INSECT PEST SUCCESSION AND THEIR ABUNDANCE ON PECAN NUT, *Carya illinoinensis* (Wangenh.) Koch

by
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(J-20-M-724)

A Thesis submitted to
Faculty of Agriculture
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MASTER OF SCIENCE IN AGRICULTURE
ENTOMOLOGY

Division of Entomology

Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu,
Main Campus, Chatha, Jammu-180009
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CERTIFICATE-I

This is to certify that the thesis entitled **"Insect Pest Succession and their Abundance on Pecan nut, *Carya illinoinensis* (Wangenh.) Koch"** submitted in partial fulfilment of the requirement for the degree of **Master of Science in Agriculture (Entomology)** to the Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, is original work and has similarities with published work not more than minor similarities as per UGC norms of 2018 adopted by the University. Further the level of minor similarities has been declared after checking the manuscript with **Urkund** software provided by the university.

The work has been carried out by **Ms. Marya Farid**, under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. It is further certified that help and assistance received during the course of thesis investigation have been duly acknowledged.

Dr. Amit Kumar Singh
(Major Advisor)

Place: Jammu

Date: 30/8/2022

Head of the Division

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CERTIFICATE-II

We, the members of the Advisory Committee of **Ms. Marya Farid,** Registration No. **J-20-M-724**, a candidate for the degree of **Master of Science in Agriculture (Entomology)**, have gone through the manuscript of the thesis entitled **"Insect Pest Succession and their Abundance on Pecan nut, *Carya illinoinensis* (Wangenh.) Koch"** and recommend that it may be submitted by the student in partial fulfillment of the requirements for the degree.

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ABSTRACT

Title of thesis	:	Insect Pest Succession and their Abundance on Pecan nut, *Carya illinoinensis* (Wangenh.) Koch
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ABSTRACT

The pecan nut *Carya illinoinensis (*Wangenh.) Koch acknowledged as the 'Queen of Nuts' is one of the most valuable nut crops grown internationally owing to its distinct flavour and ideal dietary content. However, the production and productivity of this cherished fruit crop has been threatened all over the world due to various biotic factors, especially insect pests leading to colossal monetary losses. In the Union Territory of Jammu and Kashmir, no study has ever been conducted to study the pest fauna of this nut crop. Based on this conception, the present study entitled, **"Insect pest succession and their abundance on Pecan nut, *Carya illinoinensis* (Wangenh.) Koch"** was intended to fill this gap and epitomize an exhaustive inventory of different insect pests associated with this crop in the twin districts of Poonch and Rajouri, where it is grown. Sampling was done on weekly basis in both the districts and insects were collected based on the visual observation and captured employing sweeping nets, beating and hand picking from the plantations not sprayed with any insecticide. The population build-up of different pests mostly occurred during the months of May, June and July.

The results of the present investigation indicated that the pecan plants are attractive to a wide variety of insect pests in both the districts at different study sites. In total, 10 insect species including the beneficials belonging to 4 orders and 8 families were recorded and identified. A comparison of the entomofauna of young and mature pecan plants indicated that insect pest species were more diversified on mature pecan plants than on young especially in the Poonch district. Among them, *Phyllophaga sp.*, *Hieroglyphus banian* and *Myllocerus undecimpustulatus* appeared as pests of economic significance requiring chemical control. Beneficial insects encountered during the study included *Mantis religiosa*, *Exochomus nigripennis* and *Camponotus discolor.* The results of the current investigation present an important baseline for the design and implementation of management strategies of economically important pests of pecans coupled with the exploitation of natural enemies especially in Poonch district.

Keywords: Pecans, Insect pests, Population, beneficials, baseline.

Signature of Major Advisor

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CHAPTER-1

INTRODUCTION

The pecan nut, *Carya illinoinensis* (Wangenh.) Koch is an economically important nut fruit crop grown in different parts of the world (Ravindran *et al.*, 2008). It belongs to Juglandaceae family and is a native of the southern United States and northerly Mexico. It is one of the most valuable nut crops grown internationally owing to its distinct flavour and ideal dietary content (Hal, 2000). It has been acknowledged as 'Queen of Nuts' due to its notable kernel characteristics, rich in phosphorous, potassium and vitamins A, C, E and B complex and additionally includes flavor, 65-70 per cent fat and 8-10 per cent protein (Singh *et al.,* 2011).

The United States and Mexico are the leading producers of the pecan nut worldwide accounting for 55 per cent and 38 per cent of its production, respectively (INC, 2015). In the United States, it is cultivated mainly in the states of Georgia (48,562/ha), Texas (40,468/ha), Oklahoma (38,040/ha) and New Mexico (16,187/ha) (Ojeda-Barrios, 2012). In India, it is mainly grown in of Himachal Pradesh, Jammu and Kashmir, Uttaranchal, and Nilgiri Hills, over an area of 1000 ha with the production of approximately 1000 MT all over the country (Anonymous, 2016a). In Himachal Pradesh, its cultivation is extended to Kangra, Mandi, Kullu and Solan districts, which represent about 855 ha with a production of 159 thousand MT (Anonymous, 2014).

In the Union Territory of Jammu and Kashmir, it is mainly grown in the Jammu province over an area of 413 ha with production of approximately 85 MT (Anonymous, 2016b). The twin districts of Rajouri and Poonch are the leading producers of pecans occupying an area of 163.0 ha and 125.0 ha, respectively. The existing plant population of pecans in Poonch, Rajouri, Kathua, Udhampur and Doda mainly consists of seedling origins exhibiting exceedingly good variability in growth, yield and quality attributes, thereby, offering a platform for exploitation of massive gene pool (Rani, 2018).

In spite of its rich historical account, the production and productivity of this cherished nut fruit crop has been affected all over the world due to infestations of different insect pests on different growing parts such as stem, leaves, leaflets, twigs and especially on nuts. There is a vast array of insect pests associated with the pecan nut restricting tree growth and fruit

production thereby leading to colossal monetary losses. According to an estimate, over 270 species of insect pests had been accrued from pecan trees all over the world. Amongst them, coleopterans (*Apriona germari* Hope, *Batocera horsfieldi* Hope, *Curculio caryae* Horn), lepidopterans *Acrobasis nuxvorella* Neunzig, *Arbela dea* Swinhoe, *Cnidocampa flavescens* Walk, *Congogethes punctiferalis* Guenee, *Cydia caryana* Fitch, *Zeuzera leuconotus* Walker and hemipteran (*Phylloxera notabilis* Pergande) are of economic importance (Reid, 2002; Zhang *et.al.,* 2015). The major insect pests attacking pecan nut in USA and other parts of the world are Hickory Shuckworm (*Laspeyresia caryana* (Fitch), casebearer *(Acrobasis nuxvorella)* and pecan weevil (*Curculio caryae).* The *L. caryana* (Fitch), is the most destructive insect pest causing the discolouration of nuts thereby leading to the decrease in the marketability of the nuts (Gill, 1924). Likewise, *A. nuxvorella* is another notorious insect pest especially when first-generation larvae feed on nustlet quickly after pollination leading to considerable yield loss (Mulder and Grantham, 2003). The *C. caryae* causes two types of direct damage to pecans. Prior to shell hardening, feeding punctures by adults cause immature pecans to fall from the trees. The second type of damage occurs later in the season. (Hall, 1977).

In India, four insect pests and mites namely, *Haplothrips ceylonicus* Schmutz, *Brevipalpus californicus* (Banks), *Panonychus ulmi* (Koch) *and Tetranychus* sp. have been observed on pecans (Chowdhuri and Pal, 1970; Thakur and Dinabandhoo, 2005). Recently, in Palampur, representing mid-hill area of Himachal Pradesh, pecan fruits have been found to be infested by lepidopteran larvae identified as *Garella ruficirra* (Hampson) (Lepidoptera: Nolidae) and *Conogethes* sp. (Lepidoptera: Crambidae) (Singh *et al*., 2016).

Coming to the Union Territory of Jammu and Kashmir, there is no documented evidence and information available regarding the different insect pests of pecan nuts. In the past few years, various adverse reports from different quarters and growing areas have come forth especially in the districts of Rajouri and Poonch about the insect pest damage on pecans leading to the variable yield losses. Since the prevalence and damage of different insect pests on pecan nuts particularly in district Poonch is clearly evident. Therefore, it was important to have knowledge about succession, seasonal occurrence, weather parameters and abundance of different insect pests on pecans. The present study was one of its kind and surely shall set the baseline for the future studies with respect to the insect pests of pecans in the times ahead.

Keeping in view the economic importance of pecan nuts, damage caused by different insect pests, the present study was undertaken with following objectives.

1. To record the succession and status of insect pest on pecan nut
2. To record the abundance of major insect pest on pecan nut

CHAPTER-2

REVIEW OF LITERATURE

The following chapter examines the existing literature related to "**Insect Pest Succession and their Abundance on Pecan nut, *Carya illinoinensis*** (Wangenh.) Koch". It highlights the prevalence, occurrence and extent of damage caused by different Pecan nut insect pests at various stages of its growth and development across the world besides evaluating the abundance of major insect pests attacking pecans and related fruit nuts. Since this research is first of its kind with respect to study of insect pests of pecans in Jammu province, hence the following review and cross references are put forth to strengthen and draw a broad consensus of present study. Most of the relevant areas are being presented in this chapter under the following heads.

2.1 Succession and Status of Insect Pest on Pecan nut

Harris and Ring (1979) studied about the biology of pecan weevil from oviposition to larval emergence and reported females of *Curculio caryae* (Horn) were found to oviposit in nuts when the kernels began to develop by puncturing the nut near the distal end. Although nuts appeared to be selected for oviposition at random, more than one nut was usually infested when clusters were encountered and previously infested nuts did not appear to be infested again.

Hall *et al.* (1981) conducted a study to quantify various types of damage caused by the pecan weevil in a pest-managed, commercial pecan orchard. The types of damage evaluated included premature nut drop, black spots on the kernel, shrivelled kernels and destruction of the kernel by larvae. Premature nut drop due to adult weevil feeding was the most prevalent type of weevil-induced damage observed in the study.

Mueller and Dinkins (1984) studies the seasonal incidence of *Cydia caryana* (Fitch) and *Acrobasis nuxvorella* Neunzig on pecan nut in south-eastern Kansas in 1980-81 and revealed through the use of ultraviolet-light traps, emergence cages and field observations, the emergence dates of the overwintering generation (April-June) observed the number of generations per year and the calendar date of adult emergence of each generation for both species in both years.

Foott and Timmins (1984) revealed that *Curculio caryae* is regarded as an obligatory feeder on nuts of the genus Carya and is especially troublesome in commercial hickory nut and pecan orchards and reported that beetle larvae were found infesting nuts of a Persian walnut tree, *Juglans regia* L. in Harrow, Ontario. Several larvae were reared to adults and were tentatively identified as the pecan weevil.

Van den Berg and Maritz (1995) studied the seasonal occurrence and age specific mortality of the yellow pecan aphid and reported that nymphs and adults were present from the end of October until the end of June and peaked near the end of February. Eggs were present from mid-May to the middle of October. It was also calculated that the average number of generations per year at Nelspruit was 22. The K-value between the nymphs in instars 1 and 2 and those in instars 3 and 4 were 0.652 and between instars 3 and 4 and the adults 0.450, respectively.

Smith *et al.* (1996) while studying the arthropod fauna of pecan orchard found that arthopods belonging to eight orders of Insecta, three orders of Arachnida, and one Chilopoda affect this crop. Further, they found that ground cover had little effect on the density or type of arthropods present in the pecan canopy, except that densities of *Chrysoperla rufilabris* (Burmeister) were greater during July from pecans with a legume ground cover than from those with a grass ground cover. They also reported *Chrysoperla rufilabris* as a major predator of aphids which may suppress pecan aphid density.

Harris and Chung (1998) reported that pecan nut casebearer, *Acrobasis nuxcorella* Neunzig, acts as a fruiting cycle enhancer in pecan by removing nuts early in years of low production, thereby denying late-season nut feeders such as pecan weevil, *Curculio caryae* (Horn), food. Pecan escapes nut eaters by synchronously producing nuts in a 2 to 7-yr cycle.

Dutcher (2007) conducted an experiment and released the predatory mites, *Galendromus occidentalis* (Nesbitt) *and Phytoseuili spersimilis* Athias-Henriot and found that both species suppressed or controlled populations of pecan leaf scorch mite *(Eotetranychus hicoriae* McGregor). Pecan leaf scorch mites were controlled at this high population density in the release area 24 days after the release. Release of the mites at 500 and 1000 G. occidentalis mites per tree reduced the pecan leaf scorch mite infestation by 67 and 91per cent, respectively. Release of 500 and 1000 *P. persimilis* mites per tree reduced the pecan leaf scorch mite infestation by 90 and 98 per cent, respectively. Predatory mite releases

appear to provide an effective management tactic for pecan leaf scorch mite for pecan producers in Georgia.

Fu-Castillo *et al.* (2010) examined the interactions between the pecan nut casebearer and pecan tree and found hatch of the overwintering larvae at the beginning of the bud break of pecan trees. The activation of hibernating pecan nut casebearer larvae appears when shoot growth was ≥5cm. The larval development was greatest in shoots >15 cm. A reliable correlation was found between the size of shoots and the larval instars. This is the first study that quantified the emergence of the overwintering larva with bud break.

Hartfield *et al.* (2012) studied population structure of the pecan nut casebearer *Acrobasis nuxvorella* throughout its geographical distribution and revealed casebearer is a monophagous pest of pecan *Carya illinoinensis* and is native from Louisiana west to the eastern edge of New Mexico. Recently, this pest has expanded beyond the native range of pecan into regions where pecan has been introduced for cultivation and reported that genetically distinct populations occur in those areas where the pecan nut casebearer is not native but has been invasive.

Knutson and Ree (2019) made a study on biology and management of the Pecan Nut Casebearer and revealed that economic loss in pecans is primarily due to first-generation larvae that feed internally in developing nutlets soon after pollination in the spring. Effective management requires orchard scouting to assess egg abundance and nut entry by larvae to determine the need for and optimum timing of insecticide treatment.

Blanco *et al.* (2021) measured the area of pecan nuts at weekly intervals to establish a surface area growth pattern that indicated increase between 15 and 30 per cent and found that the rapid growth left a considerable area exposed to insect attack, or having less concentration of insecticide on the expanded treated area only a week after the previous application of insecticide make nuts more susceptible to pest attack.

2.2 Abundance of Major Insect Pest on Pecan nut

Edelson and Estes (1983) while studying the distribution and seasonal abundance of the yellow pecan aphids *Monellia caryella* and *Monelliopsis nigropunctata* in pecan orchard found that the mean number of *M. nigropunctata* and *M. caryella* per leaf did not differ significantly among quadrants or heights of a pecan canopy. It was also shown that current scouting practices, based on counts of total numbers of aphids, gave a reliable estimate of the

relative number of aphids per leaf throughout the canopy. Aphid populations, treated as a two-species complex, exhibited a bimodal seasonal abundance pattern. Egg hatch of both species occurred at bud break and mean age class composition of populations over the 3 years was similar. Dates of peak abundance correspond closely among years when compared as phenological weeks. Sizes of peaks and percent species composition of peaks differed among years and seasons. And they further concluded that *M. nigropunctata* feeds mainly on secondary and tertiary veins, and *M. caryella* on primary veins; therefore, species may cause different damage, and pest management programs may have to take into account individual species prevalence.

