Studies on Pest Complex and Seasonal Incidence of Major Pests on Walnut (*Juglans regia* L.)

SHOWKAT AHMAD SHEIKH

(MSA/2019/1277)

Division of Entomology

Faculty of Agriculture, Wadura
Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir

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SHOWKAT AHMAD SHEIKH
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I Dedicate This Manuscript to

MY BELOVED PARENTS

&

MY ADVISOR

For their Love, Endless Support,

Encouragement & Guidance

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Division of Entomology, Faculty of Agriculture, Wadura
193201

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This is to certify that the thesis entitled**"Studies on Pest Complex and Seasonal Incidence of Major Pests on Walnut (*Juglans regia* L.)"**submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Entomology),** to the **Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** is a record of bonafide research work carried out by **Mr. Showkat Ahmad Sheikh (Regd. No. MSA/2019/1277)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

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Chairman
Advisory Committee

Endorsed

Head,
Division of Entomology

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Division of Entomology, Faculty of Agriculture, Wadura 193201

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We, the members of the Advisory Committee of **Mr. Showkat Ahmad Sheikh (Regd. No. MSA/2019/1277)**, a candidate for the degree of **Master of Science in Agriculture (Entomology)** have gone through the manuscript of the thesis entitled, **"Studies on Pest Complex and Seasonal Incidence of Major Pests on Walnut (*Juglans regia* L.)"** and recommend that it may be submitted by the student in partial fulfillment of the requirements for the award of the degree.

Advisory Committee

Chairman	**Dr. Sajad Mohi-Ud-Din** Senior Scientist and Head KVK, Kupwara
Members	**Dr. Munazah Yaqoob** Associate Professor Division of Entomology, FoA, Wadura
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Dean PG Nominee	**Dr. Khalid Rasool** Professor and Head Division of Horticulture, FoA Wadura

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Division of Entomology, Faculty of Agriculture, Wadura
193201

Certificate – III

This is to certify that the thesis entitled, **"Studies on Pest Complex and Seasonal Incidence of Major Pests on Walnut (*Juglans regia* L.)"** submitted by **Mr. Showkat Ahmad Sheikh (Regd. No. MSA/2019/1277)** to the **Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** in partial fulfilment of the requirements for the award of the degree of **Master of Science in Agriculture (Entomology)** was examined and approved by the Advisory Committee and External Examiner on …….....

Chairman
Advisory Committee

External Examiner

Head
Division of Entomology

Dean
Faculty of Agriculture, Wadura
SKUAST-Kashmir

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Division of Entomology, Faculty of Agriculture,
Wadura, Sopore- 193201

Name of the student	:	Showkat Ahmad Sheikh
Registration Number	:	MSA/2019/1277
Major subject	:	Entomology
Minor subjects	:	Horticulture
Major Advisor	:	Dr. Sajad Mohi-Ud-Din Senior Scientist and Head KVK, Kupwara
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ABSTRACT

The field experiment on "Studies on Pest Complex and Seasonal Incidence of Major Pests on Walnut (*Juglans regia* L.)" was conducted at Faculty of Agriculture, Wadura during 2020 to record various pests infesting walnut and to study the seasonal incidence of major pests on walnut. The results revealed that eight insect pest species and one non-insect pest species infested walnut crop. Among eight insect pest species, four insect pests viz., walnut aphid, *Chromaphis juglandicola*, dusky-veined aphid, *Panaphis juglandis*, capsid bug, *Megacoelum stramineum* and stink bug, *Apodiphus pilipes* were sucking pests, out of which three insect pests (*P. juglandis*, *C. juglandicola* and *M. stramineum*) belong to order Hemiptera and family Aphidae; one pest (stink bug) belong to order Hemiptera, family Pentatomidae; four insect pests viz., grey weevil *(Myllocerus viridanus*), green leaf weevil (*Polydrusus formosus*), flea beetle (*Altica himensis*) and walnut blue butterfly (*Chaetoprocta odata*) were defoliators, among them three (grey weevil, green leaf weevil and flea beetle) belong to order Coleoptera and family Curculionidae while as one insect pest (walnut blue butterfly) belong to order Lepidoptera, family Lycaenidae; one non-insect pest viz., blister mite

