Population Studies of Some Major Insect-Pests of Apple and their Natural Enemies in Azad Kashmir (AJK)

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CERTIFICATE

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List of Abbreviations

AJK	Azad Jammu Kashmir
FAO	Food Agriculture Organization
MM	Millimeter
IPM	Integrated Pest Management
SJS	San Jose scale
USA	United States of America
Q	*Quadraspidiotus*
C	*Cydia*
C	*Chilocorus*
SAAO	Sarfraz Abbasi Apple Orchard
MTKAO	Mohammad Tazeem Khan Apple Orchard
SwAAO	Sarwar Abbasi Apple Orchard
MZKAO	Mohammad Zafar Khurshid Apple Orchard
SQAO	Shouqat Qayyum Apple Orchard
SMKAO	Sardar Mehtab Khan Apple Orchard
SAKAO	Sardar Ashraf Khan Apple Orchard
DAP	Diammonium Phosphate
CM	Centimeter
IIBC	International Institute for Biological Control

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Abstract

The present studies on some major insect-pest of apple and their natural enemies were conducted in three localities and six sitews of districts, Bagh, Muzaffarabad and Rawalakot in Azad Kashmir, Pakistan, during 1999-2003. These studies were mainly focused on two key insect pest of apple i.e., San Jose scale (SJS), *Quadraspidiotus perniciosus* (Comstock),Codling moth,*Cydia pomonella (*L*)* as thes pests are known serious threats for the apple growers. An attempt was also made to study some of the natural enemies of these dangerous pests. The current studies are the first ever systematic scientific work on apple crop in Azad Kashmir, Pakistan.

From the present study, it is quite obvious that key pest of apple like SJS badlly infest both indigenous and introduced cultivars. It was found that out of three studied localities ,and six sites, Sarfraz Abbasi Apple Orchard (site-A) at dheerkot locality was found more infested with SJS, and at the same time, it was also identified that Star Crimson variety of apple was more susceptible for SJS attack compared to variety like Banky.

Investigation on larval infestatioin of C.pomonella was carried out during the field study. It is very clear from the current findings that out of 633 apples (fruits) of different sites of Dheerkot locality, Mohammad Tazzem Khan Apple Orchard (site-B) was found heavily infested with Codling moth larva. Interestingly, it appeared that both indigineous and introduced varieties were infested with larva of Codling moth. Kashmiri variety was more susceptible (90.26 %) at site-B, compared to Star-Crimson (8.33%) at site-A. The overall average larval infestation was 45.49 %. It appeared from the results thar larval incidence starded in the second week of June and lasted till the harvest of the fruit in mid August at Dheerkot during 1999. The monitoring of adult Codling moth was also studied at two site of Dheerkot locality during 2003.Result of this study showed a significant difference ($P<0.001$) of adult Codling moth distribution during different months. During the study two peak populations were recorded, i.e., one in the month of April and second in the month of July, which suggest two generation of the Codling moth in Dheerkot locality.

The distribution pattern of *Chilocorus infernalis* (Mulsant), a predator of SJS, on apple tree was determined. Throughout the samling period, a total of 498 specimens (larvae, pupae and adults) were collected from two localities (Rawalakot and Dheerkot). Greater numbers (471) of specimens were collected from Dheerkot locality compated to few numbers (71) from Rawalakot. Out of 427 specimens, 378 were recorded from site-A, which shows a clear indication of predator –prey interaction, because more population of prey (SJS) were also recorded from site-A at Dheerkot locality. The population of predator on apple tree varied significantly ($P<0.005$) throughout the sampling period at Dheerkot.The high population was recorded during mid April through first week of May 2000.

The predation potential of C.infernalis on SJS was examined under the field insectary condition at Rawalakot. The feature of finding showed that overall both the sexes (male and female) consumed significanftly ($P<0.001$) different number of scales, Q.perniciosus.Adult female beetle consumed more scales than male. Although both the sexes ate significantly ($P<0.001$) different number of SJS at different prey density, none of these consumed all the offered prey.

Introduction

Apple is one of the leading fruit crops of Azad Jammu and Kashmir (AJK). The AJK is in the form of a long, narrow strip, which lies on the North-East of Pakistan, situated between 73-75° longitudes east and 33-36° latitude north. The topography is mainly hilly and mountainous with valleys and plains in some places. Three districts, namely, Bagh, Muzaffarabad and Poonch enjoy ideal climatic conditions for apple production (Gardezi, 1985). The main apple growing areas are located at 1500-2000 meters above sea level. More than 80% of the apple growing areas are rainfed having mild summer and extreme cold winter with an annual precipitation of 750-1600 mm. The relatively cooled summer and winter at the high elevations provide good opportunities for temperate fruit cultivation (Gergely, 1994 and Abdul-Rashid, 1996). Fortunately, the apple crop fits both climatically and topographically to the local environment of AJK. At high altitudes, apple growing has acheived a considerable economic importance for the growers because growers can enhance their socio-economic status if proper attention is paid to the crop. The estimated number of apple trees in these districts is 8, 58,000. An annual production of 80250 metric tons with an average of 15 kg of apples per tree is recorded which is far below the standard yield. The annual production should be 45 tons/hecrare (Huang *et al.*, 2005). The major cause of low yields is insect pest attacks such as codling moth, *Cydia pomonella* (L.); San Jose scale, *Quadraspidiotus perniciosus* (Comstock), hailstorm, etc. (Anonymous, 1981; Gergely, 1994; Abdul-Rashid, 1996; Zalom *et al.*, 1999 and 2001) and other unknown reasons. Due to these harmful factors, apple crops suffer greatly and this consequently leads to economic loss to the growers. It may be worth mentioning that the threshold of acceptable damage to the fruit is very low (i.e.; =, <1 %), partly because the market demands a very high standard of appearance in the fruit and grading standards. Any fruit with a blemished skin is likely to be excluded from the class 1 standard. This highly grading standard demands that some pests and diseases are kept at a very low level (Javaid, 1995; Farooq *et al.*, 1999).

Apple trees acquire a large and diverse phytophagous and entomophagous arthropod fauna and more than 500 insects have been reported feeding on apples worldwide

(Metcalf and Flint, 1967) while Szentkiralyi and Kozar (1991) recorded 1662 insect species from Hungarian apple orchards. Several arthropods pests are known to cause damage to apples throughout the world. These include, seven main pests species, San Jose Scale, *Quadraspidiotius perniciosus* (Comstock); codling moth, *Cydia pomonella* (L.); spider mite, *Tetranychus urticae* (Koch); red spider mite, *Panonychus ulmi* (Koch); apple wooly aphid, *Erosoma lanigerum* (HSm); Mussel Scale, *Lepidosaphes ulmi* (L.); *Orgyia antique* (L.), 5 species of secondary importance and 6 occasional pests species (Gonzalez, 1984; Peter *et al.*, 2004; Wright and Diez, 2005). *Lepidosaphes gloverii* has been reported to damage citrus in Cuba (Gonzalez *et al.*, 2005). Mir and Wani, (2005) reported that walnut scale, *Q. juglansregiae* causes severe damage to walnut fruits in Kangan and Shopian in Jammu and Kashmir, India.

In general, the increasing interest in the importance of polyphagous predators (Luff, 1983 and Tolonen, 1995) for natural control has been realized in recent decades to overcome environmental contamination caused by chemicals. For instance, in Michigan and other parts of the world predaceous mites have proved their effectiveness to control plantfeeding mites and they have developed strains tolerant to many chemicals particularly where reduced pesticides have been used (Croft and Westigard 1983; Croft and MacREA, 1993; Ma *et al.*, 2004).

A number of beneficial arthropods have been found with a substantial potential for controlling important pests of horticultural crops in various parts of the world (Holling, 1959 and 1961). Surprisingly, some of them were imported from Pakistan and established in other countries which show the existing potential of several other bio-control agents that are still being unexplored. For instance, the most famous coccidophagous coccinellid *Vedalia*, *Rodolia cardinalis*; *Chilocorus infernalis* (Mulsant) and *Chilocorus nigritus* (F.) and the most effective parasitoid, *Aphids melinus* (DeBach), when explored/discovered and imported from Pakistan to the other countries (viz., USA, South Africa, etc.) to control noxious pest of citrus, proved classical pest/first dramatic biological control of scale insect (Ahmed and Ghani, 1966; DeBach, 1969, 1971 and 1974; Hagen, 1974 and Samways, 1984; Yang *et al* ., 2006). In Turkey, Ozgen and Karsavuran, (2005) investigated the natural enemies of scale insect, *Lepidosaphes pistachiae* on pistachio.

In occupied Kashmir and Himachal Pradesh (India), biological control efforts against *Q. perniciosus* on apple trees have proved both promising and practical by introducing coccinellid predators, *C. bijugus* (Mulsant), (Amin and Trali, 1987 and Rawat and Pawar, 1992). In the UK, most apple growers are exploiting the action of phytoseiids mites, *Typhloddromus pyri* (Scheuten), a predator of red spider mite, *Pannoychus ulmi* (Koch) and in pear the value of conserving *Anthocori nemoralis* as a predator of pear psyllid is generally recognized (Solomon, 1975, 1979 and 1995). Hence no more chemicals are being used for controlling mite pests in English apple orchards (Solomon, 1994). It has been studied in detail that the coccinellid predator, *Exochomus quadripustulatus* (L.) which feeds on aphids, also has a role in controlling/regulating mussel scale, *Lepidosahes ulmi* (L.) populations on apple in north-east England (Farooq-Ahmed, 1995; Farooq *et al.*, 1999). Ricci *et al.*, (2006) reported on the predatory potential of *Chilocorus spp.* in Peru. They also observed the effect of low temperature on *C.kuwanae* trophic activity and their results indicated that *C.kuvanae* is an effective predator of *Unaspis euonymi* (Comst.), a scale harmful to spindle trees. In addition, they also studied the feeding behaviour on wild adults collected from spindle trees in the Botanic Garden of Perugia University. In this study, their result shows that the female beetle has a higher feeding activity than the male.

The arthropod community on apples may be disrupted when alteration of the environment, such as using chemicals, affects species diversity. The knowledge regarding the distribution of pests and their natural enemies in the local ecological environment is a key factor in developing of pest management strategy. It increases the possibilities of ecological plant protection (Kozar *et al.*, 1994) to minimize the exclusive dependence on insecticides as pest control agents which creates problems both in insect control and the environment (Metcalf and Flint, 1967).

With the breakdown of chemical control and the distribution of biological and integrated pest management (IPM) techniques, detailed ecological and biological knowledge about the specific area and habitat is needed for better pest management (Lord, 1972; Whalon and Croft, 1984 and Blommers, 1994). This is only possible when the life cycles of arthropod species infesting/damaging fruit crops in relation to other arthropod species are studied before designing a pest management strategy.

Brown and Alder (1989) stated that these factors may vary with local situations and environments. So a study must be made for each area to allow development of their specific control programmes.

There are no reliable data on fruit trees in Kashmir (Gergely, 1994) because minimal scientific work has so far carried out in AJK which would enable the farmers to adopt proper preventive measures to protect their crop in government/public sectors. The field workers have inadequate knowledge about pests and natural enemies in the absence of research organizations and in turn, they disseminate non-realistic information to the farmers. Almost no scientific work is available that can describe the biology or ecology of the pests or natural enemies according to the local environmental conditions. However, it is vital to know the biology of the pest and its natural controlling agent while applying the pest management practices (Farooq *et al.*, 1999). In a report of FAO,(Abdul- Rashid,1996) it has been reported that insect pests like San Jose scale, codling moth and apple stem borer are widely distributed and are highly destructive. The author emphasized in his report that in order to provide plant protection programs for farmers in Kashmir, attention must be paid to the possibilities of biological/chemical control of insect pests. For this, life cycle of insect and other measures of plant protection must be carried out (Gergely, 1994). In fact, the climatic conditions of Kashmir vary from place to place; in addition, they are also greatly similar in the hilly areas of Pakistan. A threatening feature is that if proper scientific work is not carried out, sooner or latter, the growers will start to cut down the fruit trees as timber wood or for fuel purposes. This could be a setback for the whole country prosperity and may lead to a great economic loss (Zaki, 2002; Farooq *et al.*, 1999).

Description of the Pest

The San Jose scale is a pest in the USA since it was intrduced from China to San Jose, California 1873 (Flint, 1995). This pest infests at least 34 families of hosts (over 70-species) and has become a cosmopolitan pest in decidous fruit and nut orchards (Gentile and Summers, 1958; Kyparissoudas, 1990; Gonzalez, 1984; Gonzalez *et al.*, 2005). The female SJS sucks plant tissues and inject a toxin, resulting in a loss of tree vigour and productivity at low infestation levels (Zalom *et al* ., 2001a) Some of these pests cause serious losses to apple crops in Kashmir,

Pakistan, such as SJS and codling moth (Javaid, 1995; El-Sayed *et al.*, 2002; Zaki, 2002). Citrus red scale, *Aonidiella aurantii* is an important pest of citrus in Spain (Martinez *et al.*, 2006), Similarly, Miller and Davidson, 2005 reported in a study that armoured scales are very damaging for fruit and nut crops in the USA.

According to Copland (1984), scale insects are widely distributed, living on the bark of many woody plants. Bark encrusted with scales has a debilitating effect on food plants, and some species contaminate foliage by honeydew secretion. Scale insects are capable of causing serious problems in the fruit industry for instance, *Q. perniciosus* became a serious pest when introduced from China to the United States (Badenes *et al.*, 2002) and cottony cushion scale *Icerya puchasi* (Maskell) on citrus in Florida, USA (DeBach, 1973). A wide variety of plant hosts (as in Britain) such as apple, bilberry, cotoneaster, hawthorn, heath, heather, sorbus etc. are attacked by several scale insects (Gratwick, 1992). In the past few decades several other scale insects have been established in fruit growing areas, red scale *Aonidiella aurantii* (Maskell) on citrus in South Africa (Samways, 1984), armoured/purple scale (*Lepidosaphes becki* (Newman) on citrus in Egypt (Hafez, 1988), *P. corni* on citrus in Turkey (Okul *et al.*, 1987), *Q. perniciosus* on apple in Jammu and Kashmir (Amin and Tarali, 1987; Zaki, 2002) and *Q. perniciosus* (Comst.) on apple in Pakistan (Bajoi, 1983). San Jose scale is major pest of apple trees in Azad Kashmir, Pakistan and it is distributed on the upper and lower parts of apple trees (Farooq *et al.*, 1999)

San Jose scale (SJS), *Quadraspidiotus perniciosus* (Comstock)

Throughout the world, detailed studies on the biology, ecology, host plant, taxonomy, behaviour, damage, infestation, dispersal, distribution, and natural enemies, etc. of SJS have been conducted by several research workers and scientists such as Gonzalez, (1984), Kyparissoudas, (1987 and 1990); Kozar, (1988) and Kozar *et al.*, 1994; Thakur and Gupta;, 1997 ; Russo, 1986; Janjua *et al.*, 1958; Inam, 1997; Masoodi *et al.*, 1989; Hattingh and Samways, 1990 and 1995 . In Azad Kashmir, Pakistan, there is little reliable information about the biology, ecology and taxonomy of the San Jose scale on apple crops (Farooq *et al.*, 1999).