Liao *et al.* (1984) reported that the black margined pecan aphid reaches high populations throughout the growing season in managed and unmanaged orchards and in wild trees. The potential rate of increase of the black margined aphid was highest in the early season and declined to near zero by late season, and also concluded that the seasonal abundance of *M. caryella* appeared primarily affected by natural enemies and weather and to a lesser extent by the physiological condition of the pecan host.

Weber and McPherson (1984) investigated the differences in susceptibility of black walnut (*Juglans nigra* L.) trees to attack by the ambrosia beetle *Xylosandrus germanus* (Blandford) and the long-term effects on subsequent growth. The results revealed that percentage of trees attacked differed by geographic source, Kentucky trees were more susceptible and Kansas, Missouri, and Tennessee trees less susceptible. All trees attacked were less than 3.25 m in height and 4.25 cm in diameter. None of the attacked trees had died by the end of the second growing season after attack.

Messing and Aliniazee (1986) while studying the impact of predaceous insects on populations of filbert aphid, *Myzocallis coryli* (Goetze) in hazelnut found that filbert trees from which predators were excluded had significantly higher aphid populations than trees with predators. Feeding potential of one coccinellid, *Adalia bipunctata* (L.) and three mirids, *Deraeocoris brevis* (Uhler), *Heteroto mameriopterum* (Scopoli), and *Compsidolon salicellum* (Herrich-Schaeffer), was determined in the laboratory. Predators consumed from 5 to 65 aphids daily, with the coccinellid consuming more than the mirids. Data also showed that the predator complex is an important factor regulating aphid populations in filbert orchards of Oregon.

Edelson and Estes (1987) studied the seasonal abundance and distribution of predators and parasites associated with *Monelliopsis pecanis* Bissell and *Monellia caryella* (Fitch) at the Turnipseed-Ikenberry Place, Auburn University in experimental pecan orchard and revealed the presence of approximately 33 aphidophagous arthropod species. The most abundant predators included *Chrysoperla rufilabris* Burmeister, *C. quadripunctata* Burmeister, *Micromusposticus* (Walsh), *Coniopteryx simplicior* (Meinander), *Olla abdominalis* (Say), *Coleomegillam aculata* (Mulsant), *Hippodamia convergens* Guerin-Mineville, and *Allograpta oblique* (Say). Predators were most abundant at times of greatest aphid abundance; parasite abundance varied. No directional or height preferences in tree canopies were noted for predators or parasites.

Mizell and Schiffhauer (1987) investigated the Seasonal abundance of the crapemyrtle aphid, *Sarucallis kahawaluokalani*, in relation to the pecan aphids, *Monellia caryella* and *Monelliopsis pecanis* and their common predators and concluded that *S. kahawaluokalani* (Kirkaldy), and the majority of its predators that are common with the yellow pecan aphid, *Monelliopsis pecanis* Bissel, and the black margined aphid, *Monellia caryella* (Fitch), were seen in North Florida. Peaks in predator populations consisting of Coccinellidae, Syrphidae, Chrysopidae and Anthocoridae coincided with or occurred just after peak populations of *S. kahwalaoukalani.*

Heyerdahl and Dutcher (1990) monitored the four-leaf miners on pecan foliage, *Stigmella juglandifoliella* (Clemens), *Cameraria caryaefoliella* (Clemens), *Phyllonorycter caryaealbella* (Chambers), and *Coptodisca lucifluella* (Clemens) and found that larval densities of all four species were highest in late summer and fall. *S. juglandifoliella*, *C. caryaefoliella*, *P. caryaealbella* and *C. lucifluella* appear to have at least 5, 4, 4 and 4 significant increases in larval density per year, respectively. First emergence of *C. caryaefoliella* and *P. caryaealbella* adults occurred from mid- to late March. Larval mortality caused by hymenopterous parasitoids ranged from 14-61percent. Overwintering mortality of *C. caryaefoliella* and *P. caryaealbella* ranged from 31 to 95percent and 27 to 40percent, respectively.

Mansour (1993) reported the black margined aphid, *M. caryella*, exhibited a seasonal pattern with early and late peaks of the population in pecan orchards at NeweYa'ar in the Yizre'el Valley. A similar pattern was not observed at Kibbutz SedeEliyyahu in the Bet She'an Valley, where there was a single peak, late in the season. The occurrence of natural

enemies indicated that spiders and lacewing eggs were the predators most commonly associated with population fluctuations of the aphid. In most cases the increase rate of black margined aphid was highest in late season.

Dinkins *et al. (1994)* examined the predaceous neuropterans in Georgia and Kansas pecan trees and *found Chrysoperla rufilabris* (Burmeister) was the most numerous green lacewings collected in both areas. *Chrysoperla carnea* (Stephens) was the second most abundant green lacewing collected. *Micromus posticus* (Walsh) and *Hemerobius humulinus* L. were the two most commonly collected brown lacewings in both regions. Green lacewing populations were 6 to 11-fold larger in Kansas than in Georgia. Brown lacewing populations were slightly larger in Georgia than in Kansas. Green lacewing seasonal incidence was similar in both areas, with the late season peak occurring 2 to 3 weeks later in Georgia than in Kansas. Brown lacewing seasonal incidence varied considerably between regions and years. *Coniopteryx westwoodii* Melander was the primary micro neuropteran species collected.

Linit and Necibi (1995) studied black walnut curculio and concluded that the damage was independent of nut cluster height or cardinal direction within the crowns of young, nut-bearing black walnut trees. They also revealed that nut losses caused by the curculio were consistently higher in an upland versus a bottomland planting, although the differences were not significant during most years of the study. Furthermore, nut mortality caused by the curculio differed among years of the study and was negatively correlated with annual nut abundance.

Treadwell and Storch (1997) investigated the phenology, development, and mortality of larvae of the hazelnut weevil (*Curculio obtusus* (Blanchard): Curculionidae) in nuts of beaked hazelnut (*Corylus cornuta* Marshall: Betulaceae) and revealed the development of larvae through 4 instars, beginning with eggs in early June and progressing through 4th-stage grubs exiting nuts in late August. At the peak of infestation, in early August, 71 per cent of the sampled nuts were infested with weevil larvae. Decay and non-formation of nut kernels accounted for an estimated 10 per cent mortality among the larvae. Multiple infestation accounted for an additional 8 per cent mortality due to interference competition. Nut predation also caused mortality of an estimated 10 per cent of larvae.

Gantner (2000) while investigating the occurrence of hazelnut pests found that aphid species (*Myzocallis coryli* and *Corylobium avellanae*), scale insects (mostly

Parthenolecanium corni), and mite species (primarily *Phytoptus avellanae*) were the most prevalent in the protected plantation. A greater variety of pest species, such as *Operophtera brumata, Strophosoma capitatum, Haltica brevicollis, Apoderus coryli,* and *Deporasus betulae,* were discovered in the unprotected plantation and on common hazel growing in the forest.

Saruhan and Tuncer (2000) conducted survey in hazelnut orchards and found that most important and widespread pests were nut weevil (*Curculio nucum*), ambrosia beetle (*Xyleborus dispar),* big bud mites (*Phytoptus avellanae* and *Cecidophyopsis vermiformis*) and hazel long horned beetle (*Obera linearis*). Nut weevil adults appeared from early May to late June, and mean nut damage was nearly 14per cent. Big bud mites were widespread and were found in high populations. Ambrosia beetle adults were seen in late April and early June. Hazel long-horned beetle produced very serious damage numbers of injured twigs varying between, 5-14/plant. Pentatomid bugs (Hemiptera:Pentatomidae), fall webworm (*Hyphantriacunea*), filbert aphid *(Myzocalliscoryli),* brown scale (*Parthenolecanium corni*, *P. rufulum*) and *Gypsonema dealbana* were found as secondary pests at varying population densities.

Ozman and Cobanoglu (2000) investigated the status of hazelnut mites and reported forty-five mite species belonging to 20 families. The most common and important pest was *Phytoptus avellanaen* Nal., present as both "gall" and "vagrant" forms. *Cecidophyopsis vermiformis* (Nal.) was also common in hazelnut orchards but has less economic impact than *P. avellanae*. *Tetranycopsis horridus* (Can. &Fanz.) was also important, but only on a local scale. Minor pests, widespread but not important, included *Aculus comatus* Nal, *Tegonotus depressus* Nal, *Coptophylla lamimani* (Keifer), *Anthocoptes loricatus* Nal, *Eotetranychus coryli* (Reck) and *Tetranychus* sp. The beneficial mite fauna was also rich, including 23 species of predatory mites, the most common of which was *Kampimodromus aberrans* (Oud.). Additionally, *Czenspinskia transversostriata* (Oud.) and *Tarsonemus stammeri* Schaarschmidt were reported for the first time in Turkey.

Tuncer *et al.* (2004) investigated the insect pest problem affecting hazelnut kernel quality in turkey and concluded that more than 15 bug species could affect kernel quality (Heteroptera: Pentatomidae, Coreidae and Acanthosonatidae). *Palomena prasina* and *Gonocerus acuteangulatus* were found to be the main species. The pest population was above

the economic damage threshold. Kernel damage varied according to variety, locality and sample, reaching levels of around 20per cent of the total crop.

Aguilar-P*é*rez *et al*. (2007) investigated the seasonal abundance of *Xyleborus ferrugineus* (Coleoptera: Curculionidae) on pecan trees in Northern Coahuila, Mexico and revealed that abundant beetle was *X. ferrugineus*, with 93 per cent occurring from July to October. Occurrence of *X. ferrugineus* from December to May was practically zero, indicating a dormancy of the insect during this period.

Dwomoh *et al.* (2008) reported a minimum of 170 insect species on cashew in Ghana comprising of 10 species of Hemiptera, 14 of Lepidoptera, and 27 of Coleoptera. The others include two species of Dictyoptera, five of Odonata and 23 species of Hymenoptera. Most of the insects damaged the crop through sap sucking, defoliation, girdling, stem and twig boring and fruit and nut boring. Some were apparently harmless. A few beneficial species were also recorded either as pollinators or predators.

Dutcher *et al.* (2012) monitored seasonal occurrence of aphids and aphidophagous insects for six years (2006-2011) in pecans and concluded that aphid outbreaks occurred two times per season, once in the spring and later in summer. Increases in aphidophagous insect abundance coincided with aphid outbreaks in five of the six seasons. Green lacewing abundance was higher in the ground level than in the tree canopy. Brown lacewings were more abundant in the tree canopy than at the ground level. Dolichopodid and syrphid fly abundance, at the ground level increased during peak aphid abundance in the tree canopy.

Muegge and Knutson (2012) studied mating disruption of pecan nut casebearer, *Acrobasis nuxvorella* Neuzig and found that there was no significant reduction in the mean numbers of viable, non-viable, and enclosed eggs, or nut damage in the sex pheromone treatment compared to the non treated check. Further in another experiment, the mean numbers of viable and enclosed eggs, percentage of infested nut clusters, and nuts damaged by pecan nut casebearer larvae were significantly less in the sex pheromone treatment than in the non treated check. This experiment also revealed that mating disruption of pecan nut casebearer would fit well in a pecan IPM system because no other key arthropod pests of pecan require insecticidal control during the first and second generations of pecan nut case bearers. As a result, mating disruption could in many cases eliminate the need for conventional insecticides during most of the early production season and therefore preserve

biological control agents of secondary pests and reduce the potential for selecting resistant pests.

Cottrell *et al.* (2013) investigated the distribution of the black pecan aphid on pecan leaf surfaces and reported that three species of aphids regularly attack pecan (*Carya illinoinensis*) foliage. The black margined aphid and the yellow pecan aphid, were predominantly distributed on the lower leaf surface, as are adults and nymphs of most tree-feeding aphid species. Black pecan Aphid (BPA), do not follow this distribution pattern and likely move to the upper leaf surface as a predator avoidance strategy.

Agboton *et al.* (2014) employed different approaches to study the insect pests on cashew and reported 262 species in total. The most significant insect species attacking cashew amongst all were the wood borer *Apatetere brans* Pallas, the leaf miner *Eteoryctisge moniella* Stainton, the mirid bugs *Helopeltis schoutedeni* Reuter, and *Helopeltis anacardii* Miller. Some predators, parasitoids, and pollinators were among the helpful insects observed. On the trees, a few vertebrate predators were also observed.

Agboton *et al.* (2017) monitored the spatial and temporal abundance pattern of *A. terebrans* in 17 mature cashew orchards distributed across three agro-ecological zones in Benin. In each orchard, 30 cashew trees were chosen at random and inspected monthly for two consecutive years. Over the two-year observation period, they revealed that the infestations in the cashew trees by *A. terebrans* started in September, peaked in January–February and sharply declined thereafter, reaching zero by July–August.

Lima *et al.* (2017) while investigating the damage done to dwarf cashew trees by the insect *Holopothrips fulvus* (Morgan) (Thysanoptera: Phlaeothripidae) discovered that the insect's sucking mouthparts were to blame for the injuries to the leaf tissue. Additionally, *H. fulvus* fed on developing kernels and pseudo fruits, causing damage that showed up as chlorotic species, and feed at various points on the leaf surface, which develop into yellowing, wilting and ultimately abscission. Observations also revealed that populations of *H. fulvus* are present in the field throughout the year in Pacajus, although insect density is higher under warmer conditions.

Bosco *et al.* (2018) monitored *Halyomorpha halys***,** a serious threat for hazelnut in invaded areas. In semi-field trials, *H. halys* was the most harmful species, causing the highest damage in kernels, and was able to survive and reproduce at higher rates. During field

surveys in NW Italy, *H. halys* was sampled in groves late in the season in 2015 and, with higher populations, throughout the season in 2016. In W Georgia, bug population levels consistently increased in the 2-year period, resulting in a significant increase in damage at harvest in 2016. A similar trend is hence expected also in NW Italy in the following years.

Gull *et al.* (2018) investigated the assessment of damage and seasonal abundance of *Paracopium cingalensis* (lace bug) (Wal.) on *Juglans regia* (Walnut) (Lin.) in Central Kashmir and revealed that there was no significant difference in the population abundance of *P. cingalensis* in three districts of Central Kashmir. High population outbreaks were observed in the summer season followed by spring while rapid decline was reported in fall with a complete break during winters. The data further revealed that the pest fed on walnuts throughout the entire study period with peak numbers in the months of June, July and August. Of the three months, maximum damage was seen in the month of July as the temperature showed positive effect on the population build-up. *P.cingalensis* infestation can lead to severe yield and quality losses to walnuts. Adults and nymphs feed on the lower surface of leaves while depositing brownish excrement on them.

Shaziya *et al.* (2019) investigated the insect pest diversity and its nature and extent of damage on walnuts and concluded that the insects collected belonged to 3 orders, 7 families and 10 species. Order Hemiptera was highly damaging in comparison to Coleoptera and Lepidoptera while in Hemiptera, maximum damage was done by *Chromaphis juglandicola* (Kaltenbach) and the least by *Apodiphus pilipes* (Horvath). Furthermore, the results also provide a baseline data for assessing the biodiversity pattern and damaging potential of walnut pests so as to develop holistic integrated pest management programme.

Assenga *et al.* (2020) studied the incidence of sucking insect pests in cashew growing locations of South and Central Zones, Tanzania, and reported *Helopeltis* sp., *P. wayi*, *S. rubrocinctus*, *M. loripes*, and *A. trifasciata* insect pest species attacking the crop. They also noted that influences of the landscape, pesticide use, and intercropping systems may contribute to variations in incidence and severity in the southern and central zones.