(*Eriophyes erinea*) belong to order Acari, family Eriophyidae was sucking pest. With regards to natural enemies, the study revealed that nine species of natural enemies (predators) viz., pink ladybird beetle (*Coleomegilla maculata*), seven-spotted lady beetle (*Coccinella septempunctata*), two spotted lady beetle (*Adalia bipunctata*), spotted lady beetle (*Coleomegilla maculata*), convergent lady beetle (*Hippodamia convergens*), multi colored Asian lady beetle (*Harmonia axyridis*), green lacewing (*Chrysoperla carnea*), syrphid fly (*Sphaerophoria philanthus*) and predatory mite (*Phytoseiulos* sp.) were found associated with pests of walnut. Among them six natural enemies (predators) viz., *C. maculata, C. septempunctata*, *A. bipunctata*, *C. maculata, H. convergens* and *H. axyridis* belong to order Coleoptera, family Coccinellidae; two natural enemies viz, *C. carnea* and *S. philanthus* belong to order Hemiptera, family Miridae and order Diptera; family Syrphidae, respectively; one predatory mite, *Phytoseiulos* sp. belong to order Acari, family Phytoseiidae. The data generated revealed that the incidence of *E. erinea* commenced from 13th standard meteorological week (SMW) with mean incidence of 1.2 blister per leaf observed in this SMW, reached to its peak (22.7 per leaf) during 30th SMW and then decreased and reached to 0.8 blisters per leaf during 43rd SMW. The mean number of blister was found highest (18.64±1.62) in the month of July and lowest (1.25±0.2) in the month of October. Low severity (4.0%) of *E. erinea* was recorded in April, which reached to its peak (28.5%) in the month of July, thereafter, the severity decreased and reached to 1.5 per cent in the month of October. The incidence of walnut aphid, *C. juglandicola* commenced from 13th SMW with mean incidence of 1.4 aphids per leaf was recorded in this SMW, reached to its peak (28.3 aphids per leaf) during 25th SMW and then decreased and reached to 1.2 walnut aphids per leaf during 43rd SMW. The mean number of walnut aphids was found highest (24.72±1.47) in the month of June and lowest (1.85±0.23) in the month of October. The incidence of dusky-veined aphid, *P. juglandis* commenced from 13th SMW with mean incidence of 3.7 dusky-veined per leaf recorded in this SMW, which reached to its peak level (29.4 per leaf) during 28th SMW and then decreased and reached to 1.5 aphids per leaf during 43rd SMW. The mean number of dusky-veined aphids was recorded highest (25.4±1.20) in the month of July and lowest (1.92±0.16) in the month of October. The incidence of grey weevil, *M. viridanus* commenced from the 18th SMW with mean incidence of 6.4 grey weevils per 20 leaves observed in this SMW, reached to its peak (23.32 grey weevils per 20 leaves) during 28th SMW and then decreased and no incidence was recorded during 43rd SMW. The mean number of grey weevils was found highest (21.52±0.68) in the month of July and lowest (2.64±0.91) in the month of October. The blister mite exhibited positive

and significant correlation (r=0.787) with maximum temperature, however it showed negative and significant correlation (r=- 0.397) with rainfall and morning and evening relative humidity (r= -0.332, -0.330). Also blister mite showed non-significant and positive correlation (r=0.681) with minimum temperature. The walnut aphid, *C. juglandicola* exhibited positive and significant correlation (r=0.881, 0.226) with maximum temperature and relative humidity (morning), however it showed negative and significant correlation(r=-0.425) with rainfall. Also walnut aphid population showed positive and non-significant correlation (r=0.191, 0.294) with minimum temperature and relative humidity (evening). The dusky-veined aphid, exhibited positive correlation (r=0.784, 0.320) with maximum temperature and relative humidity (morning), however, it showed negative and significant correlation (r=-0.425) with rainfall. Also dusky-veined aphid population showed positive and non-significant correlation (r=0.264, 0.272) with minimum temperature and relative humidity (evening). The grey weevil exhibited positive correlation (r=0.808, 0.381) with maximum temperature and relative humidity (morning), however, it showed negative and significant correlation (-0.395) with rainfall. Also grey weevil population showed positive and non-significant correlation (r=0.589, 0.309) with minimum temperature and relative humidity (evening). Regression analysis revealed that 73.8 % (blister mite), 79.8% (walnut aphid), 70% (dusky-veined aphid) and 76.9% (grey weevil) population were influenced by the metrological parameters.