Host Plants

SJS is a polyphagous pest living on the bark of many kinds of woody plants, such as fruit trees, bushes, ornamental trees and shrubs. Its infestation is recorded on various fruit plants, which include; apple, pear, peaches, plum, cherry, sour cherry (Kozar and Drozdjak, 1988); Almond (Bhaggat *et al.*, 1988), nectarine (Vial *et al.*, 1987), and (*Zizyphus jujube*), (Ma *et al.*, 2004). Recently, Mir and Wani (2005) in Jammu and Kashmir investigated Q. *juglansregiae* infestation on walnut fruit. Ozgen *et al* . (2005) conducted research work on the host plants of SJS and they observed that more than 150 species of insects and mites have been found feeding on cultivated rose plants and one of them is a scale insect *Lepidosaphes ulmi* in Turkey.

Distribution

Many scale insect species occur in deciduous fruit orchards and have a wide range of hosts. Kozar and Drozdjak (1988) recorded 25 scale insect species in some European countries. The most frequently occurring species, in order of decreasing importance are: SJS (*Q. pernicious* (Comstock), mussels scale (*Lepidosaphes ulmi* (L.), *Epidiaspis leperii* (Signoret), pear scale (*Q. ostreaeformis* (Curtis) and brown scale (*Parthenolecanium corni* (Bouche). Of these, 14 species belong to the family Diaspididae and nine to Coccidae. The host plants recorded were apple, pear, peach, plum, cherry, and sour cherry. In the USSR Korchagin (1987) reported that SJS, *Q. perniciosus* is the most dangerous species particularly to winter apple varieties. The overwintering nymphs feed on short leaves, etc. Female produces up to 500 nymphs. Similarly, Kyprissoudas (1987) reported that SJS, *Q. perniciosus* is found on peaches and nectarines, while Vial *et al.*(1987) also verified the presence of Q. *perniciosus* on nectarines, peach and pears. Bhaggat *et al.* (1988) reported *Q. perniciosus* on almond, apple and peach orchards. Emms and McLaren (1984) recorded for the first time in Otego (New Zealand) SJS, *Q. perniciosus* on peach, pear and nectarine. The scale insect species recorded from Jordan include *Aonidiella aurantii, Aspidiotus nerii, Ceroplastes floridensis, C. rusci, Coccus hesperidum, Contigaspis zillae, Epidiaspis gennadii, Eulecanium sp., Lineaspis striata, Nilotaspis halli, Parlatoria blanchardi, P. oleae, P. pergandii, Planococcus citri, P. ficus* and *Pseudococcus longispinus* (Ben, 2006). Singh and Ojah (2005) studied the behavior of craewlers of *A.orientalis* on the leaves, fruits, and twigs of *Dalbergia sissoo*. They

further recorded that crawlers move from tree to tree in search of a proper host in India. Kozar, (2005) also studied the distribution of scale insects on apple and pear. Wardhaugh *et al* ., (2006) reported the vertical stratification and spatial distribution of paech scale insect, *Ultracoelostoma assimile* in *Nathofagus* tree canopies in New Zealand.

Biology:

Female SJS, *Q. perniciosus,* give birth to living young that emerge from under the edge of the scale covering. These tiny yellow crawlers wander in a random fashion until they find a suitable place to settle. Immediately upon settling, these crawlers insert their mouthparts into the host plant and begin feeding and secreting a white waxy material (white cap stage). Eventually the waxy covering turns black and is known as the black cap stage. Later the covers turn various shades from gray to black (Bloesh and Staubli, 1992 and Gentile *et al.*, 1958). In a report by Geoffrey *et al.*, (2006) from the U.S.A, where they conducted work on the biology and taxonomy of armoured scale insect. They found that armoured scale insects are economically important parasites of woody plants and grasses.

SJS over-winters predominantly in the black cap stage, although in mild years some adult mated females may also survive. In late January, these nymphs resume their growth. Immature male and female scales are indistinguishable until the first molt. At this time, the male scale covering begins to elongate, while the females remain circular. Male scales molt four times. Following the final molt adult male scales emerge from the scale covering as tiny, yellow winged insects. They mate with females, who remain under the scale covering. After about two months, crawlers begin to emerge from females (Campos *et al.*, 1987). The fully-grown female scale is circular, about the size of a pinhead, dark brown to black, with a raised dull yellow centre. Young scales are very light coloured, but soon become sooty black, often ashy in appearance. Near the centre of scale cover is a depressed ring surrounding a raised centre, which when show clearly, serves as a convenient mean of identification (Atwal, 1994).

Newly born lemon yellow nymphs can be recognized by the presence of three pairs of legs and a pair of antennae. These are called crawlers and migrate over the host for few hours before inserting their mouth parts into the bark, leaves or fruits to feed. After the first molt, the legs and antennae are shed; these are incorporated in the scalelike coverings that increases in size as nymphs continue to grow. Underneath these scale coverings may be found the yellow, nearly circular bodies of scale insects. Growth is completed in about six weeks and more than three generations are completed, annually (Campos *et al.* 1987).

The pest overwinters in the partly grown nymphal stage under the scale covering on the host plant and female scales produces upto 500 nymphs (Korchagin, 1987). The time of hatching of first generation nymphs of SJS, *Q. perniciousus* (Comst.) could be predicted by reference to the number of days and the sum of the effective temperature after the commencement of flight by overwintered males (Delinska, 1989).

Crawlers accomplish the local spread of SJS, many of these are beyond any doubt carried away from place to place on the feet of birds and insects. The aerial dispersal of the crawlers of SJS within the apple tree canopy and other trees shows a correlation with seasonal abundance of the crawlers on bark. Airborn crawlers are more significantly abundant within the upper portions of the canopy and in North-East and South-East quadrants (Mague and Reissig, 1983). The number of generations varies. There are usually three to four generations in a year (Amin and Trali, 1987). Summer generations overlap and crawlers are present throughout summer and fall (Campos *et al.*, 1987).

In China, Ma *et al,*(2004) studied the biology and ecology of Q. *perniciosus* in Akesu, Xingiang, China. According to to this report, *Q. perniciosus* overwintered as 2^{nd} instar nymph. Ovipositions occur in late May and early June. Adults emerged 20 days later with a female-male ratio of 1:2.74 on the leaves and 1: 0.11 on the branches and fruits. Similarly Campos *et at.*, (1987) reported that female SJS give birth to young one that merge from the under edge of the scale covering. Crawlers wander in random fashion until they find a suitable place to settle. Males moult four times and mate with females who remain under the scale covering. Kozar and

Drozdjak, (1988) described that in warmer areas, flight of SJS, began by the 1st week of May whereas in cooler areas by the 3rd week of May. Rock and Mc. Clain (1990) observed that 85% of SJS hibernate at the nymphal stage. Small numbers of all other life stages also hibernates. The development and survival of pests placed at 20 °C did not appear to be affected by day length. So the pest hibernates in a non-diapause state of dormancy and dormancy is temperaturedependent. Atwal (1994) stated that the full-grown scale is circular, dark brown to black in colour with a raised dull yellow centre. Males are smaller than females and of oval form. Near the centre, there is a depressed ring surrounding the raised centre that serves as a convenient mean for identification.

Several researchers have recorded different number of generations according to local environmental conditions throughout the world. Gonzalez (1984) observed two generations of SJS with flight of adult males occurring in late November and mid-March. The Diaspidid overwinter as eggs clustered under the scale covering of the dead female. Similarly in Kashmir, Amin and Trali (1987) reported 2 complete and a third partially complete generation, which overwinter from November. Over wintered nymphs and late males emerged in mid-March and late April, respectively. McClain *et al,*(1990) studied four seasonal generations of *Q. perniciosus.* Similarly Amin and Trali (1987) pointed out two complete generations which overwinter from November to mid-March and late April, respectively, Campos *et al,*(1987) observed more than three generations of *Q. perniciosus* (SJS). These studies were supported by many other researchers such as McClain (1990), Delinska (1989), and Ma *et al.,* (2004).

Damage/Infestation

Many research workers have reported that SJS is widely distributed, living on the bark of many woody plants, Bark encrusted with scales has a debilitating effect on fruit plants, some species contaminate foliage by honey dew excretion (Copland, 1984), other workers also reported Q. *perniciosus* infesting peach, pear (Emms and McLaren 1984). Several worker also pointed out that scale insects damage apple tree, trunks, spurs, twigs, leaves, and fruits, Mague and Reissig (1983); Gonzalez

(1984); Russo (1986); Charmillot, (1997). Infestation due to scale insect was studied by William *et al.*, (2006) in the Republic of Palau.

If heavy scale infestations are let unchecked, trees may be seriously damaged, resulting in reduced vigor, thin foliage, cracked or dying branches, and the eventual death of the tree. Young trees may be killed before fruiting. Infested fruits develop a reddish-purple ring surrounding each spot where a scale settles. Nymphs sucking sap from any part of the fruit blemish fruits. Thus fruits become unfit for marketing (Campos *et al.,* 1987). Many other research workers reported that scale insects are very dangerous to fruit crops (Tummenelli et al., 2006; Gonzalez *et al.*, 2005; Zalom *et al.*, 2001).

Dispersal

Dispersal takes place either by first instar nymphs by winds from one place to another or from plant to plant. Gonzalez (1984) stated that fallen infested leaves blown by wind were of greater importance in spreading the scale within orchards than was infested fruit because it is evident that eggs of SJS are unlikely to survive on fruit (Gratwick, 1992). According to Gonzalez (1984) the first instar or crawler is the primary dispersal phase in the life cycle of all Coccoidea. Dispersal of armoured scale crawlers is accomplished mainly by active wandering and by wind while other sources are accidental. Samarasinghe and LeRoux (1966) noted crawlers transporting on coccinelllid beetles and thrips larvae. Similarly, airborn dispersal was observed in the USA by Mague and Reissig (1983) reported that dispersal of crawlers of *Q. perniciosus* within the apple tree canopy and between trees was positively correlated with the seasonal abundance of crawlers on the bark. Airborn crawlers were significantly most abundant within the upper portions of the canopy (Gonzalez *et al.*, 2005; Kim, 2005).

Natural Enemies of SJS

Predators and parasites are helpful in reducing scale populations. Natural enemies that feed on SJS include predaceous beetles, such as lady beetle, *Chilocorus* spp, and the small beetle *Cybocephalus* spp. A small number of chalcid and aphelinid wasps also parasitize this scale. Field surveys revealed that four species of parasitoids,

Encarsia perniciosi (Tower), *Aphytis proclia, Azotus perspeciosus* and *Teleterebratus perversus* are among the effective natural enemies of SJS (Thakur *et al.,* 1989). The Percentage parasitism by *E. perniciosi* increased from 2 to more than 45 on SJS (Russo, 1986). In India, the coccinellid beetles, *Chiloclrorus bijugus* and *Pharaoscymnous flexibitis* (Coccinillidae: Coleoptera) reduce the incidence of diaspidids from 30-100% to 10-39.77% (Thakur *et al.,* 1989). Ricci *et al.*, 2006 in a laboratory study reported that the female predator beetle; *Chilocorus spp.* has more predatory potential than the male on scale insects.

Predators and parasites are helpful in reducing scale population. Natural enemies that feed on San Jose scale include predaceous beetles such as the coccinellid beetle, *Chilocorus* spp, (Rawat and Pawar, 1992). In Pakistan, coccinellid *C. infernalis* feed on SJS (Ahmad and Ghani, 1966). Four species of parasitoids, (a species of the *Aphytis proclia* group), *Azotus perspeciosus*, *Encarsia perniciosi* and *Teleterebratus perversus* and 4 species of predators *C. bijugus*, *Cocccinella septempunctata, Pharoscymnus flexibis* and *Sticholotis marginalis* were among the effective natural enemies of *Q. perniciosus* in Jammu and Kashmir while in Himachal Pradesh only one species of parasitoid *Aphytis proclia* and 2 predators of *Chilocorus* sp, *C. septempunctata* and *C. bijugus* were reported attacking the pest, SJS (Thakur *et al*, 1989). Diaspidid scale can be controlled by the coccinellid beetle, *Chilocorus bipustulatus* (Stathas *et al.*, 2005). Z.H. and Lin (2005) recorded two new species of scale insects on fruit trees.

Predaceous Coccinellids:

In the study of biological control of San Jose scale in Himachal Pradesh, India, it has been found that *Chilocorus* sp. preyed voraciously on Q. *perniciousus* (Verma and Dinabandhoo, 2005).The coccinellid *Chilocorus bijugus* was recorded as an effective predator of olive white scale *Metaceronema japonica* for the first time at Solan, Himachal Pradesh, India. The feeding rate of an adult beetle was 19.2, 20.1, 7.3 and 1.3 scale insects per day of 1st and 2nd instar nymphs, young females, and mature females with ovisacs respectively (Thakur and Gupta, (1997). Three species of *Chilocorus* and two species of *Hemisarcopetes* were introduced into New Zealand kiwi fruit (*Actinidia deliciosa)* orchards for the control of armoured scale insect

(Homoptera:Diaspididae) and were established as a biological control agent (Charles *et al*, 1995). Difference among six *C. spp., C. bipustulatus (*L.*), C. cacti* L.) *C. distigma* (Lug), C. *infernalis* (Mulsant), *C. nigritus* (Fabriclus) and *C. simony* in their usefulness as bio-control agent in South Africa were reflected in aspects of physiological and behavioural measurements derived from a quality monitoring programme in the laboratory. The feeding rate of *C. nigritus* was lower during the scoto-phase than during the photo-phase and increased as a function of duration of starvation (Hattingh and Samways, 1995). Adults of *Chilocorus infernalis* reared through the larval stages on scale insects were able to oviposit normally (Henderson *et al*, 1992). The feeding rates of three predatory coccinellid species, *Chilocorus nigritus* (F.), *Chilocorus bipustulatus* (L.) and *C. infernalis* (Mulsant) on mature oleander scale, *Aspidiotus nerri* (Bouche) were evaluated and it was found that interspecific behavioural interference does not adversely affect the feeding behaviour of adults of these coccinellid predators (Hattingh and Samways,1990). Baskaran *et al* (2006) reported the comparative biology and predatory potential of black beetle, *Chilocorus nigrita* (Fab.) on three scale insects. Abundance and spatial distribution of aphids and scales selected in relation to aphidophagus and coccidophagus of ladybird beetle predators were reported by Borges *et al*., (2006).

Codling moth, *Cydia pomonella* (L.)

According to Powel (1964), the ancestral form of *C. pomonella* was a wood borer, which followed the practice of depositing its eggs singly. *C. pomonella* continues the ancestral habit of laying eggs singly and feeding exclusively in the interior of fruit, and overwintering as fully developed larvae (Chapman (1973).

