Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2021; 9(1): 993-998

Received: 16-11-2020
Accepted: 18-12-2020

Sheikh Khursheed
Ambri Apple Research Centre, Shopian, Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India

ZA Bhat
Ambri Apple Research Centre, Shopian, Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India

GH Rather
Ambri Apple Research Centre, Shopian, Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India

H Itoo
Ambri Apple Research Centre, Shopian, Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India

AR Malik
Ambri Apple Research Centre, Shopian, Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India

Bilal A Pandit
Ambri Apple Research Centre, Shopian, Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India

Corresponding Author:
Sheikh Khursheed
Ambri Apple Research Centre, Shopian, Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, India

Occurrence of insect and mite pests and their natural enemies under high density apple agro-ecosystems in Kashmir

Sheikh Khursheed, ZA Bhat, GH Rather, H Itoo, AR Malik and Bilal A Pandit

Abstract
The microclimate under high density apple orchard ecosystems is different from traditional apple orchards. Hence the insect and mite pest incidence and their natural enemies may also be different. Therefore, the field experiments were carried out at three different locations at Ambri Apple Research Center, Pahnoo and two farmer's fields at Mohandpora, and Tharen, Shopian Kashmir during 2018 and 2019. During the period of study, eleven insect pest species were found associated with apple at all three locations, which belong to four orders viz. Hemiptera (*Aphis pomi*, *Eriosoma lanigerum*, *Anuraphis* sp. *Quadraspidiotus perniciosus* and *Halyomorpha hayla*), Lepidoptera (*Archips termias*, *Malacosoma indicum* and *Lyonetia clerkella*) and Coleoptera (*Scolytus nitidus*, *Adoretus simplex* and *Altica spp*). In addition to insect pests, two mite species *Panonychus ulmi* and *Tetranychus urticae* were also found associated with apple. Among the pests, *Aphis pomi*, *Quadraspidiotus perniciosus* and *Panonychus ulmi* were very severe. In addition to pest, twenty one species of natural enemies were also recorded belong to six orders viz Coleoptera, Hymenoptera, Neuroptera, Diptera, Acari and Araneae. The population of *Aphis pomi* and *Eriosoma lanigerum* were significantly positively correlated to coccinillid beetles (r=+0.984** & r=+0.985**), syrphid flies (r=+0.882** & r=+0.882**) and spiders (r=+0.888** & r=+0.969**). There was significant positive correlation between *Eriosoma lanigerum* and its parasitoid *Aphelinus mali* (r=+0.973**). The population of *Panonychus ulmi* showed also a postive correlation with *Amblyseius fallacies* and *Stethorus aptus* (r=+0.505 & r=+0.463).

Keywords: pests, high density, apple agro-ecosystem

Introduction
Apple (*Malus x domestica* Borkh.) is the oldest and also commercially the most important temperate fruit which ranks fourth among the most widely produced fruits in the world. It is the premier temperate fruit crop of the North-Western Himalayan region and predominantly grown in Jammu and Kashmir, Himachal Pradesh and Utrakhand in the NW region of India (Sharma 2018) [35]. Insect pest problems in agriculture have shown a considerable shift during first decade of twenty-first century due to ecosystem and technological changes (Dhaliwal 2010) [15]. Increase in global trade in agriculture has increased the chances of the introduction of exotic pests. With changes in the cropping pattern, indiscriminate use of pesticides, climate change and introduction of input intensive high yielding varieties, hybrids, and cultivars there is an imminent shift in pest status. Many pests have expanded their host horizon, developed resistance to pesticides and emerged as major pests. (Rathee 2018) [34]. The introduction of high-density apple orchards may well be one of the most important changes in apple production practices. These orchards are capable of producing early and sustained yields of quality fruit. High-density orchards will provide an efficient operation with optimum utilization of the available labor force. The introduction of high-density apple orchards seems to be one of the most important changes in apple production practices. These orchards are capable of producing early and sustained yields of quality fruit. High-density orchards will provide for an efficient operation with optimum utilization of the available labor force. Besides, the advantage of high density plantings is that the orchard space can be rapidly filled, fruited, and then maintained by utilizing the early bearing and size controlling characteristics of certain stock scion combinations. The traditional systems of planting have a long juvenile period, are labour intensive and low yielding with poor quality fruits. The orchardists of Kashmir Valley have shown keen interest to establish the high density apple orchards and

