Pakistan J. Zool., vol. 51(4), pp 1537-1545, 2019. DOI: http://dx.doi.org/10.17582/journal.pjz/2019.51.4.1537.1545

Habitat Manipulation through Intercropping for the Management of Codling Moth *Cydia pomonella* (Linnaeus) (Lepidoptera: Tortricidae) in Swat Pakistan

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Article Information
Received 12 June 2016
Revised 22 March 2018
Accepted 24 July 2018
Available online 28 May 2019

Authors' Contribution
HZ designed the experiments and collected data. AURS analysed the data and wrote the manuscript.

Key words
Habitat manipulation, Intercropping, Management, *Cydia pomonella.*

ABSTRACT

Habitat manipulation through intercropping (*Brassica campestris*, Brassacicaceae), *Glycine max*, leguminacae), *Trifolium alexandrinum*, Fabaceae) and *Triticum aestivum*, Poaceae) in the apple orchard were a substantial effect on the management of *C. pomonella* (L). Minimum mean fruit drop were recorded for the intercrop Apple + Trifolium (2.87) which were significantly lower than all other intercrops including control (Apple sole). Likewise, minimum percent infestation (57.19%) were recorded for the Apple + Trifolium, whilst maximum 85.86% were observed in the Apple sole. Same intercrop was also good impact in curtailing *C. pomonella* mean moth catch (1.46) through traps and maximum percent parasitism of *Ascogaster quadridentata* (Hymenoptera: Braconidae) and *Hyssopus pallidus* (Hymenoptera: Eulophidae) were 40.11 and 30.09%, respectively, in the said cropping system. Likewise, highest yield (kg/ plant) were produced by the plots having Apple + Trifolium intercrops (76.62±1.11), whilst minimum yield were attributed to Apple + Wheat (61.47±1.11) followed by sole (52.75±1.23). The results further confirmed that maximum yield losses (31.51%) were avoided by the intercrop Apple + Trifolium and gain in the yield (43.90%) over control was also featured to the same intercrop, whilst all other intercrops were inferior in avoiding the loses and gain in the yield.

INTRODUCTION

Habitat manipulation through intercropping is the cultivation of two or more crops within the same field, is a common method to increase beneficial insect diversity within agro-ecosystems (Vandermeer, 1989; Theunissen, 1994). Intercropping crop plants with flowering species such as clovers, mustard, soybean *etc*. can provide a favorable habitat for a variety of beneficial insects that may not otherwise survive in a single crop environment and hence intercropping may provide natural pest management by increasing the abundance and diversity of insect natural enemies in the agro-ecosystem (Theunissen, 1994). Diverse systems encourage complex food webs that involve more interactions among vegetation, pests and natural enemies, providing resources for a diverse group of organisms and allowing for alternative resources and food sources. Thus, polycultures and natural ecosystems with higher diversity tend to be more stable and less subject to fluctuations in pest and disease populations (Altieri and Nicholls, 2004). The factors that influenced pest population in intercropping might be physical protection from wind, shading, prevention of dispersal (Altieri, 1987) production of adverse stimuli, olfactory stimuli camouflaged by main crop, presence of natural enemies (Russell, 1989) and availability of food (Fukai and Trenbath, 1993). Research in diversified agro-ecosystem demonstrated that these systems tend to support less herbivores load than corresponding monoculture (Altieri and Letourneau, 1982).

The association between various microclimate variables and insect pests and natural enemies is substantial and there is a need to quantify them in a different cropping systems. Intercropping is one of the important cultural practice in pest management is based on the principle of reducing insect pests by increasing the diversity of an ecosystem (Letourneau and Altieri, 1983).

