Asian Journal of Plant Sciences

ISSN 1682-3974

science alert

ANSInet
an open access publisher
http://ansinet.com

Asian Journal of Plant Sciences 2 (12): 925-931, 2003
ISSN 1682-3974

Effects of Two Potential Pest Management Components, Intercropping and Yellow Sticky Plastic Sheet Traps in Two Differentially Resistant Potato Cultivars for the Management of *Myzus persicae* (Sulzer)

A.U.R. Saljoqi and [1]H.F. Van Emden
Department of Plant protection, NWFP Agricultural University, Peshawar, Pakistan
[1]Department of Horticulture, School of Plant Sciences, University of Reading,
Whiteknights P.O. Box 221, Reading, RG6 6AS, England, United Kingdom

Abstract: Polyculture is traditionally a low-input agricultural system and is important in many developing countries. Polycultures of interplanted crops often support fewer pests at lower densities than monoculture and tend to increase number of natural enemies. Also Yellow Sticky Plastic Sheet Traps have proved useful for trapping aphids. A field study was conducted to study the effectiveness of these potential pest management techniques along with the partially resistant (Cardinal) and susceptible (Desiree) potato cultivars, by using their different combinations for the management of *Myzus persicae* (Sulzer). Berseem, *Trifolium alexandrinum* (L.) (family: Leguminosae) was used for intercropping with potatoes. The different combinations (treatments) used in this study were: 1) Cardinal-berseem mixed cropping+yellow sticky plastic sheet traps 2) Cardinal-berseem mixed cropping 3) Cardinal+yellow sticky plastic sheet traps 4) Cardinal separately+berseem (as land area equivalents in relation to the mixed cropping treatments) 5) Cardinal (sole crop). Treatments 6-10 were the same treatments, but with Desiree as the potato cultivar. All these treatments were used to evaluate their effects as management techniques for *M. persicae*, their percent parasitism, percent emergence rate of the parasitoid, *Aphidius matricariae* Haliday and yield of Cardinal and Desiree. Mixed cropping of Cardinal and berseem together with the yellow sticky plastic sheet traps reduced aphids by over 90% compared with numbers on the sole Cardinal crop. This combination proved in this experiment the most effective for reducing the aphid populations as compared with all other treatments. Maximum percent parasitism i.e. 6.97 and 6.94% (almost double that in the other treatments) was recorded in the potato berseem mixed cropping, with and without traps respectively. In the same two treatments, yield was increased significantly as compared with all other treatments. However no significant effects of any of the variable was evident on the percent emergence of *A. matricariae*.

Key words: Potato, berseem, mixed cropping, yellow sticky plastic sheet traps, *Myzus persicae, Aphidius matricariae*

Introduction

Intercropping can play an important role in reducing insect pests infestation (Root, 1973; Potts, 1990). van Emden and Wratten (1990) have given a number of examples of the effect of intercropping on insect population densities. Intercropping may reduce pest damage by attracting pests to a less valuable crop or one where the pest is less serious (van Emden, 1989). The number of aphids on potatoes undersown with grass were found generally to be smaller than the aphid numbers on potatoes not undersown with grass (McKinlay, 1985). Smith (1976a) recorded a lower number of aphids and other pest insects in cabbage plots with weeds than in weed-free plots. However, oat suffer higher infestation by cereal aphids, when intercropped with faba bean (Helenius, 1990).

Diverse agroecosystem created by multiple cropping tend to increase numbers of natural enemies (Root, 1973; O'Donnel *et al.*, 1975). Natural enemies are attracted to diverse systems of shelter, alternative prey, humidity and flowers (Dempster and Coaker, 1974; smith, 1976b). Andow (1983) reported that natural enemy population often increase and seldom decrease in polycultural systems. By contrast Risch *et al.* (1983) claimed that natural enemies are rarely responsible for the herbivore reductions, which often occur, in diversified systems.