Nebie *et al*. (2021) conducted field surveys to collect and identify the insect fauna of cashew in the South Sudanese area and found various insect species associated with cashew trees. The identified insect species included pollinators, predators, parasitoids and pests. Twenty-one of the species were classified as insect pests of the cashew trees because of the damage they inflicted to different parts of the trees. Some of the species identified were

economically important in West Africa, including wood borers (*Apate terebrans, Plocederus* sp.), aphids (*Aphis gossypii*, *Aphis crassivora*), mealybugs (*Ferrisia virgata*), bugs (*Myrperus jaculus, Nezara viridula, Anoplocnemis curvipes),* thrips (*Selenothrips* sp.), fruit flies and termites. They also concluded that the flowering-fruiting stage of cashew trees appeared to be the most favourable stage for outbreaks of insect pests.

Tuo *et al.* (2022) investigated the diversity of insects on four cashew nut varieties and the found that 16 families of insects belonging to 7 orders infested the cashew nut. Among the insect families, Apidae emerged as the most abundant family (32.15percent). *Apis mellifera* (Apidae) was the main visitor of cashew tree inflorescences. The aphid activity was more on "Yellow Benin" and "Henry" varieties compared to "James" and "Costa Rica". For all varieties of cashew trees, honey bee activity varied throughout the day with two peaks, one between 7 a.m. and 8 a.m. and the other between 5 p.m. and 6 p.m. It was inversely proportional to temperature ($p < 0.05$; $r = - 0.59$) and evolved in the same direction with relative humidity ($p < 0.05$; $r = 0.49$).

CHAPTER-3

MATERIALS AND METHODS

The present study entitled "**Insect Pest Succession and their Abundance on Pecan nut, *Carya illinoinensis*** (Wangenh.) Koch" was carried out in the twin districts of Poonch and Rajouri during 2022, as both the districts are ideally suited for the growth/cultivation of pecan nuts. The details of the experimental techniques, materials used and methods adopted during the course of investigation are detailed in this chapter.

3.1 Experimental Site

3.1.1 Location of study

Pecan nut is grown in the different areas of Jammu and Kashmir, especially in the districts of Poonch and Rajouri. The district Rajouri has a latitude of 33.3716° N and a longitude of 74.3152° E. It is at a height of 915 meters above the sea level with annual rainfall of around 509 mm. The maximum and minimum temperatures of district during the summers have been recorded at 37ºC and 20ºC, respectively and the humidity levels ranging from 26.0 to 45.0 per cent. Likewise, district Poonch with a latitude of 33.7670° N and a longitude of 74.0924° E. It is at a height of 1021 meters above the sea level with annual rainfall of around 769 mm. The maximum and minimum temperatures of the Poonch district during the summers have been recorded at 30ºC and -6ºC respectively and the humidity levels ranging from 38.0 to 63.0 per cent. Both the districts possess the ideal climatic conditions for the growth of pecans. However, numerous reports of insect pest damage in pecans have come to fore of late, which prompted to conduct this study to focus on the insect pests that are responsible for the damage of pecans in these twin districts. In order to assess succession of different insect pests, an extensive survey from March – July, 2022 was conducted in the twin districts. It essential to mention here that emphasis was placed on surveying both nursery and medium aged pecan plants to find out hotspot areas where diversity and infestation of insect pests was more. A preliminary list of 05 villages in each district were screened with on-site visits targeted at diversity and infestation level. Of the 05 initial villages screened in each district, we selected 02 villages in each district with significant levels of infestation. A composed and meaningful survey was planned in above mentioned villages to obtain and draw the most interpretative information with regard to diversity of insect pests on pecans. Such information/data collection is critical for validation

of control measures and for assisting in decisions on research priorities as well as pesticide guidelines in future times.

3.1.2 Sampling methods and study of succession

After the exploratory survey of the pecan growing areas, well established nursey plants (2-3 years old) and medium aged plants (5-6 year old) were selected from the hotspot villages (Behrote and Thanamandi) in Rajouri and (Darradullian and Qazi Morah) in Poonch for the purpose of study of diversity of different insect pests. Weekly visits were paid to the selected village sites during March- July, 2022. Five (05) plants at each village were randomly selected and marked for the purpose of recording the insect pests. All the plants selected at all locations were of same variety and no pesticide treatments were applied in the plants during the course of study. In order to record the insect pest succession and status, the population of different insect species was observed and recorded on weekly basis during morning and evening hours from five branches of each plant viz., two from the bottom, two from the middle and one from the top of the plant. The insect pests were observed through visual observation methods infesting the different parts of pecan plants in selected areas. The collected insect pest specimens comprised of adults and were pinned in the insect box. The collected insect pests were identified and labelled as per the available literature and running taxonomic keys. The collected insect pests were classified into different orders and families as per the characteristic features.

3.1.3 Abundance of major insect pest on pecan nut

On the basis of visual observation and succession, different types of insect pests were reported on pecans in both the districts. For the purpose of collection and recording the abundance of major insect pest on pecan nut, pesticide free plants at different locations of pecan nut growing areas of twin districts were selected. For the purpose of collection, sampling was done at weekly intervals by selecting five plants randomly in each location. Five sub terminal branches (both nursery and medium aged plants) were randomly selected from lower and middle canopy in each direction (East, West, North, South) and marked for the purpose of collection, study of abundance and natural enemy fauna on pecan nut. The population count was recorded during morning hours except June beetles which was done during evening time and mean population count was worked out accordingly. Since during the course of survey different insect pests were reported on pecans, hence accordingly

different techniques were employed for collecting the flying insects and insects associated with the pecan plants as under:

a. **Sweep netting method:** This methodology was employed for the collection of grasshoppers. Since the grasshoppers are active fliers, a net with a long pole and deep mesh bag was used by sweeping the net over foliage in a back-and-forth way. Each sweep was repeated after a gap of 10 minutes with an overall 10 sweeps at one time (Kumar and Naidu, 2010).

b. **Foliage beating method:** This technique was employed for the counting of bugs from pecan plants. A beating sheet and beating net was held under pecan vegetation and the foliage was firmly tapped with a beating stick to dislodge bugs from the branches falling into the net. The bugs were counted off the sheet and net by hand into dry vials. The samples from each plant were kept separate to avoid the mixing.

c. **Hand Collecting and Visual Checking method:** This technique was used for the monitoring and collection of minute insects like aphids. A magnifying glass (10X) was also used during the observation of aphids. The aphids were counted separately from different compound leaves and counted accordingly.

d. **One man - one hour method:** For the study of beetle population, counting and collection was done by 'one man - one hour method' by sweep nets in the late evening hours (Khairmode and Sathe, 2013). The collected beetle specimens comprising of adults were preserved in 75 per cent alcohol.

Mean abundance of insect pest population was calculated by following formula

$$\text{Mean Abundance / branch} = \frac{\text{Total number of insect pests counted}}{\text{Number of branches}}$$

3.2 Statistical analysis

All statistical analysis was performed using an online statistical software ″OPSTAT″ and MS excel 2007 for the analysis of experimental data. Since our experimental data possessed some small values especially zero values existed, hence square root transformation was carried out so that values become more uniformly distributed. The abundance of insect pests was compiled as mean percent in each district. The analysis of variance (ANOVA) was widely used to statically evaluate experimental data.

Plate: 3.1: Selection and tagging pecan plants randomly

Plate 3.2: Collection of insect pests using sweep nets

Plate 3.3: Observing Aphids using magnifying glass

CHAPTER 4

RESULTS

The results obtained in the present study entitled "**Insect Pest Succession and their Abundance on Pecan nut, *Carya illinoinensis*** (Wangenh.) Koch" are presented as under:-

4.1 Status of Insect Pest on Pecan nut

The results of the present investigation revealed rich pest diversity on pecan plants at different study sites especially in Poonch district with an overall of seven insect species, belonging to 3 orders and 7 families in Poonch district and three pest species belonging to 3 orders and 3 families in Rajouri district. Out of different insect species reported in Poonch, 42.85 per cent were Coleopterans, 42.85 per cent, Hemipterans and 14.28 per cent, Orthopterans while as Rajouri district Coleopterans, Hemipterans and Orthopterans were found in equal proportion of 33.33 per cent, respectively. The detailed report on pests, plant part affected and peak period of population build up is tabulated in Table 4.1, 4.2 and 4.3. Among all the species reported, *Phyllophaga* sp. and *Hieroglyphus banian* were found to be more abundant and intense on the basis of occurrence and damage inflicted on the leaves in both the districts. To the best of our knowledge, it is the first report from Jammu and Kashmir especially from Poonch and Rajouri about the occurrence of different types of insect pests on pecans.

4.2 Succession of Insect Pests on Pecans Plants in Poonch and Rajouri

The results on the insect pests succession revealed that the adults of *Myllocerus undecimpustulatus* and *Monelliopsis pecanis* in nursery plants at Qazi Morah Poonch were first to appear and visible during the first week of April (Table 4.4) While as infestation of aphids was visible during third week and first week of April in nursery and medium sized plants in Rajouri, respectively (Table 4.6 and 4.7). *Hieroglyphus banian* and *Halyomorpha halys* were visible during second week of April while *Phyllophaga* sp. was visible during the third week of May in nursery and as well as in medium aged plants at Poonch (Table 4.4 and 4.5). In Rajouri, *H. Banian* and *Phyllophaga* sp. were visible during the third week of March and second week of May in Nursery plants (Table 4.6) while they were visible in the first week of April and first week of May in medium aged plants, respectively (Table 4.7). The infestation of *Cotinis nitida* was found only in medium aged plants in Poonch district from

the last week of May (Table 4.5). The results revealed that each selected area varied in species diversity, richness and evenness in both the districts.

4.3 Abundance of insect pests on pecans plants in Poonch and Rajouri

The results of diversity and mean abundance of insect pests in district Poonch revealed that at the onset of spring season there was reduced pest load in nursery plants. While examining the occurrence and abundance of *H. banian* on nursery plants in Poonch, it was found that highest populations (Fig.4.1) occurred during the last week of June (1.08±.0.04 mean no./10 sweeps) showing significant variations ($F = 15.519$; $df = 4, 16$; $P < 0.000$) while as in case of *H. halys* highest mean population per branch was observed during the second week of June (0.68±0.19) showing significant variations ($F = 3.265$; $df = 4, 16$; $P < 0.000$). The mean abundance per branch in case of *M. undecimpustulatus* was highest during the last week of June (0.84±0.09) with minimum values of (0.00±0.00) during the last week of July. Significant variations (($F = 3.433$; $df = 4, 16$; $P < 0.000$) were observed in *M. undecimpustulatus* abundance on nursery plants in Poonch. Likewise, the mean abundance per five leaves and per branch in case of *M. pecanis* and *Phyllophaga* sp. was highest (Fig.4.1) during third week of June (4.64±0.65) and second of June (4.70±0.40) respectively with significant variation ($F = 4.034$; $df = 4, 16$; $P < 0.000$ &$F = 12.271$; $df = 4, 16$; $P < 0.000$) in district Poonch.

4.4 Abundance of insect pests on pecans in nursey plants in Rajouri district.

The results of mean abundance of different insect pests on nursery plants in Rajouri district revealed that infestation of Grasshoppers and yellow pecan aphids was visible during the month of March while as that of June beetle in the month May (Table 4.6 and Fig.4.3). While examining the occurrence and abundance of *H. banian* on nursery plants in Rajouri, it was found that highest populations (Fig.4.3) occurred during the last week of June (0.96±0.09 mean no./10 sweeps) with significant differences ($F = 7.804$; $df = 4, 18$; $P < 0.000$) while as in case of *M. pecanis*, highest mean population (4.52±0.68) was observed during the last week of June showing significant variations ($F = 14.670$; $df = 4, 18$; $P < 0.000$). The mean abundance per branch of June beetle was highest during the last week of June (4.30±0.37) with significant differences ($F = 96.694$; $df = 4, 18$; $P < 0.000$) among the weeks.

Table 4.1: Diversity and intensity of insect pests on pecan plants (2-3 years old) in Poonch District

Plant Age	Common name	Scientific name	Order (family)	Peak period of Population buildup	Intensity
2-3 years old	June beetle	*Phyllophaga* sp. Harris	Coleoptera (Scarabaeidae)	May-June	Very High
	Short-horned Grasshopper	*Hieroglyphus banian* (Fab.)	Orthoptera (Acrididae)	May-July	High
	Brown marmorated stinkbug	*Halyomorpha halys* (Stal)	Hemiptera (Pentatomidae)	May-July	Low
	Grey weevil	*Myllocerus undecimpustulatus* Faust	Coleoptera (Curculionidae)	May-July	Moderate
	Yellow pecan aphid	*Monelliopsis pecanis* Bissell	Hemiptera (Aphididae)	May-July	Low

Table 4.2: Diversity and intensity of insect pests on pecan plants (5-6 years old) in Poonch District

Plant Age	Common name	Scientific name	Order (family)	Peak period of Population buildup	Intensity
5-6 years old	June beetle	*Phyllophaga* sp. Harris	Coleoptera (Scarabaeidae)	May-June	Very High
	Green shieldbug	*Palomena prasine* L.	Hemiptera (Pentatomidae)	May-June	Low
	Brown marmorated stinkbug	*Halyomorpha halys* (Stal)	Hemiptera (Pentatomidae)	May-July	Low
	Short-horned Grasshopper	*Hieroglyphus banian* (Fab.)	Orthoptera (Acrididae)	May-July	High
	Yellow pecan aphid	*Monelliopsis pecanis* Bissell	Hemiptera (Aphididae)	May-July	Low
	Green june beetle	*Cotinis nitida* (Linnaeus)	Coleoptera (Scarabaeidae)	June-July	Moderate

Table 4.3: Diversity and intensity of insect pests on pecan plants in Rajouri district

Plant Age	Common name	Scientific name	Order (family)	Peak Period of Population buildup	Intensity
2-3 years old	Grasshopper	*Hieroglyphus banian* (Fab.)	Orthoptera (Acrididae)	April-July	High
	Yellow pecan aphids	*Monelliopsis pecanis* Bissell	Hemiptera (Aphididae)	May-June	Low
	June beetles	*Phyllophaga* sp. Harris	Coleoptera (Scarabaeidae)	May-June	Very high
5-6 years old	Grasshopper	*Hieroglyphus banian* (Fab.)	Orthoptera (Acrididae)	April-July	High
	Yellow pecan aphids	*Monelliopsis pecanis* Bissell	Hemiptera (Aphididae)	May-June	Low
	June beetles	*Phyllophaga* sp. Harris	Coleoptera (Scarabaeidae)	May-June	Very high

Plate 4.1: Brown marmorated stinkbug
Halyomorpha halys

Plate 4.2: Short-Horned Grasshopper
Hieroglyphus banian

Plate 4.3: Yellow Pecan Aphids
Monelliopsis pecanis

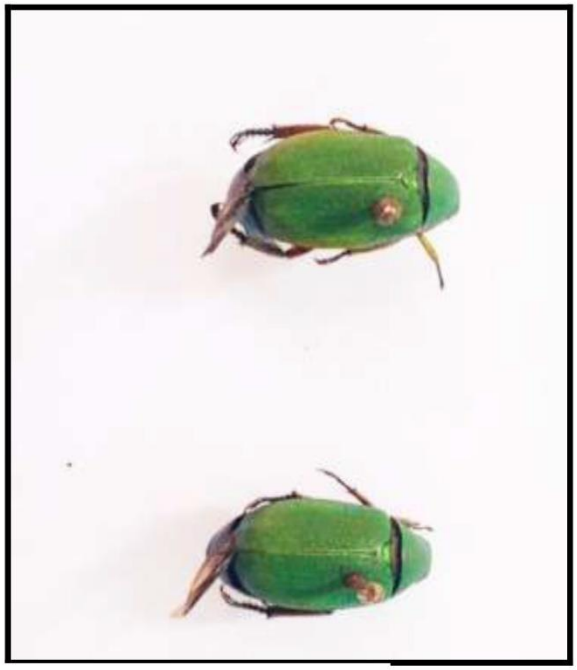

Plate 4.4: Green June Beetle
Cotinis nitida

Plate 4.5: June Beetle *Phyllophaga* sp.