replacing the traditional orchards with high density plantation at a large scale. The perennial character of orchards poses a great pest management challenge since the various organs of the tree structure provide multiple suitable habitats for arthropod colonization (Beers *et al*. 2003) [5]. The pome fruits especially apple grown in Kashmir having worldwide fame for their unique taste and delicacy, but fruit yield, fruit quality and even growth of the apple plants are directly influenced by several biotic and abiotic factors. Among these factors, a number of insect pests and diseases usually at all the stages of growth causing huge economic loss to growers as they have to invest so much in pesticide applications (Altaf *et al*. 2019) [1]. The microclimate under high density apple orchard ecosystems is different from traditional apple orchards. Besides, the introduction of early and high yielding varieties of apple with intensive care and management in the recent past under changing climatic conditions with early stage exploitation of plant may also lead to certain severe pest and disease problems. Therefore, the present investigation was undertaken to know the occurrence of pests and their natural enemies under high density apple eco-systems.

Materials and Methods

A fixed orchard survey was conducted during the growing seasons of 2018 and 2019 in different three high density orchards in district Shopian of Kashmir valley. Looking at the specific conditions of Shopian district, three villages were selected and from each village one high density orchard was selected for the study. From among the three high density orchards, ten plants of each existing variety were selected from each orchard. These high density orchards were visited fortnightly and observations were made on the incidence of different insect and mite pests and their natural enemies.

The observation on pest occurrence was recorded on 20 branches in each variety randomly and averaged to per branch basis for expression. Standard procedure was followed to record the observations on the incidence of insect pests of apples (Bentur *et al*. 2012) [6]. The damaged leaves and total leaves from 20 randomly selected branches were observed in each orchard. The percentage of leaf damage was calculated from randomly selected 100 leaves from each variety. The percentage of fruit damage was also calculated from randomly selected 100 fruits from each variety at the time of harvesting. The sample of predators and parasitoids were collected by sweep net, sticky traps and hand collection method. The population of beetles and spiders were counted on 20 branches and averaged to per branch basis for expression. The correlation coefficients were worked out by adopting multiple correlation analysis to find out the relationship between insect and mite pest of apple and their natural enemies in high density apple ecosystems of Shopian district.

Results and Discussion

During the present study, twelve insect pests and two mite species belonging to four orders and eight families were recorded on apples at different crop growth stages. Among them, San jose scale, *Quadraspidiotus perniciosus* (Comstock), green apple aphid, *Aphis pomi* (De Geer), woolly apple aphid, *Eriosoma lanigerum* (Hausmann), pin hole borer, *Scolytus nitidus* (Schedl) apple leaf folder and fruit scrapper, *Archips pomivora* (Meyrick) and European red mite, *Panonychus ulmi* (Koch) were found as major pests. The tent caterpillar, *Malacosoma indicum* (Walker), black aphid, *Anuraphis spp*, Chafer beetles, *Adoretus simplex*, (Razoumowsky), apple Leaf Miner, *Lyonetia clerkella* (Linnaeus), flea beetle, *Altica spp.*, stink bug, *Halyomorpha hayla* (Stal) and spider mites, *Tetranychus urticae* (Koch) moderately damaging the crop (Table- 1).