Provision of food resources by plants interspersed within crops can play an important role in increasing parasitoid and predator abundance (Kruess and Tscharntke, 1994; Landis *et al*., 2000; Tscharntke *et al*., 2005) and plants may also promote beneficial by providing overwintering sites, refuge from disturbance such as crop harvesting and access to alternative hosts (Tscharntke *et al*., 2005). A number of studies have shown that an increase in natural enemies following provision of plants can contribute to the biological control of pests within a crop (Hickman and Wratten, 1996; Hooks and Johnson, 2003; Gurr *et al*.,

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0030-9923/2019/0004-1537 $ 9.00/0

2004; Ponti *et al*., 2007). Provision of intercrops increased abundance of natural enemies and resulted in decreased pest infestation from cabbage aphids (Hooks and Johnson, 2003). Intercrops in corn and soybean increased the abundance of carabid beetle predators and consumption of European corn borer *Ostrinia nubilalis* (Hubner) (Lepidoptera; Crambidae) pupae used as sentinel prey (Prasifka *et al*., 2006). An increase in predators including ladybird beetles and fire ants resulted in reduced levels of Heliothine pests in conservation tillage cotton with cover crops compared with conventional tillage cotton without cover crops (Tillman *et al*., 2004). However an increase in numbers of parasitoids and predators through cover crops may not necessarily improve pest control particularly if natural enemies do not target pests (Baggen and Gurr, 1998).

The present studies were therefore undertaken to know the impact of habitat manipulation through intercropping in the apple orchards for the effective management of *Cydia pomonella* (L.), its associated parasitoids and ultimately on apple yield for two consecutive years.

MATERIALS AND METHODS

The experiment was laid out in a Randomized Complete Block Design (RCBD) with single factor having five treatments including control and was replicated four times. Mustard *Brassica campestris*, (Brassacicaceae), soybean *Glycine max* (leguminaceae), Trifolium *Trifolium alexandrinum*, (Fabaceae) and wheat *Triticum aestivum*, (Poaceae) were intercropped with apple. Five apple orchards of a red delicious variety having same age and size were selected from in same nearer locality. Each orchard was consists of 25-30 plants having plant to plant and row to row distance 18 x 18 fts. Three rows of apple trees were kept as buffer zone between each replicate and treatment. The intercrops were sown between the rows on their appropriate time of sowing for habitat manipulation. Observations were recorded on number of percent infested dropped fruits on fortnightly basis by using the following formula:

$$\text{Infestation (\%)} = \frac{\text{Infested fruit with } C.pomonella \text{ larvae}}{\text{Total dropped fruit}} \times 100$$

The effect of these intercrops were evaluated on two associated biological control agents *i.e.* egg-larval parasitoid *Ascogastor quadridentata* (Hymenoptera: Braconidae) and gregarious ectoparasitoid *Hyssopus pallidus* (Hymenoptera: Eulophidae).

Ascogaster quadridentata

All the apple trees in the respective intercrops were banded with corrugated cardboard bands having opening less than 1/20 inch (1.3 mm) with the folds facing down to collect parasitized *Cydia pomonella* larvae migrating down the trunk to pupate in Mid-July and at the end of September during the year 2012 and 2013. Bands were wrapping around the trees trunk at a distance of 2-3 feet from the ground and were replaced weekly. Corrugated bands along with overwintering larvae of *C. pomonella* were kept in a wooden rearing cages (45x45x45cm) at 25±2°C and 60-70% relative humidity (R.H) (Tomkins, 1984). The cages were checked weekly for possible emergence of *Ascogaster quadridentata* and percent parasitism of adult parasitoids were determined by using following formula:

$$\text{Parasitism (\%)} = \frac{\text{No. of parasitoid emerged from parasitized } C.pomonella \text{ larvae}}{\text{Total No. of overwintering larvae in corrugated bands}} \times 100$$

Hyssopus pallidus

The effects of these different intercrops were also evaluated on another associated biological control agent *i.e.* gregarious ectoparasitoid *Hyssopus pallidus* (Hymenoptera: Eulophidae). For this purpose the dropped infested fruits with *Cydia pomonella* larvae were brought to the laboratory put them in the wooden rearing cages (45x45x45cm) on 25±2°C and 60-70% relative humidity (R.H). The cages were checked weekly for the possible emergence of this parasitoids and it's percent parasitism in the respective treatments were computed by using the following formula:

$$\text{Parasitism (\%)} = \frac{\text{No. of parasitoid emerged from infested fruit by } C.pomonella}{\text{Total infested fruit by } C.pomonella \text{ larvae}} \times 100$$

Further, a pheromone traps were also fixed in each replicate to know male adults moth activities and catches with percent drop and infestation for the effectiveness of these intercrops on fortnightly basis following the procedures of Sigsgaard (2014) with some necessary modifications.