Plate 4.6: Grey Weevil
Myllocerus undecimpustulatus

Plate 4.7: Green shield bug
Palomena prasina

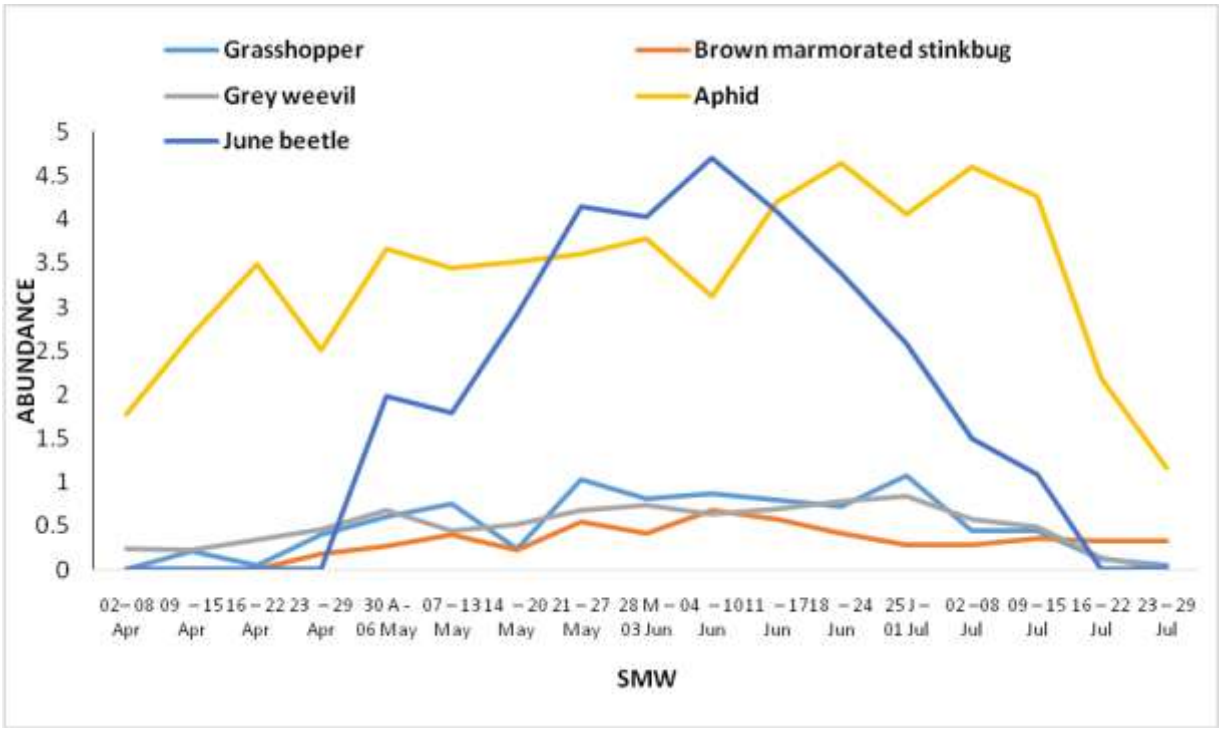

Fig.4.1: Abundance of different insect pests on young (2-3years old) pecan plants in Poonch district

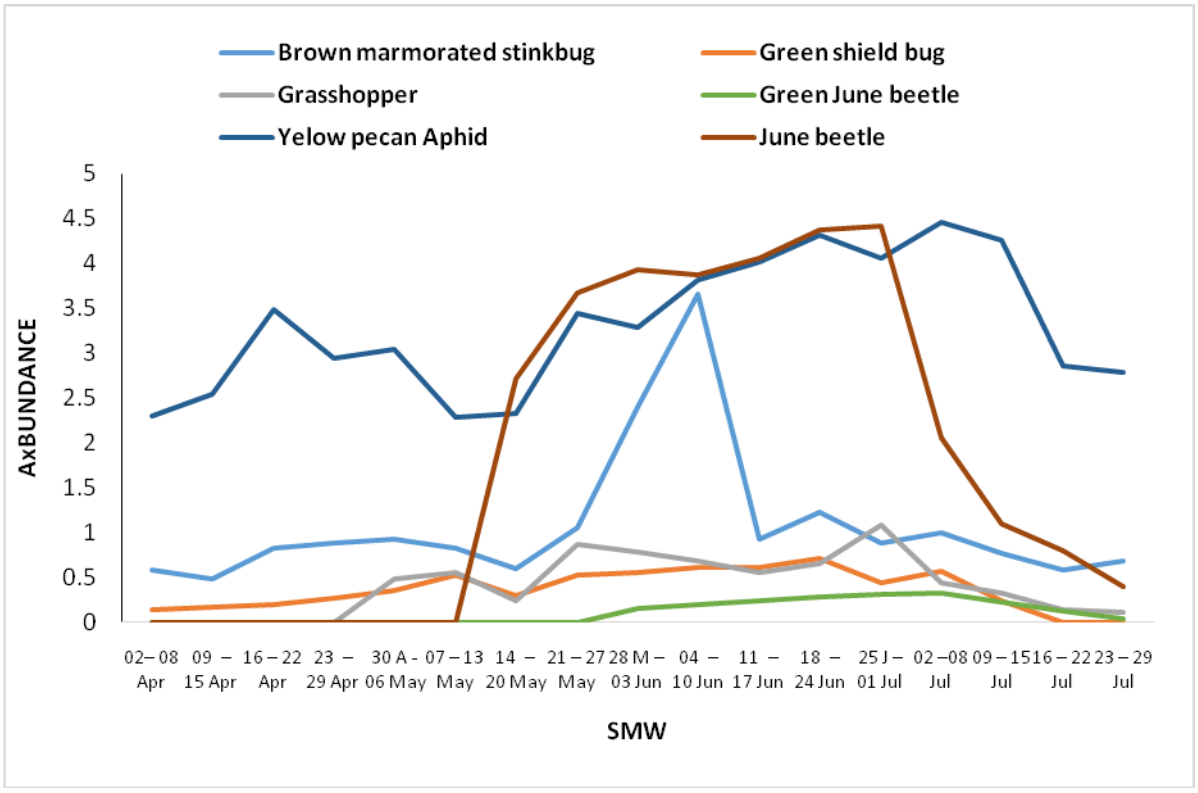

Fig.4.2: Abundance of different insect pests on medium (5-6years old) pecan plants in Poonch district

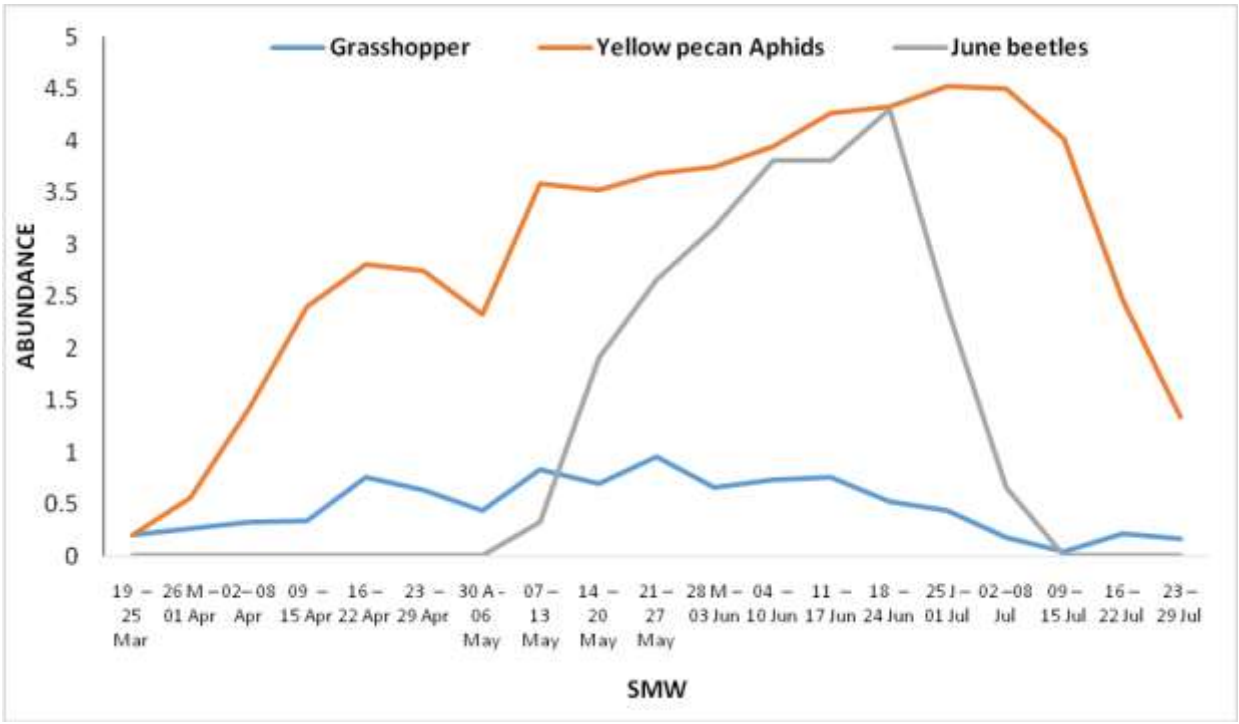

Fig. 4.3 Abundance of different insect pests on young (2-3years old) pecan plants in Rajouri district.

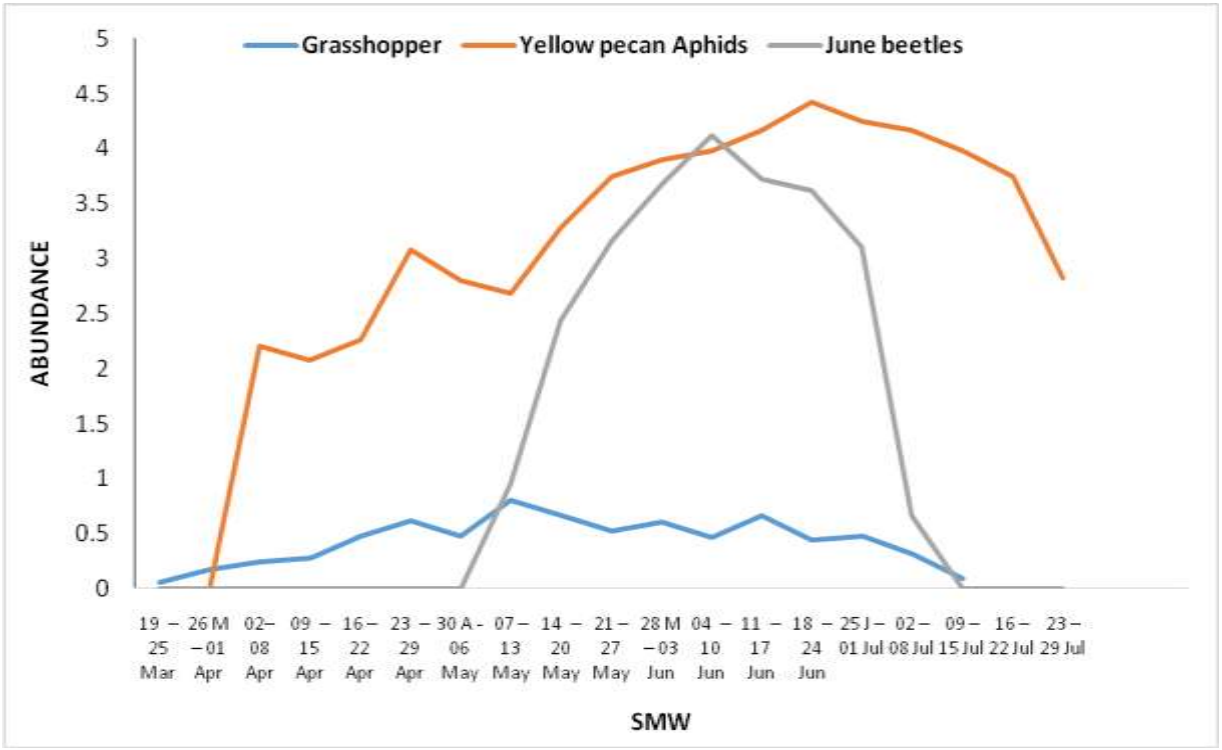

Fig.4.4: Abundance of different insect pests on young (5-6years old) pecan plants in Rajouri district.

4.5 Abundance of Insect Pests on Medium aged Plants (5-6years old) in Poonch district districts

The results of diversity and mean abundance of insect pests on medium aged plants in district Poonch are presented in (Table 4.5). The results reveal more diversity of insect pests compared to nursery plants. Significant variation (F = 1.974; df = 4, 16; P < 0.000) were observed in *H. halys* with highest mean population per branch (3.66± 1.77) observed during the first week of June (0.68±0.19) compared to lowest population (0.48±0.13) observed during the second week of April. The mean abundance per branch in case of *P. prasine* and *C. nitida* was found to be highest (Fig.4.2) during the third week of June (0.72±0.04) and first week of July (0.32±0.04), respectively with significant differences (F = 4.034; df = 4, 16; P < 0.000 &F = 17.714; df = 4, 16; P < 0.000) respectively. The mean abundance per five leaves and per 510 sweeps in case of *M. pecanis* and *H. banian*was highest (Fig.4.2) during the first week of July (4.46±0.20) and last week of June (1.08±0.04) with significant variation (F = 13.046; df = 4, 16; P < 0.000 and F = 16.454; df = 4, 16; P < 0.000), respectively. In case of *Phyllophaga* sp. highest mean abundance (Fig.4.2) per branch was found to be (4.42±0.52) during the month of June showing significant variations (F = 73.854; df = 4, 16; P < 0.000).

4.6 Abundance of Insect Pests on Medium aged Pecan plants in Rajouri district

The results of mean abundance of different insect pests on medium aged plants in Rajouri district revealed that infestation of *H. banian* and *M. pecanis* was visible during the month of April while as that of *Phyllophaga* sp. in the month May (Table 4.7 and Fig.4.4). While examining the occurrence and abundance of *H. banian*on medium aged plants in Rajouri, it was found that highest populations (Fig. 4.4) occurred during the last week of May (0.80±0.09 mean no./10sweeps) with significant differences (F = 6.843; df = 4, 18; P < 0.000) while as in case of *M. pecanis* highest mean population (4.52±0.68) was observed during the third week of June showing significant differences (F = 30.863; df = 4, 18; P < 0.000). Significant differences (F = 96.694; df = 4, 18; P < 0.000) were observed in *Phyllophaga* sp. populations with the highest mean abundance (Table 4.7) per branch during the first week of June (4.12±0.12).