Among them, the green apple aphid, *Aphis pomi* has become a more severe pest in Kashmir apple production in the past few years. It was found mostly in large numbers on young, tender and non-bearing shoots and almost all the existing varieties were infested. It feeds on the sap of plants, which was damaging enough on its own, but to get to the sap they chew up the leaves with their efficient jaws. The leaves of an aphid-infested plant started to turn yellow and curl inwards, and new shoots are often deformed. They also secrete a sticky substance called honeydew which falls on leaves and fruits resulted in blackening of fruits and leaves. The infested trees and fruits looked ugly and hence reduced the market value of produce. Honey sew also invited the ants which hindered the predation of its insect predators. Infestation with *A. pomi* can stunt plant growth and stimulate lateral shoot growth, especially on young, nonbearing plants with high infestation levels on shoot tips (Arbab *et al*. 2006) [4]. Mature trees are mostly affected by the honeydew production of the aphids dripping onto foliage and fruit. Honeydew stimulates sooty mold growth, which hinders key leaf functions and fruit ripening (Coleson and Miller 2005) [13]. Honeydew, in addition also attracts ants that protect aphid colonies on apple trees from predation (Stewart-Jonesetal. 2008) [39].

Black aphid, *Anuraphis spp* was also recorded but its population was low and not caused economic damage. It was also reported from apple nursery in Kashmir (Altaf *et al*, 2019) [1]

San Jose scale, *Quadraspidiotus perniciosus* was recorded as the most destructive and major insect pest of the apple crop in all the locations. The appearance of this pest starts in the beginning of June and remained active throughout the crop season. Scale populations quickly grew into a problem because the insect multiplies so rapidly. An infested apple has thousands of scales on it. A red spot appeared around the scales as they start to feed on the fruit, and often the feeding caused slight depression. The spots are a brilliant red at first, but as the fruit is grown and the spots increased in size, they fade to light red or pink. On red apples, spots are difficult to see. Trees infested with San Jose scale produced small, immature apples, and infested apples were poorly colored. Besides making fruit unmarketable, San Jose scale kills twigs and limbs. It has been found major threat to the high density orchards in comparison to traditional orchards. Packed fruit may be rejected, particularly in export markets and under storage conditions, the infested fruits became decaying. Despite targeting San José scale with recommended control measures, apple growers have sustained severe economic losses due to the build-up of populations in their orchards (Irish-Brown and Pochubay, 2019) [19].

Woolly apple aphid, *Eriosoma lanigerum* attacks both aerial parts as well as roots of the tree. During the summer it remains on aerial parts of the tree and migrates into roots in the winter. Galls were formed on the plant where aphid colonies feed on twigs or roots. It was not very noticeable after one year of feeding but increase in size as feeding continues in an area. Roots of infested trees have large, abnormal galls. It is continued feeding killed roots and caused reduced growth of young trees. The aphid secretes honey dew which falls on fruits resulted in poor fruit colour development, sooty mould and hence reduced the market value of produce.

It also causes allergy to the skin of human beings at the time of harvesting and pruning. Above-ground damage by WAA includes the destruction of developing buds in the leaf axils and a reduction in tree vigor due to aphid feeding in leaf axils (Annecke & Moran 1982; Heunis & Pringle 2006; Pringle *et al*. 2015) [3, 18, 33]. In severe infestations colonies near spurs can deposit honeydew on fruit, which serves as a substrate for sooty mould (Stokwe and Malan 2016) [38].

Tent Caterpillar, *Malacosoma indicum* has a wide host range including apple, forest trees and ornamental plants in Jammu and Kashmir and Himachal Pradesh. However, in the present study its population was found very low and caused minor damage. The caterpillar web a tent like a nest at the forking of twigs and hide in it during the day and at night they congregate on leaf lamina and feed voraciously leaving behind only the midribs and portions of hard veins (Sherwani *et al*. 2016) [36].

Apple Leaf Miner, *Lyonetia clerkella* was only observed in few plants with low leaf injury. It was not fond to harm the plants health to cause any economic damage. The larvae made irregular tunnels (mines) and feed between the upper and lower surfaces of leaves. The larvae were found in mines with unaided eyes. However, in case of severe mines excavated by the larvae can reduce the photosynthetic capacity of leaves, cause premature leaf abscission, and permit pathogen entry into plant tissue (Parrella and Jones, 1987; Maier, 2001) [31, 25].