Yellow traps have been used by different previous workers and were found very effective as a management technique for aphids (Broadbent, 1948; A'Brook, 1973). Many aphids are attracted to yellow colours (Moericke, 1950; Hottes, 1951). Zimmerman-Gries (1979) used sticky yellow polythene sheets around potato plots and reported a remarkable reduction in the spread of aphid-transmitted potato leaf roll virus. The same result was found by Rogerson (1975) when he compared two automobile greases as the adhesive on sticky traps for aphids and found that light yellow calcium grease was superior to darker lithium grease. The information regarding the use of Yellow sticky plastic sheet traps as a management technique for *Myzus persicae* (Sulzer) in the potato crop is still lacking.

Berseem, *Trifolium alexandrinum* (L.) belongs to the family Leguminosae, is a major fodder crop in Pakistan and it is grown at the same time as potatoes. Potato-berseem intercropping is a common practice in most of the areas in Pakistan. A field study was therefore conducted to explore the possibilities of reducing *M. persicae* populations on potatoes by studying the effectiveness of potato-berseem mixed cropping, land area equivalents in relation to the mixed cropping treatments and yellow sticky plastic traps as management techniques for populations of *M. persicae,* their percent parasitism, percent emergence rate of the parasitoid, *Aphidius matricariae* Haliday and yield of partially resistant (Cardinal) and susceptible (Desiree) potato cultivars.

Materials and Methods

This field experiment was laid out in a randomized complete block design on an area of 1667 m^2 (63.50×26.25 m) as 30 plots, representing 10 treatments in three replications, during the autumn of 1996. The size of each plot was 52.5 m^2. The following ten treatments were used.

- Cardinal-berseem mixed cropping+yellow sticky plastic sheet traps
- Cardinal-berseem mixed cropping
- Cardinal+yellow sticky plastic sheet traps
- Cardinal separately+berseem (as land area equivalents in relation to the mixed cropping treatments).
- Cardinal (sole crop)

Treatments 6-10 were the same treatments, but with Desiree as the potato cultivar.

In the intercropped plots the potato cultivars were mixed grown with berseem (no distinct rows for berseem). In the land area equivalents plot, the area of the plot was divided into two halves one of which was sown with potatoes and the other with berseem. Yellow sticky plastic sheet traps measuring 60×30 cm were fixed 1 m above the ground level. The traps were operated from emergence of the potato seedlings to harvest. One trap per plot was erected in the middle of each plot. Mobil engine oil (SAE 40/60) was used on these sheets as an adhesive. The aphids stuck to these traps were counted at weekly intervals. All the treatments were compared to the sole potato crop as the control.

The data recorded were: the number of *M. persicae*, percent parasitism, emergence rate of the parasitoid and yield of potatoes. When the aphid infestation started, aphids were counted at weekly intervals. 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 (Singh and Verma, 1985; Trivedi and Misra, 1989) Percent parasitism was recorded after every two weeks. 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 4th 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:

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

Percent emergence rate of the parasitoid was recorded once at the middle of the cropping season. 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:

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

After hand harvesting the crop, the yield obtained was weighed separately for each plot in kg, which was then converted to t ha^{-1}. 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 Duncun's Multiple Rang Test (DMRT) (Steels and Torrie, 1960).

The abbreviations used in this paper for the treatments to which the two potato cultivars were subjected are shown in Table 1.

Table 1: Abbreviations used for the treatments

S.No.	Name of the treatment	Treatment identifier
1.	Potato-berseem mixed cropping+yellow sticky plastic sheet traps	PB+YT
2.	Potato-berseem mixed cropping	PB
3.	Potato crop+yellow sticky plastic sheet traps	P+YT
4.	Land area equivalents (potato and berseem)	LAE
5.	Sole crop potatoes	P

Results

Population of *M. persicae*: Table 2 shows the means for the interaction of cultivars×treatments. The sole crop plots show as expected that Cardinal had fewer aphids than Desiree and this phenomenon was seen in the other treatments also. In some cases aphid numbers were half as large again on Desiree as on Cardinal, but the difference was fourfold with the combination of intercropping with traps, when very few aphids were found on Cardinal. All treatments gave significantly lower aphid numbers than the sole crop, but the effect of intercropping was significantly greater than the same two crops grown as land area equivalents.