Riedle (1983) found that adaptations of the life cycle of the *C. pomonella* to the seasonal rhythm of the climate and the periodicity in the fruiting of the apple is maintained by the geographical variability of photoperiodic reactions. The temperature reaction of the active stages and cold resistance remain permanent specified attributes and are not subjected to variability. Angus (1993) found that the *C. pomonella* is distributed in Asia, Europe and America. Several other researchers showed that *C. pomonella* is a very destructive pest introduced from Europe by settlers. Some research work on the biology and infestation of codling moth was reported by Zaki(2002) in Kashmir and he further observed that codling moth is

widely distributed in all growing areas or villages of Ladakh. The mean infestation of the pest on apple was 49.7-42.5 % in Kargil and Ladakh districts, respectively. Zaki, (2002) reported some preliminary study on infestation and development of codling moth in Kashmir.

The egglaying behaviour of *C. pomonella* varies through the world (Celeste 1991). Female moths lay single eggs on the fruit and leaves. According to Ric (1994), female moths lay the scale like eggs singly on developing fruit or on adjacent leaves or on stems just after sundown each night. Flint (1995) reported that the eggs are laid singly on fruits, nuts or on nearby leaves. Nraes (1997) observed that females lay eggs on leaves near clusters of newly set fruit and some on fruit. Peter et al., (2004) conducted a study on infestations of codling moth larvae and reported that infested apples are more attractive to neonate larvae of codling moth.

Celeste (1991) observed that the egg of the codling moth is tiny, whitish, flattened, discshaped and almost transparent. According to Angus (1993), the egg is very small, flattened almost transparent, elliptical and measuring 1 to 1.2 mm in diameter. Flint (1995) observed that that the egg is about the size of a pinhead, discshaped and transparent white when first laid. As it matures it becomes opaque white and develops a red ring. Balevaski *et al.* (1958) observed an oviposition period of 2-7 days and on an average 42 eggs per female. Studies showed that each female lays an average of 50 – 60 eggs (Celeste 1991), or up to 100 eggs (Angus 1993). Flint (1995) reported that each female deposits 30- 70 eggs singly on fruits. Pasqualini and Boselli (2005) studied the biology and infestation of *C. pomonella* in Italy. They reported that the codling moth is the most dangerous species due to either suitable climatic conditions of the last decade or the occurrence of insect populations resistant to the most commonly used insecticides.

Blomefield *et al,* (1997) observed more eggs of codling moth from the bottom half the tree. Moths of the first generation preferred the bottom half of the tree, while second and third generation moths preferred the top half of the tree for oviposition. Several researchers found that the incubation period varies from place to place under different climatic conditions. Balevaski *et al,* (1958) reported that the eggs hatch in

7-15 days at 16-21.3 °C. Balevaski, (1958) also studied an incubation period 17-15 days. Nraes (1997) reported that the egg hatching period is 8-14 days.

Development

The time from egg hatch to successful entry into the fruit and internal development is critically important period in the biology of *C. pomonella*. Balevaski *et al* (1958) found that the larval feeding period ranged between 25-45 days. Hussain (1981) observed 13-40 days as the feeding period. According to Celeste (1991), the larva spends about 3- weeks feeding and growing inside the apple. Angus (1993) also observed 3 - weeks feeding period of the larva. Ric (1994) found that the larval feeding and development is completed in 3-5 weeks. Nraes (1997) reported that the larva feed inside the apple for about 3-4 weeks.

Hussain (1981) recorded that the life cycle of themoth was completed in 76-280 days for both generations. In Pakistan, Gardezi and Manzoor-ul-Haq (1985) found that the life cycle is completed in 51-97 and 271-309 days in the first and second generation, respectively.

Natural enemies of codling moth

Several researches have reported worldwide about natural enemies of the codling moth. The codling moth and its various stages are attacked by a number of natural enemies (Oatman and Brooks 1964). The Egg stage is parasitized by an egg parasitoid, *Trichogramma minutum* (Riley). Predators of the codling moth are *Chrysopid,* mites species, two species of thrips, and four species of mired bugs (Rawat and Pawar,1992). Bhattacharya *et al.* (2006) studied management of lepidopteran insect predators of lac insects through habitat manipulation in India. In their study they showed that suppression of lac predators may be attributed to higher incidence of *Trichogramma chilonis*, an egg parasitoid of lepidopteran insects. *T. chilonis* parasitizes the eggs of the white butterfly *Catopsilia pyranthe* laid on the leaves of *C. occidentalis* also which favours the build-up of the parasitoid population

Monitoring of codling moth activity

Researchers throughout the world have attempted to manage pests by a number of insecticides but effective control could not be done because of well-known facts that the uses of pesticides without considering the proper time of application and their effects on the non-target species have created many environmental problems. Traps baited with synthetic sex pheromone are mostly used to forecast the timing of pesticide application against the codling moth. In the past, many research workers have worked and reported that pheromone traps are an effective tool used worldwide to monitor and suppress insect-pest populations. (Ledee *et al.*, 1998; Mani and Schwaller, 1992; Khattak *et al.*, 1989; Farooq et *al.*, 1999).

Many researchers throughout the world have worked on synthetic pheromone traps to monitor codling moth populations, phenology, timing, flight activity, forecasting, chemical control, mass trapping programme, pest suppression, trap density and trap height experiments and different generation studies (El-Sayed *et al.* 2004, 2005, and 2006., Suckling *et al.*, 2006; Gibbs *et al*, 2006; Charmillot, 1990; Brown *and* Howell, 1989; Howell, 1972; Thwaite and Madsen, 1983; Glen and Brain, 1982; McNally and Barnes, 1981; Madsen and Davis, 1979; Madsen and Carty, 1979; Madsen and Vakenti, 1973).

Keeping the above facts in view, it appeared necessary to investigate the existing bio-ecological status of both insect pests and their natural enemies on apple in AJK in relation to the scientific basis and evaluate its possible impacts on any future pest management strategy with the following objectives:

Specific objectives:

- To provide data on identification and distribution of some major insect pests of apple and their natural enemies at different localities of apple growing areas.
- To study some aspects of biology and ecology of key - pests (codling moth and San Jose scale) and their natural enemies under field and insectary/laboratory conditions at Dheerkot and Rawalakot, Azad Kashmir.
- To determine the role of major biotic agents and other factors contributing toward the regulation of key pests of apple in different ecological zones.
- To evaluate the possible ways of developing and designing a pilot IPM program based on the findings of the current project for key pests of apple.

Materials and Methods

Plan of Orchards

The studies pertaining to both field and laboratory work of this research work were carried out from February 1999 to September 2003. The sites of study of apple orchards are located at altitudes from 1615 to 1921 meters above sea level in three districts of Azad Kashmir (AK) namely, Bagh, Muzaffarabad and Poonch. The detailed plans of the orchards are given in Table 2.1 and Fig 2.1.

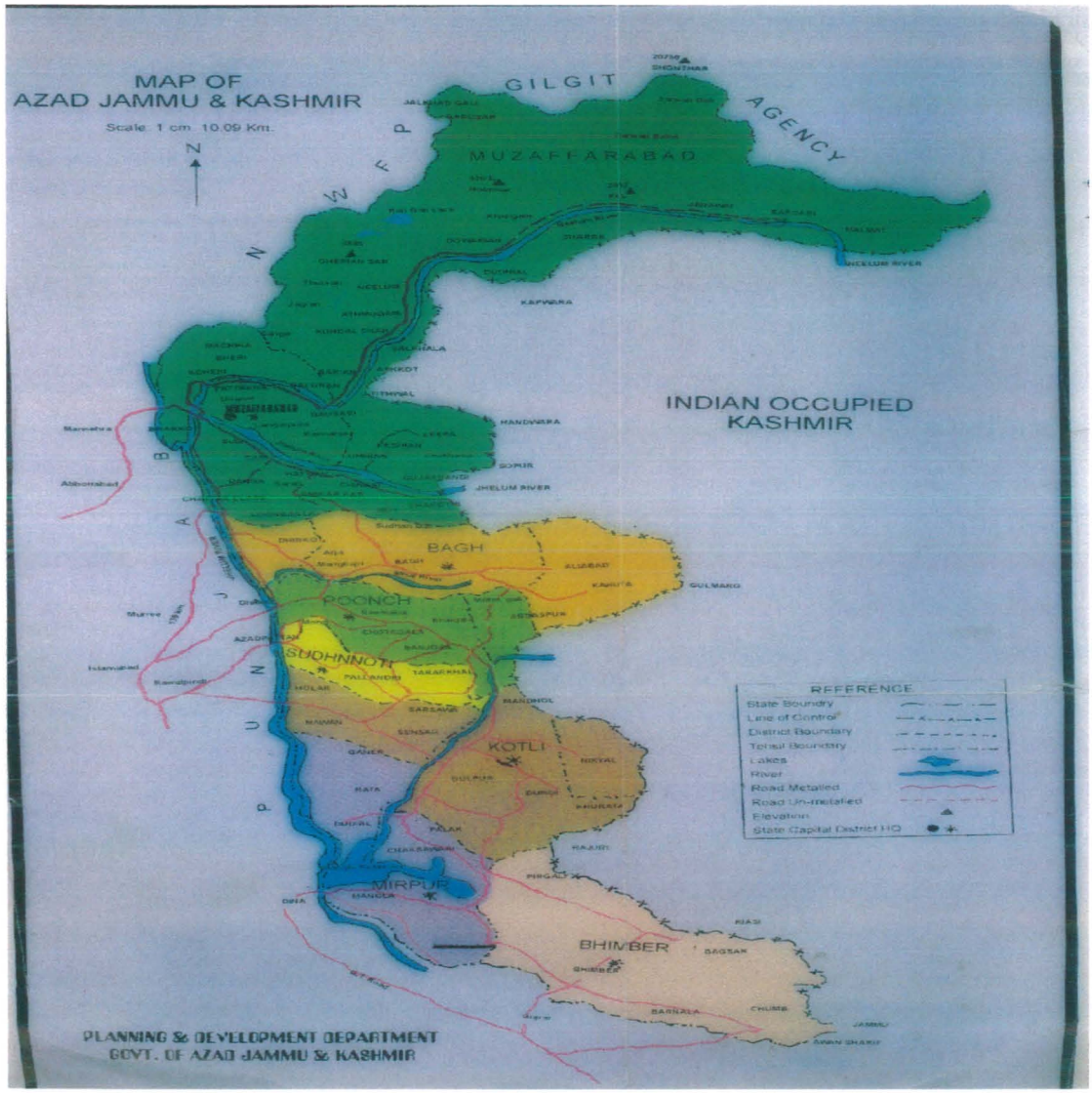

Fig 2.1 Map of Azad Jammu and Kashmir

Table 2.1: The plan of the orchards in three localities of Azad Kashmir during 1999-2003

Sr. No. District	Farmer	Locality	Sites	Locality Height (Metres)	No. of Trees	Type of plants
1. Bagh	Sarfraz Abbasi		Chamyati (A)	1686	200	Banky, Star-Crimson, Star-King, Amri
	M.Tazeem Khan	Dheerkot	Chamyati (B)	1676	300	Banky, Golden, Kashmiri, Star-King
	Sarwar Abbasi Apple Orchard		(B-2)	1790	200	Banky,Starcrimson,Golden, Kashmiri,Amri
2. Muzafarabad	M. Zafar Khurshid		Panjera (A)	1971	72	Banky, Red-Delicious
	Shaukat Qayyum Abbasi	Lamniyan	Qayyumabad (B)	1921	230	Golden,Red-Delicious, Banky
3. Poonch	S.Mahtab Khan		Kharik (A)	1615	200	Banky,Kulou,Quetta-Amri, Star-King
	S.Ashraf Khan	Rawalakot	Panjalc (B)	1615	45	Banky, Golden

- =Site B-2 (Sarwar Abbasi Apple Orchar) was selected for monitoring of codling moth at Bagh, Dheerkot locality

Material

Experimental Trees, Location and Description

At each locality, apple orchards were selected from two different sites and each site was given a code name A and B. During the first year of the study (in 1999), 6 apple orchards at 6 sites were investigated. In the following years (2000 and 2001) 4-6 sites were selected according to the nature of the experiment. The four sites at Dheerkot and Rawalakot locality were selected for the distribution of the ladybird beetle, *Chilocorus infernalis,* a natural enemy of San Jose scale. However, another site with the name site B-2 was added in the Dheerkot locality for monitoring the codling moth and the monitoring of codling moth was carried out at different heights in two sites (A and B-2) at Dheerkot locality in District Bagh. No chemical was applied throughout the study period on apple trees. A brief background of each apple orchard is described as follows.

Field insectary

The studies of the development of immature stages of the specimens were carried out under ambient conditions in the field insectary. The insectary walls were surrounded by wire gauze with steel sheets on the roof. The insectary measures 10 m in length, 5 m in width and 3 m in height. It is located towards the East West side of the Faculty of Agriculture, Rawalakot. A polythene sheet was also temporarily attached on the southwest side of the insectary to avoid severe seasonal winds and rain. The glassed rearing cages were also kept in the field insectary to study different biological aspects of the specimens as and when required.

District Bagh

Sarfraz-Abbasi Apple Orchard at Dheerkot Chamyati (Site A):

Sarfraz-Abbasi Apple Orchard (SAAO) at hill Chamyati, lies at 1686m above sea level and comprises more than 200 trees of mixed apple varieties. From this orchard, six trees of two varieties namely "Star Crimson" and "Banky" were selected and tagged for detailed study. According to the owner's statement, the experimental trees were planted about 10 years ago. Fertilizers like urea and potash were applied to these trees, whereas, manuring was also carried out once a year. These trees were

pruned to maintain the plant vigor and minimize the insect pest attack. These trees were sprayed once in a year with some unknown chemicals in the month of March-April. The natural vegetation of this hilly area is composed of trees like poplar (*Populus spp),* Kikar (*Acacia spp)* and different types of weeds. During the year 1998, the apples yield was approximately 10 Kg/tree. Severe codling moth attack was also observed in 1998.

Fig 2.2 Sarfraz Abbasi Apple orchard (site A) during April, 1999

Muhammad Tazeem Khan Apple Orchard at Dheerkot (Chamyati, Site B):

Muhammad-Tazeem-Khan Apple Orchard (MTKAO) in the same locality (1676 m above sea level) comprises 300 trees with mixed varieties of apple like Star King, Golden, Banky, and Kashmiri. From this orchard, six apple trees of two varieties, namely Star King and Banky, were selected for study purpose. The orchard was isolated, surrounded by mixed vegetation and intercropped with wheat and maize. According to the farmer's statement, the orchard was established in 1988. The orchard was sprayed with some unknown chemicals in 1997. The trees were grafted and pruned once in a year. On an average approximately 30 Kg/tree apples were harvested despite 60-70% damage caused by codling moth (Orchardist's statement).