Yield data (Kg/Plant) was taken in each replicate and treatments after harvest of fruits following the procedures of Saljoqi *et al*. (2003) with some necessary modifications. Combine mean yield of plots treated with various treatments during the year 2012 and 2013 were calculated. Finally the percent gain due to intercrops and avoidable loss in yield of the apple fruit caused by *Cydia pomonella* in each plot were determined following the procedures of Sathi *et al*. (2008) with some necessary modifications:

$$\text{Loss in yield (\%)} = \frac{T - C}{T} \times 100$$

$$\text{Gain in yield (\%)} = \frac{T - C}{C} \times 100$$

Where, T is yield obtained from treated plot (protected) and C is yield obtained from control plot (unprotected).

Standard agronomic practices were used in the apple orchard that was including normal weeding, irrigation practices, fertilization and sanitation *etc*. The apple orchard was not treated with insecticides for the management of *Cydia pomonella* and was relied only on different intercrops for habitat manipulation and conservational biological control.

Statistical analysis

The data were statistically analyzed by using analysis of variance technique appropriate for Randomized Complete Block Design (RCBD) (Steel and Torrie, 1980) by using a statistical software "Statistics 8.1®" version. The significant means were separated by Fischer's Protected LSD test at *α* 0.05 level of probability. All the replicated data regarding fruit dropped, mean infestation, Adult moth catches and percent parasitism of the parasitoids were square root transformed (√0.5+X) prior to statistical analysis.

Table I.- Treatment combinations for intercropping in the apple orchard during the year 2012 and 2013.

S. No	Tr.	Cropping system
1.	T1	Apple+Mustard (*Brassica campestris)*
2.	T2	Apple+Soybean (*Glycine max*)
3.	T3	Apple+Trifolium (*Trifolium alexandrinum*)
4.	T4	Apple+Wheat (*Triticum aestivum*)
5.	T5	Apple (sole) - Control

RESULTS

Mean fruit drop

The results pertaining to the mean drop of apple fruit disclosed that maximum mean fruit drop were recorded for apple sole (8.44), whilst the lower mean fruit drop was observed for the intercrop apple + trifolium (2.87). Apple + mustard also proved effective in reducing the mean fruit drop of apple (4.15) and ranking second after apple + trifolium in the current experiment. Nonetheless, intercrops such as apple + wheat and apple + soybean demonstrated as inferior (6.18 and 5.40, respectively) among all other intercrops in curtailing the mean fruit drop of apple fruit during the year 2012 and 2013.

Mean percent infestation

The data related to mean percent infestation due to *C. pomonella* revealed that maximum percent infestation of *C. pomonella* was observed in the apple sole (88.91 and 82.83%), whilst minimum percent infestation were noticed for the intercrop apple + trifolium (60.90 and 53.48%) and consequently exhibited very effective in curtailing the mean percent infestation of *C. pomonella* during the current experiments. Nevertheless, the intercrops such as apple + wheat (76.73 and 77.87%) and apple + soybean (66.37 and 68.26%) comparatively least effective in reducing the mean percent infestation of *C. pomonella* during the year 2012 and 2013.

Table II.- Mean dropped of the apple fruit in apple orchard having different intercropping during the year 2012 and 2013.

Cropping system	Mean dropped		Pooled Mean
	2012	2013	
Apple+Mustard	3.85^{cd} (1.96)	4.45^{cd} (2.13)	4.15^{c} (2.04)
Apple+Soybean	5.10^{bc} (2.24)	5.70^{bc} (2.41)	5.40^{bc} (2.32)
Apple+Trifolium	2.57^{d} (1.62)	3.17^{d} (1.83)	2.87^{d} (1.71)
Apple+Wheat	5.55^{b} (2.38)	6.82^{b} (2.64)	6.18^{b} (2.51)
Apple sole (control)	7.77^{a} (2.81)	9.12^{a} (3.03)	8.44^{a} (2.92)
LSD (0.05) value	1.34	1.30	1.28

Means sharing similar letters are not significantly different by Fischer's LSD test at α = 0.05. Data in the parenthesis are square root transformed (√0.5+X).