The means for the interaction of cultivars×time intervals are given in Table 3. On both cultivars, the population of aphids increased with the passage of time up to a peak at week 7. The lowest number of aphids was recorded on the last week of the observations, after which the crop was harvested. The table also shows that again overall Cardinal had fewer aphids than Desiree.

The treatments also interacted with the time intervals (Table 4). All the treatments significantly depressed the aphids population compared with the control ($P<0.05$). Lower number of aphids was recorded initially in PB+YT followed by PB, P+YT and LAE and these numbers consistently increased with the passage of time up to week 7, when the highest number of aphids was recorded and the numbers then started to decline on each treatment respectively. Low numbers of aphids were recorded mostly in the last week of data recording.

Percent parasitism: Table 5 shows that the percent parasitism recorded on the intercrop, whether with or without traps was significantly higher than in all other treatments ($P<0.05$). The percent parasitism recorded on the intercrop was statistically higher than with land area equivalents, which gave no improvement in parasitism over the sole crops. There was a progressive increase in percent parasitism up to week 7 ($P<0.05$), which coincided with peak aphid numbers (Table 5).

Emergence of *A. matricariae*: Means for the effect of cultivars, treatments and their interactions are given in Table 6. No significant effects of any of the variables were evident.

Aphids on yellow sticky plastic sheet traps: In both PB+YT and P+YT, the number of aphids trapped on the YT increased with time up to a peak at week 7. The lowest numbers of aphids were recorded on the YT in both treatments on the last week of the observations (Table 7). These results seem to follow very closely the trend of the results described for the numbers of aphids recorded on the plants leaves at different time intervals. Fig. 1 shows the relationship of the number of aphids on the six leaves of the potato plants and on the yellow sticky plastic sheet traps in PB+YT and in P+YT at different time intervals (weeks). The model $Y = 52.342X-9.9783$ explained 86% variability. The t-test value (6.539) was significant at $P<0.001$. This suggested that there was a strong positive relationship between the number of aphids recorded on the YT and on the crop plants at different time intervals. For the number of aphids on the six leaves of the potato plants and on the yellow sticky plastic sheet traps in P+YT at different time intervals, the model $Y = 33.486x-104.27$ explained 96% variability. The t-test value (12.289) was significant at $P<0.001$, which also showed strong positive relationship.

Yield: Table 8 shows that PB+YT and PB had yields statistically inseparable from each other ($P>0.05$), but significantly higher than in all other treatments ($P<0.05$). Yellow traps gave some control but not as much as intercropping. The lowest yield was recorded from LAE, which was statistically similar to P (control) ($P>0.05$).

Discussion

The population of *M. persicae* was significantly reduced in all treatments compared to the sole crop, for both potato cultivars. PB+YT had up to 79% fewer aphids compared with the control and was the most effective treatment for reducing aphid populations in both cultivars, followed by PB, P+YT and LAE. Root (1973) and Andow (1992) suggested that herbivores were more likely to find and remain on host plants that occur in large, dense and pure stands due to the resource concentration factor. Koestoni and Sastrosiswojo (1985) also found 76% fewer aphids (*M. persicae*) on potato leaves when intercropped with maize or sunflower. In the present study Cardinal was superior in reducing the number of aphids compared to the Desiree. These results suggest that