Pin hole borer, *Scolytus nitidus* infestation was observed in segregated plants. The infested plants showed symptoms of wilting, branch die-back, shoot breakage, chronic debilitation, sun-scorch or a general decline in vigor and dried. This pest was found one of the serious concerns in high density apple plants as compared to traditional apple trees which can bear the damage of pin hole borer to some extent. The pest was found surviving on pruned branches, staking wood material and surrounded trees especially walnut trees from which it migrated to healthy apple plants. The scolytids are of great economic importance to forestry and horticulture in the temperate zones including the Kashmir Valley. It is a predominant shot-hole borer that has caused considerable losses to fruit trees in the fruit growing areas of the valley since 1961 (Malik 1966) [26] and its population has increased enormously during the past decade due to favorable environmental conditions, mainly, drought (Buhroo and Lakatos, 2007) [12].

Flea beetle, *Altica* spp damage often can be observed on weed hosts like *Rumex* sp. before it becomes apparent on apple plants. It was primarily found feeding on weed *Obeg* (local name), *Rumex hastatus* and rarely fed on apple leaves in the absence of weed in Kashmir apple orchards. It emerges from hibernation in late May and feed mainly on weeds and was observed as a minor pest on apple. The adults were feeding by chewing a small hole in a leaf, moving a short distance, then chewing another hole and so on. Flea beetles are a diverse group of leaf beetles. Some of them are important economic pests, while others are beneficial weed biological control agents (Parker, 2017) [32]. Stink bug, *Halyomorpha hayla* was found in negligible number and not caused any economic damage. Both the nymph and adults suck plant sap from tender parts and the plant was not found to show any symptom.

European red mite, *Panonychus ulmi* and two spotted spider mite, *Tetranychus urticae* were found feeding on leaves caused characteristic leaf injury referred to as bronze. However, the population of two spotted spider mite occurred in small number and European red mite was found as major species. Mites inserted their needle-like mouth-parts into leaf cells and suck out cell contents, including chlorophyll. The affected leaves of severely infested plants appeared stippled and become bronzed resulted in defoliation. Prolonged feeding by high mite populations stressed the tree, leading to reduced shoot growth and fruit bud set of the following year. Fruit colour, size and weight of the fruit were also found affected and hence growers have to bear the huge economic loss. European red mite has established itself as a serious pest of apple trees in Jammu and Kashmir (Anonumous, 2014; Bhalla and Gupta, 1993) [2, 8].

The natural enemies recorded in the present investigation were given in table-2. Natural enemies of pests are a cornerstone to sustainable apple and other crop production. The ecology of orchards helps itself to the application of various management options that provide suitability of biological control. Orchards remain in place for decades, allowing for an evaluation of a stable, mature community of biological control agents (Brown 2008) [11].

The natural enemies recorded in the present studies were found associated with almost all the pests. Among the predators, the lady bird beetles were the most important predominant natural enemies and eleven species were recorded under high density apple agro-ecosystem. Majority of coccinellid species are predaceous feeding on small insects (Joshi, *et al*, 2012) [20]. They are one of the most important groups of the natural enemy complex of many horticultural and agricultural crop pests such as scale insects, mealy bugs, aphids, mites (Dixon, 2000; Omkar and Pervez, 2002) [16, 30]. In addition to these coccinellid beetles, predatory mite, *Amblyseius fallacies* (Garman) was also recorded as an important predator of mite. The black Coccinellid species Stethorus aptus (Kapur) was identified as a predator on the European red mite, *Panonychus ulmi* (Koch.) for the first time in Kashmir (Govindasamy and Khursheed, 2018) [17].

Syrphids commonly known as hoverflies and two species were recorded from the selected high density apple orchards which are identified up to the genetic level as *Syrphus* sp. and *Eristalis* sp. They are one of the most important predators of aphids and are known to regulate the prey population effectively (Ssymank, *et al*., 2008) [37]. They are also considered important predators of aphids and have a dominant role next to coccinellids (Khan, *et al*., 2016) [23].