4.7 Relative Percentage of Different Insect orders Occurring in Poonch and Rajouri districts

The results of present investigation revealed that different insect species infesting pecan nut in Poonch district belonged to order Coleopterans, Hemipterans and Orthopterans reported in proportion of 42.85 per cent, 42.85 per cent, and 14.28 per cent, respectively (Fig.4.5) in Poonch district. While as in Rajouri district Coleopterans, Hemipterans and Orthopterans were found in equal proportion of 33.33 per cent, respectively (Fig.4.6).

4.8 Incidence of Natural Enemies on Pecans in Poonch and Rajouri districts

During the present investigation different types of natural enemies on pecan plants were observed in both Poonch and Rajouri with more diversity in the former than latter. The different species of natural enemies, family and order are present in (Table 4.8)

Table 4.4: Abundance of different insect pests on young (2-3 year) Pecan plants in Poonch district

SMW	Date of week	*Hieroglyphus banian* (Mean ± SE)/10sweeps	*Halyomorpha halys* (Mean ± SE)/ branch	*Myllocerus undecimpustulatus* (Mean ± SE)/ branch	*Monelliopsis pecanis* (Mean ± SE)/5 leaves	*Phyllophaga* sp. (Mean ± SE)/ branch
14	02– 08 Apr	0.00±0.00 (1.00±0.00)	0.00±0.00 (1.00±0.00)	0.24±0.09 (1.11±0.04)	1.78±0.40 (1.64±0.13)	0.00±0.00 (1.00±0.00)
15	09 – 15 Apr	0.20±0.06 (1.09±0.02)	0.00±0.00 (1.00±0.00)	0.22±0.06 (1.10±0.03)	2.68±0.25 (1.91±0.06)	0.00±0.00 (1.00±0.00)
16	16 – 22 Apr	0.04±0.04 (1.01±0.01)	0.00±0.00 (1.00±0.00)	0.34±0.07 (1.15±0.03)	3.48±0.33 (2.11±0.08)	0.00±0.00 (1.00±0.00)
17	23 – 29 Apr	0.40±0.07 (1.18±0.03)	0.18±0.08 (1.08±0.03)	0.46±0.06 (1.20±0.02)	2.50±0.32 (1.86±0.09)	0.00±0.00 (1.00±0.00)
18	30 A - 06 May	0.60±0.11 (1.26±0.04)	0.26±0.06 (1.12±0.02)	0.68±0.19 (1.28±0.07)	3.66±0.45 (2.14±0.10)	1.98±0.33 (1.71±0.09)
19	07 – 13 May	0.76±0.13 (1.32±0.05)	0.40±0.13 (1.17±0.05)	0.44±0.14 (1.19±0.06)	3.44±0.69 (2.07±0.18)	1.78±0.25 (1.65±0.08)
20	14 – 20 May	0.24±0.10 (1.11±0.04)	0.22±0.10 (1.10±0.04)	0.52±0.04 (1.23±0.02)	3.52±0.58 (2.10±0.14)	2.92±0.27 (1.97±0.07)
21	21 – 27 May	1.04±0.07 (1.42±0.02)	0.54±0.10 (1.23±0.04)	0.68±0.13 (1.29±0.05)	3.60±0.33 (2.13±0.07)	4.14±0.24 (2.26±0.05)
22	28 M – 03 Jun	0.82±0.15 (1.34±0.05)	0.42±0.11 (1.18±0.04)	0.74±0.09 (1.31±0.03)	3.78±0.10 (2.18±0.02)	4.02±0.27 (2.23±0.05)
23	04 – 10 Jun	0.88±0.10 (1.36±0.03)	0.68±0.19 (1.28±0.07)	0.64±0.11 (1.27±0.04)	3.12±0.40 (2.02±0.09)	4.70±0.40 (2.38±0.06)
24	11 – 17 Jun	0.80±0.15 (1.33±0.05)	0.58±0.12 (1.25±0.04)	0.70±0.08 (1.30±0.03)	4.20±0.30 (2.27±0.06)	4.08±0.31 (2.25±0.08)
25	18 – 24 Jun	0.72±0.13 (1.30±0.05)	0.42±0.14 (1.18±0.06)	0.78±0.13 (1.33±0.05)	4.64±0.65 (2.35±0.14)	3.38±0.27 (2.08±0.07)
26	25 J – 01 Jul	1.08±.0.04 (1.44±0.01)	0.28±0.10 (1.12±0.04)	0.84±0.09 (1.35±0.03)	4.06±0.39 (2.24±0.09)	2.58±0.10 (1.89±0.07)
27	02 –08 Jul	0.44±0.07 (1.19±0.03)	0.28±0.08 (1.12±0.03)	0.58±0.11 (1.25±0.04)	4.60±0.18 (2.36±0.04)	1.50±0.14 (1.57±0.04)
28	09 – 15 Jul	0.44±0.04 (1.20±0.01)	0.36±0.11 (1.16±0.05)	0.48±0.15 (1.21±0.06)	4.26±0.37 (2.28±0.08)	1.08±0.16 (1.43±0.05)
29	16 – 22 Jul	0.12±0.05 (1.05±0.02)	0.32±0.13 (1.14±0.05)	0.14±0.07 (1.06±0.03)	2.18±0.24 (1.77±0.06)	0.00±0.00 (1.00±0.00)
30	23 – 29 Jul	0.04±0.04 (1.01±0.01)	0.32±0.13 (1.14±0.05)	0.00±0.00 (1.00±0.00)	1.16±0.19 (1.46±0.02)	0.00±0.00 (1.00±0.00)
(C.D.)		0.102	0.128	0.125	0.283	0.158
SE(m)		0.051	0.045	0.063	0.01	0.056

The values in parenthesis are square root transformed.

Table 4.5: Abundance of different insect pests on medium (5-6years old) pecan plants in Poonch district

SMW	Date of week	*Halyomorpha halys* (Mean ± SE)/ branch	*Palomena prasine* (Mean ± SE)/ branch	*Hieroglyphus banian* (Mean ± SE)/10sweeps	*Cotinis nitida* (Mean ± SE)/ branch	*Monelliopsis pecanis* (Mean ± SE)/5 leaves	*Phyllophaga* sp. (Mean ± SE)/ branch
14	02–08 Apr	0.58±0.11 (1.25±0.04)	0.14±0.04 (1.06±0.01)	0.00±0.00 (1.00±0.00)	0.00±0.00 (1.00±0.00)	2.30±0.31 (1.80±0.08)	0.00±0.00 (1.00±0.00)
15	09–15 Apr	0.48±0.13 (1.21±0.05)	0.18±0.06 (1.08±0.03)	0.00±0.00 (1.00±0.00)	0.00±0.00 (1.00±0.00)	2.54±0.16 (1.87±0.04)	0.00±0.00 (1.00±0.00)
16	16–22 Apr	0.82 ± 0.11 (1.34±0.04)	0.20±0.03 (1.09±0.01)	0.00±0.00 (1.00±.00)	0.00±0.00 (1.00±0.00)	3.48±0.33 (2.11±0.08)	0.00±0.00 (1.00±0.00)
17	23-29 Apr	0.88± 0.08 (1.37±0.02)	0.28±0.06 (1.13±0.02)	0.00±0.00 (1.00±0.00)	0.00±0.00 (1.00±0.00)	2.94±0.28 (1.98±0.07)	0.00±0.00 (1.00±0.00)
18	30 A-06 May	0.92± 0.17 (1.38±0.06)	0.36±0.08 (1.16±0.03)	0.48±0.08 (1.21±.03)	0.00±0.00 (1.00±0.00)	3.04±0.24 (2.00±0.06)	0.00±0.00 (1.00±0.00)
19	07 – 13 May	0.82± 0.16 (1.34±0.06)	0.54±0.06 (1.12±0.02)	0.56±0.11 (1.24±.04)	0.00±0.00 (1.00±0.00)	2.28±0.26 (1.80±0.07)	0.00±0.00 (1.00±0.00)
20	14–20 May	0.60 ± 0.16 (1.25±0.06)	0.30±0.09 (1.13±0.04)	0.24±0.10 (1.11±0.04)	0.00±0.00 (1.00±0.00)	2.32±0.28 (1.81±0.07)	2.72±0.27 (1.92±0.07)
21	21 – 27 May	1.06± 0.16 (1.43±0.06)	0.54±0.08 (1.23±0.03)	0.86±0.09 (1.36±0.03)	0.00±0.00 (1.00±0.00)	3.44±0.11 (2.10±0.02)	3.68±0.24 (2.16±0.05)
22	28 M–03 Jun	2.40± 1.40 (1.73±0.31)	0.56±0.02 (1.24±0.01)	0.78±0.13 (1.33±0.05)	0.16±0.04 (1.07±0.01)	3.28±0.32 (2.06±0.08)	3.94±0.04 (2.23±.00)
23	04–10 Jun	3.66±1.77 (1.99±0.41)	0.62±0.04 (1.27±0.01)	0.68±0.10 (1.29±0.03)	0.20±0.05 (1.09±0.02)	3.82±0.25 (2.19±0.05)	3.88±0.18 (2.20±0.04)

24	11 – 17 Jun	0.92± 0.21 (1.37±0.07)	0.62±0.13 (1.26±0.05)	0.56±0.14 (1.24±0.05)	0.24±0.05 (1.11±0.02)	4.02±0.21 (2.23±0.04)	4.06±0.11 (2.24±0.02)
25	18 – 24 Jun	1.22± 0.16 (1.48±0.05)	0.72±0.04 (1.31±0.01)	0.66±0.14 (1.28±0.05)	0.28±0.02 (1.13±0.00)	4.32±0.28 (2.30±0.06)	4.38±0.25 (2.31±0.05)
26	25J – 01 Jul	0.88± 0.215 (1.36±0.07)	0.44±0.13 (1.19±0.05)	1.08±0.04 (1.44±0.01)	0.30±0.04 (1.13±0.02)	4.06±0.39 (2.24±0.09)	4.42±0.52 (2.31±0.11)
27	02–08 Jul	1.00± 0.00 (1.41±0.00)	0.58±0.09 (1.25±0.03)	0.44±0.07 (1.19±0.03)	0.32±0.04 (1.14±0.02)	4.46±0.20 (2.33±0.04)	2.06±0.45 (1.72±0.13)
28	09 – 15 Jul	0.76± 0.07 (1.35±0.03)	0.24±0.07 (1.11±0.03)	0.32±0.04 (1.14±0.03)	0.22±0.04 (1.10±0.02)	4.26±0.37 (2.28±0.08)	1.1±0.45 (1.46±0.05)
29	16 – 22 Jul	0.58± 0.08 (1.25±0.03)	0.00±0.00 (0.00±0.00)	0.14±0.06 (1.06±0.02)	0.12±0.02 (1.05±0.00)	2.86±0.51 (1.94±0.13)	0.8±0.51 (1.33±0.02)
30	23 – 29 Jul	0.38 ± 0.12 (1.29±0.04)	0.00±0.00 (0.00±0.00)	0.12±0.04 (1.05±0.02)	0.04±0.02 (1.02±0.01)	2.78±0.27 (1.93±0.06)	0.4±0.67 (1.14±0.03)
(C.D.)		0.381	0.92	0.095	0.038	0.195	0.151
SE(m)		0.134	0.33	0.33	0.013	0.069	0.053

The values in parenthesis are square root transformed

Table 4.6: Abundance of different insect pests on young (2-3years old) pecan plants in Rajouri district

SMW	Date of week	*Hieroglyphus banian* (Mean S ± E)/10 sweeps	*Monelliopsis pecanis* (Mean ± SE)/5 leaves	*Phyllophaga* sp. (Mean ± SE)/ branch
12	19 – 25 Mar	0.20±0.05 (1.09±0.02)	0.20±0.05 (1.09±0.02)	0.00±0.00 (1.00±0.00)
13	26 M– 01 Apr	0.26±0.04 (1.12±0.01)	0.56±0.11 (1.24±0.04)	0.00±0.00 (1.00±0.00)
14	02– 08 Apr	0.32±0.08 (1.14±0.03)	1.42±0.19 (1.55±0.06)	0.00±0.00 (1.00±0.00)
15	09 –15 Apr	0.34±0.24 (1.15±0.01)	2.40±0.14 (1.84±0.04)	0.00±0.00 (1.00±0.00)
16	16 – 22 Apr	0.76±0.04 (1.32±0.01)	2.80±0.18 (1.94±0.05)	0.00±0.00 (1.00±0.00)
17	23 – 29 Apr	0.64±0.11 (1.27±0.04)	2.74±0.34 (1.92±0.09)	0.00±0.00 (1.00±0.00)
18	30 A - 06 May	0.44±0.15 (1.19±.06)	2.32±0.58 (1.79±0.14)	0.00±0.00 (1.00±0.00)
19	07 –13 May	0.84±0.06 (1.35±0.02)	3.58±0.50 (2.12±0.12)	0.32±0.19 (1.13±0.08)
20	14 –20 May	0.70±0.16 (1.29±0.06)	3.52±0.25 (2.12±0.06)	1.90±0.21 (1.69±0.06)
21	21– 27 May	0.96±0.09 (1.39±0.03**)**	3.68±0.26 (2.16±0.06)	2.66±0.30 (1.90±0.08)
22	28 M– 03 Jun	0.66±0.16 (1.28±0.06)	3.74±0.48 (2.16±0.10)	3.16±0.37 (2.03±0.08)
23	04 –10 Jun	0.74±0.07 (1.31±0.02)	3.94±0.42 (2.21±0.09)	3.80±0.35 (2.18±.08)
24	11 – 17 Jun	0.76±0.20 (1.31±0.07)	4.26±0.27 (2.29±0.05)	3.80±0.24 (2.18±0.05)
25	18 – 24 Jun	0.52±0.04 (1.23±0.02)	4.32±0.24 (2.30±0.05)	4.30±0.37 (2.29±0.07)
26	25 J – 01 Jul	0.44±0.06 (1.19±0.02)	4.52±0.68 (2.33±0.14)	2.38±0.19 (1.83±0.05)
27	02 –08 Jul	0.18±0.08 (1.08±0.03)	4.50±0.32 (2.34±0.07)	0.66±0.24 (1.27±0.09)
28	09 – 15 Jul	0.04±0.04 (1.01±0.01)	4.02±0.36 (2.23±0.08)	0.00±0.00 (1.00±.00)
29	16 – 22 Jul	0.22±0.06 (1.10±0.03)	2.46±0.88 (1.79±0.25)	0.00±0.00 (1.00±.00)
30	23 – 29 Jul	0.16±0.05 (1.07±0.02)	1.34±0.24 (1.52±0.07)	0.00±0.00 (1.00±.00)
(C.D.)		0.112	0.273	0.146
SE(m)		0.04	0.097	0.052

The values in parenthesis are square root transformed.

Table 4.7: Abundance of different insect pests on medium (5-6years old) pecan plants in Rajouri district.