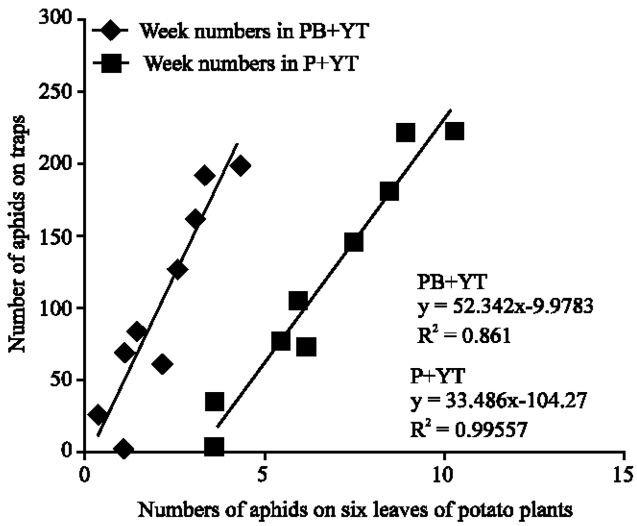

Fig. 1: Relationship between number of aphids recorded on potato plants and on yellow traps at different time intervals (weeks) in potato-berseem mixed cropping with yellow traps (PB+YT) and in sole potato crop with yellow traps (P+YT)

partial plant resistance further increased the effectiveness of intercropping in suppressing the aphid population. No past work was found in the literature search where an experiment has previously compared partially resistant and susceptible plants in an intercropping system.

In LAE higher number of aphids was recorded compared with PB with or without traps. The reason may be the visual and olfactory effects produced by the mixed cropping which affect the behaviour and colonization of *M. persicae*. It may be because of the dilution effect of having more plants to choose from, because the aphids were also observed on berseem crop. Intercropping is known to have changed the micro-climate of crops and this can affect insect development (Potts, 1990). Also in LAE the bare soil was the same as in the P. The dense plant cover provided by the intercropping of potatoes with berseem was probably the main cause of the reduction in the invasion and subsequent colonization by aphids. Smith (1976a) obtained similar results on unweeded Brussels sprouts. She discussed the factors affecting insect colonization of brassicas grown on different backgrounds and concluded that insect preference for plants which stand out against bare soil is partly due to their phototactic reaction and more importantly to their optomotor reaction to the plants 'looming up' along their path (Kennedy *et al*., 1961). Thus the effect is accentuated when plants are high-lighted against a bare soil background which is characteristic of brassica crops most of the time. Plant cover might, therefore, diminish the optomotor landing response of the migrating insect with intercropping providing the appropriate level of camouflage. When clover was used as the intercrop, a larger reduction of *Brevicoryne brassicae* (L.) infestations was obtained than from strips of clover between the brassica rows (O'Donnell and Coaker, 1975). In the interaction of cultivars×time intervals (weeks) and also treatments×time intervals, the population of aphids increased with time, up to week 7, when the peak population of aphids was recorded. After this numbers started to decline, perhaps due to poor foliar growth, very low temperature (0 to-3°C) and heavy rainy weather conditions. These results agree with those of Hughes (1963) and Way (1968), who reported that plants become unsuitable for aphids, either by aging or by the damage inflicted by the insects and reproductive rate of the population declines. Carter (1972) and Watt and Dixon (1981) reported that adverse changes in weather and food quality can result in very poor survival of aphids. Adams (1962) stated that the critical low temperature for survival of apterae of *M. persicae* is 2 °C. Heie and Peterson (1961) also suggested that *M. persicae* can survive only at above 4 °C temperature.

Yellow sticky plastic sheet traps were found a good management technique for suppressing the aphid populations. In both treatments the number of aphids stuck on the YT was strongly correlated with the number of aphids on the crop plants on each time interval. Previous researchers, Rehman and Shahid (1988), who also used yellow plastic sheets and found them very effective against aphids.

The highest percent parasitism was recorded on PB with or without traps which was significantly higher than on all other treatments ($P<0.05$). A likely reason for these differences in percent parasitism is that the berseem crop may have been releasing some volatile compounds stimulating parasitism. Khan *et al.* (1997) investigated the effectiveness of combined cropping regimes of cultivated and wild plants for reducing stem-borer damage. In a field trial a non-host molasses grass, *Melinis minutiflora* P. Beauv. planted in alternate rows with maize resulted in a significant increase in parasitism by the larval braconid parasitoid, *Cotesia sesamiae* (Cameron). They attributed this increase to the attraction of *C. sesamiae* by the λ volatile component released by intact *M. minutiflora,* which attracts parasitoids and is produced by herbivore-damaged plants and is implicated more widely as a cue for stimulating parasitism and predation. Raymundo and Alcazar (1983) also noted an increase in the numbers of *Diglyphus* spp. which parasitised the leaf miner fly *Liriomyza huidobrensis* Blanchard in a potato-wheat