Fig 2.3 M.Tazeem Khan Apple Orchard at Dheerkot (site B) during April 1999

Sarwar Abbasi Apple OrcharD (SwAAO) at Dheekot,Chamyati, site B-2 (Height 1 and 2) Sarwar Abbasi Apple Orchard was used for monitoring of codling moth activity which is also located at hill Chamayati, lies at 1790 meters above sea level and comprises more than 200 trees of mixed apple varieties. From this orchard two heights, height 1(site A) and height- 2 (site B-2) were selected for placement of pheromone traps. The apple varieties of height 1 and 2 were Star Crimson and Kashmiri, respectively. The difference between these two heights (Sites) was 104 m

(aerial). The orchard (site B-2) was planted 40 years ago according to the owner's statement. The orchard was not intercropped.

District Muzaffarabad

M.Zafar Khurshid Apple Orchard at Lamniyan (Panjera, Site A):

Muhammad-Zafar-Khurshid Apple Orchard (MZKAO) at Lamniyan (Panjera) at 1971m above sea level, was planted during 1985-86. The orchard comprises 150 apple trees mainly of two varieties of apple, Banky and Red Delicious. From this orchard six trees i.e. 3 of Banky and 3 of Red Delicious varieties were selected for detailed observations. The study trees were manured and pruned to maintain the plant vigor once a year. The orchard was never sprayed with any chemical. In 1998, the farmer obtained a high yield of 20-30 Kg apples/tree compared to 10 kg apples/tree in 1997.

Fig 2.4: M. Zafar Khurshid Apple Orchard. Lamniayan (site A) during April, 1999

Shoukat-Qayyum-Abbasi Apple Orchard at Qamniyan, Qayyumabad, site B): Shaukat-Qayyum-Abbassi Apple Orchard (SQAAO) is located at 1921m above sea level in the same locality. The orchard was established in 1986 with a total number of 230 apple trees. In this orchard, six apple trees of two varieties, namely Golden and Banky, were selected and tagged for detailed study. Some fertilizers like urea and diammonium phosphate (DAP) were applied once in a year. The orchard was sprayed with chemical, "Dithane M-45", in early 1997. The studied trees were grafted and pruned once in alternate year. No intercropping was done for the last 3 years. This orchard appeared a managed orchard, where agricultural practices like pruning, manuring, etc were being carried out.

Fig: 2.5 A view of Shoukat Qayyum Abbasi Apple Orchard. (site B) during April 1999

District Poonch (Rawalakot):

Sardar-Mahtab-Khan Apple Orchard at Rawalakot, Poonch (Kharick, sites A):

At Rawalakot locality, the Sardar-Mehtab-Khan Apple Orchard (SMKAO) lies at 1615m above seal level. It was established in 1975 with a total of 200 apple trees. From this orchard, six apple trees, two varieties, namely Banky and Star King, were selected for detailed study. Before commencing the study, fertilizers (Nitrophos) were applied to the studied trees once a year but no chemicals were applied since 1990. The trees were grafted and pruned every year to maintain the proper shape and vigor of the apple trees. Wheat and maize crops had been used for intercropping. The orchard is surrounded by mixed vegetation of *Populas* spp and *Acacia* spp.

Fig 2.6 Sardar Mehtab Khan Apple orchard.Rawalakot (site A) during April 1999

Sardar-Ashraf-Khan Apple Orchard at Rawalakot, Poonch (Panjal, Site B):

Sardar-Ashraf-Khan Apple Orchard (SAKAO) in Panjal lies at 1615m above sea level. The orchard comprises 45 apple trees and was established in 1986. Six trees of two varieties, namely Banky and Golden, were selected and marked for study purpose. Before commencing the present study, fertilizers like urea and DAP were applied to the studied trees once a year but no chemical was ever sprayed. The orchard was isolated, surrounded by mixed vegetation (*Acacia spp., Populas spp,* and pine trees).

Fig: 2.7 Sardar Ashraf Khan Apple Orchard Raalakot (Site B) during April, 1999

General Methods

Selection of Experimental Apple Trees

Before commencing proper studies, a preliminary survey for the selection of apple orchards was conducted in the month of February 1999 in order to determine the suitable apple orchards for detailed studies. Three localities, namely Dheerkot (Bagh), Lamniyan (Muzaffarabad), Rawalakot (Poonch), were selected for study purpose. In each locality, two sites and at each site six apple trees of two varieties were selected. A total of 36 apple trees from three localities were selected and tagged.

The selected apple trees were marked with red paint and were vertically stratified into two equal halves/strata by measuring the height of each tree. The stratum level was also marked with red paint and was easy to differentiate the upper and lower strata. The lower level was from the base to the midpoint of plant height whereas the upper level was from midpoint of the tree to the tip of highest branch that was pruned in the previous year. Tree height and stem thickness was measured in order to maintain homogeneity among experimental trees. The stem circumference was measured 30 cm above the ground level with a measuring scale. The same procedure was followed throughout the studied trees at each site (Farooq-Ahmad *et al.*, 1999). The observations were made on 36 apple trees, 12 in each locality and 6 trees at each site. The details of selected trees in different localities, with variety names, stem-circumference and tree heights are given in Tables 2.2, 2.3 and Table 2.4.

Table 2.2: Circumference and tree height of selected apple trees at (Dheerkot), District Bagh, Azad Kashmir

Site	Tree No.	Variety	Circumference (cm)	Tree Height (cm)
A	1	Star-Crimson	30.00	242.50
	2.	Star-Crimson	30.00	260.00
	3.	Star-Crimson	27.50	255.00
	4.	Banky	40.00	310.00
	5.	Banky	67.00	315.00
	6.	Banky	32.50	332.50
B	7.	Banky	75.00	44.00
	8.	Banky	72.50	275.00
	9.	Banky	77.50	375.00
	10.	Star-King	32.50	312.50
	11.	Star-King	35.00	410.00
	12.	Star-King	20.50	270.00

Table2.3: Circumference and tree height of selected apple trees at Lamniyan, District Muzaffarabad, Azad Kashmir

Site	Tree No.	Variety	Circumference (cm)	Tree Height (cm)
A	1	Banky	28.50	300.00
	2.	Banky	37.50	340.00
	3.	Banky	46.50	480.00
	4.	Red Delicious	75.00	337.50
	5.	Red Delicious	45.00	435.00
	6.	Red Delicious	40.00	302.50
B	7.	Golden	46.25	335.00
	8.	Golden	42.50	335.00
	9.	Golden	46.25	330.00
	10.	Banky	32.50	330.00
	11.	Banky	30.00	375.00
	12.	Banky	30.00	510.00

Table 2.4: Circumference and tree heights of selected apple trees at Rawalakot, District (Poonch), Azad Kashmir

Site	Tree No.	Variety	Circumference (cm)	Tree Height (cm)
A	1	Banky	60.00	420.00
	2.	Banky	32.50	397.00
	3.	Banky	42.50	480.00
	4.	Star King	70.00	480.00
	5.	Star King	42.50	540.00
	6.	Star King	37.50	495.00
B	7.	Banky	28.75	467.00
	8.	Banky	40.00	480.00
	9.	Banky	27.50	395.00
	10.	Golden	35.00	510.00
	11.	Golden	40.00	510.00
	12.	Golden	60.00	655.00

Sampling Plan

The samples of apple spur measuring 2.5-3 cm, with or without fruit, were cut with a scateuer and transferred to transparent polythene bags (8x13 inch) to keep them fresh. Three samples (either spur or fruit) from the lower and three from the upper level were taken randomly, in order to keep homogeneity. A total of 36 samples from each site and an overall 72 samples from each locality on each sampling date, (Table 2.5) were collected fortnightly. The collected samples comprising spurs, leaves and fruits were kept in a plastic container (common plastic water-cooler being used for drinking water) containing ice at the bottom and were carried from the field to the Entomology laboratory at the University College of Agriculture, Rawalakot and were stocked in the refrigerator at 4°C temperature for further studies. These samples were collected at comparative stages (spurs, leaves and fruits) of growth and development marked with the name of the locality, site, sampling date and other necessary details at the end of each sampling. The length and diameter of collected samples (spurs and fruit) was measured with the help of a measuring scale and vernier caliper, respectively. Each apple sample was divided into three levels, (upper, middle and lower) to take an average diameter. A binocular stereomicroscope was used to examine the arthropod fauna present on the field-collected samples. The collected specimens from samples were preserved in 90% ethanol in small glass vials for further identification.

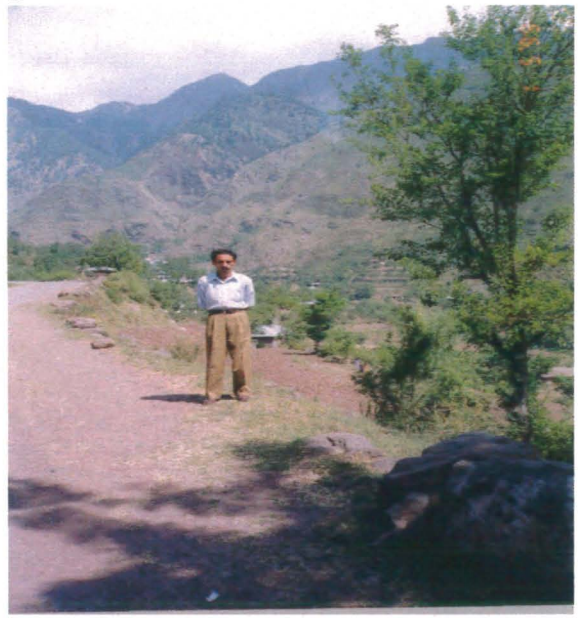

Fig 2.8 A view of Lamniayan (Muzaffarabad) during April 1999

SPECIFIC METHODS FOR THE STUDIES ON APPLE PESTS

Population Study of San Jose scale (SJS)

In order to determine the distribution level of San Jose scale (SJS), *Quadraspidiotus perniciosus* (Comstock), on different apple varieties at various localities, the samples were taken randomly (as mentioned above) in order to keep homogeneity. The numbers of SJS on each sample (Spur, leaf and fruit) were counted under a binocular stereomicroscope.

Statistical analysis

Chi – square test was applied to find the population differences and difference in distribution of San Jose scale at upper and lower level of apple trees at all site and localities.

Studies on codling moth, *Cydia pomonella* (L.)

Infestation of codling moth on different varieties

Apple leaves and fruits were examined under a binocular stereo microscope to determine the developmental stage of the pest. The apple was cut into two bilateral symmetrical halves to examine the apple for codling moth infestation. The presence of an exit hole, and larvae were considered as an infestation caused by *C. pomonella*. In the case of larval presence, the cut parts of the apple were re-attached with the help of paper-tape to prevent the escape of larvae. The infested apple with larva was transferred to a rearing chamber. The chamber consisted of a glass chimney covered by muslin cloth and placed over a petri-dish (4-inch diameter). A labeled tag with a specific code showing the locality, site, date of collection, etc. was also tagged to each rearing chamber and these chambers were placed in a wooden tray. At Dheerkot locality, six different varieties of apple trees (three varieties at each site) were selected at site A and site B for determination of codling moth larvae. Each apple tree was divided into two halves, upper and lower half, as described in the general methods. A total of 633 apple fruits were collected from site A and site B of Chamyati, Dheerkot, locality for study purposes.

Statistical analysis

Chi-square test was applied to find the differences in infestation on different varieties of apple trees at site A and B of Dheerkot. Chi-square test was also applied to see if there is any significant difference in two sites (A and B) for larval infestation.

Specific method for the studies on predator of San Jose scale

The selection of trees and their detailed descriptions are described in General Methods. However, the specific technique for sampling *Chilocorus infernalis* (Mulsant) and its predation potential on San Jose scale is given separately in the following lines:

Population distribution of ladybird beetle, *Chilocorus infernalis*

The observations were made on 24 apple trees i.e. 6 trees each from site A and site B of the Dheerkot locality District Bagh and also 12 trees each from sites A and B of the Rawalakot, locality. Similarly, 6 trees from each site, 6 branches, and 3 branches per level from each tree and a total of 72 branches were selected systematically from each locality at an interval of 10 days between 9:30 a.m to 2 p.m. Each branch was beaten with a wooden stick to collect the adult *C. infernalis*. The adult beetles which fell on the white cloth tray (size 95 x 49 cm) were collected and kept in plastic vials for further observations. The immature stages (larvae and pupae) were also collected from the cloth tray with the help of a camel hair brush and were kept in plastic vials. These specimens were brought to the Entomology Laboratory for further study. Specimens were identified with the available literature and compared to previously collected specimens. (Farooq *et al.,* 1999).

Fig 2.8 Limb beating method for distribution of *Chilocurus infernalis* at Dheerkot, District Bagh during May 2000

Study of adult codling moth, *Cydia pomonella* (L.) activity using Pheromone trap:

An experiment was conducted in Dheerkot, District Bagh to monitor codling moth, *Cydia pomonella* (L.) populations throughout seasons. at different heights. Height-1 was 1686m high from sea level at site A and similarly, Height-2 was 1790m high from sea level at site B-2.

The experiment was commenced on April 20 and terminated on September 14, 2003. Two synthetic pheromone traps were installed in two different apple orchards at (site A and Site B-2) at the Dheerkot locality. These traps were donated by the Department of Agriculture (Entomology Laboratory), Government of Azad Jammu and Kashmir, for the present study. The traps were imported from Zecon Corporation, (Pherocon Supply Service, 975 California Avenue, Palo Alto, Calif. 94304, 415/855-6326) under the Trade Name "Pherocon" (Zecon Corporation 1975). The pheromone traps were triangular in shape, made of cardboard with a smooth shiny inner surface and a rubber capsule containing 1 mg of codlemone (trans-8, Trans-10, dodecadien-1-01) placed in the middle of the shiny surface to attract the codling moth. The synthetic sex pheromone for codling moth was suspended in the centre of the trap. At the bottom of the trap, a cardboard sheet with sticky material was placed to prevent the trapped moth from escaping.

Each pheromone trap was hung at about the middle of the apple crown approximately at head height (Khattak, *et al;* 1989*)* in the centre of the apple orchard. The trapped moths were counted with the help of a stick, already fixed in the pheromone trap. The trapped moths (both dead and semialive) were removed after each observation from the the sticky sheet. The codlemone capsule was replaced every week. The observation on moth catches was taken at weekly intervals between 9:30 to 10:00 A.M. The observations were made on all sites simultaneously on the same date in the Dheerkot locality.

Data Analysis

Regression analysis of variance was applied to find out effects of height on codling moth distribution and also to see seasonal variations on the distribution of adult codling moth at site-A and site-B-2 in Dheerkot locality.

Statistical Analysis

The Chi-square test was carried out to determine variation in the distribution of larvae, pupae and adults of *C.infernalis* at two sites (A&B) of Dheerkot locality during different sampling time.

Predation potential of *C. infernalis*

In order to determine the predaceous potential of *C. infernalis* on San Jose scale, an experiment was conducted under insectary conditions in the field insectary between 3-5-2000 to 12-5-2000 at the Rawalakot campus. The adult beetles were collected from apple trees as described above and brought to the laboratory for further study. Male and female beetles were sexed with the help of a key and confirmation of proper identification was also made by the International Institute of Biological Control (IIBC), Murree Road, Rawalapindi. To differentiate the sexes, a separate code number from 1,2,3....15 and '1,'2,'3,.....'30 was marked on the containers was given to male and female beetles respectively.