Key words: Walnut pests, Natural enemies, Seasonal incidence, weather parameters.

Signature of Student
Dated: _____

Signature of Major Advisor
Dated: _____

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Place: *Wadura*
Dated:

CONTENTS

Chapter	Particulars	Page No.
1.	INTRODUCTION	1-4
2.	REVIEW OF LITERATURE	5-15
2.1	To identify pest complex and natural enemies on walnut.	5
2.2	To study the seasonal incidence of major pests and their relationship with weather parameters.	8
3.	MATERIALS AND METHODS	16-18
3.1	To identify pest complex and natural enemies on walnut	16
3.2.1	To study the seasonal incidence of Blister mites	16
3.2.2	Severity index	17
3.2.3	Walnut aphids	17
3.2.4	Dusky- veined aphids	18
3.2.5	Leaf defoliators	18
3.2.6	Statistical analysis	18
4.	EXPERIMENTAL FINDINGS	19-37
4.1	To identify pest complex and natural enemies on walnut	19
4.1.1	Pest complex of walnut	19
4.1.2	Natural enemies associated with walnut pests	20
4.2	To study the seasonal incidence of major pests and their relationship with weather parameters	23
4.2.1	Incidence of blister mite on walnut	23

	4.2.2	Correlation of blister mite with important weather parameters	23
	4.2.3	Regression studies of blister mite with weather parameters	24
	4.2.4	Severity of blister mite on walnut	24
	4.2.5	Incidence of walnut aphid on walnut	29
	4.2.6	Correlation of walnut aphid with weather parameters	29
	4.2.7	Regression studies of walnut aphid with weather parameters	29
	4.2.8	Incidence of dusky-veined aphid on walnut	32
	4.2.9	Correlation of dusky-veined aphid with weather parameters	32
	4.2.10	Regression studies of dusky- veined aphid with weather parameters	32
	4.2.11	Incidence of grey weevil on walnut	35
	4.2.12	Correlation of grey weevil with weather parameters	35
	4.2.13	Regression studies of grey weevil with weather parameters	35
5.		DISCUSSION	38-45
6.		SUMMARY AND CONCLUSION	46-49
		LITERATURE CITED	I-VIII

LIST OF TABLES

Table No.	Particulars	Page No.
1	Different pests observed on walnut (*Juglans regia* L.)	21
2	Different natural enemies associated with walnut (*Juglans regia* L.) pests	22
3	Incidence of blister mite (*Eriophyes erinea*) on walnut	25
4	Correlation between blister mite (*Eriophyes erinea),* walnut aphid (*Chromaphis juglandicola*), dusky-veined aphid (*Panaphis juglandis)* and grey weevil (*Myllocerus viridanus*) with weather parameters on walnut (*Juglans regia* L.)	26
5	Regression between incidence of blister mite (*Eriophyes erinea*) with weather parameters on walnut (*Juglans regia* L.)	27
6	Percent severity index of walnut blister mite (*Eriophyes erinea*) on walnut	28
7	Incidence of walnut aphid (*Chromaphis juglandicola*) on walnut	30
8	Regression between incidence of walnut aphid (*Chromaphis juglandicola*) with weather parameters on walnut (*Juglans regia* L.)	30
9	Incidence of dusky- veined aphid (*Panaphis juglandis*) on walnut	33
10	Regression between incidence of dusky- veined aphid (*Panaphis juglandis*) with weather parameters on walnut (*Juglans regia* L.)	34
11	Incidence of grey weevil (*Myllocerus viridanus*) on walnut	36
12	Regression between incidence of grey weevil (*Myllocerus viridanus*) with weather parameters on walnut (*Juglans regia* L.)	37

LIST OF FIGURES

Figure No.	Particulars	After page
1.	Incidence of blister mite (*Eriophyes erinea*) on walnut	25
2.	Incidence of walnut aphid (*Chromaphis Juglandicola*) on walnut	30
3.	Incidence of dusky-veined aphid (*Panaphis juglandis*) on walnut	33
4.	Incidence of grey weevil (*Myllocerus viridanus*) on walnut	36

LIST OF PLATES

Plate No.	Particulars	After page
1.	General overview of experimental field at FoA, Wadura	18
2.	Monitoring of pests on walnut at experimental field	18
3.	Sucking pests of walnut	22
4.	Leaf defoliators of walnut	22
5.	Natural enemies of walnut pests	22