Table III.- Mean infestation of the apple fruit caused by *C. pomonella* in apple orchard having different intercrops during the year 2012 and 2013.

Cropping system	2012		2013		Pooled Mean
	Mean Infestation	Mean infestation (%)	Mean infestation	Mean infestation (%)	
Apple + Mustard	2.82 cd (1.70)	64.85	3.12cd (1.79)	65.53	2.97 cd (1.74)
Apple + Soybean	3.72 bc (1.92)	66.37	3.95 c (2.01)	68.26	3.8 bc (1.96)
Apple + Trifolium	2.05 d (1.46)	60.90	2.10 d (1.49)	53.48	2.07 d (1.47)
Apple + Wheat	4.37 b (2.12)	76.73	5.30 b (2.34)	77.87	4.83 b (2.23)
Apple sole (control)	6.90 a (2.65)	88.91	7.60 a (2.77)	82.83	7.25 a (2.71)
LSD (0.05) value	1.17	--	1.13	--	1.09

Means sharing similar letters are not significantly different by Fischer's LSD test at α = 0.05. Data in the parenthesis are square root transformed (√0.5+X).

Table IV.- Mean *C. pomonella* catch in apple orchard having different intercrops during the year 2012 and 2013.

Cropping system	Mean *C. pomonella* catch		Pooled Mean
	2012	2013	
Apple+Mustard	2.42^{cd} (1.55)	2.60^{cd} (1.53)	2.51^{c} (1.54)
Apple+Soybean	2.42^{bc} (1.73)	3.62^{bc} (1.76)	3.02^{bc} (1.74)
Apple+Trifolium	1.32^{d} (1.21)	1.60^{d} (1.27)	1.46^{d} (1.24)
Apple+Wheat	4.40^{b} (2.03)	4.62b (1.98)	4.51^{b} (2.00)
Apple sole(control)	6.60^{a} (2.48)	7.47^{a} (2.57)	7.03^{a} (2.52)
LSD (0.05) value	1.38	1.70	1.81

Means sharing similar letters are not significantly different by Fischer's LSD test at α = 0.05. Data in the parenthesis are square root transformed (√0.5+X).

Mean catches of C. pomonella *adults*

The results related to mean catches of *C. pomonella* disclosed that mean maximum number of *C. pomonella* catch were witnessed in the intercrop apple sole (6.60 and 7.47) whilst the most effective intercrop was apple + trifolium where minimum number of *C. pomonella* adults (1.32 and 1.60) were caught in the traps during both the years of studies. Nonetheless, the intercrop such as apple + mustard was also efficient in curtailing the adult moth catches in the trap (2.42 and 2.60). The intercrop such as apple + wheat and apple + soybean were least effective in the management of *C. pomonella* and reducing the moth catches (4.40 and 4.62; 2.42 and 3.62, respectively) during both the years of studies.

Impact on the biological control agents

The results pertaining to the percent occurrence of *Ascogaster quadridentata* disclosed that maximum number of *A. quadridentata* were attracted to the intercrops such as apple + trifolium (42.57 and 37.65%), whilst lower number of *A. quadridentata* were noticed in the intercrop Apple Sole (1.35 and 2.55%). Apple + mustard also showed good performance in attracting good number of *A. quadridentata* (23.95 and 20.12%) during the current experiment. However, other intercrops such as apple + wheat and apple + soybean inferior in attracting maximum number of *A. quadridentata* (2.64 and 5.45%; 5.22 and 6.64%, respectively) for the effective management of *C. pomonella* during the year 2012 and 2013.

Table V.- Mean percent parasitism of *A. quadridentata* in apple orchard having different intercrops during the year 2012 and 2013.