To assess the predaceous potential of *C.infernalis*, 30 plastic containers (5x9cm) were used; 15 containers one for each male and 15 for each female beetle were used during the experiment. Each male and female beetle was kept in a separate container. Before commencing the experiment, these beetles were kept hungry for 48 hours after collecting from the field. San Jose scale-infested spurs (twigs) were brought from apple trees to laboratory and were kept in a cooled refrigerator as stock. These SJS infested spurs were observed under the stereomicroscope. The SJS were given to beetles (male and female) at a density of 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, and 75 on spurs to assess their predacious potential. After 24 hours of predation, observations were taken by examining each spur under microscope and number of SJS consumed by each beetle was counted and recorded. After every observation, the old spur was removed and a new spur having SJS with the above density was given to each beetle. The experiment was repeated 10 times to determine the predaceous potential of the beetle *C. infernalis.*

Statistical analysis

The analysis of variance and regression analysis of variance were carried out to find differences in rates of prey consumption potential in male and female beetles (predators) depending upon the density of prey provided to them. Statistical levels of significance were determined at probability 0.05; 0.02; 0.01 and 0.001 for all tests of

Table: 3.1 Distribution of San Jose scales on different apple varieties at Site A (SAAO) and Site B (MTKAO), Dheerkot, District Bagh, Azad Kashmir

Locality			Upper Level		Lower Level		Total
			No. of SJS	Percentage	No. of SJS	Percentage	
Dheerkot District Bagh,Azad Kashmir	A (SAAO)	Star Crimson	409	37.08	694	62.91	1103
		Banky	128	36.36	224	63.63	352
	B(MTKAO)	Banky	188	58.70	132	41. 25	320
		Star King	363	66.97	179	33.02	542

Fig: 3.1 San Jose scale infestations on apple variety (Star Crimson at site A,

Dheerkot Locality

Comparison of distribution of San Jose scales on Banky variety at site A (SAAO) and site B (MTKAO) in Dheerkot locality, District Bagh Azad Kashmir

The distribution of San Jose scales on Banky apple trees at site A and site B was compared to see whether the pest is evenly distributed on the same tree at two different sites. At site B, the highest (58.75%) percentage of the pest was distributed at the upper level of Banky trees whereas at site A, the highest distribution of SJS was at the lower level of Banky trees (63.63%). A highly significant association in the distribution of SJS was observed at upper and lower levels in Banky trees at site A and site B (x^2=33.72; P=0.0001) (Table 3.1).

Distribution of San Jose scales on Star Crimson and Star King apple varieties at site A (SAAO) and site B (MTKAO) in locality-1

The following results describe the distribution of San Jose scales on Star Crimson apple trees at site - A and Banky at site B of Dheerkot locality. In all, 1103 SJS were recorded on Star Crimson apple trees. The percentage distribution of San Jose scale was recorded as a maximum (66.97%) on the upper level of Star King apples and a minimum (33.02%) percentage on the lower level. However, the percentage distribution of San Jose scale was high (62.91%) at the lower level of Star Crimson apple trees compared to low (37.08%) SJS distribution on the upper level of Star Crimson trees at site A (SAAO). Chi-square test showed a highly significant association of San Jose scales on the upper level in Star King trees at site B and the upper level of Star Crimson trees at site A in the Dheerkot locality. (x^2=130.04; P=0.0001 ;Table 3.1).

Locality –2

Rawalakot, District Poonch, Azad Kashmir

Distribution of San Jose scale (SJS), *Quadraspidiotus perniciosus (Comstock)* at site A (Sardar Mahtab Khan Apple Orchard (SM KAO)) in locality-2

The results regarding the distribution of San Jose scale in locality - 2 and its sites on different apple varieties are given in Table 3.2. In the Star King and Banky apple trees a total of 253 and 303 San Jose scales was recorded, respectively. At the upper level in Banky (45.84%) and Star King (46.53%), the percentage distributions of San

Jose scale were observed at site A in the Rawalakot locality.There is no significant difference in the distribution of the pest. A similar picture is seen in the lower level of Banky (54.15%) and that of Star King (53.46%) trees. This shows that San Jose scales were evenly distributed on the upper and the lower levels of the two different cultivars (Banky and Star King) of apple trees (X2= 0.062; P=0.87 ; Table 3.2).

Table: 3.2 Distribution of San Jose scales on different apple varieties at Site A (SMKAO) and Site B (SAKAO), Rawalakot, District Poonch, Azad Kashmir.

Locality	Site	Variety	Upper Level		Lower Level		Total
			No.of SJS	Percentage	No.of SJS	Percentage	
Dheerkot	A (SMKAO)	Star King	141	46.53	162	53.46	303
District Poonch,Azad Kashmir		Banky	116	45.84	137	54.15	253
	B (SAKAO)	Banky	108	42.68	145	57.31	253
		Golden	84	30.10	195	69.89	279

Distribution of San Jose scale (SJS), *Quadraspidiotus perniciosus (Comstock)* at site B (Sardar Ashraf Khan Apple Orchard (SAKAO)) in locality - 2

Distributions of San Jose scales on Banky apple trees at site B of Rawalakot locality are given in Table 3.2. An overall higher (279) distribution of San Jose scales was observed on Golden apple trees. The maximum (69.89%) percentage distribution of San Jose scale was recorded on the lower level of Golden apple trees compared to the minimum (30.10%) percentage distribution on their upper level. Percentage distribution of San Jose scale was also high (57.31%) at the lower level of Banky apple trees. Chi-square test shows highly significant (x^2=9.10; P=0.0026) association of San Jose scales distribution in the upper and lower levels of Banky and Golden apple trees. The upper level of Banky showed a higher concentration of the pest than the expected value. Both these apple trees constituted 5.82 values of the total 9.10 Chi-square value (Table 3.2).

Distribution of San Jose scale (SJS), *Quadraspidiotus perniciosus (Comstock)* on Banky variety of apple trees at site A (Sardar Mahtab Khan Apple Orchard (SMKAO)) and site B (Sardar Ashraf Khan Apple Orchard (SAKAO) in locality - 2

The Distribution of San Jose scales on Banky apple trees at site A and B of Rawalakot locality is given in Table 3.2. In total (253), San Jose scales were observed on Banky apple trees at both upper and lower levels. The percentage distribution of San Jose scales was recorded as a maximum (57.3 %) on the lower level of Banky apple trees compared to the minimum 42.68 % on the upper level at site B. At site A, the distribution of San Jose scale was also high (54.15%) at the lower level of Banky apple trees compared to its upper level (45.84 %). At site A and site B an even distribution of this pest on Banky apple trees was observed (X^2= 0.51; P=0.47), (Table 3.2).

Distribution of San Jose scale (SJS), *Quadraspidiotus perniciosus (Comstock)* on Banky and Golden apple trees at site A (Sardar Mahtab Khan Apple Orchard (SMKAO)) and site B (Sardar Ashraf Khan Apple Orchard (SAKAO) in Rawalakot (Locality-2)

The distributions of San Jose scales on Banky and Golden apple trees at sites A and B in Rawalakot locality are given in Table 3.2. In total, 279 San Jose scales were observed on Golden apple trees. The San Jose scale distribution was recorded as a maximum (69.89 %) on the lower level of Golden apple trees compared to the low (30.10 %) percentage on the upper level of these trees. A higher percentage distribution (54.15%) of San Jose scale was at the lower level of Banky apple trees compared to the upper level (45.84%). There is a highly significant association in the distribution of San Jose scales on the lower levels of Banky and Golden apple trees at site A and site B (X^2= 14.02; P=0.0002) compared to their upper levels (Table 3.2).

Distribution of San Jose scale (SJS), *Quadraspidiotus perniciosus (Comstock)* on Starking and Golden varieties of apple trees at site A (Sardar Mahtab Khan Apple Orchard (SMKAO)) and site B (Sardar Ashraf Khan Apple Orchard (SAKAO) in Rawalakot (Locality -2)

The distribution of San Jose scales on Star King and Golden trees was observed at site A and site B apple trees. A total of (303) San Jose scales were recorded on Star King apple trees. The highest percentage of the pest was observed at the lower level (53.46 %) and low percentage at the upper level (46.53 %) of Star King apple trees. In the case of Golden apple trees, a total of 279 San Jose scales were recorded, of which the highest percentage was seen in the lower level (69.89 %) and a lower percentage on the upper level (30.10 %).The distribution of San Jose scale varied highly significantly over the upper and lower levels of the two varities of apple, i.e, Star King and Golden (X^2= 16.53; P=0.0001). In Star King (site A) and Golden (site B) San Jose scales tend to gather on the lower levels of these trees (Table, 3.2).

Locality 3

Lamniayan, District Muzaffarabad, Azad Kashmir

Distribution of San Jose scale (SJS), *Quadraspidiotus perniciosus (Comstock)* on Banky and Red Delicious varieties of apple trees at site A (M.Zafar Khurshid Apple Orchard (MZKAO)) in Lamniayan (Locality 3)

The results pertaining to the distribution of San Jose scales are presented in Table, 3.3. The distribution of San Jose scales on the two varieties of apple, i.e, Banky and Red Delicious apple trees at site A (M.Zafar Khurshid Apple Orchard) of Lamniayan locality was recorded. A total of 550 San Jose scales was recorded from Banky apple trees, of which 44.54 % was on the upper level and 55.45 % on the lower level. San Jose scales collected from Red Delicious apple trees were 398 in numbers. A higher percentage (61.31) was distributed over the lower level and a lesser percentage (38.69) on the upper level. There was no significant difference in the distribution of the pest on the upper and lower levels in these two varieties of apple (X^2= 3.244; P=0.0717) (Table 3.3) indicating that distribution of the pest is more or less even on the upper and lower levels of the trees.

Table: 3.3 Distribution of San Jose scales on different varieties of apple trees at Site A (MZKAO), and Site B (SQAO) Lamniayan, District Muzaffarabad, Azad Kashmir

Locality	Site	Variety	Upper Level		Lower Level		Total No.
			No of SJS	Percentage	No of SJS.	Percentage	
Lamniayan District Muzaffarabad Azad Kashmir	A MZKAO	Banky Red Delicious	245	44.54	305	55.45	550
			154	38.69	244	61.31	398
	B SQAO	Golden	57	27.81	148	72.91	205
		Banky	117	34.51	222	65.48	339

Distribution of San Jose scale (SJS), *Quadraspidiotus perniciosus (Comstock)* on Banky and Golden varieties of apple trees at Site B (Shouqat Qayyum Apple Orchard (SQAO) in Lamniayan (Locality 3)

The results are presented in Table 3.3. The distribution of San Jose scales on Banky and Golden apple trees at site B (Shouqat Qayyum Apple Orchard (SQAO)) of Lamniayan locality was recorded. A total of 339 San Jose scales was recorded on Golden apple trees at two levels and in Banky 205 pests were collected. In Banky (72.19%) as well as in Golden (65.48%), a higher percentage of the pest was distributed on the lower level than on the upper level of Banky and Golden (27.81%; 34. 51%) respectively. Chi-square test shows that San Jose scales are evenly distributed on the upper and lower levels of these two varieties of apple (Banky and Golden) (X^2= 2.64; P=0.104), (Table 3.3).

Distribution of San Jose scale (SJS), *Quadraspidiotus perniciosus (Comstock)* on Banky variety of apple tree at site A (M.Zafar Khurshid Apple Orchard (MZKAO) and site B (Shouqat Qayyum Apple Orchard (SQAO)) in Lamniayan, District Muzaffarabad, Azad Kashmir

San Jose scales on Banky apple trees were recorded at both sites of Lamniayan locality. A higher number (550) of San Jose scales on Banky apple trees was collected from site A and a smaller number (339) was collected from site B. Both at site A (55.45%) and site B (65.48%) on the lower levels of Banky trees. A low percentage of this pest was collected from upper level of Banky trees, at site A (44.54%) and site B (34.51%). A highly significant difference in the distribution of San Jose scales on the upper and lower levels of Banky trees at site A and site B (X^2= 17.43; P=0.003) indicates an association of the pest to the lower levels of these trees, where their higher distribution was observed compared to the upper levels (Table 3.3).

Distribution of San Jose scale (SJS), *Quadraspidiotus perniciosus (Comstock)* on Red Delicious and Golden varieties of apple trees at Site A (Zafar Khurshid Apple Orchard (ZKAO) and Site B (Shouqat Qayyum Apple Orchard (SQAO) in Lamniayan (Locality 3)

The distribution of San Jose scales on Red Delicious and Golden apple trees was observed at both sites (A and B) of the Lamniayan locality on the upper and lower levels of these apple trees. At the lower level of Red Delicious (61.31%) and Golden apple varieties (72.91%), a higher percentage of the pest was seen than on the upper level of Red Delicious (38.69%) and Golden apple varieties (27.81%). The distribution of San Jose scale on upper and lower levels of Red Delicious and Golden varieties was highly significant This shows that both in Red Delicious and Golden varieties of apple, this pest (San Jose scale) tends to remain thickly distributed in the lower part of these apple trees. An association to the lower part of the apple trees was observed (X^2= 5.30; P=0.0079); Table 3.3).

Pest 2

Study on codling moth, *Cydia pomonella* (L.) at Dheerkot, District Bagh, Azad Kashmir

Field and insectary studies were carried out pertaining to the infestation of *C. pomonella* on apple fruits under field and insectary conditions at two different sites, site A (Sarfraz Abbasi Apple Orchard and Site B (Tazeem Khan Apple Orchard) in Dheerkot locality, District Bagh, Azad Kashmir.