Spiders were recorded as general predators of apple pests and three species were found in all three locations. They were found as the most important general predators under high density apple agro-ecosystems of Kashmir. Generally, spiders are regarded as polyphagous (preying on a wide variety of prey) and opportunistic (taking their prey as a function of each prey species' availability), although some degree of selectivity in foraging is often observed (Nentwig, 1980; Whitney *et al*., 2018) [29, 41]. In agro-ecosystems, spiders can contribute significantly to pest control by consuming a large number of various insect pests (Young and Edwards, 1990; Birkhofer *et al*., 2008; Suenaga & Hamamura, 2015; Lefebvre *et al*., 2017) [42, 9, 40, 24]. Spiders form abundant and diverse assemblages in apple orchards and can contribute to the suppression of various apple pests (Bogya, *et al*, 2000; Michalko and Pekár, 2015) [10, 27] although their function in biological control has been less studied in orchards (Michalko *et al*., 2019) [28].

Other important natural enemies of insect pests of apple recorded as parasitoid and three parasitoids were recorded

which belongs to the hymenopterans order. The recorded hymenopterans were identified as, *Aphelinus mali* (Haldeman), which is considered the most important biocontrol agent of woolly apple aphid worldwide. The other two parasitoids were *Encarsia perniciosi* (Tower) and *Aphytis proclia* (De Bach) and were effective parasitoids of San Jose scale. Parasitoids form perhaps the largest, most diverse and important group of natural enemies of apple and pear pests and most documented attempts to control apple and pear aphids with parasitoids have concentrated on using the aphelinid *A. mali* against the woolly apple aphid, *E. lanigerum* (Cross, *et al*, 1999) [14]. Karsemeijer (1973) [21] reported three species of parasitoids eulophid ectoparasites *Aphytis mytilaspidus* and *Aphytis proclia* and the encyrtid endoparasite *Zaomma* (Apterencyrtus) *microphagus* from mussel scale in the Netherlands. Attempts of biological control have also been made, using the aphelinid parasitoid *Encarsia perniciosi*, with some success against *Q. perniciosus* (Katsoyannos and Argyriou, 1985) [22]. In addition to all these natural enemies, *Chrysoperla zastrowi* was also found but its population was negligible and mostly invisible. However, its occurrence is reported from almost all the ecosystems including agro-ecosystems and could not be underestimated.

The population of *Aphis pomi* and *Eriosoma lanigerum* were significantly positively correlated to coccinillid beetles (r=+0.984** & r=+0.985**), syrphid flies (r=+0.882** & r=+0.882**) and spiders (r=+0.888** & r=+0.969**). There was also a significant positive correlation between *Eriosoma lanigerum* and its parasitoid *Aphelinus mali* (r=+0.973**). The population of *Panonychus ulmi* showed also a positive correlation with *Amblyseius fallacies* and *Stethorus aptus* (r=+0.505 & r=+0.463) (Table-3).

Table 1: List of insect and mite pest of apple in different high density apple ecosystems during 2018-19.

S. no	Common name	Scientific name	Order	Family	Nature of feeding
1	Green apple aphid	*Aphis pomi* (De Geer)	Hemiptera	Aphididae	Sucking plant sap
2	Black aphid	*Anuraphis spp*	Hemiptera	Aphididae	Sucking plant sap
3	Woolly apple aphid	*Eriosoma lanigerum* (Hausmann)	Hemiptera	Aphididae	Sucking plant sap
4	San jose scale	*Quadraspidiotus perniciosus* (Comstock)	Hemiptera	Diaspididae	Sucking plant sap and infesting fruits
5	Apple leaf folder and fruit scrapper	*Archips pomivora* (Meyrick)	Lepidoptera	Tortricidae	Damaging leaves and fruits
6	Tent Caterpillar	*Malacosoma indicum* (Walker)	Lepidoptera:	Lasiocampidae	Damaging leaves and fruits
7	Apple Leaf Miner	*Lyonetia clerkella* (Linnaeus)	Lepidoptera	Lyonetiidae	Making tunnels in leaves
8	Pin hole borer	*Scolytus nitidus* (Schedl)	Coleoptera:	Scolytidae	Bore into tree trunk and shoots
9	Chafer beetles	*Adoretus simplex* (Razoumowsky)	Coleoptera	Scarabaeidae	Damaging roots and foliage
10	Flea beetle	*Altica spp*	Coleoptera	Chrysomelidae	chewing a small hole in a leaf
11	Stink bug	*Halyomorpha hayla* (Stal)	Hemiptera	Pentatomidae	Sucking plant sap
12	European red mite	*Panonychus ulmi* (Koch)	Acarina	Tetranychidae	Sucking plant sap
13	Spider mites	*Tetranychus urticae* (Koch)	Acarina	Tetranychidae	Sucking plant sap

Table 2: Fauna of natural enemies in different high density apple ecosystems during 2018-19.