Cropping system	2012		2013		Pooled Mean
	Mean *A. quadridentata*	Parasitism (%)	Mean *A. quadridentata*	Parasitism (%)	
Apple + Mustard	0.75 b (1.05)	23.95	0.65 b (1.00)	20.12	0.70b(1.02)
Apple + Soybean	0.22 c (0.82)	5.22	0.22 c (0.82)	6.64	0.22c(0.82)
Apple + Trifolium	1.20 a (1.21)	42.57	1.12 a (1.20)	37.65	1.16a(1.20)
Apple + Wheat	0.12 c (0.77)	2.64	0.20 c (0.81)	5.45	0.16c(0.79)
Apple sole (control)	0.10 c (0.75)	1.35	0.20 c (0.81)	2.55	0.15c(0.78)
LSD (0.05) value	0.31	--	0.28	--	0.44

Means sharing similar letters are not significantly different by Fischer's LSD test at α = 0.05. Data in the parenthesis are square root transformed (√0.5+X).

Table VI.- Mean percent parasitism of *H. pallidus* in apple orchard having different intercrops during the year 2012 and 2013.

Cropping system	2012		2013		Pooled Mean
	Mean *H. pallidus*	Parasitism (%)	Mean *H. pallidus*	Parasitism (%)	
Apple + Mustard	0.40 b (0.90)	11.20	0.45 b (0.91)	1.18	0.42b (0.90)
Apple + Soybean	0.27 bc (0.84)	5.77	0.27 bc (0.84)	6.84	0.27b (0.84)
Apple + Trifolium	0.87 a (1.09)	28.67	0.95 a (1.13)	31.51	0.91a (1.11)
Apple + Wheat	0.17 bc (0.79)	5.60	0.22 bc (0.82)	5.59	0.19b (0.80)
Apple sole (control)	0.02 c (0.72)	0.41	0.15 c (0.78)	1.39	0.08b (0.75)
LSD (0.05) value	0.26	--	0.27	--	0.40

Means sharing similar letters are not significantly different by Fischer's LSD test at α = 0.05. Data in the parenthesis are square root transformed (√0.5+X).

Table VII.- Comparison of the means values for the data regarding yield (kg/ plant) at the time of harvest in apple orchard having different intercrops during the year 2012 and 2013.

Cropping system	Mean yield (kg/plant) ±SE		Pooled Mean	Avoidable losses in yield (%)	Gain in yield due to intercrops (%)
	2012	2013			
Apple + Mustard	70.87 ± 1.02 b	69.50 ± 1.59 b	70.18±1.30 b	24.13	31.80
Apple + Soybean	67.12 ±1.23 c	66.75 ±0.47 b	66.93±0.84 c	20.45	25.70
Apple + Trifolium	77.00 ±1.30 a	76.25 ±0.96 a	76.62±1.11 a	30.51	43.90
Apple + Wheat	64.00 ± 0.84 c	61.47 ± 1.11 c	62.73±0.92 d	15.12	17.81
Apple sole (control)	53.75 ± 0.72 d	52.75 ± 1.23 d	53.25±0.64 e	--	--
LSD (0.05) value	5.03	5.21	4.63	--	--

Means sharing similar letters are not significantly different by Fischer's LSD test at α = 0.05.

The data revealed that mean maximum number of *H. pallidus* occurred in the intercrop apple + trifolium (28.67 and 31.51%) and proved very effective in parasitizing *C. pomonella* population during both the years of studies, whilst the lower number of *H. pallidus* was observed in the apple sole (0.41 and 1.39%). Nevertheless, the cropping system such as apple + wheat and apple + soybean demonstrated inferior and attracted least mean percent number of *H. pallidus* (5.60 and 5.59%; 5.77 and 6.84%, respectively) during both the years of studies.

Average yield (kg/plant)

The data pertaining to the yield (kg/plant) of the apple orchard having different intercrops revealed that maximum yield was obtained from the apple + trifolium (77.00±1.30 and 76.25±0.96 kg/plant) during the year 2012 and 2013, whilst the lowest yield was recorded for the Apple Sole (53.75±0.72 and 52.75±1.23 kg/plant). However, apple + mustard also showed maximum performance (70.87±1.02 and 69.50±1.59 kg/plant) and ranking second after Apple + trifolium in increasing the yield of apple. Nonetheless, the cropping system such as apple + wheat and apple + soybean were inferior and comparatively gave least yield (64.00±0.84 and 61.47±1.11; 67.12±1.23 and 66.75±0.47 kg/plant, respectively) during both the year of studies. However, influence of intercropping in term of enhancement in yield of marketable apple fruit were found to be in order of: apple + trifolium > apple + mustard > apple + soybean > apple + wheat > apple sole (having no intercrop), which are amounting to be in order of: 77.00±1.30 and 76.25±0.96 > 70.87±1.02 and 69.50±1.59 > 67.12±1.23 and 66.75±0.47 > 64.00±0.84 and 61.47±1.11 > 53.75±0.72 and 52.75±1.23 kg/plant, respectively in both the years of studies.