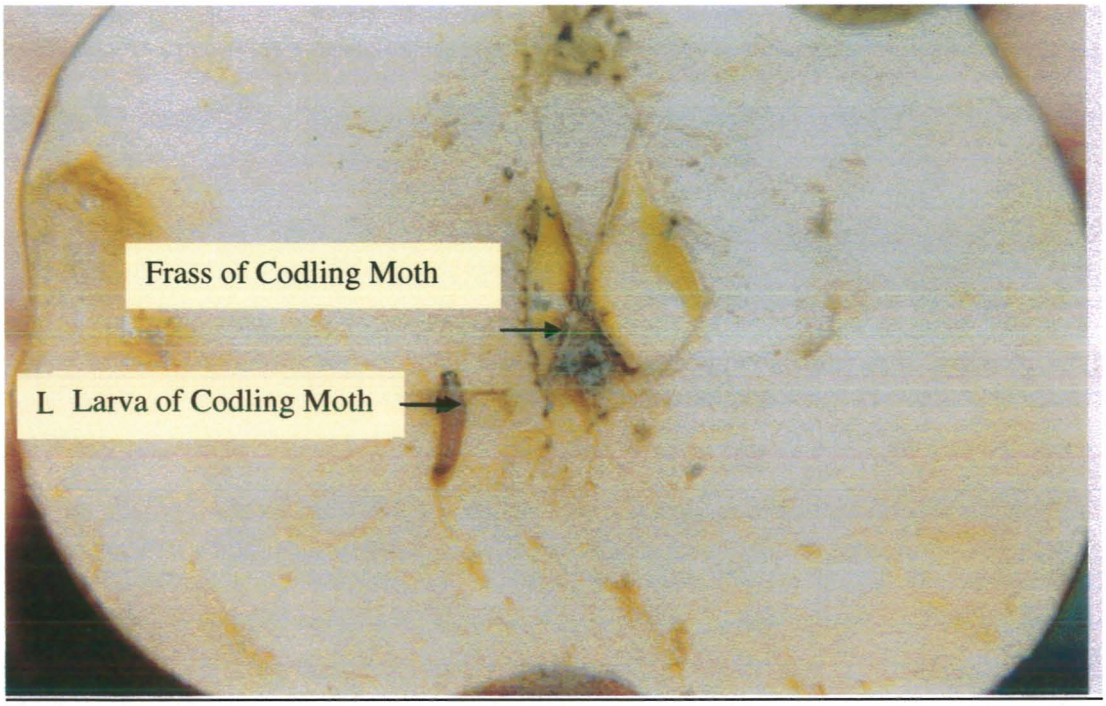

Fig: 3.2 A view of codling moth larval infestation and frass

Larval infestation of codling moth, *Cydia pomonella* (L.) on different apple varieties in Dheerkot, District Bagh, Azad Kashmir

The results on larval infestation are given in Table 3.4. A total of 633 apples of five different varieties, namely Banky, Golden, Kashmiri, Star-king and Star Crimson were examined fortnightly from the two private apple orchards, Sarfraz Abbasi Apple Orchard and Tazeem Khan Apple Orchard at Dheerkot, District Bagh. Of these pooled, (288) apples were found infested. Larval infestation was identified due to the presence of larvae or exit holes in the apples. Percentage infestation of *C. pomonella* ranged from 8.33 to 90.26%. Star Crimson variety was the least infested (8.33%) whereas the indigenous cultivars Kashmiri, was highly infested (90.26%) with codling moth. The next highly infested variety with codling moth larvae was Golden (72.67%) apples. All the five varieties of apple showed highly significant variations for infestation of codling moth larvae (x^2=74.43; P< 0.0001). An association of codling moth larval infestation with Kashmiri variety was observed (x^2=172.22; P<0.001). Star Crimson (8.33%), Starking (26.92%) and Banky (29.76%) were the least infested apple varieties of codling moth larvae at the Dheerkot locality (Table 3.4).

Table 3.4: Number of infested, not infested and overall percent infestation of codling moth, *C. pomonella* in different apple varieties at Dheerk (Bagh), Azad Kashmir, during 1999

Sr. No.		Number of apple			
	Variety	Not infested	Infested	Total	% Infestation
1.	Banky	139	50	189	26.45
2.	Golden	44	117	161	72.67
3.	Kashmiri	11	102	113	90.26
4.	Star Crimson	132	12	144	8.33
5.	Starking	19	7	26	26.92
Total:		345	288	633	45.49

(x^2=74.43; P< 0.0001)

Codling moth larval infestation on different apple varieties at different timings from May – August, 1999 at Dheerkot, District Bagh, Azad Kashmir

Sampling of codling moth larvae on apple varieties was started in the last week of May, 1999. No larval infestation was observed during this period. In the middle of June, 1999 2.80 % infestation was recorded.This infestation increased to (13.09 %) in the last week of June, 1999. The infestation with codling moth larvae was high (96.91 %) in the first week of July, 1999. This infestation continued until the start of second week of July with a slight reduction in the infestation (94.86%) during the month of July, 1999. In the last week of July, the infestation decreased to 57.13%. In the second week of August, 1999, there was an increase in the larval infestation reaching a maximum of 99.57% (Table 3.5).

Table 3.5: Codling moth, *Cydia pomonella* (L.), infestation in apples at Dheerkot, District Bagh, Azad Kashmir, during May- August, 1999

Sample No.	Date of Sampling	Number of different apple varieties observed	Cause of infestation		Percentage infestation		
			Presence of Larva	Exit hole	Larval existence	Exit hole	Total (Larva + exit hole)
1.	25.5.1999	87	0	0	0.00	0.00	0.00
2.	13.6.1999	106	1	2	0.94	1.86	2.80
3.	23.6.1999	145	1	18	0.68	12.41	13.09
4.	01.7.1999	130	20	106	15.38	81.53	96.91
5.	09.7.1999	78	17	57	21.79	73.07	94.86
6.	27.7.1999	49	4	24	8.16	48.97	57.13
7.	11.8.1999	38	5	33	13.15	86.42	99.57

Codling moth infestation of apple fruits through larvae and exit holes

The result regarding infestation of apple fruits due to larvae and exit holes is presented in the Table 3.6.

Table 3.6 Percentage infestation of codling moth due to Larvae and exit holes on apples varieties at Dheerkot, District Bagh, Azad Kashmir

Total no. of apples obs.	Larvae	Exit holes
633	48(7.5%)	240 (37.91%)

A total of 633 apple fruits of the different varieties were observed at Dheerkot locality. The percentage of larval infestation as determined by the presence of larvae was (7.5%), whereas percentage larval infestation as determined by the presence of exit holes in the apple fruits was (37.91%) at the Dheerkot locality.

Distribution of codling moth, *Cydia pomonella* (L.) and percentage infestation at site A and site B on different levels in apples varieties at Dheerkot locality

Distributions of codling moth larval infestation on different levels of apple trees and sites are given in Table 3.7. At site A (Sarfraz-Abbasi-Apple-Orchard) overall infestation with larvae of *C. pomonella* was less (21.8%) than at site B (Mohammad Tazeem-Khan-Apple-Orchard) where the overall infestation was very high (70.05%) at Dheerkot (Bagh) locality. At site A, the percentage infestation range was between 8.45 to 26.92%, which was low compared to the high infestation range between 40.56 to 89.47% at site B. In site A, at lower level of Banky apple trees infestation with codling moth larvae was low (10.34) compared to that in Banky apple trees at site B, which shows higher infestation (312.57%). At the upper level of the Banky apple trees at site A has less larval infestation (9.30%) but higher larval infestation (39.24%) was in the Banky trees at upper level in site B. In the Star Crimson apple variety, the upper level was found more infested (12.04%) at site A (SAAO) compared to the low value on the lower level (3.39%) at the site A. At the Sarfraz Abbasi Apple Orchard in the Starking apple variety on its lower level, a higher

infestation (37.5%) of codling moth larvae was recorded whereas a lower (22.22%) codling moth larval infestation was observed on the upper level of Star-King. The percentage codling moth larval infestation was high (93.10%) on the upper level in Kashmiri apple variety compared to low (85.71%) on its lower level at site-B (Mohammad Tazeem Khan Apple Orchard). However, in the Golden apple variety, the codling moth larval infestation was 72.04% and 56.81% on the upper and lower levels at site B. Analysis of variance shows that a highly significant ($P<0.001$) variation in codling moth infestation was recorded at site-A and site-B in the Dheerkot locality whereas a significant ($P<0.03$) variation in the infestation of codling moth larvae was also observed when the two sites A and B and their apple trees were compared at the Dheerkot locality (Table 3.8).

Table 3.7 Distribution of codling moth, *Cydia pomonella* (L.) and % infestation at different levels of apple trees on apple varieties at Dheerkot (Bagh), Azad Kashmir, from May 25 to August 11, 1999

Site	Variety	Lower-Level			Upper-Level			Overall % infestation
		uinfested	Infested	% Infestation	uinfested	Infested	% Infestation	
Sarfraz Abassi Apple orchard (Site A)	Banky	26	3	10.34	39	4	9.30	11.29
	Star-Crimson	57	2	3.39	75	10	12.04	8.45
	Star-King	5	3	37.5	14	4	22.22	26.92
Overall infestation:		***88***	***8***	***9.30***	***128***	***18***	***12.5***	***21.8***
Tazeem Khan Apple orchard (Site B)	Banky	26	12	31.57	48	31	39.24	40.56
	Kashmiri	8	48	85.71	4	53	93.10	89.47
	Golden	18	50	56.81	26	67	72.04	63.58
Overall infestation:		***52***	***110***	***72.84***	***78***	***151***	***68.16***	***70.05***

Table 3.8 Analysis of Variance for codling moth larval infestation at site A (SAAO) and site B (MTKAO) in Dheerkot, District Bagh Azad Kashmir

S.O.V	Df	SS	MS	F	P
Sites	2	732.7	366.3	5.846	0.03
Site A and B	1	4641	4641	74.06	0.001
Trees	2	806.0	403.0	6.431	0.03
Residual	6	376.0	63.67		

Monitoring of adult codling moth, *C. pomonella* (L.) at site A (Sarfraz Abbasi Apple Orchard (SAAO) and site B-2 (Sarwar Abbasi Apple Orchard (Sw AAO) by using pheromone traps in District Bagh, Azad Kashmir

Mean Population of codling moth trapped per week during different months at site A and site B in Dheerkot locality

The mean population of adult codling moth is given in Table 3.9. Codling moths were trapped from two sites (A and B-2) at Dheerkot, District Bagh. Site A and B are located at different heights. Site A is located at a height of 1686 m and site B-2 is located at a height of 1790 m from sea level.

The highest mean collection of codling moth was in the month of April (12.25± 3.29), (11.25± 2.65) at site A and site B respectively. From the month of May onward up-to the month of September, the mean collection of codling moth at both the sites started declining. The lowest mean collection was in the month of September(1.25± 0.25, 1.25± 0.47) at site A and site B respectively. Regression analysis of variance shows highly significant reduction in mean population of codling moth by the end of September at site A, (b=-1.99 ± 0.54; F=13.50, P=0.021) as well as at site B-2 (b =-1.84 ± 0.50; F= df=1,4; F=13.07; P=0.022). The decline in the mean population of codling moth was significantly higher at site A than at site B with the advance in months of the year.

Table 3.9 Mean Population of codling moth, *Cydia pomonella* trapped during different months at site A (SAAO) and site B- 2 (SwAAO) at Dheerkot, District Bagh, Azad Kashmir

Months	Site-A	Site-B
April	12.25 ± 3.29	11.25 ± 2.65
May	7.62 ± 0.80	9.75 ± 1.33
June	2.30 ± 0.92	4.70 ± 0.61
July	4.50 ± 1.74	8.75 ± 2.55
August	1.90 ± 0.56	3.60 ± 0.58
September	1.25 ± 0.25	1.25 ± 0.47

Differences in distribution of codling moth, *C. pomonella* between sites (A and B-2) and between months at Dheerkot locality

The results are given in table 3.10. Analysis of variance was carried out to see the differences in the distribution of adult codling moth between sites(A and B-2) and between months.There is a non significasnt difference in the distribution of codling moth between the two sites (A and B-2); (F=4.35;df=1,4;P=0.09). However, between months of collection, there is a highly significant difference in the collection of codling moths between months (F=18.42; df =1, 4; P=0.0031). This indicates that variance in collection of codling moths between months is very high at site A and site B-2. Overall mean collection of codling moth at site A was 4.97± 1.74 and at site B-2 was 6.55 ±1.61 but the two means do not differ significantly (F=0.66; df =10; P=0.52). This also shows that the difference in heights (although only 104 m) between site A and site B-2 has no effect on distribution of codling moth at these two sites of the Dheerkot locality.

Table 3.10 Analysis of variance shows difference in distribution of codling moth, *Cydi pomonella* population at site A and site B-2 and also mean difference in codling moth distribution between months at Dheerkot locality, District Bagh, Azad Kashmir.

S.O.V	D.f	SS	MS	F	P
Between sites	1	7.52	7.52	4.35	0.09
Between months	5	159.3	31.65	18.42	0.0031
Residual	5	8.65	1.73		

Distribution of *Chilocorus infernalis* (Mulsant): a predator of San Jose scale, *Q.perniciosus* (Comstock) in Dheerkot (Bagh) and Rawalakot (Poonch) localities.

The field study was conducted for distribution of *Chilocorus infernalis* (Mulsant) on apple trees during 27th March to 10th September 2000. The distribution pattern of *C. infernalis* was examined in two localities (Dheerkot and Rawalakot) at four sites, A and B in each locality. Another experiment on the predatory potential of *C .infernalis* on San Jose scale, *(Q. perniciosus)* was also conducted under insectary conditions at Rawalakot.

Distribution of *C. infernalis* (Mulsant)

During the sampling period in 2000, a total of 498 specimens (larvae, pupae and adults) of *C. infernalis* were collected from different varieties of 24 apple trees from Rawalakot and Dheerkot localities (Table 3.11). A large number of *C. infernalis* (n=427) was collected from the Dheerkot locality at site A and site B, compared to a low number (n==71) from Rawalakot locality at site A and site B. The stages of *C. infernalis* available at the time of study were larvae, pupae and adults. From Dheerkot, site A, 55.29 % larvae, 19.05%, pupae and 25.66% adults were collected. From site B of Dheerkot 38.77% larvae, 30.61 %pupae and 30.61% adult were collected. All stages collected from site A (Dheerkot) were 88.52 % (n = 498) and from site B (Dheerkot), this was 11.47 % (n=49). In the the Rawalakot locality at site A no developmental stages were recorded because larvae, pupae and adults were not available during the period of collection. It was only at site B of Rawalakot locality that 16.91 % of larvae, 19.72% pupae and 63.38% of adults were recorded. A highly significant difference (x^2=261.8; d.f.=1; P<0.001) in the distribution pattern of *C. infernalis* developmental stages was observed in Dheerkot and Rawalakot localities in their respective sites A and B (Table 3.11). The possible reason for absence of *C .infernalis* at site A of locality Rawalakot is difficult to suggest.

Table 3.11: Overall percentage distribution of different stages of *C. infernalis* on apple trees collected from two localities (Dheerkot and Rawalakot), Azad Kashmir.