Insect order	Family	Scientific name	Host
Coleoptera	Coccinellidae	*Coccinella septempunctata* (Linnaeus)	General predator
		Adalia tetraspilota (Hope)	General predator
		Hippodamia variegate (Goeze)	General predator
		Coccinella undecimpunctata (Linnaeus)	General predator
		Chilocorus infernalis (Mulsant)	Mostly feed on San jose scale
		Coccinella transversalis (Fabricius)	General predator
		Oenopia conglobata (Linnaeus)	General predator
		Cheilomenes sexmaculata (Fabricius)	General predator
		Harmonia dimidiata (Fabricius)	General predator
		Propylea luteopustulata (Mulsant)	Woolly apple aphid
		Stethorus aptus (Kapur)	European red mite
Hymenoptera	Aphelinidae	*Aphelinus mali* (Haldeman)	Endoparasitoid of woolly apple aphid
		Encarsia perniciosi (Tower)	San jose scale
		Aphytis proclia (De Bach)	San jose scale
Neuroptera	Chrysopidae	*Chrysoperla zastrowi* (Stephens)	General predator
Diptera	Syrphidae	*Syrphus* sp.	Aphids
		Eristalis sp.	Aphids
Acari	Phytoseiidae	*Amblyseius fallacies* (Garman)	Predator of European red mite
Araneae	Araneidae	*Neoscona mukerjei* (Tikader)	General predator
		Neoscona sp.	General predator
	Theridiidae	*Theridula* sp.	General predator

Table 3: Correlation coefficient between pests and their natural enemies in high density apple agro- ecosystems

Name of pest	Natural enemies								
	Coccinellids	**Syrphidae**	**Spiders**	***Aphelinus mali***	***Encarsia perniciosi***	***Aphytis proclia***	***Chilocorus infernalis***	***Amblyseius fallacies***	***Stethorus aptus***
Aphis pomi	0.984**	0.882**	0.888**	-	-	-	-	-	
Eriosoma lanigerum	0.945**	0.844**	0.969**	0.973**	-	-	-	-	
Quadraspidiotus perniciosus	-	-	-	-	0.588*	0.862**	0.859**	-	-
Panonychus ulmi	-	-	-	-	-	-	-	0.505*	0.463*

** highly Significant at 1% level of significance
* Significant at 1% level of significance

Conclusions

It can be concluded from the present studies that the insect and mite pests pose more threat to the high density apple orchards than traditional apple orchards. Because high density apple orchards require extensive care and would be less tolerant to biotic and abiotic factors than traditional apple orchards. Fortunately, several species of predators and parasitoids were also found under high density apple orchards associated with almost all the pests, but the harmful effects of pesticides need to be avoided as much as possible. Therefore, further investigation is needed on the choice and use of pesticides to minimize their adverse effects on natural enemies. Furthermore, conservation efforts need to be undertaken for the enhancement of beneficial arthropod populations such as biological control agents in high density apple agro-ecosystems.