The results further showed that maximum yield losses (31.51%) were avoided by the intercrop apple + trifolium and gain in the yield (43.90%) over control was also attributed to the same intercrop, while all other intercrops were inferior in avoiding the yield loses and gain.

DISCUSSION

Results regarding fruit drop are in close concordance with the findings of Abdel-Aziz *et al*. (2008), who reported that the fruit drop was decreased with the cover crop such as clovers treatments in the citrus orchard as compared to fallow orchard. These results are also corroborated with the findings of Lovat (1990) who reported the reasons of flower and immature fruit drop include lack of pollination or fertilization, drought and frost, lack of sufficient resources, defoliation, and seed and fruit loss due to insects infestation.

Thies and Tscharntke (1999) reported that in structurally complex landscapes, parasitism of the *C. pomonella* larvae were higher and infestation due to pest was lower than in apple sole having simple landscapes. Carlsen and Fomsgaard (2008) also reported that intercropping with white clover in apple and peach orchards increased arthropod community diversity and the numbers of natural enemies, reducing herbivore pest infestation incidence. However, according to Shaw (2008), In California, IGRs should probably be applied in May, but the timing needs to be verified by phenological monitoring using pheromone traps for adult males, so that the flare up and infestation of *C. pomonella* may minimized. These results are also in close validation with the findings of Harcourt (1986) who investigated that monitoring can indicate the densities of pests, the incidence of parasitism and the efficacy of the pest management program. Monitoring of pest activity and damage using pheromone traps and direct plant inspection should be done at intervals related to prevailing weather. When warm and dry conditions prevail, majority of the pest develops more quickly and typically has greater survival, hence monitoring should be more frequent at these times. Hence, the results further clarified that minimum mean infestation were afforded by intercrops apple + trifolium

(2.07) among all other intercrops including apple sole in these studies.

According to Altieri (1995) intercropping of trifoium in apple orchard has a substantial effect on the incidence of *C. pomonella* and providing nectar and pollen to beneficial insects with short probosci including parasitoid wasps and hoverflies. Results are also in close collaboration with findings of Holmgren (2002) who reported that intercropping legumes with apple has the potential to attract natural enemies such as predators and parasitoid and consequently reducing the target pest incidence in the apple orchard. It is further evident from the results that low number of adults moth (1.46) were captured in the traps having apple + trifolium as intercrops due to abundant number of its parasitoids available in the field for curtailing its population.

According to Velcheva *et al*. (2012) percent parasitism of *A. quadridentata* from the family Braconidae was 31.6% in Bulgaria having trifolium as intercrop in the young apple orchard. Haynes (1980) also reported that several legumes crops lana vetch, trifolium and *Medicago* spp. and grasses such as brome, rye and barley have been recommended to be sown annually in the orchard in the fall or early spring for attracting natural enemies such predators and parasitoid to feed on pollen and nectar and provide them shelter for the effective management of *C. pomonella.* These results are also corroborated with findings of Sigsgaard (2014) who reported that there was increased predation activity and increased mortality of *C. pomonella* larvae from near flower strips that could be predator or parasitoids induced. According to previous workers (Jervis *et al*., 1993; Landis *et al*., 2000) considerations have combined to produce an expectation that biological control can be improved by the incorporation of flowering cover crops as intercrops or other sources of sugar to parasitoids in the apple field for the effective management of *C. pomonella*. Wan *et al*. (2014) also reported that when peach orchards were covered with *Trifolium repens* the abundances of aphids and *G. molesta* decreased, respectively, by 31.4% and 33.3% and by 30.1% and 33.3% at two different orchards. Moreover, the abundance of generalist predators increased by 116.7% and by 115.8%. It is obvious from these results that apple + trifolium encouraged maximum number of *A. quadridentata* (1.16) higher among all other intercrops including apple sole.