SMW	Date of week	*Hieroglyphus banian* (Mean S ± E)/10 sweeps	*Monelliopsis pecanis* (Mean ± SE)/5 leaves	*Phyllophaga* sp. (Mean ± SE)/ branch
12	19 – 25 Mar	0.00±0.00 (1.00±0.00)	0.00±0.00 (1.00±0.00)	0.00±0.00 (1.00±0.00)
13	26 M – 01 Apr	0.00±0.00 (1.00±0.00)	0.00±0.00 (1.00±0.00)	0.00±0.00 (1.00±0.00)
14	02– 08 Apr	0.06±0.04 (1.02±0.01)	2.20±0.43 (1.77±0.12)	0.00±0.00 (1.00±0.00)
15	09 – 15 Apr	0.18±0.09 (1.08±0.04)	2.08±0.39 (1.73±0.11)	0.00±0.00 (1.00±0.00)
16	16 – 22 Apr	0.24±0.10 (1.11±0.04)	2.26±0.43 (1.78±0.12)	0.00±0.00 (1.00±0.00)
17	23 – 29 Apr	0.28±0.12 (1.12±0.05)	3.08±0.13 (2.01±0.03)	0.00±0.00 (1.00±0.00)
18	30 A - 06 May	0.48±0.10 (1.21±0.03)	2.80±0.12 (1.94±0.03)	0.96±0.47 (1.17±0.17)
19	07 – 13 May	0.62±0.08 (1.27±0.03)	2.68±0.48 (1.90±0.12)	2.44±0.38 (1.31±0.41)
20	14 – 20 May	0.48±0.10 (1.21±0.04)	3.28±0.33 (2.06±0.08)	3.16±0.11 (1.90±0.09)
21	21 – 27 May	0.80±0.09 (1.34±0.03)	3.74±0.20 (2.17±0.04)	3.16±0.11 (2.06±0.02)
22	28 M – 03 Jun	0.66±0.14 (1.28±0.05)	3.90±0.16 (2.21±0.03)	3.68±0.25 (2.18±0.59)
23	04 – 10 Jun	0.52±0.16 (1.22±0.06)	3.98±0.21 (2.23±0.04)	4.12±0.12 (2.20±0.06)
24	11 – 17 Jun	0.60±0.10 (1.26±0.04)	4.16±0.31 (2.26±0.07)	3.72±0.36 (2.25±0.07)
25	18 – 24 Jun	0.46±0.07 (1.20±0.03)	4.42±0.27 (2.32±0.06)	3.62±0.48 (2.09±0.09)
26	25 J – 01 Jul	0.66±0.15 (1.28±0.06)	4.24±0.31 (2.28±0.06)	3.10±0.63 (1.80±0.20)
27	02 –08 Jul	0.44±0.07 (1.19±0.03)	4.16±0.18 (2.27±0.04)	0.66±0.24 (1.22±0.20)
28	09 – 15 Jul	0.48±0.04 (1.21±0.02)	3.98±0.24 (2.22±0.05)	0.00±0.00 (1.00±0.00)
29	16 – 22 Jul	0.32±0.10 (1.14±0.04)	3.74±0.26 (2.17±0.06)	0.00±0.00 (1.00±0.00)
30	23 – 29 Jul	0.10±0.04 (1.04±0.02)	2.82±0.18 (1.95±0.04)	0.00±0.00 (1.00±0.00)
(C.D.)		0.111	0.197	0.245
SE(m)		0.039	0.07	0.087

The values in parenthesis are square root transformed

Table 4.8 Diversity of natural enemies on pecan plants in Poonch and Rajouri Districts

District	Common name	Scientific name	Order (family)	Type
1.Poonch	Praying mantis	*Mantis religiosa* (Linnaeus)	Mantodea (Mantidae)	Predator
	Ladybug/beetle	*Exochomus nigripennis* (Erichson)	Coleoptera (Coccinellidae)	Predator
	Carpenter ant	*Camponotus discolor* (Buckley)	Hymenoptera (Formicidae)	Predator/ scavenger
	Red Soldier Beetle	*Rhagonvcha fulva* (Scopoly)	Coleoptera (Cancharidae)	Predator
	Kissing Bug	*Triatoma sanguisuga* (LeConte)	Hemiptera (Reduviidae)	Vector/ predator
2.Rajouri	Ladybug/beetle	*Coccinella septempunctata* (Linnaeus)	Coleoptera (Coccinellidae)	Predator
	Praying mantis	*Mantis religiosa* (Linnaeus)	Mantodea (Mantidae)	Predator

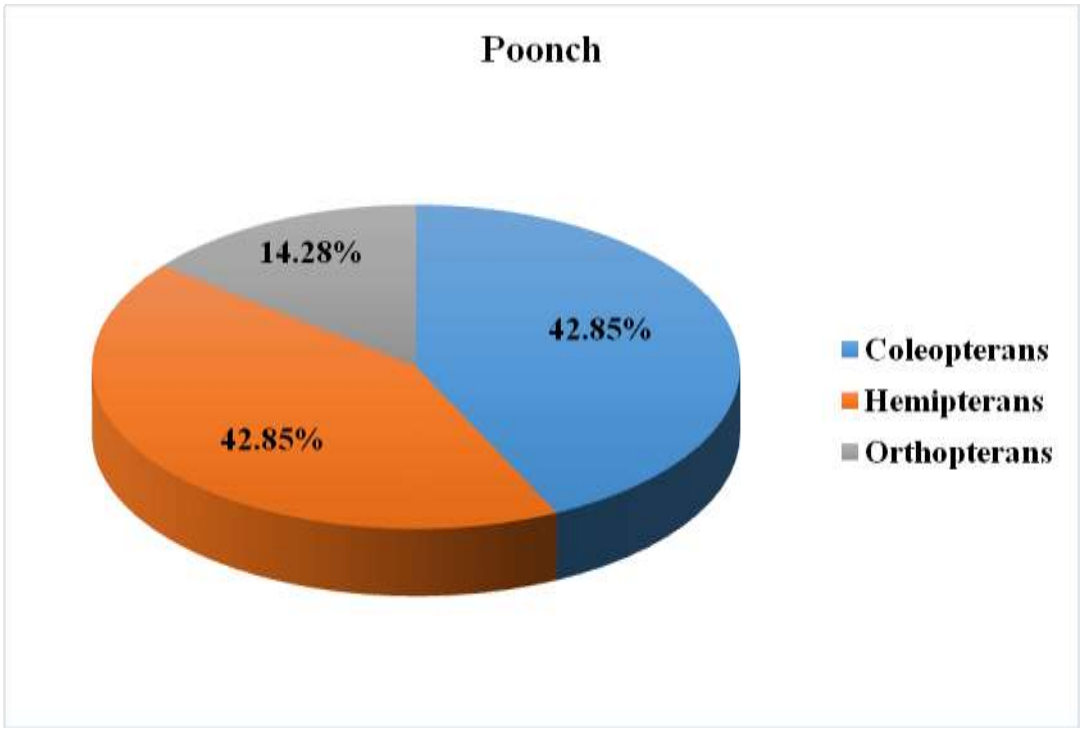

Fig. 4.5: Overall composition of insect order infesting pecan nut in Poonch (percent)

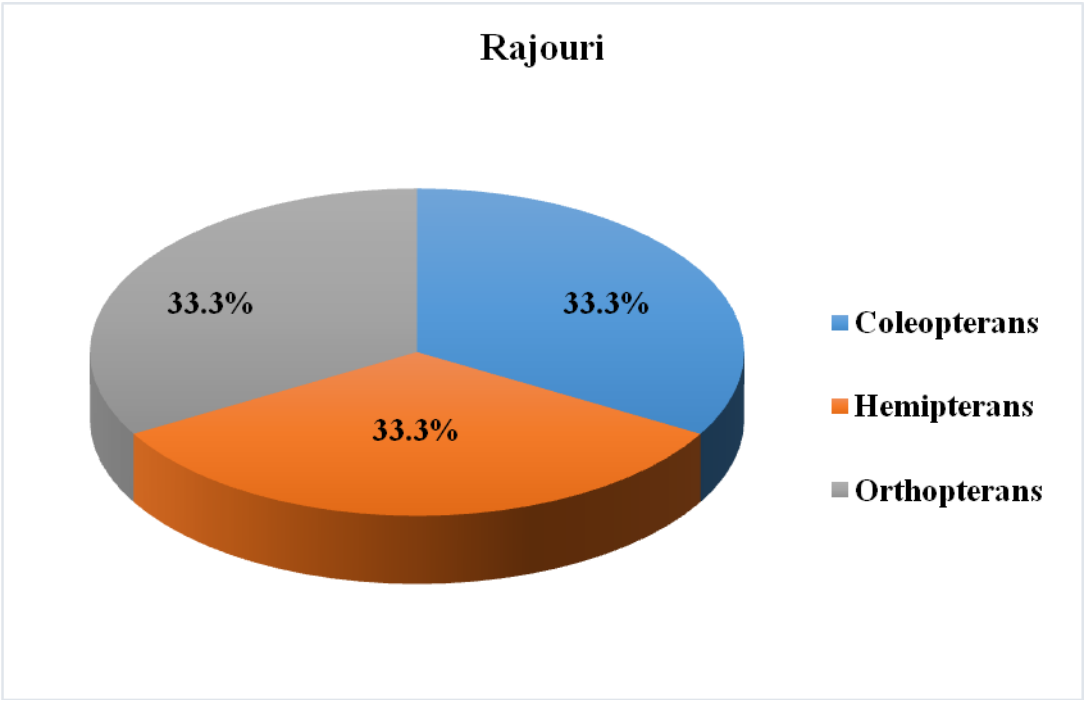

Fig.4.6: Overall composition of insect order infesting pecan nut in Rajouri (percent)

Plate 4.8: Praying Mantis
Mantis religiosa

Plate 4.9: Ladybug
Coccinella septempunctata

Plate 4.10: Ladybug
Exochomus nigripennis

Plate 4.11: Carpenter Ant
Camponotus discolor

Plate 4.12: Kissing Bug
Triatoma sanguisuga

Plate 4.13: Red Soldier Beetle
Rhagonvcha fulva

CHAPTER- 5

DISCUSSION

The results obtained during the present investigation entitled "**Insect Pest Succession and their Abundance on Pecan nut, *Carya illinoinensis*** (Wangenh.) Koch" are discussed under the following heads: -

5.1 Succession and Status of Insect Pests on Pecan nut

Pecan nut acknowledged as 'Queen of Nuts' is an economically important fruit grown in different parts of the world, especially in the United States of America, some European countries, China and South Africa. Owing to widespread cultivation in the different parts of world, numerous potential insect pests and mites (Payne, 1979) have detracted it in terms of cultivation, production and market value by feeding and causing injury. Although numerous studies have been conducted previously in different parts of the world to comparatively study the occurrence of different types of insect pests such as weevils, leaf defoliators and sap suckers and bark borers (Dutcher *et al*., 2006) on pecans and the ways to manage them through chemical and biological means (Dutcher *et al*., 2003), however, there have been no complex studies concerning their occurrence and degree of harmfulness in the Union territory of Jammu & Kashmir. Hence this study was conducted with an aim to characterize the species and quantify the composition of the fauna occurring on pecan trees especially in the twin districts of Poonch and Rajouri where they are grown mostly, nonetheless in scattered and isolated areas. This survey of the insect fauna associated with pecan plants is the first one ever carried out in twin districts. The results of the present investigation revealed that across different areas, pecan plants are very attractive to a wide diversity of insect species, ranging from pests to beneficials. However, each site surveyed does not differ much in terms of species diversity, species richness and evenness prevailing in pecan grown areas in Poonch and Rajouri. During study it was found that seven insect species, belonging to 3 orders and 7 families and three pest species belonging to 3 orders and 3 families occur on pecan plants in Poonch district and in Rajouri district, respectively. The majority of insect species encountered in the nursery and other pecan plantations in both the districts fall into the orders of Coleoptera, Hemiptera, and Orthoptera. The orders Coleoptera and Hemiptera were represented mostly by pest species such as leaf defoliators and sap suckers. To the best of our knowledge, none of the insect pests was reported from nuts and stems. In our study, *Phyllophaga* sp. and *Hieroglyphus banian* appeared as the most important insect pests due to

their damage potential and their wide distribution throughout the surveyed areas. These two species were visible during second week of April and third week of May, respectively in nursery and medium aged plants at Poonch. While as in Rajouri, they were visible during the third week of March and second week of May in Nursery plants and in the first week of April and first week of May in medium aged plants, respectively. *H. banian* move into pecan trees from nearby crops, pastures, and weedy areas and feed on pecan leaves. Both adults and nymphs cause damage by chewing on the leaves and stems of plants, and if infestations are severe, may defoliate entire fields. Occurrence and damage to pecan leaves has been reported in other parts of the world such as United States of America (Ring *et al*., 1985; Capinera, 1993) not only on the pecans but on other crops because of its polyphagous nature. Although the emergence of *Phyllophaga* sp. was seen in the month of May, however it is not so always because emergence of *Phyllophaga* sp. has also been noticed in the Month of June or July (Erler and Ozgur, 2015) flying during evenings and nights and feeding on the leaves. The creamy white C shaped larvae known as white grub feeds on the root system of many plants causing wilting and serious damages (Woodruff and Beck, 1989; Buss, 2006). The results of our investigation revealed the infestation of adults of grey weevil and aphids in nursery plants during the first week of April in Poonch while infestation of aphids was visible during third week and first week of April in nursery and medium sized plants in Rajouri, respectively. Grey weevil infestation has also been reported on other nut crops such as walnut (Gull *et al*., 2018) feeding on leaf margins and are serious leaf defoliators. The occurrence and infestation of this pest only in nursery plants may be due to its preference of young shoots and new foliage (Gull *et al*., 2018). The pests cause holes in leaves, causing curling of leaf tips and finally blackening (Mir & Wani, 2005). There are numerous species of aphids that have been reported to infest the pecans such as *M. pecanis*, black margined aphids and the black pecan aphids (Dutcher et al., 2012), however in our case only *M. Pecanis* were reported on pecans in both the districts. *Halyomorpha halys* and *Cotinis nitida* were reported only in Poonch during second week of April in nursery as well as in medium aged plants and only in medium aged plants in Poonch district from the last week of May, respectively. No infestation of *H. halys* and *C. nitida* were reported from the district Rajouri.

5.2 Abundance of Major Insect Pest on Pecan nut

The results of diversity and mean abundance of insect pests in district of Poonch and Rajouri revealed the reduced pest load initially during the spring both in nursery plants and

medium aged plants. During the present investigation, infestation of *H. halys* was found from the last week of April with more mean population per branch (Table 4.4) during the second week of June (0.68±0.19) while as its infestation was reported during the first week of April in medium aged plants with highest population of (3.66±1.77) during the first week of June, in Poonch district (Table 4.5). *H.halys* as an invasive pest has been reported on many annual and perennial agricultural products and is an awful highly polyphagous pest feeding on beans, hazelnut, kiwi, corn, orange and blueberry etc. (Kibar *et al*., 2019). It is native to East Asia (China, Korea, and Japan) and has been discovered in the USA and Switzerland, as a serious pest it has been reported from USA (Funayama 2012), Italy (Cesari *et al*., 2015) and European countries like France, Serbia, Georgia etc. (Vetek *et al*., 2014; Haye *et al*., 2015) with reports of serious damage from Italy (Kibar *et al*., 2019) of late. Although the damage on pecans by this insect pests is not so serious in Poonch, however it has the capability of inflicting the serious loss if not kept blow the threshold level. There are numerous reports where it has inflicted the serious losses. For example, in USA alone, it has caused economic losses to the tune of 21 billion dollars (Leskey *et al*., 2012) and has become harmful for hazelnut orchards in Italy (Bosco *et al*., 2018). This pest has the potential of reproducing at a rapid rate especially in the border areas as seen in the border areas of Georgia and Russia (Kibar *et al*., 2019). In our results, we found the population build-up and peak abundance of this pest in the month of June, while as its abundance was found more in in late August and mid-September (Kibar *et al*., 2019) in Italy and from early September to mid-October in USA (Leskey *et al*., 2012). Since this pest is highly invasive and has high reproductive rate, hence eradication procedures, destruction of adults through selected insecticides during June-July months, attention to internal quarantine measures should be placed in action before it may act as a threat to pecan industry especially in Poonch district.