References

1. Altaf S, Ahad I, Pathania SS, Lone GM, Peer FA, Maqbool S. Insect pest complex of apple nurseries in North Kashmir. Journal of Entomology and Zoology Studies 2019;7(3):697-700.
2. Anonymous. Management of pests on apple in Kashmir, Division of Entomology, Directorate of Extension education, SKUAST-K, Shalimar 2014.
3. Annecke DP, Moran VC. Insects and Mites of Cultivated Plants in South Africa. Butterworths, Durban/Pretoria, South Africa 1982.
4. Arbab A, Kontodimas DC, Sahragard A. Estimating development of *Aphis pomi* (DeGeer) (Homoptera: Aphididae) using linear and nonlinear models. Environmental Entomology 2006;35:1208-1215.
5. Beers EH, Suckling DM, Prokopy RJ, Avilla J. Ecology and management of apple arthropod pests. In: Ferree D., Warrington I. J. (eds) Apples: botany, production and uses. CAB Intern. CABI, Wallingford 2003, 489-519.
6. Bentur JS, Siddegowda DK, Prasannakumar, Vennila S, Yogananda SB, Darshini GM. Insect pests and diseases of rice and their management. Dire. Res., UAS, Bangalore 2012, 14.
7. Bhagat KC, Masoodi MA, Koul VK. Note on the incidence of *Archips pomivora* Meyrick as a new pest of apple in Kashmir. Journal of Insect Science 1994;7(1):112-113.
8. Bhalla OP, Gupta PR. Insect pest of temperate fruits. Advances in Horticulture - Fruit Crops Malhotra Publishing House, New Delhi, India 1993;3:1557-1589.
9. Birkhofer K, Gavish-Regev E, Endlweber K, Lubin YD, Von Berg K, Wise DH *et al*. Cursorial spiders retard initial aphid population growth at low densities in winter wheat. Bulletin of Entomological Research 2008;98(3):249-255.
10. Bogya S, Marko V, Szinetar C. Effect of pest management systems on foliage- and grass-dwelling spider communities in an apple orchard in Hungary. International Journal of Pest Management 2000; 46(4):241-250.
11. Brown MW. Sustainable biocontrol of apple insect pests. Pest Technology 2008;2(2):98-103.
12. Buhroo AH, Lakatos F. On the Biology of the Bark Beetle *Scolytus nitidus* Schedl (Coleoptera: Scolytidae) Attacking Apple Orchards. Acta Silvatica et Lignaria Hungarica 2007;3:65-74.
13. Coleson JL, Miller RH. Antibiosis and antixenosis to *Aphis gossypii* (Homoptera: Aphididae) in Colocasia esculenta. Journal of Economic Entomology 2005;98:996-1006.
14. Cross JV, Solomon MG, Babandreier D, Blommers L, Easterbrook MA, Jayl CN *et al*. Biocontrol of Pests of Apples and Pears in Northern and Central Europe: 2. Parasitoids. Biocontrol Science and Technology 1999;9:277-314.
15. Dhaliwal GS, Jindal V, Dhawan AK. Insect pest problems and crop losses: changing trends. Indian Journal of Ecology 2010;37(1):1-7.
16. Dixon AFG. Insect predator-prey dynamics, ladybird beetles and biological control. Cambridge University Press, London 2000.
17. Govindasamy M, Khursheed S. A new host and distribution record for the black coccinellid, *Stethorus aptus* Kapur (Coccinellidae: Coleoptera). Egyptian Journal of Biological Pest Control 2018;28:53.
18. Heunis JM, Pringle KL. Field biology of woolly apple aphid, *Eriosoma lanigerum* (Hausman) and its natural enemy, *Aphelinus mali* (Haldeman), in apple orchards in the Western Cape province. African Entomology 2006;14:77-86.
19. Irish-Brown A, Pochubay E. Early season sprays for managing San Jose scale. MSU Extension Fruit & Nuts, Michigan State University Extension. https://www.canr.msu.edu 2019.
20. Joshi PC, Khamashon L, Kaushal BR, Kumar K. New Additions of Coccinellid Beetles (Coleoptera: Coccinellidae) to the already reported Species from Uttarakhand, India. Nature and Science 2012;10(6):26-30.
21. Karsemeijer MMD. Observations on the enemies of the oyster shell scale, *Lepidosaphes ulmi*, on apple in The Netherlands. Netherlands Journal of Plant Pathology 1973;79:122-124.
22. Katsoyannos PI, Argyriou L. The phenology of the San Jose scale. *Quadraspidiotus perniciosus* (Hom.: Diaspididae) and its association with its natural enemies on almond trees in northern Greece Entomophaga