Chapter-1

INTRODUCTION

Walnut (*Juglans regia* L.) is the most widespread tree nut in the world. It belongs to genus *Juglans* and family Juglandaceae (Ogunmoyole *et al.,* 2011). The genus *Juglans* include about 21 species among which *Juglans regia* is the most important being commercially cultivated in many countries. The wild seedlings of walnut (*Juglans regia* L.) have been found growing in vast region right from Carpathain Mountains in Eastern Europe to the north western Himalayas (Woodroof, 1979). It is therefore, believed to have originated in Iran and areas surrounding it. Romans liked it so much that they named it in honor of the king of all their gods, Jupiter's Acorn or in Latin Jovis-glans which later on became *Juglans*.

China ranks number one in walnut production throughout the world with production of 1439127.93 MT followed by US (Anonymous, 2018 a). India is the 8th largest producer of walnut in the world with production of 299.71 MT (Anonymous, 2018 b) and Western Himalayan region of India produces high quality walnuts. The major walnut growing states of India include Uttarakhand, Himachal Pradesh, Arunachal Pradesh and UT of Jammu and Kashmir. All the walnut trees in India are of seedling origin except few seedlings locally named as cultivars or some cultivars introduced from abroad which are grown at regional research stations. The survey of walnut germplasm in all the three states Jammu and Kashmir, Himachal Pradesh and Uttar Pradesh cultivating this fruit have resulted in identifying potential seedlings which can be released as cultivars after further evaluation (Qureshi and Dalal,1985).

Every part of the plant has some utility and as such it has carved a special place in socio-religious and economic well-being of the people (Sharma and Sumbali, 2014).Walnut is a high energy food, rich in oil including omega-3 fatty acids, vitamins and minerals and valued as healthy snack food and bakery ingredients (Rana *et al*., 2007). It also reduces the incidence of cancer and delays

neuro-degenerative diseases of aging (McGranahan *et al*., 2012). Walnut oil can be used for cooking as it is rich in polyunsaturated fatty acids, linoleic acid and oleic acid. The bark and hulls of walnuts are employed in naturopathic medicines. Walnut and its preparations are being promoted for treating a number of skin conditions (ringworm, athlete's foot, jock itch, psoriasis, eczema, wounds), constipation, internal parasites, and as a gargle for sore throats (Linda, 2009). Furniture and wood carved products are made from walnut trees and wood carving is the major source of income for many Kashmiri families (Shah and Bakshi, 2016).

Walnut demand has risen steadily throughout the years, both domestically and internationally. In 2009-10, India exported 9073.38 metric tonnes of walnut for Rs 1978.15 million, compared to 5696.33 metric tonnes worth Rs 1412.36 million in 2008-09 (Vigneshwara, 2011). To fulfill the predicted demand, the country will need to expand its land area and enhance productivity. Even though domestic and international demand for walnut has grown over time in India, the crop's cultivation and production have been slowed by a number of factors, including a lack of scientific research, incorrect and random classification, a long gestation period, and pre-harvest and post-harvest problems.

Walnut is grown on 85.62 hectares in Jammu and Kashmir, with a yield of 275.45 MT, which is the most in the country when compared to other states (Anonymous, 2018 b). Jammu and Kashmir UT is having almost a monopoly in growing dry fruits like walnut. There is a tremendous demand for walnuts produce both for domestic as well as export purposes. To meet such demand, there is a greater scope to bring more and more area under its cultivation. No doubt, the agro climatic condition of this particular region are quite conducive for growth and development of excellent quality nuts and kernels of walnut but the various factors mainly responsible for limiting walnut production include the gigantic size of walnut trees, unscientific management, non-availability of regular orchards, long gestation period and attack of insects and diseases. Also due to lack of information on certain

important traits like homogenous blooming behavior, bearing habit, cultural, nutritional and management practices affect the production in several ways. Furthermore, the existing plantations are of seedling origin which are gigantic trees and their nut and kernel quality are variable.