Locality	Specimens	Sites		Total
		A	B	
Dheerkot	Larvae	209 (55.29%)	19(38.77%)	228
	Pupae	72(19.05%)	15(30.61%)	87
	Adults	97(25.66%)	15(30.61%)	112
Sub-total (a)		378(88.52%)	49(11.47%)	**427**
Rawalakot	Larvae	0	12(16.90%)	12
	Pupae	0	14(19.72%)	14
	Adults	0	45(63.38%)	45
Sub-total (b)		0	71	**71**
Grand Total (a+b):		378	120	**498**

(x^2= 261.8; df=1, P<0.001

Table 3.12 Monthly percentage distribution of *C. infernalis* developmental stages at site A and site B in Dheerkot, District Bagh, Azad Kashmir during March-September, 2000

	Dheerkot					
Month	Site A			Site B		
	Larvae	Pupae	Adults	Larvae	Pupae	Adults
March	43(20.59%	0	0	5(23.31%)	0	0
April	80(38.27%)	52(72.0%)	35(36.08%)	12(63.15%)	11(73.39%)	6(40%)
May	10(4.78%)	8(11.11%)	34(35.05%)	2(10.52%)	2(13.33%)	5(33.0%)
June	15(7.17%)	5(6.99%)	13(13.40%)	0	0	4(26.66%)
July	48(22.96%)	3(4.16%)	3(3.09%)	0	0	0
August	13(6.22%)	4(5.55%)	12(12.37%)	0	2(13.33%)	0
September	0	0	0	0	0	0
	209(55.27%)	72(19.04%)	97(25.60%)	19(38.77%)	15(13.61%)	15(13.61%)

Table 3.13 Percentage distribution of *C. infernalis* developmental stages at site A and site B in Rawalakot, District Poonch, Azad Kashmir during March-September, 2000

Month	Rawalakot					
	Site A			Site B		
	Larvae	Pupae	Adults	Larvae	Pupae	Adults
March	0	0	0	0	0	0
April	0	0	0	0	0	0
May	0	0	0	0	2(14.28%)	33(73.35%)
June	0	0	0	0	0	9(20.0%)
July	0	0	0	9(75.0%)	5(35.71%)	1(2.22%)
August	0	0	0	3(25%)	7(1(50.0%)	2(4.44%)
September	0	0	0	0	0	0
	0	0	0	12(16.90%)	14(19.71%)	45(63.38%)

Distribution of *C. infernalis* at site A and site B in Dheerkot and Rawalakot locality

Distributions of *C. infernalis* at two sites of Dheerkot and Rawalakot are given in Table 3.12 and 3.13. Results show distribution of *C. infernalis* developmental stages (larvae, pupae and adults) at site A in Dheerkot as per monthly collection showed a higher percentage of larvae (38.77%), pupae (72.0%) and adults (36.08%) in the month of April. From the month of May until September no regular pattern of distribution of these developmental stages was seen. September was the month where not a single stage of the predator was recorded in the localities, i.e, Dheerkot and Rawalakot. At site B, Dheerkot locality, larvae (63.05%), pupae (73.33%) and adults (40.0%) were collected in the month of April and May. This suggests that the locality Dheerkot has suitable conditions for the emergence of large number of larvae, pupae and adults in the month of April.

In Rawalakot locality at not a single developmental stage was recorded from the month of April upto the month of September. At site B, there was a patchy distribution of developmental stages of the *C.infernalis* larvae in the months of July and September. Pupae were seen during the months, May, July and August. Adults were recorded from the month of May to the month of August.(Table 3.13).

Distribution of Prey (SJS) and Predator, *C .infernalis* at Site A and Site B in Dheerkot and Rawalakot localities

The distribution of prey (SJS) and predator (*C. infernalis*) in Dheerkot and Rawalakot at their respective sites, site A and site B is shown in Table 3.14. In Dheerkot at site A the highest number of prey and that of predator compared to that in site B. At site B, compared to site A, less number of preys and predators were recorded. In total, there were 64.85% (n=2007) of preys and 85.47 % (n=427) predators at site A and B. In Rawalakot, compared to Dheerkot, total percentage of preys at site A and site B was 35.51 % and of predators was 14.26 % (Table 3.14).

Chi-Square test shows highly significant predator-prey association in the Dheerkot than in the Rawalakot (X^2=85.72; df=1; P<0.001; Table 3.15).

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Table 3.14 Distribution of Prey (SJS) and Predator (*C .infernalis*) at Site A and Site B in Dheerkot and Rawalakot locality, Districts Bagh and Poonch, Azad Kashmir

	Dheerkot			Rawalakot			G.T
	Site A	Site B	Total	Site A	Site B	Total	
Prey(SJS)	1145	862	2007 (64.85 %)	556	532	1088 (35.15%)	3095
Predator *C.infernalis*	378	49	427 (85.47 %)	0	71	71 (14.26%)	498
			21. 27 %			6.52%	

Table 3.15 Distribution of Population of Prey and Predator in Dheerkot and Rawalakot and the test of significance shows an association between Prey and Predator

	Locality		
	Dheerkot	Rawalakot	Total
Prey	2007	1088	3095
Predator	427	71	498
Total	2434	1159	3593

X^2= 85.72; df = 1; P<0.001

Predation potential of *Chilocorus infernalis* (Mulsant) on San Jose scale, *Q. perniciosus* (Comstock)

The study of the predation potential of *Chilocorus infernalis* (Mulsant) on San Jose scale, *Q .perniciosus* was carried out at Rawalakot between 3- 5- 2000 and 12-5-2000.

Experiments were performed under insectary conditions to find out the predation potential of *Chilocorus infernalis* on San Jose scale at Rawalakot. The experiment was based on 30 predators, of which 15 predators were male and 15 were female. Each predator was provided with a specific number of preys for 10 days. Predator no.1 was provided with 5 preys daily for 10 days and prey consumption for each day was recorded. From predator no.2 onward up to predator no.15, five preys were added successively, ending up with 75 preys for predator no.15. Table 3.16 shows the predators, number of preys given to each predator, mean prey consumption by each predator (both male and female predators). Mean consumption of prey was based on 10-days duration.

Total mean consumption of prey by male predators was 27.77 ± 3.34 and the female predator was 29.29 ± 3.51. Two way analysis of variance showed a highly significant ($P< 0.0011$) difference in predation potential in the two sexes and in the prey consumption by the male and female predators Table, 3.17).

Table 3.16: Mean consumption of male and female predators of *C. infernalis* under inectary condition at Rawalakot Azad Kashmir

Predator no	Prey given/ day	Prey consumption by male predator / day	Prey consumption by female predator / day
1	5	4.8 ± 0.69	4.1 ± 0.88
2	10	6.8 ± 2.01	8.6 ± 1.34
3	15	12.8 ± 2.3	12.4 ± 1.49
4	20	14.6 ± 2.21	17.2 ± 1.47
5	25	20.0 ± 1.9	20.6 ± 2.41
6	30	23.8 ± 2.8	25.3 ± 2.86
7	35	30.2 ± 2.61	30.3 ± 2.98
8	40	32.5 ± 3.09	33.5 ± 3.06
9	45	35.0 ± 3.5	30.4 ± 2.27
10	50	35.8 ± 2.63	40.3 ± 3.74
11	55	38.1 ± 2.84	40.1 ± 4.02
12	60	39.0 ± 3.23	41.1 ± 4.93
13	65	39.9 ± 2.63	43.6 ± 5.08
14	70	41.3 ± 1.82	42.7 ± 3.16
15	75	41.9 ± 1.91	42.2 ± 7.14

Table 3.17 Analysis of variance for consumption by male and female predator, *C .infernalis* on San Jose scale prey under insectary condition at Rawalakot, District Poonch, Azad Kashmir

S.O.V	D.f	SS	MS	F	P
Male Vs Female	1	17.48	17.48	16.61	0.0011
Prey cons.	14	4933	352.3	334.8	0.0001
Residual	14	14.73	1.05		

Both male (b=2.79 ± 0.21; F =178.2; df =1, 13; P<0.0001) and female (b=2.92 ± 0.24; F= 150.9; df=1, 13; P<0.0001) predators showed highly significant increase in the prey consumption. There was difference in prey consumption from predator no. 10 onward (in male and female). In male and female prdators, fifty preys were provided for 10-days. The male predators consumed on an average of 35.8% ± 2.63 preys and the female predators consumed on an average of 40.3 ± 3.74 preys. A higher mean consumption of preys by female predators continued upto the predator no.15 (42.2 ± 7.14) compared to the male predatos. The Female predators maintained plateau in the prey consumption from no.10-15. Among the male predators, mean increase in the prey consumption at predator no.14 (41.3 ± 1.82) and predator no. 15 (41.9 ± 1.91) was observed (Table 3.16). Starting from predator no. 1 to 9, the overall mean prey consumption of male (20.05 ± 2.35) and female (20.26 ± 2.08) predators showed not much difference. From the predator no. 10 onward, the overall mean consumption by male was 39.33 ± 2.51 and by female predators, it was 41.67 ± 4.67. The results suggest that acceleration in the prey consumption depends on density of prey. At predator no. 10, both for the male and female predators, the preys provided were 50 and on addition of 5 preys later on continued upto the predator no.15. As the prey density increase female predators were more voracious in the prey consumption than the male predators

In the female predators from predator no. 10 to predators no.15, the mean prey consumption showed no appreciable difference and showed a non-significant increase in the prey consumption (b=0.56 ± 0.24; F=5.42; df=1,4; P = 0.08). However, in the male predators, there was a gradual, highly significant increase in the prey consumption starting from predator no. 10 to predators no.15 (b=1.17 ± 0.11; F=109.3; df =1, 4; P<0.0005). In the female predators, the highest mean prey consumption was observed in the predator no.10 (40.3 ± 3.74) and it was 42.2 ± 7.14 by the predator no.15, which indicates that from predators 10-15, a plateau in prey consumption was maintained.

Chi- Square test was applied to find difference in the consumption of prey by male and female beetles. Prey consumed and prey not consumed of male and femle beetles show that female beetles were significantly more predaceous compared to the male beetles(x^2= 44.05; df =1; P<0.001). From the predator numbers 10 to 15, total preys provided to male predators were 3489 and they consumed 60.47% (n=2110) of these. The female predators were provided 3733 preys of which they consumed 67.96% (n=2537)(Table 3.18, Fig 3.3, Fig 3.4, 3.5 and 3.6).

Table 3.18: Total number of consumed and not consumed San Jose Scales by male and female predators no. 10-15 under insectary condition at Rawalakot, District Poonch, Azad Kashmir

Predator	Prey consumed	Prey Not Consumed
Male	2110	1379
Female	2537	1196

(x^2=44.05; df =1; P<0.001)

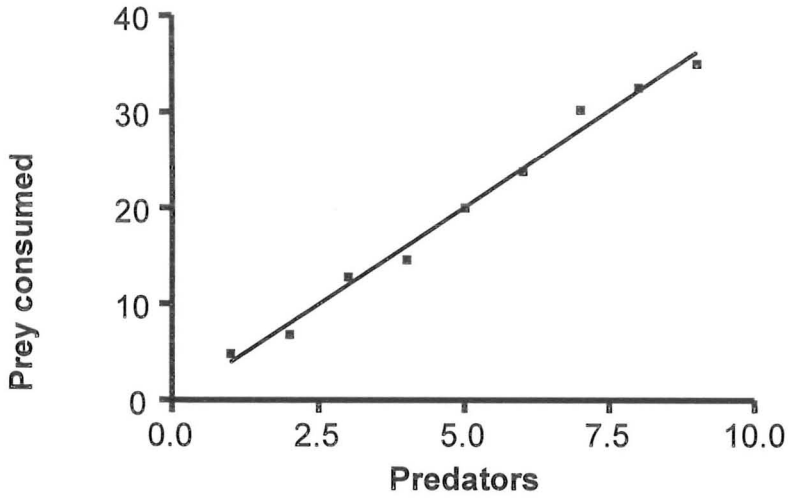

Fig: 3.3 Prey consumed by male predators no. 1 to 9.

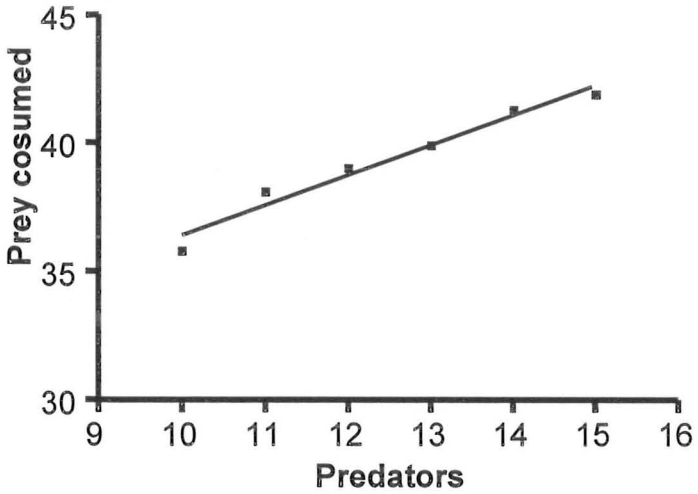

Fig: 3.4 Prey consumed by male predators no. 10 to 15.

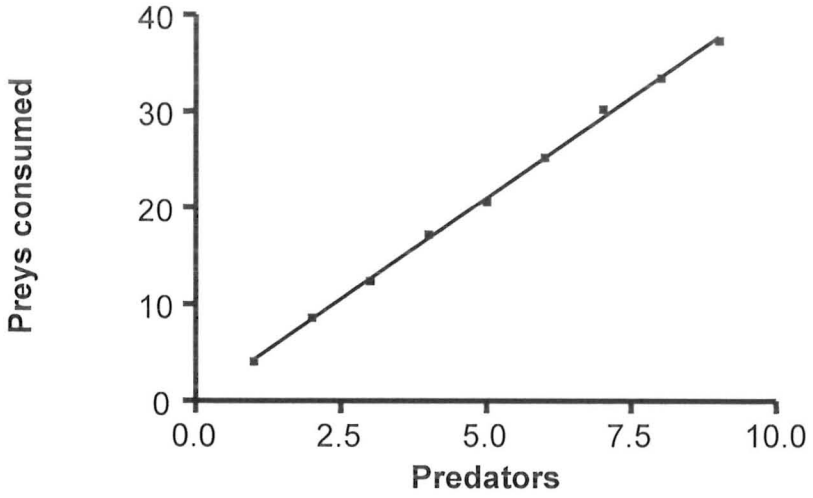

Fig: 3.5 Preys consumed by female predators no. 1 to 9

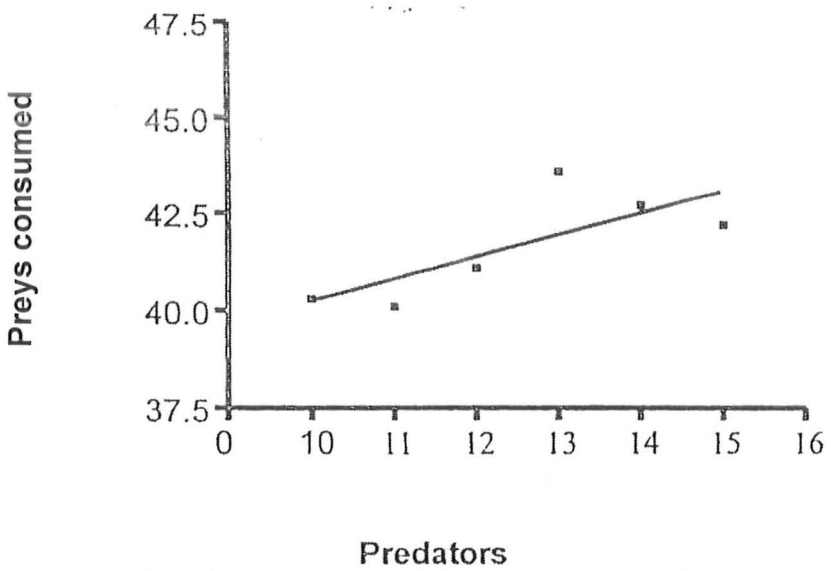

Fig: 3.6 Preys consumed by female Predator No. 10 to 15

DISCUSSION

The focus in this study was on distribution of pests, i.e, San Jose scale and codling moth on different types of apple trees in three localities, i, e, Dheerkot (Bagh), Lamniayan (Muzaffarabad) and Rawalakot (Poonch), Azad Kashmir. Th distribution of San Jose scale was studied in all the three localities. In case of codling moth, distribution was studied only in the Dheerkot because we were unable to record this pest from the other two localities, i, e., Rawalakot and Lamniayan. Infestation of this pest was also studied in detail. The distribution of lady bird beetle, *C. infernalis* a predator of San Jose scale was studied in the Dheerkot and Rawalakor but this predator was not recorded in the lamniayan locality. Further, a predation potential of this predator was also focused.