Table 2: Effect of the interaction of potato-berseem mixed cropping+yellow sticky plastic sheet traps (PB+YT), potato-berseem mixed cropping (PB), potato crop+yellow sticky plastic sheet traps (P+YT), land area equivalents (potato and berseem crops) (LAE) and sole crop potatoes (P) × partially resistant (Cardinal) and susceptible (Desiree) potato cultivars on the number of *Myzus persicae* (Sulzer), per six leaves of potato plants (means of 3 replicates)

	Treatments					
Cultivars	PB+YT	PB	P+YT	LAE	P	Mean
Cardinal	0.88i	3.35h	5.45g	7.05e	9.53b	5.25
Desiree	3.40h	5.81f	7.85d	8.91c	10.77a	7.35
Mean	2.14	4.58	6.65	7.98	10.15	

Means followed by a different letter are significantly different from one another (P<0.05; DMRT method)

Table 3: Effect of the interaction of partially resistant (Cardinal) and susceptible (Desiree) potato cultivars×time intervals (weeks) on the number of *Myzus persicae* (Sulzer) per six leaves of potato plants (means of 3 replicates)

	Weeks									
Cultivars	1	2	3	4	5	6	7	8	9	Mean
Cardinal	2.78k	4.16i	4.43i	6.03g	6.45f	7.23e	8.51d	4.91h	2.78k	5.25
Desiree	3.65j	6.03g	6.46f	8.35d	9.46c	10.11b	11.50a	6.96e	3.63j	7.35
Mean	3.21	5.10	5.45	7.19	7.95	8.67	10.00	5.94	3.20	

Means followed by a different letter are significantly different from one another (P<0.05; DMRT method)

Table 4: Effect of the interaction of potato-berseem mixed cropping+yellow sticky plastic sheet traps (PB+YT), potato-berseem mixed cropping (PB), potato crop+yellow sticky plastic sheet traps (P+YT), land area equivalents (potato and berseem crops) (LAE), sole crop potatoes (P) × different time intervals (weeks) on the number of *Myzus persicae (Sulzer),* per six leaves of potato plants (means of 3 replicates)

	Weeks									
Treatments	1	2	3	4	5	6	7	8	9	Mean
PB+YT	0.37z'	1.12z	1.41z	2.58xy	3.08vw	3.29uv	4.29s	2.12y	1.04z	2.14
PB	2.70wx	3.41uv	3.75tu	5.00pq	5.70no	6.62m	7.41k	4.25s	2.37xy	4.58
P+YT	3.62u	5.41op	5.95n	7.45k	8.50j	8.91ij	10.25ef	6.12n	3.62u	6.65
LAE	4.37rs	6.79lm	7.12kl	9.45gh	9.62g	10.50e	12.45c	7.37k	4.16st	7.98
P	5.00pq	8.75ij	9.00hi	11.45d	12.87c	14.04b	15.62a	9.83fg	4.83qr	10.15
Mean	3.21	5.10	5.45	7.19	7.98	8.67	10.00	5.94	3.20	

Means followed by a different letter are significantly different from one another (P<0.05; DMRT method)

Table 5: Effects of potato-berseem mixed cropping+yellow sticky plastic sheet traps (PB+YT), potato-berseem mixed cropping (PB), potato crop+yellow sticky plastic sheet traps (P+YT), land area equivalents (potato and berseem crops) (LAE) and sole crop potatoes (P) on the percent parasitism of *Myzus persicae* (Sulzer) by the parasitoid, *Aphidius matricariae* Haliday, at different time intervals (means of 3 replicates)

	Weeks					
Treatments	1	3	5	7	9	Mean
PB+YT	3.56	6.52	8.34	11.71	3.80	6.79a
PB	3.98	6.30	8.76	11.68	3.97	6.94a
P+YT	1.73	2.53	4.24	7.09	1.26	3.37b
LAE	1.79	2.94	4.43	7.13	2.25	3.71b
P	1.60	2.48	4.15	6.83	1.20	3.25b
Mean	2.53d	4.15c	5.98b	8.89a	2.50d	

