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Selective Toxicity of Different Granular Insecticides to the Peach-potato Aphid, *Myzus persicae* (Sulzer) (Homoptera: Aphididae) and its Parasitoid *Aphidius matricariae* Haliday (Hymenoptera; Aphidiidae) in two Differentially Resistant Potato Cultivars

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Abstract: Field studies were conducted in Pakistan to examine the effects and the interaction of two differentially resistant potato cultivars i.e. Cardinal and Desiree (one partially resistant and one susceptible to *Myzus persicae* (Sulzer), respectively) with different dosage rates of granular insecticides, at different time intervals after application in relation to percent kill of *M. persicae* and effects on the parasitoid *Aphidius matricariae* Haliday (i.e. the third trophic level) within the aphid mummies, percent parasitism and Thimet 10G (phorate) was found about 30% more effective in reducing aphid population than the Furadan 3G (carbofuran). The highest doses of each insecticide caused maximum aphid mortality, in general aphid mortality appeared dose dependent. Mostly all the higher and lower doses of the tested insecticides were about 10% more effective on Cardinal than on Desiree. The most significant result was the synergistic interaction at the lower doses with plant resistance, so that the same level of control was recorded with the second highest dose on Cardinal as with the highest dose on Desiree. Also the same level of control was observed at the lowest dose on Cardinal as with the second last lowest dose on Desiree. Furadan 3G was found least toxic to the *A. matricariae* in terms of percent parasitism, emergence of parasitoids and number of mature eggs in the emerging females. Furadan 3G gave 13, 15 and 6% higher figures, respectively from the parasitoid characteristics than Thimet 10G. The highest doses of both insecticides were clearly toxic to the parasitoid. In general, the effects on the parasitoid were dose dependent. The second highest dose of Thimet 10G, gave the maximum yield.

Key words: Potato, *Myzus persicae*, Furadan 3G, Thimet 10G, *Aphidius matricariae*, selective toxicity

Introduction

Potato has emerged as an important cash crop and one of the leading vegetables in Pakistan, with an average total production of 1,106,000 tons potato tubers (Anonymous, 2000). It is attacked by a number of insect pests. Of these, Green peach aphid, ***Myzus persicae*** (Sulzer) is the most important (Shah, 1988). ***M. persicae*** is also considered to be a major pest of potatoes worldwide (Raman, 1988). Heavy infestation of ***M. persicae*** can cause considerable damage to the potato crop by severely dwarfing and curling the leaflets and by dwarfing and spindling the tops. In extreme cases, the whole plant may be killed (Painter, 1951). This aphid is the known vector of several viruses of potato plants (Kennedy ***et al.***, 1962) the most important being potato virus Y (PVY) and potato leafroll virus (PLRV) (Broadbent, 1953). Yield loses caused by these viruses can be as high as 90% depending on cultivar, infestation and environmental conditions (Raman, 1988).

Continuous usage of the broad-spectrum insecticides has sometimes been followed by target pest resurgence, secondary pest outbreaks and the development of insecticide resistance in target pests (van den Bosch and Stern, 1962; Smith, 1970; Luck ***et al.***, 1977). Aphids have responded in all of above ways (Starý, 1970). A solution to these problems is the implementation of integrated pest management (IPM) (Metcalf, 1982). The strategy behind IPM is to use as many methods as available to keep the pest population below economic status. An ideal crop protection programme should be based on the cultivation of resistant varieties, which are then integrated to achieve the desired level of crop protection e.g. (Ellis, 1988). It has been long known that host plants can alter the susceptibility to insecticides of certain phytophagous arthropods (Richardson and Casanges, 1942; Markos and Campbell, 1943; Wieb and Radcliffe, 1973; Yu ***et al.***, 1979). Kennedy (1984) has demonstrated that in wild trichome-bearing tomatoes, the allelo-chemical 2-tridecanone enhances the level of tolerance to the carbamate insecticide carbaryl in ***Heliothis zea*** (Boddie).

