, it is concluded that the tested toxicants, especially aldicarb at the rate of 1-3 kg ha^{-1} could be used as a component of integrated control of cabbage aphid. Further bioassays on the pattern of absorption, persistence and degredation of toxicants particularly at the time of crop maturity are suggested to determine safe residue limits. A continuous, two- to three-season study is needed to evaluate the potential of the parasitoid as a means of biological control of cabbage aphid. However, the significant information in this paper may enhance the understanding of the selectivity of soil-applied systemic insecticides and their role in cabbage aphid management strategies.

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