In the past, descriptive walnuts of short statured grafted walnut trees were not available to farmers and thus they couldn't establish regular orchards. The walnut trees cultivated by farmers were scattered, difficult to manage and thus hampered the better production in many ways. Also pest management was really a big constraint in the walnut because of the difficulty faced to spray these gigantic trees. So, need was always felt to have descriptive short sized grafted trees and regular orchards for better production. In last few years, SKUAST-Kashmir and other organizations like Central Institute of Temperate Horticulture, Srinagar have propagated different cultivars of grafted walnut plants besides the SKUAST-K released varieties Hamdan and Sulaiman and thus provide an opportunity to walnut growers and other farmers to establish regular orchard. These regular orchards may pave an opportunity to manage them in a better way and thus can increase the production and yield with good quality kernels.

There are numerous insect pests associated with walnuts that have been reported from all over the world, inflicting severe harm to walnut trees and walnut products. Although there are various insect pests reported on walnut in Kashmir valley but among them walnut weevil, stem borer, hairy caterpillar, walnut aphid, dusky-veined aphid, leaf roller, gypsy moth, bark beetle, walnut blister mite and tortrix moth present a severe threat and cause considerable economic damage to the plant and their attack thus reduce quality as well as quantity of walnuts (UCIPM, 2011). Like in traditionally cultivated giant and isolated walnut trees, there are also apprehensions of pests and other diseases which may destroy the plant under regular orchard conditions. Though some work has been carried out in Kashmir regarding

studies on pests affecting traditional walnut trees but no such work has been carried out in regular/compact walnut orchards having short sized grafted trees.

In view of the above considerations, it is necessary to know the pest complex and about their incidence pattern in short statured grafted walnut trees in compact orchards for promoting better management practice. Thus, it was considered pertinent to undertake proposed studies with the following objectives:

1. To identify pest complex and natural enemies on walnut.
2. To study the seasonal incidence of major pests and their relationship with weather parameters.

Chapter-2

REVIEW OF LITERATURE

The available literature revealed that no such work regarding to pests affecting walnut orchards in regular/compact having short sized grafted trees has been carried out. However, some work has been carried out by earlier workers in India and abroad regarding the studies on pests affecting traditional walnut trees which are reviewed under the following heads:

2.1 To identify pest complex and natural enemies on walnut.

Schlinger *et al.* (1960) found that *Trioxys pallidus* is a solitary endoparasite of dusky veined aphid and their strains showed a great impact in France but failed in areas having dry climatic conditions in Central valley of Northern California, a parasite *Trioxys pallidus* introduced from Iran and France in 1960 showed satisfactory biological control on walnut aphid.

Sluss (1967) observed in walnut Orchards of Northern California that coccinellid beetles were the most important predators reducing the walnut aphid population in the orchard by affecting the carrying capacity of the leaflet for the aphids.

Bosch *et al.* (1970) found that a parasitic wasp, *Trioxys pallidus* (Haliday) performed well against aphid population particularly on the coastal plain of southern California, and spread rapidly over the areas of milder climate. They further reported that the parasite was capable of destroying a high percentage of the aphid population under favorable conditions.

Sheikh (1975) reported that *Lymantria obfuscata* was sporadic and endemic in Kashmir and was confined to willows but for the last few years the pest has shifted to fruit trees like apple, peach, plum and walnut and causes severe defoliation.

Barnes *et al.* (1978) found that in walnut orchards of State University of California, a parasite *Trioxys pallidus* showed satisfactory biological control of walnut aphids.

Frazer *et al*. (1973) found that in walnut orchards of Iran, a parasite (*Trioxys pallidus*) of walnut aphid, *Chromaphis juglandicola* impacts its abundance and is responsible for keeping aphid numbers low.

Grant *et al.* (1975) reported that the walnut scale, *Quadraspidiotus juglansregiae* is reduced in walnut orchards in California by the twice stabbed lady beetle, *Chilocorus orbus* and the little beetle, *Cybocephalus californicus*. They also found that two parasitic wasps, an *Aphytis* and *Encarsia* species parasitize walnut scale in walnut orchards.

Dharamadikari *et al*. (1985) conducted survey on *Lymantria* and its natural enemies in India and reported that the larvae defoliate popular willows and walnut orchards in Kashmir Valley and causes retarded growth and mortality.

Rather (1989) found that the coccinellid predators and predatory mites were seen as promising predators generally in the undisturbed and commercial orchards of walnut and he further reported that insect predators such as *Stethorus* sp., *Oligota* sp., *Scolothrips*., *Adalia tetraspilota* (Hope), *Hippodamia* sp., *Scymnus* sp., *Coccinella indecimpunctata* (Linneus), *Halyzia* sp. and the predatory mites, *Anystos* sp. and *Agistemus* sp. were active and kept the population of phytophagous mites under control.