During our study, infestation of *H. banian* was reported both in Poonch and Rajouri with highest abundance of this pest in the month of June (1.08±0.04mean/10 sweeps) in nursery plants and medium plants in Poonch district while as in Rajouri highest population (0.96±0.09) and (0.80±0.09) in Nursery and medium aged plants respectively was found in the month May. Although the population of this insect pest in both the districts was found low, however the damage inflicted on the leaves was more because of its aggressive nature. The attack of the similar species of *H. banian* in pecans can be attributed to its polyphagous nature chewing and feeding on rice, grasses. Since both grasses and rice are grown in plenty in both the districts and because of fast flying nature of *H. banian*, we may assume that it

might be shifting on pecans from these crops and vice-versa. During the study, *Monelliopsis pecanis* infestation was reported in both the districts with highest aphid population of (4.64±0.65 and 4.46±0.20) and (4.52±0.68 and 4.42±0.27) per fives leaves in nursery and medium aged plants in Poonch and Rajouri districts, respectively. No much difference was observed in the abundance of aphids in twin districts; however, occurrence saw a variation which may be due to the climate variation of two districts. Any type of aphid species attack is a major contributing factor for reduced tree vigour, nut size and yield because they consume the cell contents of the leaves (Ginzel, 2010). Besides, aphids are responsible for the excretion of honey dew which attracts black sooty mould fungus leading to reduced light penetration to leaves, make them black and cause sunburn to fruits and thereby, reducing market value of fruits (Gull *et al*., 2018). Our results revealed that peak abundance of yellow aphids did not sustain long which may be due to the debilitation of vascular system in the pecan leaf, prevalence of natural enemies and influence of high temperature or rainfall (Tedders and Gottwald, 1983; Pickering *et al*., 1990; Dutcher, 1998; Kaakeh and Dutcher, 1993). The yellow aphids were found evenly distributed on the lower side of leaves. Similar results were found by Edelson*et al*. 1983 who reported that yellow pecan and blackmargined aphids are evenly distributed on pecan whereas, black pecan aphids initially colonize the foliage of the lower branches of the interior of the tree canopy and then spread to the foliage of periphery and upper branches. Reduced populations of aphids may be attributed to the presence of natural enemies such as *Exochomus nigripennis* and *Coccinella septempunctata* as both the species were reported in the present study feeding on aphids. The presence of such natural predators prevents the outbreaks and honeydew accumulation and leaf defoliation due to these aphids (Dutcher *et al*., 2012). Management of pecan aphids through aphidophagous predators has been previously documented through the introduction of *Harmonia axyridis* (Pallas) managing all the three species of aphids (Abbas *et al*., 2013).

The infestation of *Phyllophaga* sp. was reported in both districts with peak abundance in the first and last week of June in nursery and medium aged plants in Poonch and third week of June and second week of June Rajouri district, respectively. Although we witnessed the extensive damage of *Phyllophaga* sp. on pecan leaves almost defoliating whole plants during the evening hours, nevertheless, it has also been reported to affect the young fruit orchards, vineyards, ornamentals, turfgrass, potatoes, and many other crops (Anonymous 2011a). The presence of this insect on different host plants suggests that it may pose a

constant threat to pecans and other plants. This is because insects with a wide host range are able to reproduce on a number of host plants and when most plants in a mixed system are pleasant to a polyphagous pest, then in every likelihood may stay longer and become more numerous posing greater threat (Speight, 1983). Therefore, necessary measures are mandatory to control this pest timely otherwise it has the capability of destroying the whole plantations as both its larvae and adults cause the serious damage. Numerous species of June beetles such as Common cockchafer *(M. melolontha*), Summer chafer (*Amphimallon solstitiale* L.), and Garden chafer (*Phyllopertha horticola*) etc. have been reported in different parts of the world inflicting serious damages (Benker and Leuprecht, 2005) on various crops. Since in our study we found the extreme defoliation of pecans both in in nursery and medium aged plants, hence it is mandatory to keep the field clean as its larvae mostly remains in the soil feeding on roots and during the summer adults emerge and defoliate both grasses as well pecans. Hence, timely application of tested insecticides such as imidacloprid and chlorpyrifos should be sprayed to stop the infestation (Erler and Ates, 2015). Besides, application of entomopathogenic fungi should be encouraged as the pest spends major portion of life cycle (2-3 years) as larvae inside the soil as young larvae are more susceptible to the fungal products (Erler and Ates, 2015). Our results also revealed the infestation of *Palomena prasine* and *C.nitida* in medium aged plants with more infestations during the months of June and July respectively, in Poonch. No infestation of these two pests was reported in Rajouri district. Although no threatening infestation of shield bugs was found during present study, however they have the ability to feed in large groups on plants such as apples, nuts and sorghum as reported in southern and eastern Africa (Mohamed and Bilal, 2011), thus posing a consistent threat of damage to pecans, hence it is essential that a regular monitoring of this pest may be ensured in district Poonch. Our results also suggested the infestation of grey weevil in the nursery at Poonch with more infestation during the last week of June. Infestation of grey weevil has also been reported in walnuts (Gull *et al.*, 2018) in various parts of J and K. Since walnut and pecan belong to same Juglandaceae family and as both are found in abundance in Poonch, hence it cannot be ruled out that the population may accentuate anytime. Hence regular monitoring is the need of hour at this stage without resorting to insecticide application. The composition of the insect fauna as revealed in the present study showed variation with respect to area, age and growth stage of pecan plants as less insects were encountered in Rajouri both in nursery and medium aged plants as compared to Poonch where more diversity was found. Although many of the above pests as

of now are not so serious, however the continuous expanding of growing areas under pecans together with human induced activities leading to ecological disturbances may induce changes in the status of some of the above insect pests, thus demanding regular monitoring especially in Poonch district. Our study also revealed that Coleopteran and Orthopteran pest posed greater threat as of now than the hemipterans.

Our study also revealed some of the beneficial insects which regulate and may prove helpful in future in keeping the different insect pests under check. Important predators found include *Exochomus nigripennis*, *Coccinella septempunctata* and *Mantis religiosa* etc. The diversity of the predators found during present study is both noteworthy and encouraging. This may offer a potential for natural strategy against the economically important pecan pests if populations of these natural enemies are more investigated, augmented and released in pecan ecosystems in future. Since this study was first of its kind, we are optimistic that it may serve as a valuable baseline in future times keeping in the view the importance of pecans and will serve a valuable tool for those who are devoted with plant protection systems.

CHAPTER -6

SUMMARY AND CONCLUSIONS

The investigation on the **"Insect Pest Succession and their Abundance on Pecan nut, *Carya illinoinensis* (Wangenh.) Koch"** presented and discussed in preceding chapters are summarized and concluded as follows:

The present study was carried out in twin districts of Poonch and Rajouri during 2022, as both the districts are ideally suited for the growth of pecans. A significant level of pest diversity on pecan plants at various study sites, particularly in Poonch district, with seven insect species belonging to three orders and seven families in Poonch district and three pest species belonging to three orders and three families in Rajouri district was found. The majority of insect species encountered in the nursery and other pecan plantations in both the districts fall into the orders of Coleoptera, Hemiptera, and Orthoptera. *Phyllophaga* sp. and *Hieroglyphus banian* were discovered to be more abundant and intense in both districts based on occurrence and damage inflicted on the leaves. The infestation of *Monelliopsis pecanis* and *Myllocerus undecimpustulatus* was visible in nursery plants in Poonch during the first week of April, while as same was visible in nursery and medium-sized plants at Rajouri respectively. The second week of April saw the appearance of the short-horned grasshopper and the *H.halys*, while as in third week of May, *Phyllophaga* sp. occurred in nurseries and on medium-aged plants in Poonch. In Rajouri, *Phyllophaga* sp. Harris and *H. banian* were visible in nursery plants during the third week of March and the second week of May, respectively, while they were visible in medium-aged plants during the first week of April and the first week of May. Only medium-aged plants in the Poonch district have been infested with the *Cotinis nitida* from the last week of May.

The outcome of mean abundance per branch of different insect pests in district Poonch and Rajouri revealed the reduced pest load initially during the spring both in nursery and medium aged plants. Although the abundance of marmorated stinkbug was found more on medium aged plants during the month of June with no serious damage to pecans but it's necessary that its population must be kept under check as it has the ability of inflicting serious damages as reported in other countries. The mean abundance per 5 sweeps of *H.banian* in nursery and medium aged plants in Poonch and Rajouri districts revealed lower populations with significant differences, but it was found to inflict more damage to the leaves. The mean abundance per branch of *M. undecimpustulatus* was highest in the last week

of June and lowest in the last week July in Poonch district. The abundance of *M. pecanis* in both the districts were found to be (4.64±0.65 and 4.46±0.20) and (4.52±0.68 and 4.42±0.27) per fives leaves in nursery and medium aged plants in Poonch and Rajouri districts, respectively. The infestation of *Phyllophaga* sp. was reported in both districts with peak abundance in the first and last week of June in nursery and medium aged plants in Poonch and third week of June and second week of June Rajouri district, respectively. Extreme defoliation of pecans both in in nursery and medium aged plants, was found due to this pest especially during night.

Various types of natural enemies on pecan plants were observed during the current study in both Poonch and Rajouri, with greater diversity in the former. In Poonch district Praying mantis, Ladybug, Carpenter ant, red soldier beetle and kissing bug were found while as in Rajouri district only Ladybug and Praying mantis were found. The conclusion drawn during present investigation is summarized below-

- Pecan nuts attract a wide array of arthropods ranging from insect pests to beneficials.
- It is the first ever study conducted on the diversity of pecan nuts insect pest in extensively grown areas of Poonch and Rajouri from UT of Jammu and Kashmir.
- The results revealed the abundance and infestation of various insect pests such as *Halyomorpha halys, Palomena prasina, Phyllophaga* sp., *H. banian*, *M. pecanis, C.nitida* and *M. undecimpustulatus* belonging to different insect orders.
- Among all the insect pest, *Phyllophaga* sp. and *H. banian* inflict the greater damage to pecan plants irrespective of the age of plants
- Further, the present study showed the presence of many beneficial insects which are both noteworthy and encouraging, as they have the ability to regulate the abundance of various insect pests.
- To augment the findings in this thesis, it is now important to study individually all these insect pests so as to draw conclusively their exact status with respect to pecan nuts.

REFERENCES

Abbas, M.G., Karar, H. and Dutcher, J.D. 2013. Efficacy of multicolored Asian ladybeetle (Coleoptera: Coccinellidae) as a control for aphids in pecan orchards. *Journal of Entomological Science*, **48**(1): 70-74.

Agboton, C., Onzo, A., Ouessou, F.I., Goergen, G., Vidal, S. and Tamò, M. 2014. Insect Fauna Associated with *Anacardium occidentale* (Sapindales: Anacardiaceae) in Benin, West Africa. *Journal of Insect Science*, **14**(229): 1-11.

Agboton, C., Onzo, A., Korie, S., Tamo, M. and Vidal, S. 2017. Spatial and temporal infestation rates of *Apate terebrans* (Coleoptera: Bostrichidae) in cashew orchards in Benin, West Africa. *African Entomology*, **25**(1): 24-36.

Aguilar-Pérez, H., Rodríguez-del-Bosque, L.A., Aguilar-Pérez, C.H. and de la Peña, N.D. 2007. Seasonal abundance of *Xyleborus ferrugineus* (Coleoptera: Curculionidae) on pecan trees in northern Coahuila, Mexico. *Southwestern Entomologist*, **32**(2):105-109.

Anonymous. 2014. Annual Administrative Report, State Department of Horticulture, Government of Himachal Pradesh, pp. 59.

Anonymous. 2011a. June beetles. Available online: http://www.bahcesel.net/ forumsel/genel zararlilar/12225-haz304ran-bocekler304-polyphylla-fullo/

Anonymous. 2016 a. Indian Horticulture Database. National Horticulture Board, Guregoan.

Anonymous. 2016 b. Statement of J&K, Department of Horticulture, Jammu.

Assenga, B., Masawe, P., Tarimo, T., Kapinga, F. and Mbega, E. 2020. Status of sucking insect pests in cashew growing locations of South and Central Zones, Tanzania. *International Journal of Biosciences*, **16**(4): 34-45.

Benker, U. and Leuprecht, B. 2005. Field experience in the control of Common cockchafer in the Bavarian region Spessart. *Comptes Rendus de la Réunion*, **28**(2): 21-24.

Blanco, C.A., McGee, J.W., Hernández, G. and Kirkpatrick, M. T. 2021. Increase by Growth of Pecan Nut Surface Area and Implication for Pest Management. *Southwestern Entomologist*, **46**(2): 397-402.

Bosco, L., Moraglio, S.T. and Tavella, L. 2018. *Halyomorpha halys*, a serious threat for hazelnut in newly invaded areas. *Journal of Pest Science*, **91**(2): 661-670.

Buss, E.A. 2006. White grub biology and management. *EDIS. Available online: http://edis. ifas. ufl.edu/LH037*. Assessed on 14 August, 2022.

Capinera, J.L. 1993. Host-plant selection by *Schistocerca americana* (Orthoptera: Acrididae). *Environmental entomology*, **22**(1): 127-133.

Cesari, M., Maistrello, L., Ganzerli, F., Dioli, P., Rebecchi, L. and Guidetti, R. 2015. A pest alien invasion in progress: potential pathways of origin of the brown marmorated stink bug *Halyomorpha halys* populations in Italy. *Journal of Pest Science*, **88**(1): 1-7.

Chowdhuri, A.N. and Pal, S.K. 1970. Thrips damaging pecan nut in Himachal Pradesh. *Indian Journal of Entomology,* **32**(2): 65.

Cottrell, T.E., Wood, B.W., Paulsen, C.M., Ni, X. and Ruberson, J.R. 2013. Distribution of the black pecan aphid on pecan leaf surfaces: an overview. In *International Symposiumon Pecans and Other Carya in Indigenous and Managed Systems,***1070**. pp.159-165.

Dinkins, R. L., Tedders, W. L. and Reid, W. 1994. Predaceous neuropterans in Georgia and Kansas pecan trees. *Journal of Entomological Science*, **29**(2):165-175.

Dutcher, J. 1998. Conservation of aphidophaga in pecan orchards. In *Conservation biological control*, pp 291-305.

Dutcher, J. D., Harris, M. K. and Dean, D. A. eds. 2003. *Integration of Chemical and Biological Insect Control in Native, Seeling, and Improved Pecan Production*. *Society of Southwestern Entomologists*, **27**: 21-38.

Dutcher, J. D., Fonsah, E. G. and Hudson, W. G. 2006. Management of insect and mite pests in pecan orchards. *Recent Research Development Entomol*ogy, **5**: 95-109.

Dutcher, J. D. 2007. Impact of predatory mite releases on the abundance of pecan leaf scorch mite (Acari: Tetranychidae). *Journal of Entomological Science*, **42**(4): 517-524.

Dutcher, J. D., Karar, H. and Abbas, G. 2012. Seasonal abundance of aphids and aphidophagous insects in pecan. *Insects*, **3**(4): 1257-1270.