Means followed by a different letter are significantly different from one another (P<0.05; DMRT method)

Table 6: Effect of the potato-berseem mixed cropping+yellow sticky plastic sheet traps (PB+YT), potato-berseem mixed cropping (PB), potato crop+yellow sticky plastic sheet traps (P+YT), land area equivalents (potato and berseem crops) (LAE) and sole crop potatoes (P) in partially resistant (Cardinal) and susceptible (Desiree) potato cultivars on the percent emergence of the parasitoid, *Aphidius matricariae* Haliday (means of 3 replicates)

	Treatments					
Cultivars	PB+YT	PB	P+YT	LAE	P	Mean
Cardinal	76.66	75.00	73.00	71.66	71.66	73.66
Desiree	75.00	75.00	70.00	70.00	73.33	72.66
Mean	75.83	75.00	71.66	70.83	72.50	

Table 7: *Myzus persicae* (Sulzer), captured by the yellow sticky plastic sheet traps of size (60×30 cm) in potato-berseem mixed cropping and in potato crop, at different time intervals (means of 3 replicates)

	Weeks									
Treatments	1	2	3	4	5	6	7	8	9	Mean
PB+YT	25.33	68.33	84.00	126.50	162.66	192.50	198.83	60.83	2.00	102.33
P+YT	35.33	77.50	104.66	146.16	180.50	220.50	224.16	74.16	3.50	118.50
Mean	30.33f	72.91de	94.33d	136.33c	171.58b	206.50a	211.50a	67.50e	2.75g	

Means followed by a different letter are significantly different from one another (P<0.05; DMRT method)

Table 8: Effect of potato-berseem mixed cropping+yellow sticky plastic sheet traps (PB+YT), potato-berseem mixed cropping (PB), potato crop+yellow sticky plastic sheet traps (P+YT), land area equivalents (potato and berseem crops) (LAE) and sole crop potatoes (P) on the mean yield (t/ha) of potato crop (means of 3 replicates)

Treatments	Mean yield (t ha^{-1})
PB+YT	14.05a
PB	13.20a
P+YT	9.18b
LAE	5.73c
P	7.32bc

Means followed by a different letter are significantly different from one another (P<0.05; DMRT method)

intercrop. They attributed this increase to the attraction of *Diglyphus* by the sweet smell of wheat at anthesis.

Among the time intervals (weeks), maximum percent parasitism was recorded in week 7, maybe because of favourable temperature (20-25°C) and weather conditions. Initially the temperature was high, gradually becoming cool and in the last week there was freezing temperature and very heavy rain. These results agree with those of Campbell and Mackauer (1977) and Tamaki *et al.* (1980), who suggested that among the biotic and abiotic factors influencing the natural enemy and its host in the field, temperature would have the greatest effect on the parasitoid, *Diaeretiella rapae* (M'Intosh), because temperature greatly influences parasitoid biology and abundance. Shijko (1989), who studied the different parameters for mass rearing of *A. matricariae* under different constant temperatures, recorded 36.2, 78.3 and 121.9 eggs per female at temperatures of 15, 20 and 25 °C respectively. He also found a deterioration of all the biological parameters of *A. matricariae* when the temperature rose above 30 °C. He reported that at 25 °C, the optimal temperature for the parasitoid, the parasitoid increased 7.5-fold per week. *Aphidius smithi* Sharma and Subba Rao was exposed to six constant temperatures by Wiackowski (1961), who also reported no development at 1.7 or 32.2 °C.

The highest yield was recorded when aphid numbers were lowest i.e. in the intercropped plots. Moreover, berseem belongs to family Leguminosae, which stores nitrogen in the nodules present on the roots. It is possible that this nitrogen might have been used by the potato crop for growth and development. Wilson and Burton (1938) reported that in pot studies, legumes could produce nitrogen during growth and so benefit an associated non-legume. Willey and Osiru (1972) also observed higher yield of maize per plant in the maize-bean intercrop than monocrop maize.