Atlihan *et al.* (2011) conducted research in Lake Van Basin River in Turkey and found that dusky-veined aphid is an autoceious, holocyclic species specific to Persian walnut. They cause kernel shriveling in late summers and they feed sap on the upper surface of leaves.

Sharma *et al.* (2012) reported that in Kashmir Valley, the parasitic wasp, *Trioxys pallidus* has virtually eliminated dusky veined aphid and reduced the chemical control.

Uwais *et al*. (2013) reported that in walnut trees of China, *Allothrombium* sp., *Chrysoperla carnea* (Stephens), *Chrysopa phyllochroma* (Wesmael), *Chrysopa formosa* (Brauer), *Oenopia conglobata* L., *Coccinella undecimpunctata* Linnaeus, *Chilocorus geminus* and spiders were found to be associated with insect pests of walnut as natural enemies.

Flint (2014) reported that Lady beetles are voracious aphid feeders, with an adult beetle feeding 50 or more aphids per day, and the convergent lady beetle feeding almost entirely on aphids, avoiding staying on plants with low aphid concentrations.

Atlihan *et al*. (2015) in Turkey studied the seasonal abundance of aphids and their natural enemies and reported that the commonly observed predators and parasitoids were *Orious majuscules, Anthocoris nemorum, Chrysoperla carnea, Hemerobius humulinus* of Hemiptera, *Adalia fascioptera, Oenopia* sp., *Hippodomia variegate, Adalia bipunctata* and *Scymnus rubromaculatus* of Coloeptera as predators and *Trioxy spallidus* of Hymenoptera as parasitoid.

Lambdin *et al.* (2015) while studying in Beaver Dam Baptist Church, Emory Road in USA revealed fourteen coleopteran species as potential predators of the walnut twig beetle. They also found that larvae of three species *Enoclerus nigripes* (Say), *Madoniella dislocatus* (Say) and *Pyticeroides laticornis* (Say) were observed to feed on walnut twig beetle larvae within the galleries.

Gull *et al*. (2019) during survey in Kashmir found nine different pests viz., stink bug, *Apodiphus pilipes* (Horvath), walnut blue butterfly, *Chaetoprocta odata* (Hewitson), walnut aphid, *Chromaphis juglandicola* (Kaltenbach), *Erschoviella musculana* (Erschoff), *Megacoelum stramineum* (Walker), *Myllocerus fotedari* (Ahmad), dusky-veined aphid, *Panaphis juglandis* (Goeze), *Paracopium cingalensis* (Walker), and *Scolytus nitidus* (Schedl) infesting walnut.

Wang *et al*. (2020) while conducting laboratory and field experiments in walnut orchards in Yili, China, to assess the potential of *Orius sauteri* (Anthocoridae), a predatory bug, as a biological control agent against two walnut aphid species, the dusky-veined aphid, *Panaphis juglandis* (Goeze) and the walnut aphid, *Chromaphis juglandicola* (Kaltenbach) found that *O sauteri* has a high capacity for digesting both aphid species. They also reported that *O. sauteri* had a high biocontrol efficacy for both species in laboratory and field trials, with 77 percent for *P. juglandis* and 80 percent for *C. juglandicola*.

2.2 To study the seasonal incidence of major pests and their relationship with weather parameters.

Sluss (1967) observed in walnut Orchards of Northern California that early spring temperature influence the leafing out of the walnut trees and cool spring temperature can delay the leafing out of trees, thus postponing the aphid population increase.

Weber (1980) reported that the velvet gall mite, *Eriophyes cauliseifer* causes a noticeable velvety red growth up to an inch long on the leaf stem in orchards of black walnut in the Eastern United States, forcing the leaf to curl or twist over on it.

Nowierski (1981) studied components like aphid developmental rates, calculation of developmental thresholds, aphid survivorship, fecundity and distribution of eggs and found that average fecundity/female/day and survivorship is high in spring and becomes very low in summer in Russia.