1985;30:3-11.
23. Khan AA, Shah MA, Majid S. Functional response of four syrphid predators associated with green Apple aphid (Hemiptera: Aphididae) in Laboratory. Journal of Economic Entomology 2016;109(1):78-83.
24. Lefebvre M, Franck P, Olivares J, Ricard JM, Mandrin JF, Lavigne C. Spider predation on rosy apple aphid in conventional, organic and insecticide-free orchards and its impact on aphid populations. Biological Control 2017;104:57-65.
25. Maier CT. Exotic lepidopteran leaf miners in North American apple orchards: rise to prominence, management, and future threats. Biological invasions 2001;3:283-293.
26. Malik RA. Improved technique to control shot-hole borers and bark beetles. Plant Protection Bulletin 1966;18:29-30.
27. Michalko R, Pekár S. The biocontrol potential of Philodromus (Araneae, Philodromidae) spiders for the suppression of pome fruit orchard pests. Biological Control 2015;82:13-20.
28. Michalko R, Pekár S, Entling MH, An updated perspective on spiders as generalist predators in biological control. Oecologia 2019;189(1):21-36.
29. Nentwig W. The selective prey of linyphiid-like spiders and of their space webs. Oecologia 1980;45(2):236-243.
30. Omkar, Pervez A. New record of coccinellids from Uttar Pradesh. II. Journal of Advance Zoology 2002;21(1):43-47.
31. Parella MP, Jones VP. Development of integrated pest management strategies in floricultural crops. Bulletin of the Entomological Society of America 1987;33:28-34.
32. Parker JE. Managing Cruciferous and Solanaceous Flea Beetles in Organic Farming Systems USDA National Institute of Food and Agriculture, Division of Community and Education (USDA NIFA DOCE), William E. Snyder, Washington State University, Department of Entomology 2017; https://eorganic.org/node/12461.
33. Pringle KL, Barns BN, Blomefield TL. Apple. In: Prinsloo, G.L. & Uys, V.M. (Eds) Insects of Cultivated Plants and Natural Pastures in Southern Africa Entomological Society of Southern Africa, Pretoria, South Africa. 2015, 350-365.
34. Rathee M. Emerging insect pests in Indian agriculture. Indian Journal of Entomology 2018;80(2):267-281.
35. Sharma SK. Apple High Density Orcharding – Performance Reckoning Studies in Respect of the Agro-ecological Challenges of Kinnaur. International Journal of Science and Research 2018;8(4):636-642.
36. Sherwani A, Mukhtar M, Wani AA. Insect Pests of Apple and their Management. In. I nsect Pests Management of Fruit Crops 2016, 295-306.
37. Ssymank A, Kearns CA, Pape T, Thompson FC. Pollinating flies (Diptera): A major contribution to plant diversity and agricultural production. Biodiversity 2008;9(1, 2):86-89.
38. Stokwe NF, Malan AP. Woolly apple aphid, *Eriosoma lanigerum* (Hausmann), in South Africa: biology and management practices, with focus on the potential use of entomopathogenic nematodes and fungi. African Entomology 2016;24(2):267-278.
39. Stewart-Jones A, Pope TW, Fitzgerald JD, Poppy GM. The effect of ant attendance on the success of rosy apple aphid populations, natural enemy abundance and apple damage in orchards. Agricultural and Forest Entomology 2008;10:37-43.
40. Suenaga H, Hamamura T. Effects of manipulated density of the wolf spider, *Pardosa astrigera* (Araneae: Lycosidae), on pest populations and cabbage yield: a field enclosure experiment. Applied Entomology and Zoology 2015;50(1):89-97.
41. Whitney TD, Sitvarin MI, Roualdes EA, Bonner SJ, Harwood JD. Selectivity underlies the dissociation between seasonal prey availability and prey consumption in a generalist predator. Molecular Ecology 2018; 27(7):1739-1748.
42. Young OP, Edwards GB. Spiders in United States field crops and their potential effect on crop pests. Journal of Arachnology 1990;18:1-27.