Implicit in IPM is the maximum utilization of natural enemies, supplemented with selective use of insecticides when necessary (Metcalf, 1982). In the development of IPM programmes, the side effects of insecticides on beneficial arthropods, i.e. parasitoids and predators should be evaluated (Franz, 1974). Interest in studying effects of insecticides on predators has increased, where as very few studies have dealt with their effects on parasitoids, especially on aphid parasitoids (Linski, 1977; Horn, 1983; Mishra and Sapathy, 1985). In assessing the effects of insecticides on parasitoids, it is necessary to evaluate not only the direct mortality caused by contact or by residual toxicity but more importantly any absence of such effects and also sub-lethal effects on emergence, survival, fecundity and predation/parasitism behavior if the insecticide impact is to be related to the total performance of natural enemies in the filed (Croft, 1977). Adult parasitoids are especially likely to be killed by insecticides while in the process of emerging from their host (Bartlett, 1964; Kot and Plewka, 1970).

In the literature, there are some conflicting results available on the performance of different types of insecticides on the growth and development of ***M. persicae*** and its parasitoid, ***Aphidius matricariae*** Haliday. Very little information is available on the integrated pest management of ***M. persicae*** on the potato crop. More information is needed regarding the effects of broad-spectrum insecticides, especially the carbamates and organophosphates, on the population of ***M. persicae*** and on the percent parasitism, percent emergence and fecundity of the parasitoid. Therefore the present study was initiated to find out the most effective granular insecticide and its minimum effective dose and to look more closely at the effects of and the interaction between two differentially resistant potato cultivars with different concentrations of the different groups of granular insecticides, at different time intervals after application in relation to percent kill of ***M. persicae*** and effect on its major parasitoid, ***A. matricariae*** within the aphid mummies, percent parasitism and potato yield.

Materials and Methods

The experiment was conducted at the Potato Research Centre Abbotabbad (Buttakundi), Pakistan during the summer season of 1996. The partially resistant Cardinal and the susceptible Desiree cultivars were grown in a factorial randomized complete block design of 80 plots, representing twenty treatments (2 active ingredients×4 doses (and a control)×2 potato cultivars) in four replications. For each treatment, there was a separate sub-plot having six rows, replicated four times. Plant to plant and row to row distance was 20 and 75 cm, respectively. Two granular insecticides of two different group, i.e. the carbamate Furadan 3G (carbofuran) and the organophosphate Thimet 10G (phorate) were used. These insecticides were the available granular insecticides, commonly used by the farmers of Pakistan in the potato fields for the control of ***M. persicae***. Both of these insecticides were applied at four different doses (Table 1). Dose 1 was the recommended dose and doses 2, 3 and 4 were reduced dosage rates (½, 1/4 and 1/8 of the recommended dose, respectively) with dose 0 as the control, i.e. no insecticide application. These insecticides were applied by hand in the furrows at the time of sowing. Natural parasitism by ***A. matricariae*** was allowed to occur. All agronomic practices i.e. irrigation, fertilizer application, hoeing, weeding and earthing-up were done as necessary. The data recorded were: the number of aphids, percent parasitism of ***M. persicae***, emergence rate and fecundity of the parasitoid and yield of potatoes. Their detail is given below:

M. persicae population estimate

Aphids were counted on six tagged leaves, two each in the top, middle and lower region of four randomly selected plants, avoiding the border rows, from each plot. The data were recorded on the same leaves on the different sampling occasions.

Percent parasitism of *M. persicae* by *A. matricariae*

Percent parasitism was recorded by collecting 50 leaves (fixed number) from each plot. The mummies were removed and the remaining aphids were counted and kept in polythene bags (32×46 cm) still on the leaves with two filter papers (11.0 cm) for absorbing condensation. After five days, which would have allowed parasitoids to develop to 4 and 5th instar nymphs and adult aphids to form mummies, the number of mummies formed was counted and the percentage parasitism was calculated by the following formula:

$$\text{Percentage parasitism} = \frac{\text{Number of mummies formed at the end}}{\text{Total initial number of nymphs and adult aphids}} \times 100$$

Emergence rate of the female parasitoid, *A. matricariae* from the mummified peach-potato aphid, *M. persicae*