Leius (1967) found that the presence of wild flower in the apple orchard resulted in five times increase in the parasitism of *C. pomonella* larvae by different larval parasitoids. Rieux *et al*. (1999) reported that different plants cover sown in the alleys provides a higher richness and diversity of the natural enemies such as predators and parasitoids for the effective management of pests of apple and pear compared with a bare ground. As for as natural enemies percent parasitism are concerned, our results are also supported by natural enemies hypothesis which stated that states that predators and parasitoids are more diverse and abundant, and more effective at controlling herbivore populations in the intercropped habitats compared with monoculture habitats, because of the increased availability of alternate prey, nectar sources, and suitable microhabitats (Root, 1973; Russell, 1989). Similar results were also observed in other systems, for instance, the aphid abundance decreased and the abundance of the major predator of aphids, *Chrysoperla rufilabris* increased in response to ground cover in pecan orchards (Smith *et al*., 1996). Hence these results divulged that maximum *H. pallidus* (0.91) were encouraged by apple + trifolium among all other treatments in the current studies.

These results are further corroborated with findings of previous workers (Boller *et al*., 2004; Debras *et al*., 2007) who reported that the manipulation of the orchard plant diversity may affect communities living within or near the orchard through an increase in the resource range, *i.e.* habitat, shelter and food. Herbivores, including orchard pests, polyphagous and disease vector arthropods, pollinators, and predatory and parasitoid arthropods are involved and the manipulation can result in beneficial or detrimental effects for the orchard pest control and on the yield. Agreda *et al*. (2006) also find out that the potential of leguminous crops improve the ecological stability in traditional fruit orchards. The soil cover integrating leguminous crops increases soil fertility and benefits insect populations. Yield was highest in combination with *Phaseolus acutifolius* (9.13 t/ha) and *Cajanus cajan* (7.42 t/ha). Additionally, more abundance and diversity of insect population was observed when intercropping leguminous crops between the mango trees. These results are also in close concordance with the findings of Abdel-Aziz *et al.* (2008) who reported the impact of two legume cover crops (Egyptian clover) plus the fallow as control. The results showed that fruit set and fruit yield were enhanced and fruit drop was decreased with the cover crop treatments. Intercropping cultivation methods with the Egyptian clover gave the best results regarding yield and soil fertility in the citrus orchard. It is also apparent from the results that maximum yield (76.62±1.11 kg/plant) were obtained from the apple + trifolium treatment, whilst all other treatments were inferior in producing substantial yield.

These results regarding average yield are fully corroborated with the findings of Sathi *et al*. (2008) who also calculated percent avoidable losses and gain in the yield for the management of lepidopterus pest by habitat manipulation through intercrops in India.

CONCLUSION

The results divulged that in all cropping system, adults moth catch were directly proportional to the fruit drop and infestation and inverse relationship were observed for the biological control agents and yield. Habitat manipulation through different prevailed practice of intercropping in the apple orchard were a profound effect on the fruit drop, infestation, biological control agents and yield of the orchard. Thus we conclude that trifolium is the most appropriate plant species of those tested for the attraction of its associated parasitoids *Asogaster quadridentata* and *Hyssopus pallidus.* Mustard and soybean also showed potential for attracting the said parasitoid. Different crops may be intercrop in the apple orchard for the effective management of *C. pomonella* by increasing agricultural biodiversity for the biological control agents until and unless they may not uphold the pests. To increase natural enemies' abundance early in the apple orchard, it may be possible to plant trifolium alongside mustard and soybean. Trifolium and mustard will produce large amounts of flowers early in the crop cycle, while soybean will continue to flower and attract the parasitoid and other biological control agents throughout the season. Further studies are needed that look at the potential role of competition in influencing the usefulness of flowering strips in attracting the parasitoids and other natural enemies.

ACKNOWLEDGEMENT

The research article is a part of PhD thesis of the senior author submitted to The University of Agriculture Peshawar Pakistan sponsored by Higher Education Commission of Pakistan (HEC). Financial support for the research work by the HEC is highly acknowledged.

Statement of conflict of interest

The authors declare no conflict of interest.

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