References

McKinlay, R.G., 1985. Effect of under sowing potatoes with grass on potato aphid numbers. Ann. Applied Biol., 106: 23-29.

Root, R.B., 1973. Organization of a plant arthropod association in simple and diverse habitats : the fauna of collards (*Brassica oleracea*). Ecological Monographs, 43: 95-124.

A'Brook, J., 1973. Observations on different methods of aphid trapping. Ann. Applied Biol., 74: 263-277.

Adams, J.B., 1962. Aphid survival at low temperatures. Can. J. Zool., 40: 951-956.

Andow, D., 1983. Plant diversity and insect populations: Interactions among Beans, Weeds and Insects. Ph.D. Thesis, Cornell University.

Andow, D., 1992. Population density of *Emposca fabae* (Homoptera : Cicadellidae) in weedy beans. J. Econ. Entomol., 85: 379-383.

Broadbent, L., 1948. Aphids migration and the efficiency of the trapping method. Ann. Applied Biol., 35: 379-394.

Campbell, A. and M. Mackauer, 1977. Reproduction and population growth of the pea aphid (Homoptera: Aphididae) under laboratory and field conditions. Can. Entomol., 109: 277-284.

Carter, C. I., 1972. Winter temperatures and survival of the green spruce aphid. Forestry Commission Forestry Record, 84: 1-10.

Dempster, J.P. and T.H. Coaker, 1974. Diversification of crop systems as a means of controlling pests. In : D.P. Jones and M. E. Solomon (Eds). Biology in Pest and Disease Control. Blackwell Scientific Publications, Oxford, pp: 106-114.

Heie, O. and B. Peterson, 1961. Investigations on *Myzus persicae* Sulz., *Aphis fabae* Scop. and virus yellows of beet (Beta virus 4) in Denmark. Condensed reports from the virus committee. Danish Acad. Technical Sci., Copenhagen, pp: 52.

Helenius, J., 1990. Plant size, nutrient composition and biomass productivitiy of oats and aba beans in intercropping and the effect of controlling *Rhopalosiphum padi* (Hom., Aphididae) on these properties. J. Agri. Sci. Finland, 62: 21-31.

Hottes, F.C., 1951. A method for taking aphids in flight. Pan-Pacific Entomologist, 27: 190.

Hughes, R.D., 1963. Population dynamics of the cabbage aphid *Brevicoryne brassicae*. J. Anim. Ecol., 32: 393-424.

Kennedy, J.S., C.O. Booth and W.J.S. Kershaw, 1961. Host finding by aphids in the field, III. visual attraction. Ann. Applied Biol., 49: 1-21.

Khan, Z.R., K.A. Nyarko, P. Chiliswa, A. Hassanali, S. Kimani, W. Lwande, W.A. Overholt, J.A. Pickett, L.E. Smart, L.J. Wadhams and C.M. Woodcock, 1997. Intercropping increases parasitism of pests. Nature, London, 388: 631-632.

Koestoni, T. and S. Sastrosiswojo, 1985. Pengaruh pola tanam kentang-jagung, kentang-bunga matahari dan kentang-gandum terhadap tingkat populasi kutu daun persik (*Myzus persicae* Sulz.) pada tanaman kentang di lapangan. Hama dan Penyakit, Balai Penelitian Hortikultura, Lembang, Indonesia, pp: 54-59.

Mead, R., R.N. Curnow and A.M. Hasted, 1993. Statistical Methods in Agriculture and Experimental Biology (2nd Ed.). Chapman and Hall, London, pp: 514.

Moericke, V., 1950. Uber den Farbensinn der Pfirsichblattlaus Myzodes persicae Sulz. Zeitschrift für Tierpsychologie, 7: 265-274.

O'Donnell, M.S. and T.H. Coaker, 1975. Potential of intercrop diversity for the control of brassica pests. Proceedings of the 8th British Insecticide and Fungicide Conference, Brighton, 1: 101-107.