Twenty mummies were collected from plants in each plot and placed in Petri-dishes, lined with filter papers. The Petri-dishes were covered and left in the laboratory. After ten days the number of emerged parasitoids, ***A. matricariae*** were recorded for each replicate and the percent adult emergence was calculated by using the following formula.

$$\text{Percentage emergence} = \frac{\text{Number of adult emerged}}{\text{Total number of mummies}} \times 100$$

Fecundity of the parasitoid, *A. matricariae*

Fecundity of the female parasitoids was determined in terms of mature eggs present in the ovaries at emergence. Mummies were collected from each plot and placed in petri-dishes. The newly emerged adult parasitoids were collected by means of a battery-operated aspirator from each petri-dish and were provided with honey/water solution (30% on cotton balls). Sixteen adult female parasitoids were killed in 70% ethyl alcohol. The abdomen was removed and placed in glycerol on a microscope slide. The ovaries were extracted, using an insect mounting pin and placed in 1% acid fuchsin for 30 seconds. The ovaries were then punctured under a low power stereo binocular microscope with an insect mounting pin to expel the eggs. These could then be counted under a high power microscope using a tally counter.

Yield

After hand harvesting the crop, the yield obtained was weighed separately for each plot in kg, which was then converted to tones ha^{-1}.

Data analysis

The data were analyzed by analysis of variance of Factorial Randomized Complete Block Design with repeated measures 'split-plot in time' approach (Mead ***et al.***, 1993), using 'MSTAT-C computer programme and the means were compared by using Least Significant Differences (LSD) (Steels and Torrie, 1960). For dose 0, mean for the various data recorded was calculated separately for Cardinal and Desiree, combining all the untreated plots for each cultivar for each time interval. These plots were not included in the analysis of variance, to see only the effect of insecticides on ***M. persicae*** at different time intervals without having the control figures. The untreated means are given in the tables, so that the effect of the insecticide treatments can be seen.

Results

Population of *M. persicae*

Table 2 shows the means for the interaction of cultivars×insecticides×dosage rates. All treatments gave significantly lower aphid numbers than the untreated plants and recorded a higher number of aphids on Desiree than Cardinal ($P<0.05$). On Desiree, Thimet 10G was found superior and recorded a lower number of aphids at all dosage rates compared with Furadan 3G ($P<0.05$). The interaction lay in the progressive increase in number of aphids as Thimet 10G dose decreased, contrasted with no similar increase in number of aphids at dose 2 for Furadan 3G ($P<0.05$). A similar picture was seen on Cardinal. Thimet 10G again showed superiority at all dosage rates compared with Furadan 3G ($P<0.05$). The highest doses of each insecticide caused maximum aphid mortality, which decreased significantly by reducing their dosage rates ($P<0.05$), but the equality of aphid control with doses 1 and 2 of Furadan 3G was not found (Table 2). The table also shows that the recommended doses of both insecticides on susceptible (Desiree) cultivar gave no better control than that recorded for their half dosage rates on the partially resistant cultivar (Cardinal). Also no differences in the results were observed at the lowest dose of Furadan 3G on Cardinal and the higher dosage rate 3 on the Desiree. Thus there were several indications that control of aphids was more effective on the partially resistant than on the susceptible potato cultivar.

Table 1: Different dosage rates of the granular insecticides

Name of the insecticides	Doses	Doses ha^{-1}
Thimet 10G	Dose 1	12.50 kg
	Dose 2	6.25 kg
	Dose 3	3.125 kg
	Dose 4	1.562 kg
	Dose 0	Control
Furadan 3G	Dose 1	20 kg
	Dose 2	10 kg
	Dose 3	5 kg
	Dose 4	2.5 kg
	Dose 0	Control

Table 2: Effect of the interaction of potato cultivars × granular insecticides×doses on the number of ***Myzus persicae***

		(Insecticide doses)			
Cultivars	Insecticides	1	2	3	4
Desiree	Thimet 10G	2.72h	3.55g	4.80e	5.73c
	Furadan 3G	4.76e	4.70e	6.40b	6.85a
Cardinal	Thimet 10G	2.25i	2.81h	4.26f	5.33d
	Furadan 3G	3.80g	4.66e	5.87c	6.49b