Distribution of Pest (San Jose scale) in Dheerkot Locality

The distribution of the pest at particular region of apple trees, i.e, upper level and lower level was observed in particular. In Dheerkot locality, the apple trees on the eastward direction were designated as site A and those on the westward direction were designated as site B. In site A, concentration of SJS was both on the upper and lower levels of varieties, Star crimson and Banky but this distribution was not significantly different. In site B, there was a highly significant concentration of SJS on the upper level of the apple trees, Star King and Banky. Although, not a signicant difference was seen in the upper and lower levels at site A but a higher concentration of SJS was recorded on the lower levels of apple trees. Both the sites showed minor change in the concentration of SJS. One factor could also be the geographic direction of the two sites.

The concentration of pest has been reported by different research workers. Candolf (1992) studied spatio- temporal distribution of *Panonychus ulmi* (Koch) on grapevines in Switzerland. He observed distribution of mites at different strata but more on the lower levels of the grapevines. Erkilic and Uygun (1995) examined the distribution of peach scale, *Pseudaulca pentegona* on four quadrant of the tree in Turkey. They observed that this pest was thickly distributed on the branches and twigs (upper level of tree). In these two studies behaviour of different pests indicates that they tend to concentrate on the lower and upper levels of the trees. Mague and Reissig (1983) carried out study on the distribution of crawlers, *Q. perniciosus* within

apple tree canopy. They observed abundance of the crawlers on the upper part of the tree canopy in norh-east and south-east direction. In this study, site A (eastward), the higher distribution of the SJS was seen on the lower part of the trees.

Valerie *et al.*, (2004) worked on the population dynamics and distribution of mites, *Calcarus flagellieta* in Hawaii. They showed that mites had abundant concentration in the mid and lower vertical strata of plant canopy. Further, they observed thick concentration of the mites on the upper and lower leaf surfaces. Other workers studies show location specific concentration of pests depends much on their preference for the location on different plants. This study also shows preference for location of concentration as well as the plant species to which they attack. San Jose scale is the same pest which shows concentration on lower strata of apple trees, Star Crimson and Banky at site A, but at site B, its concentration is on the upper strata in the apple trees Star King and Banky. The location specific concentration was observed by Hubard and Potter (2005) in Kentuky for calico scale, *Eulecanium cerasorum*. They observed the distribution of calico scales towards basal ends of shoots.

Distribution of San Jose scale (SJS) at Rawalakot Locality

Apple trees were studied at site A (southeast direction) and site B (northeast direction) in this locality. At site A, there was no significant difference in the distribution of SJS on the upper and lower levels of Star King and Banky apple trees. However, highly significant distribution of SJS was observed on the lower levels of Banky and Golden apple trees compared to to the upper levels. Banky apple tree is the same variety at site A and site B, but in site B on this tree a highly significant distribution of pest (SJS) was on the lower level but not in the site A. Erkilic and Uygun (1995) did not find significant difference in the distribution of the white peach scale on peach trees in the four compass direction. They found average number of scales ranged from 117 in the eastern direction to 147 in the north facing direction. In this study, site B is in the north east direction. Both the studies show distribution of respective pests is in the north facing direction. Mohammad *et al.*, (2005) reported the distribution of soft scale, *Pulvinaria tenuivalvata on* the middle and upper part in sugarcane in Egypt. A study from Brazil by Gusmao *et al.*, (2004) on outdoor tomato pest, *Bemisia tabaci* showed that larger densities of nymphs and adults were in the bottom part rather than in the upper level of the plants. Also, a higher density of adults and nymphs of *B. tabaci* were on the basal leaves of the plants. They suggested

that the basal leaves are older than upper apical leaves of the plant. The basal leaves have larger space for a longer colonization of this pest on tomato plants.

Distribution of San Jose scale (SJS) at Lamniayan Locality

The distribution of SJS at site A (northwest direction) and site B (southwest direction) showed a highly significant association regarding the distribution in the lower part of apple trees varieties, Red Delicious and Golden. Abdel-Moneim *et al.*, (2005) in Egypt, studied vertical distribution of piercing sucking insects on roselle varieties. They reported severe attack of this pest on the top nodes (from 8^{th} to 11^{th}) at the tip of the plant. They also showed that white flies were abundant on the 4^{th} stem node (lower part of the plant). Gonzalez *et al.*, (2005) worked on the biology and ecology of *Lepidosaphes gloverii* on citrus crop in Cuba. They reported that this pest was distributed mostly on the middle and upper surfaces of leaves. They also observed that on the citrus trees, this pest was distributed on the three strata of the tree with not much difference in the distribution.

Larval infestation of codling moth, *Cydia pomonella* (L.) at site A (SAAO) and site B (MTKAO) in Dheerkot locality

This study was carried out on different apple cultivars with regards to larval infestation and distribution of codling moth at two sites of the Dheerkot locality.

During the study, a total of five different cultivars namely Banky, Golden, Kashmiri, Star King and Star Crimson were examined and it was observed that indigenous and introduced cultivars were infested with codling moth larvae with varying degrees of susceptibility. Our results clearly indicate that the introduced apple variety Star Crimson was least infested with codling moth larvae whereas the indigenous Kashmiri variety of apple was highly infested with codling moth larvae in the Dheerkot locality. The present results also indicate that all five varieties of apple fruit vary highly significantly for infestation of codling moth larvae. The findings of this study show inaccordance with Zaki, (2002) who studied the infestation and distribution of codling moth, *C.pomonella* in Ladakh, Kashmir, India. His results indicated that the mean infestation of the pest on apple was 49.7% and 42.5 % in Kargil and Ladakh districts, respectively. Infestation on the fallen fruits was more severe (69.9) percent than on the fruits still on the tree (27.5 %). He also observed that all the indigenous and introduced cultivars of apple were found infested by the

pest. However, his result indicated that the local variety Thaksau was comparatively less infested, whereas this study shows that local apple variety, Kashmiri was highly infested with codling moth larvae at site B in the Dheerkot locality.

The present study also shows temporal variation in the infestation of codling moth larvae during the different months. It was seen that the percentage infestation was very low in the second week of June whereas it was very high in the second week of August in 1999. However, the percentage larval infestation was also recorded as high in the month of July. The overall codling moth larval infestation throughout the sampling period was 45.49% in the Dheerkot locality. In this study, site B was highly significantly infested with codling moth larvae compared to site A in the Dheerkot locality. This is may be due to Kashmiri and Golden apple cultivars which were found highly infested with codling moth larvae at site B in the Dheerkot locality. Peter *et al.*, (2004) showed that apple fruits infested with codling moth were more attractive to neonate codling moth larvae in Washington. They further observed that the Red Delicious and Golden Delicious apple varieties were found more attractive to neonate codling moth larvae and they also described that codling moth larvae were less attractive to uninfested fruit of the same variety. Hagley, (1977) also studied the arthropod fauna in unsprayed apple orchards in Ontario. He reported that codling moth is the major pest of Ontario, Canada and he found that average seasonal infestation is higher than the other pest like apple maggot, *Rhagoletis pomonella* (Walsh) in apple growing areas. In some orchards total fruit damage from these pests was 100%. He also showed that percent damage of codling moth ranged 23.4 %-41.8% from 1968 to 1972, whereas this study showed a wide range (8.33% to 90.26%) of larval infestation of the codling moth.

Monitoring of codling moth, *C. pomonella* (L.) at site A and site B-2 in Dheerkot locality on different heights of Distrct Bagh, Azad Kashmir

The present study on monitoring of adult codling moth was carried out at two sites (Aand B) on different heights in the Dheerkot locality.The activity of adult codling moth, *C.pomonella* was monitored by using pheromone traps in Dheerkot at site A and site B-2 on the different heights.

Codling mot activity was observed with the use of pheromone. The sex pheromone was applied in the month of March (year 2003) and as a result highest catches of this moth was obtained in April, 2003 at site A and B. A highly significant decline in the

mean codling moth collection was observed from May to September, 2000. A higher catches of the adult codling moth was also observed by Mani and Wildobolz (1975) and Howell and Quist (1980) in the first week of trapping by the use of sex pheromone.

Stribu and Manolache (2000) recorded maximum collection of codling moth in the month of July. Suckling *et al* (2005) observed 3-4 folds increase in the leaf skeletonizer, *Uraba lugens* catches during the months of November and December, 2003 and March and April, 2004. This study showed the highest catches of the codling moth during the month of April, 2003 but from May to September, 2003, there was a sharp decline in the catches.

Influence of the height on trap catches has also been conducted by different workers. Khattak *et al* (1989), Knight *et al* (1999) did not find any influence of heights on the trap catches. Suckling *et al* (2005) recorded that catches increased with heights in the case of leaf skeletonizer, *Uraba lugens*. Nansen *et al* (2004) investigated that trap efficiency increased when traps were placed along the side walls and near the ground.

Distribution of *C. infernalis* (Mulsant) at Dheerkot and Rawalakot localities

This study showed that maximum number of *C .infernalis* (larvae, pupae and adults) was collected from site A and site B in Dheerkot compared to very low from site B (SAKAO) of the Rawalakot locality. A highly significant ($P<0.001$) difference in the distribution of the adult and developmental stages of the *C. infernalis* was observed in the Dheerkot and Rawalakot localities and their respective sites (A and B). At site A larvae were collected from March to August, 2000 and pupae from April to August, 2000, but at site B, larvae and pupae wre collected from March to May, 2000 and April and May, 2000 respectively. Farooq *et al.*, (1999) also observed that the spatial distribution and phenology of adult *C. infernalis* populations on apple trees in Kashmir, Pakistan, indicated that the population density of *C. infernalis* varied between the years and the sites. They also found a significant difference in the distribution of *C. infernalis* at different sites. Adult predator distribution has been studied by different workers. Ozgen *et al.*, (2005) studied the natural enemy of *Lepidosaphes pistachiae* in Turkey. They reported in their results that 11 coccenellid

and one nitidulid species were found in the pistachio areas and out of which 7 species were found distributed in pistachio growing areas of Turkey. Brown and Miller, (1998) reported that coccenellid beetles are distributed in apple orchards of West Virginia in the U.S.A. They found 25 species of Coccenellidae were present on apple orchards in eastern West Virginia from 1983 to 1996. The spatial distribution of parasitic wasps was studied by Wang *et al.*, (2006) in China. They further observed that *A .ohgushii* and *M. pulvinarae* were the most abundant, constituting 88.1 % of the population of the parasitic wasps. Parasitism was higher on the upper than on the lower twigs of tree. Lord, (1972) conducted his work in Canada on the influence of the proportion of fruiting to non-fruiting clusters on the distribution of insect predators (*Diaphnocoris pellencida* and *Attractotomus musculus)* on apple trees. He showed that the nymphal stage crawls most efficiently from tree to tree. Nymphs in both the cases preferred those limbs whose fruiting clusters were more prevalent.

This study shows that the adults of *C. infernalis* were found in abundance in the Dheerkot locality compared to considerably low numbers at Rawalakot. Farooq *et al.*, (1999) in Kashmir, Pakistan; Erkilic and Uygun, (1995) in Turkey have also reported that predatory beetles are site/host dependent.

Predation potential of *Chilocorus infernalis* (Mulsant) on San Jose scale(SJS), *Q. perniciosus* (Comstock)

There was a highly significant increase in the prey consumption in the male and female predators. The female predators were more voracious compared to the males with the increase in density of preys. This study shows among female predators acceleration in the prey consumption depends on increase in density of preys. Ahmed and Ghani, (1966) reported that *C. infernalis* feed on egg, body fluid, nymphs and adult female scale. They can devour 1-3 second stage nymphs of scale insects like *Q. perniciosus* in a day. The third and fourth instar larvae and adult can consume 14, 34 and 65 individual of *Q .perniciosus* per day, respectively. The variation in feeding of both the sexes may be due to the fact that females usually consume more prey than adult as she has to lay eggs. Yinon (1969) reported that female *C. bibustulatus* consume 30% more Florida red scale, *Chrysomphalus aonidum* than male *C. bibustulatus*. Sharma *et al.*, (1990) studied the predatory potential of *Pharoschymnus flexibilis* on SJS in Solan, Himachal Pardesh. They reported in their study that *P .flexibilis* consumed on an average 1362, 2537 and 2110 crawlers of *Q. perniciosus*

respectively, throughout its larval and adult life span. This study showed that *C. infernalis* consumed 64.34 % of the total prey provided to them. Thakur and Gupta (1997) recorded the coccinellid, *Chilocorus bijugus* was an effective predator of olive white scal, *Metaceronema japonica* for the first time at Solan, Himachal Pradesh, India. The feeding rate of an adult beetle was 19.2, 20.1, 7.3 and 1.3 scale insects per day of 1st and 2nd instar nymphs, young females and mature females with ovisacs, respectively. Ricci *et al.*, (2006) recorded that female predator Chilocorus kuwanae showed much higher feeding activity than the male predators when temperature was raised to 13 degree centigrade and 15 degree centigrade. In contrast to these findings, the present study also showed that female predators had higher feeding activity at room temperature.

CONCLUSIONS

The present studies were conducted on the two key pests of apple crop in three localities, viz, Dheerkot (District Bagh), Lamniayan (District Muzaffarabad) Rawalakot (District Poonch), Azad Kashmir. The results were presented and discussed in the prvious lines. Based on the current results, the conclusions of the studies are as follows.

- The locality Dheerkot, District Bagh was declared as a problem area for apple crop with regard to codling moth and San Jose scale.
- The locality Dheerkot was more infested with San Jose scale both at Safraz Abbasi Apple Orchard (site A) and Mohammad Tazeem Khan Apple Orchard (site B) compared to Lamniayan and Rawalakot
- At Dheerkot locality, site B, a severe infestation of codling moth was recorded on the apple varieties Kashmiri and Golden. However, a least infestation was observed on the apple variety Star Crimson.
- The distribution of San Jose scale and its natural enemy was mostly recorded on the lower level of the apple trees.
- An association of predator- prey interaction was also recorded in the two localities.
- The present study on the monitoring of the codling moth indicates that codling moth has two generations in the Dheerkot locality.
- Pheromone traps were found an effective tool for the monitoring and control of codling moth.
- The study on the predaceous potential of C. *infernalis* on SJS suggests that female predator is more effective and voracious than male predator.
- Future studies are required on natural enemies of codling moth to develop an Integrated Pest Management Programme (IPM).

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