Potts, M. J., 1990. The influence of intercropping on pests and diseases of potato in warm climates with special reference to their control. Field Crops Res., 25: 133-144.

Raymundo, S.A. and J. Alcazar, 1983. Effects of polyculture (mix cropping) on the incidence and severity of potato pests and diseases. In : W.J. Hooker (Ed.). Research for the potato in the year 2000. pp. 159-160. Proceedings of the International Congress in Celebration of the Tenth Anniversary of the International Potato Center, 22-27 February 1982, Lima, Peru. CIP, Lima.

Rehman, A.U. and M. Shahid, 1988. Control of sarsoon aphid with color traps. M. Sc. thesis, Department of Entomology, NWFP Agricultural University, Peshawar, Pakistan.

Risch, S.J. D. Andow and M.A. Altieri, 1983. Agroecosystem diversity and pest control : data, tentative conclusions and new research directions. Environ. Entomol., 12: 625-629.

Rogerson, J.P., 1975. Grease-coated traps for catching alate aphids in potato crops. Entomologist's Monthly Magazine, 3: 229-230.

Shijko, E.S., 1989. Rearing and application of the peach aphid parasite, *Aphidius matricariae* (Hymenoptera, Aphidiidae). Acta Entomologica Fennica, 53: 53-56.

Singh, B.R. and S.R. Verma, 1985. Bioefficacy of some foliar insecticides against *Myzus persicae* (Sulzer) on potato. Indian J. Plant Prot., 13: 75-77.

Smith, J.G., 1976a. Influence of crop background on aphids and other phytophagous insects on Brussels sprouts. Ann. Applied Biol., 83: 1-13.

Smith, J.G., 1976b. Influence of crop back ground on natural enemies of aphids on Brussels sprout. Ann. Applied Biol., 83: 15-29.

Steels, R.G. and J.H. Torrie, 1960. Principles and Procedures of Statistics. McGraw Hill, New York, pp: 481.

Tamaki, G., M.A. Weis and G.E. Long, 1980. Impact of high temperatures on the population dynamics of the green peach aphid in field cages. Environ. Entomol., 9: 311-337.

Trivedi, T.P. and S.S. Misra, 1989. Chemical control of *Myzus persicae* (Sulzer) potato in deccan plateau of maharshtra. Indian J. Plant Prot., 17: 109-111.

Van Emden, H.F. (Ed.), 1989. Pest Control (2nd Ed.). Edward Arnold, London, pp: 117.

Van Emden, H.F. and S.D. Wratten, 1990. Tri-trophic interactions involving plants in the biological control of aphids. In : D.C. Peters, J.A. Webster and C.S. Chlouber (Eds.). Aphid-Plant Interactions: Populations to Molecules. USDA/Agricultural Res. Service, Oklahoma State University, pp: 29-43.

Watt, A.D. and A.F.G. Dixon, 1981. The role of cereal growth stages and crowding in the induction of alatae in *Sitobion avenae* and its consequences for population growth. Ecological Entomol., 6: 441-447.

Way, M.J., 1968. Intra-specific mechanisms with special reference to aphid population. In : T.R.E. Southwood (Ed.). Insect Abundance. Royal Entomological Society, London, pp: 18-36.

Wiackowski, S.K. and I. Wiackowska, 1961. Wstepne proby introdukejii aklimatyzacji obcysh ofidofagow w polsce. Postepy Nauk Rolniczych, 35: 211-218.

Willey, R.W. and D.S.O. Osiru, 1972. Studies on mixtures of maize and beans with particular reference to plant populations. J. Agri. Sci., 79: 517-529.

Wilson, P.W. and J.C. Burton, 1938. Excretion of nitrogen by leguminous plants. J. Agri. Sci., 28: 334-343.

Zimmerman-Gries, S., 1979. Reducing the spread of potato leaf hopper roll virus in seed potato by sticky yellow polyethylene sheets. Phytoparasitica, 7: 41. (Reveiw of Applied Entomol., (A), 68: 132, 1980).