Untreated mean for Desiree=8.20, Untreated mean for Cardinal=7.64, LSD for interaction=0.35

Table 3: Effect of the interaction of potato cultivars × doses × post treatment time intervals on the number of ***Myzus persicae***

		(Days post-treatments)				
Cultivars	Insecticides doses	27	34	41	48	55
Desiree	1	0.00 u	2.25 q	3.03 o	5.06 jk	8.37 cd
	2	0.00 u	3.12 o	4.00 n	4.75 klm	8.75 bc
	3	0.78 st	4.62 klm	5.87 h	7.43 ef	9.28 b
	4	1.25 rs	4.90 jkl	7.00fg	8.18 d	10.12a
	Untreated means	4.50	5.84	9.50	9.40	10.87
Cardinal	1	0.00 u	1.50 r	2.46 pq	4.21 mn	6.93fg
	2	0.25 tu	2.25 q	2.96 op	5.31 ij	7.90 de
	3	0.25 tu	4.00 n	5.75 hi	6.59 g	8.75 bc
	4	0.75 st	4.50 lmn	6.87 g	7.93 de	9.87 a
	Untreated means	4.25	5.53	9.00	9.00	10.43

LSD for interaction = 0.55, (An even smaller LSD would apply to any comparison with control means, in view of the larger number of replicates contributing to the control means), Means followed by a different letter are significantly different from one another ($P<0.05$), using LSD test

The interaction of cultivars × dosage rates × post treatment time intervals is given in table 3. All the dosage rates were found significantly superior to control and recorded lower number of aphids on all sampling occasions as compared with the control ($P<0.05$). Cardinal overlapped with Desiree statistically at all dosage rates on day 27. Mostly on all other sampling occasions Cardinal showed superiority over Desiree at all dosage rates, apart from overlapping with Desiree at the lowest dosage rate on days 34 and 48, while on days 41 and 55 at the two lowest doses (3, 4). The table also shows that lowest numbers of aphids were recorded on day 27 and with the passage of time as the toxicity of the dosage rates decreased, a progressive increase in aphid numbers (higher on Desiree than Cardinal) was recorded on subsequent observations.

Insecticides×post treatment time intervals also interacted with dosage rates (Table 4). Thimet 10G gave the best control throughout the experiment ($P<0.05$), apart from the same control given by Furadan 3G on day 27 at all dosage rates and also on day 41 at the lowest dosage rates of both insecticides ($P > 0.05$).

Percent parasitism

Table 5 shows that both insecticides at each dosage rate significantly reduced percent with dose reduction (though not significantly between doses 2 and 3). So a significantly parasitism compared with the control ($P<0.05$). Thimet 10G was found to be consistently more toxic to

Table 4: Effect of the interaction of the granular insecticides × doses × post treatment time intervals on the number of ***Myzus persicae***

Cultivars	Insecticides doses	Days post-treatments 27	34	41	48	55
Thimet 10G	1	0.00t	1.25r	2.12pq	2.63op	6.43h
	2	0.00t	2.00q	2.84no	3.53lm	7.53f
	3	0.28st	3.53lm	5.00j	5.56l	8.28e
	4	0.78rs	4.06kl	6.75gh	6.84gh	9.25bc
Furadan 3G	1	0.00t	2.50opq	3.37mn	6.65gh	8.87cd
	2	0.25st	3.37mn	4.12k	6.53h	9.12c
	3	0.75rs	5.09ij	6.62gh	8.46de	9.75b
	4	1.21r	5.34ij	7.12fg	9.28bc	10.75a
	Untreated means	4.37	5.68	9.25	9.20	10.65

LSD for interaction =0.55

Table 5: Effect of granular insecticides and their different dosage rates on the percent parasitism of ***Myzus persicae*** by its parasitoid (***Aphidius matricariae***) in potatoes

Insecticides	Insecticide doses 1	2	3	4	Mean
Thimet 10G	2.04	5.12	6.15	8.34	5.41
Furadan 3G	2.20	6.94	7.61	8.39	6.29
Mean	2.12c	6.03b	6.88b	8.37a	

Untreated mean=10.31, LSD for doses=1.24, (An even smaller LSD would apply to any comparison with control means, in view of the larger number of replicates contributing to the control means), Means followed by a different letter are significantly different from one another ($P<0.05$), using LSD test parasitoids than Furadan 3G at all doses. The toxicity of both insecticides decreased increased percent parasitism was recorded by the application of dose 4 ($P<0.05$), followed by doses 3 and 4, which were statistically similar with one another ($P > 0.05$) and the lowest percent parasitism was recorded by the application of dose 1 ($P<0.05$).