Dwomoh, E.A., Ackonor, J.B. and Afun, J.V.K. 2008. Survey of insect species associated with cashew (*Anacardium occidentale* Linn.) and their distribution in Ghana. *African. Journal of Agriculture Research*, **3**(3): 205-214.

Edelson, J.V. and Estes, P.M. 1983. Intracanopy distribution and seasonal abundance of the yellow pecan aphids *Monellia caryella* and *Monelliopsis nigropunctata* (Homoptera: Aphididae). *Environmental Entomology*, **12**(3): 862-867.

Edelson, J.V. and Estes, P.M. 1987. Seasonal abundance and distribution of predators and parasites associated with *Monelliopsis pecanis* Bissell and *Monellia caryella* (Fitch) (Homoptera: Aphidae). *Journal of Entomological Science*, **22**(4):336-347.

Erler, F. and Ates, A.O. 2015. Potential of Two Entomopathogenic Fungi, *Beauveria bassiana* and *Metarhizium anisopliae* (Coleoptera: Scarabaeidae), as Biological Control Agents Against the June Beetle. *Journal of Insect Science*, **15**(1):1-6.

Foott, W.H. and Timmins, P.R. 1984. Occurrence of the pecan weevil, *Curculio caryae* (Coleoptera: Curculionidae), in persian walnut, *Juglans regia*. *The Canadian Entomologist*, **116**(1): 107-107.

Fu-Castillo, A.A., Harris, M.K. and Vargas-Arispuro, I. 2010. Activation of hibernating *Acrobasis nuxvorella* (Neunzig) larvae as an effect of *Carya illinoinensis* (Wang.) K. Koch bud break. *Southwestern Entomologist*, **35**(4): 551-556.

Funayama, K. 2012. Control effect on the brown-marmorated stink bug, *Halyomorpha halys* (Hemiptera: Pentatomidae), by combined spraying of pyrethroid and neonicotinoid insecticides in apple orchards in northern Japan. *Applied Entomology and Zoology*, **47**(1): 75-78.

Gantner, M. 2000. August. Occurrence of hazelnut pests in southeastern Poland. In *V International Congress on Hazelnut*, **556**: 469-478.

Gill, J.B.1924. Important pecan insects and their control. US Dep. Agric. *Farmers Bulletin*, **1364**: 43-47.

Ginzel, M. D. 2010. Walnut insects: Ecology and control. *Encyclopedia of Pest Management*, **1**(1): 1-3.

Gull, S., Ahmad, T., Rasool, A. and Rasheed, R. 2018. Assessment of damage and seasonal abundance of *Paracopium cingalensis* (lace bug) on (*Juglans regia* L.) in central Kashmir, India. *Uttar Pradesh Journal of Zoology*, **38**(3): 74-83.

Hal, G. D. 2000. Pecan food potential in prehistoric North America. *Economic botany*, **54**(1): 103-112.

Hall, M. J. 1977. *Development of a sampling scheme for pecan weevil damage: causes of nut loss and damage*. Doctoral dissertation, Oklahoma State University. Stillwater, Oklahoma.

Hall, M. J., Hedger, G. H., Eikenbary, R. D. and McNew, R.W. 1981. Impact of pecan weevil on pecan production in a pest-managed commercial orchard. *Environmental Entomology*, **10**(5): 668-672.

Harris, M. and Chung, C.S. 1998. Masting enhancement makes pecan nut casebearer pecans ally against pecan weevil. *Journal of Economic Entomology*, **91**(5): 1005-1010.

Harris, M. K. and Ring, D. R. 1979. Biology of pecan weevil from oviposition to larval emergence. *Southwestern Entomologist*. **4**: 73– 85.

Haye, T., Gariepy, T., Hoelmer, K., Rossi, J.P., Streito, J.C., Tassus, X. and Desneux, N. 2015. Range expansion of the invasive brown marmorated stinkbug, *Halyomorpha halys*: an increasing threat to field, fruit and vegetable crops worldwide. *Journal of Pest Science*, **88**(4): 665-673.

Hartfield, E.A., Harris, M.K. and Medina, R.F. 2012. Population structure of the pecan nut casebearer *Acrobasis nuxvorella* throughout its geographical distribution. *Agricultural and Forest Entomology*, **14***(*2): 119-125.

Heyerdahl, R.H. and Dutcher, J.D. 1990. Seasonal abundance and overwintering mortality in populations of lepidopterous leaf miners of Pecan. *Journal of Entomological Science*, **25**(3): 394-408.

INC, I. 2015. Nut And Dried Fruit Global Statistical Review. 1-72.

Kaakeh, W. and Dutcher, J. D. 1993. Survival of yellow pecan aphids and black pecan aphids (Homoptera: Aphididae) at different temperature regimes. *Environmental Entomology*, **22**(4): 810-817.

Khairmode, P.V. and Sathe, T.V. 2013. Seasonal abundance of weevils *Myllocerus* spp. On mulberry in Kolhapur region. *Bio Science Research Bulletin*, **29**(2): 79-82.

Kibar, Ak., Uluca, M., Aydin, Ö. and Gokturk, T. 2019. Important invasive species and its pest status in Turkey: *Halyomorpha halys* (Stål) (Heteroptera: Pentatomidae). *Journal of Plant Diseases and Protection*, **126**(5): 401-408.

Knutson, A. E. and Ree, B. 2019. Biology and Management of the Pecan Nut Casebearer (Lepidoptera: Pyralidae). *Journal of Integrated Pest Management*, **10**(1): 29.

Kumar, D. and Naidu, B. 2010. A contribution towards the insect fauna of Vadodara, Gujarat (India): The Order Hemiptera. *Halteres*, **1**(2): 73-80.

Leskey, T.C., Hamilton, G.C., Nielsen, A.L., Polk, D.F., Rodriguez-Saona, C., Bergh, J.C., Herbert,D.A., Kuhar, T.P., Pfeiffer, D., Dively, G.P. and Hooks, C.R. 2012. Pest status of the brown marmorated stink bug, *Halyomorpha halys* in the USA. *Outlooks on Pest Management*, **23**(5): 218-226.

Liao, H. T., Harris, M. K., Gilstrap, F. E., Dean, D. A., Agnew, C. W., Michels, G. J. and Mansour, F. 1984. Natural enemies and other factors affecting seasonal abundance of the blackmargined aphid on pecan. *The Southwestern entomologist*, **9**: 404-420

Lima, M. G., Dias-Pini, N. S., Lima, É. F., Maciel, G. P. and Vidal-Neto, F. C. 2017. Identification and pest status of *Holopothrips fulvus* (Thysanoptera: Phlaeothripidae) on dwarf-cashew crops in northeastern Brazil. *Revista Brasileira de Entomologia*, **61**: 271-274.

Linit, M. J. and Necibi, S. 1995. Black walnut curculio: patterns of nut damage in a plantation environment. *Agroforestry systems*, **29**(3): 321-331.

Mansour, F.A. 1993. Natural enemies and seasonal abundance of the blackmargined aphid (*Monellia caryella*) in pecan orchards in Israel. *Phytoparasitica*, **21**(4): 329-332.

Messing, R.H. and Ali Niazee, M.T. 1986. Impact of predaceous insects on filbert aphid, *Myzocallis coryli* (Homoptera: Aphididae). *Environmental entomology*, **15**(5): 1037 -1041.

Mir, G. M. and Wani, M. A. 2005. Severity of infestation and damage to walnut plantation by important insect pests in Kashmir. *Indian Journal of Plant Protection*, **33(**2): 188-193.

Mizell, R. F. and Schiffhauer, D. E. 1987. Seasonal abundance of the crape myrtle aphid, *Sarucallis kahawaluokalani*, in relation to the pecan aphids, *Monellia caryella* and *Monelliopsis pecanis* and their common predators. *Entomophaga*, **32**(5): 511-520.

Mohamed, E.E. and Bilal, A.F. 2011. Distribution patterns and abundance of the duraandat, Agonoscelis pubescens (thunb.) and other pentatomids across habitat patches in the

central clay plain of Sudan. *University of Khartoum Journal of Agricultural Sciences (Sudan)*, **19**(1): 91-99.

Muegge, M.A. and Knutson, A.E. 2012. Mating Disruption of Pecan Nut Casebearer, *Acrobasis nuxvorella* Neuzig1, in Pecans. *Southwestern Entomologist*, **37**(3): 315-324.

Mueller, M. and Dinkins, R. L. 1984. The Seasonal Incidence of the Pecan Nut Casebearer, *Acrobasis nuxvorella* Neunzig (Lepidoptera; Pyralidae), and Hickory Shuckworm, *Cydia caryana* (Fitch) (Lepidoptera: Tortricidae), in Kansas. *Journal of the Kansas Entomological Society*, 328-332.

Mulder, P.G. and Grantham, R.A. 2003. The pecan nut casebearer. Oklahoma Cooperative Extensions Service Publication 7189. Oklahoma State University, Oklahoma.

Nébié, K., Coulibaly, S.L., Dabiré, R.A., Sankara, F., Zida, I., Sawadogo, A. and Ouattara, D. 2021. Insect fauna associated with *Anacardium occidentale* (Sapindales: Anacardiaceae) in the South Sudanese area of Burkina Faso, West Africa. *Journal of Entomological Research*, **45**: 839-850.

Ojeda-Barrios, D., Abadía, J., Lombardini, L., Abadía, A. and Vázquez, S. 2012. Zinc deficiency in field-grown pecan trees: changes in leaf nutrient concentrations and structure. *Journal of the Science of Food and Agriculture*, **92**(8): 1672-1678.

Ozman, S.K. and Cobanoglu, S. 2000. Current status of hazelnut mites in Turkey. In *V International Congress on Hazelnut*, **556**: 479-488.

Payne, J.A., Malstrom, H.L. and Ken Knight, G.E. 1979. Insect pests and diseases of the pecan *[Carya illinoensis*, includes injuries and non-parasitic plants on limbs and bark, *Tillandsia usneoides]*. *Agricultural Reviews and Manuals. ARM-S. 5*:0193 3779.

Pickering, J., Dutcher, J.D. andkbow, B.S. 1990. The effect of a fungicide on fungal-induced mortalityof pecan aphids (Homoptera: Aphididae) in the field. *Journal of Economic Entomology*, **83**(5): 1801-1805.

Rani, S., Sharma, A., Wali, V.K., Kour, K., Sharma, M. and Gupta, R. 2018. Diversity for tree growing habit in the natural population of pecan nut (*Carya illinoensis* K.) in

Jammu Province, India. *Int. Journal of Current Microbiology Applied Science*, **7**(1): 2760-2767.

Ravindran, C., Sharma, M. and Kher, R. 2008. Present status and problems of pecan nut (*Carya illinoinensis* (Wang.) K. Koch) cultivation in Jammu and Kashmir. *Acta horticulturae*, **772**: 179-18.

Reid, W. 2002. Current pest management systems for pecan. *Horticulture Technology*, **12**(4): 633-639.

Ring, D. R., Harris, M.K. and Olszak, R. 1985. Life tables for pecan leaves in Texas. *Journal of economic entomology*, **78**(4): 888-894.

Saruhan, İ. and Tuncer, C. 2000. Population densities and seasonal fluctuations of hazelnut pests in Samsun, Turkey. In *V International Congress on Hazelnut*, **556**: 495-502.

Shaziya, G., Tariq, A. and Ajaz, R. 2019. Studies on diversity indices and insect pest damage of walnuts in Kashmir, India. *Acta Agriculturae Slovenica*, **113**(1): 121-135.

Singh, D., Kumar, K., Sharma, S.D. and Sharma, V.K. 2011. Selection of indigenous pecan [*Carya illinoensis* (Wang) K. Koch.] trees for better nut and kernel quality characters. *Journal of Hill Agriculture*, **2**(1): 85-89.

Singh, V., Sood, A.K. and Shashank, P.R. 2016. New record of lepidopteran husk feeders, *Garella ruficirra* (Hampson) and Conogethes sp. on pecan from India. *Himachal Journal of Agricultural Research*, **42**(1): 94-95.

Smith, M.W., Arnold, D.C., Eikenbary, R.D., Rice, N.R., Shiferaw, A., Cheary, B.S. and Carroll, B.L. 1996. Influence of ground cover on beneficial arthropods in pecan. *Biological Control*, **6**(2): 164-176.

Speight, M.R. 1983. The potential of ecosystem management for pest control. *Agriculture, ecosystems& environment*, **10**(2): 183-199.

Tedders, W.L. and Gottwald, T.R. 1987. Flight behavior of *Monelliacaryella, Monelliopsis pecanis,* and *Melanocallis caryaefoliae* (Homoptera: Aphididae) during *M. caryella* population crash. *Special publication-University of Georgia. College of Agriculture. Experiment Stations*, **38**:51-57.

Thakur, M. and Dinabandhoo, C.L. 2005. Predatory mites associated with phytophagous mites of temperate and sub-tropical fruit trees in Himachal Pradesh. *Journal of Biological Control*, **19**(1): 81-84.

Treadwell, L.W. and Storch, R.H. 1997. Observations on phenology, development, and mortality of larvae of the hazelnut weevil (*Curculio obtusus* (Blanchard): Curculionidae) in nuts of beaked hazelnut (*Corylus cornuta* Marshall: Betulaceae) in thickets in Maine. *Journal of the New York Entomological Society*, **105**: 221-229.

Tuncer, C., Saruhan, I. and Akca, I. 2004. The insect pest problem affecting hazelnut kernel quality in Turkey. In *VI International Congress on Hazelnut*, **686**: 367-376.

Tuo, Y., Coulibaly, D., Koné, M., Traoré, S., Koné, K., & Koua, K. H. 2022. Diversity of Insects on Four Cashew Nut Varieties Inflorescences "*Anacardium occidentale* L." In Niofoin "Côte d'Ivoire". *Entomology and Applied Science Letters*, **9**(1), 31-38.

Van den Berg, M.A. and Maritz, M. 1995. Predators of the yellow pecan aphid, *Monelliopsis pecanis* (Homoptera: Aphididae), in the eastern parts of South Africa, *African Plant Protection*, **2**(2): 123-125.

Vetek, G., Papp, V., Haltrich, A. and Rédei, D. 2014. First record of the brown marmorated stink bug, *Halyomorpha halys* (Hemiptera: Heteroptera: Pentatomidae), in Hungary, with description of the genitalia of both sexes. *Zootaxa*, **3780**(1): 194-200.

Weber, B.C. and McPherson, J.E. 1984. Attack on black walnut trees by the ambrosia beetle *Xylosandrus germanus* (Coleoptera: Scolytidae). *Forest Science*, **30**(4): 864-870.

Woodruff, R.E. and Beck, B.M. 1989. *The scarab beetles of Florida (Coleoptera:Scarabaeidae) Part II.The May or June beetles (genus Phyllophaga).* Florida Department of Agriculture and Consumer Services, Division of Plant Industry.

Zhang, R., Peng, F. and Li,Y. 2015. Pecan production in China. *Scientia Horticulturae,* **100**(197): 719-727.

CERTIFICATE- IV

Certified that all necessary corrections as suggested by the external examiner and advisory committee have been duly incorporated in the thesis entitled **"Insect Pest Succession and their Abundance on Pecan nut, *Carya illinoinensis* (Wangenh.) Koch"** submitted by **Ms. Marya farid,** Registration No. **J-20-M-724.**

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