Emergence of *A. matricariae*

Table 6 presents the effects of insecticides and their different dosage rates on the mean percent emergence of the ***A. matricariae***. These results seem to follow very closely with the results described for the percent parasitism. The table shows that all dosage rates of both insecticides significantly reduced the percent emergence of the ***A. matricariae*** compared with the control ($P<0.05$). Furadan 3G was superior to Thimet 10G in giving a greater mean percent emergence of the parasitoids compared with the Thimet 10G. The table also shows that decreasing the dosage rates allowed the emergence of the parasitoids to increased. Significantly reduced percent emergence of the parasitoids was recorded by the application of dose 1 followed by dose 2 and dose 3. The highest mean percent emergence of the parasitoids was recorded by the application of the lowest dosage rate i.e. dose 4.

Fecundity of the parasitoid, *A. matricariae*

The means for the interaction of insecticides and their dosage rates are given in Table 7. A significantly higher numbers of eggs were recorded from the female parasitoids collected from control compared with all other treatments. Again Furadan 3G was superior at all dosage rates and gave the maximum number of eggs in the female parasitoids compared with Thimet 10G ($P<0.05$). The table also shows that decreasing dosage rates of both Furadan 3G by and Thimet 10G increased the number of mature eggs recorded from the parasitoids ($P<0.05$).

Yield

Table 8 presents the means for the interaction of insecticides×dosage rates. The table shows that all treatments other than Furadan 3G dose 4 increased yield compared with the control. Thimet 10G was superior and recorded the best yields at all dosage rates as compared with Furadan 3G. With both insecticides, the full dose did not give the highest yield and (significantly so for Thimet 10G) it was dose 2 at which maximum yields were recorded, suggesting that particularly Thimet 10G gave some phytotoxicity and also loss of biocontrol at the highest dose. Only the lowest dose of Thimet 10G showed a lower yield than the full dose treatment. By contrast, for Furadan 3G the lowest dose did not give a yield reduced significantly compared with the control.

Table 6: Effect of granular insecticides and their different dosage rates on the percent emergence of ***Aphidius matricariae*** from mummified ***Myzus persicae*** (means of 3 replicates)

	(Insecticide doses)				
Insecticides	1	2	3	4	Mean
Thimet 10G	16.66	54.16	62.50	70.83	50.00
Furadan 3G	25.00	66.66	66.66	75.00	59.37
Mean	20.83c	60.41b	64.58ab	72.91a	

Untreated mean=87.50, LSD for doses = 12.35

Table 7: Effect of the interaction of granular insecticides and their different dosage rates on the fecundity of the female parasitoid ***Aphidius matricariae***

	(Insecticide doses)				
Insecticides	1	2	3	4	Mean
Thimet 10G	96.56g	141.78e	159.15c	168.85b	141.58
Furadan 3G	109.55f	149.20d	168.60b	179.17a	151.63
Mean	103.05	145.49	163.87	174.01	

Untreated mean=200.00, LSD for interaction=2.15, LSD for doses=1.52

Table 8: Effect of the interaction of granular insecticides and their different dosage rates on the yield (t/ha) of potato crop (means of 4 replicates)

	(Insecticide doses)				
Insecticides	1	2	3	4	Mean
Thimet 10G	13.07b	15.75a	11.96bc	11.14cd	12.98
Furadan 3G	11.27cd	11.91bc	10.83cd	10.19d	11.05
Mean	12.17	13.83	11.39	10.67	

Untreated mean=9.33, LSD for interaction=1.59, LSD for doses=1.13, (An even smaller LSD would apply to any comparison with control means, in view of the larger number of replicates contributing to the control means), Means followed by a different letter are significantly different from one another ($P<0.05$), using LSD test

Discussion

The organophosphate insecticide Thimet 10G was more effective in reducing aphid populations than the carbamate insecticide, Furadan 3G. These results corroborate those of Rizvi ***et al.*** (1976), Prasadro ***et al.*** (1982) and Misra and Raj (1986) who reported that Thimet 10G was more effective against ***M. persicae*** than Furadan 3G. The highest dose of each insecticide caused maximum aphid mortality, which appeared dose dependent. This is also consistent with the results of Shorey (1961) reported that maximum numbers of aphids were killed at higher dosage rates as compared with the lower doses used. The partially resistant cultivar (Cardinal) had significantly fewer aphids than the susceptible cultivar (Desiree). The recommended dosage rates of both insecticides on the susceptible cultivar showed the same level of control as that recorded from half dosage rates on the partially resistant cultivar, also showing that the same control level was achieved at the lowest dose of Furadan 3G on the partially resistant cultivar compared with the next higher dose on the susceptible cultivar. van Emden (1990) stated that insects on resistant plant cultivars are usually smaller, slower breeding, more restless and more stressed than when on susceptible varieties. These characteristics are known to increase the susceptibility of insects to insecticides. It is therefore to be expected that a lower concentration of insecticide than required for pests on a susceptible cultivar should give an equivalent kill on a cultivar that is antibiotic. This phenomenon was indeed shown by Selander ***et al.*** (1972) for ***M. persicae*** on chrysanthemum in the laboratory. The concentration of parathion needed to kill half the population (LC 50) on a susceptible variety was double that needed on one that was partially resistant.

Fewer aphids were recorded after the 27th day (Ist time interval) of the insecticides application compared with all other post treatment time intervals. Also the number of aphids increased with each increment of time interval. No aphids were recorded at doses 1 and 2 of Thimet 10G and dose 1 of Furadan 3G on the 27th day after application. Misra and Raj (1986) reported that the population of aphids increased with post treatment time intervals i.e. from 27 to 62 days after insecticide application. They found a progressive increase in aphid numbers as the post treatment time intervals increased and recorded maximum number of aphids on day 62 after the Furadan application followed by Thimet 10G on the same day. The aphid population in the untreated plots also increased with the time intervals, but as compared with the treated plots, lower increased rate was recorded. This may be because, in the treated plots especially at the highest dosage rates the natural enemies population might be affected sufficiently which also help in reducing the aphid populations. So therefore higher rate of population increase was recorded in the treated plots as compared with the untreated plots.

Percent parasitism, emergence and the number of mature eggs extracted from female parasitoids were depressed by both insecticides, but less so by Furadan 3G. Singh ***et al.*** (1994) studied the effect of seven insecticides including Furadan 3G and Thimet 10G on Telonomus dignoides Nixon (Scelionidae; Hymenoptera) an egg parasitoid of yellow stem borer, Scirpophaga incertulus (Walker) (Pyralidae; Lepidoptera). They found that both these insecticides decreased parasitism compared with the untreated control. The lowest percent parasitism was recorded at the highest dosage rates and better percent emergence was recorded as dose decreased.

The maximum number of mature eggs was found with the lowest dosage rate of Furadan 3G followed by the lowest dosage rate of Thimet 10G.

The partially aphid-resistant Cardinal showed a higher yield, due to aphid resistance both in untreated and insecticide treated plots than Desiree. Highest yield of potatoes was recorded with the application of Thimet 10G at half of the recommended dosage rate.

The overall conclusions from this experiment was that the highest doses of each insecticide caused maximum aphid mortality, but on the other hand caused significant reduction in the percent parasitism of ***M. persicae*** by ***A. matricariae***, its emergence rate and fecundity. Dose 2 of both insecticides seemed to provide a satisfactory level of control on Cardinal, because it reduced the number of aphids sufficiently and also did not damage parasitism, emergence, or fecundity of the parasitoids generally. The highest yield was achieved with both insecticides at this dose. Although percent parasitism, emergence and fecundity of the parasitoids with dose 3 and dose 4 of both the insecticides was good, they gave increased aphid numbers. Also the yield was lower compared with dose 2.

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