Masoodi *et al*. (1987) while studying the seasonal incidence of dusky veined walnut aphid, *Callaphis juglandis* in walnut orchard at Shalimar during 1985 found that the initial incidence of population was recorded in the first week of May when the day temperature was 24.8 °C and also found that the highest population of 22.20 aphid per 10 leaves was recorded at 27.3 °C in the first week of June, thereafter population showed a declining trend and lowest mean population of 0.9 aphids per sample was recorded at 29.4 °C.

Rather (1989) conducted survey and found that walnut blister mite, *Eriophyes erinea* (Nelepa) occur in epidemic form in all agro climatic zones of Jammu & Kashmir and prevails as a major acarine pest of walnut due to which affected leaves showed galls on upper surface of leaves, dense hairy growth on lower surface and were distorted. He also found that heavily infested trees bore less fruit and smaller nut.

Ciampolini and Trematerra (1992) reported that the walnut husk fly which is a pest of numerous *Juglans* species in North America destroys the mesocarp and in severe infestations, can even harm the pericarp and the nut itself.

Cranshaw *et al*. (1994) reported that the fruit-tree leaf roller moth, *Archips agryrospila* larvae do severe harm to almost all hard wood trees, chewing leaves and developing fruits, causing significant damage during pest outbreaks.

Sibbett and Whiteside (1994) found that the fruit tree leaf roller, *Archips agryrospila*, produces only one generation each year, which overwinters as an egg, and succeeding instars feed intensively on growing leaves and nuts, causing denudation of fruiting shoots and nut abortion.

Williams and Liebhold (1995) observed that the *Lymantria dispar* is affected by weather variables such as maximum temperature, minimum temperature and precipitation and these variables are highly connected with defoliation.

Dhar *et al*. (2000) revealed that the temperature and relative humidity were found to be important abiotic factors exerting influence on population build up of red spider mite, *Tetranychus urticae*, infesting Okra. They further revealed that temperature is positively and relative humidity is negatively correlated with the population build up of the mite. The highest incidence was observed with an ambient temperature of 31.30°C and 78.5% relative humidity. Rainfall was found to have no significant effect on the population build up.

Hajizadeh *et al.* (2005) reported three eriophyeid mites in walnut orchards in West Iran viz., *Eriophyes tristriatus* (Nalepa), *Eriophyes erineus* (Nalepa) and *Eriophyes brachytarsus* (Keifer) and also found that *Eriophyes tristriatus* being the dominating species causing considerable deformations of the leaves of walnut.

Mir and Wani (2005) while studying pest infestation and damage to walnut plantations in Jammu and Kashmir's Srinagar, Pulwama and Kupwara districts found that the leaf defoliator *Chaetoprocta odata* causes substantial defoliation in all of the places surveyed.

Carlo and Giulio (2006) reported that the first larvae of the walnut husk fly were found in early August and mature larvae began to leave the husks in late August to pupate in the soil. The seasonal patterns of nut infection revealed

significant growth in August after peak oviposition, however nut infestation levels in the two orchards' untreated plots ranged from 74 to 91 per cent.

Jaskiewiez and Kmiee (2007) observed walnut pests in urban areas of Lublin and revealed that there exists a positive correlation of population of dusky-veined aphid, *Panaphis juglandicola* with maximum temperature and relative humidity and negative correlation with rainfall.

Hougardy and Mills (2009) found that walnut aphid population multiplied and reached to peak in spring and in late June in California and reported Aphid population reached up to 100 aphids per leaflet, leading to leaf drop, exposing nuts to sunburn, reduction of tree vigor, nut size and quality.

Camper and Cranshaw (2009) reported that the fruit tree leaf roller is the most prevalent pest of yards and gardens in Colorado and also found that it infests a wide range of host plants such as apple, apricot, cherry, pear, plum, prune, raspberry, English walnut, ash, oak, poplar and willow and rose.

Fadamiro *et al.* (2009) while studying in citrus orchard in Southern Alabama region of United States reported that the phytoseiid mites were more abundant in the spring with populations declining at the start of the summer and remaining at very low levels through the fall and winter.

Mills *et al.* (2009) predicted that in commercial walnut orchards of California due to unusual spring weather during 2011 and 2012 resulted in low population of aphids and mites.

Bentley (2010) reported that fruit leaf roller, *Archips argyrospila* is the most frequent pest in landscapes in the United States and found that it attacks on ash, birch, California buckeye, box elder, maple rose, walnut trees, willow, apple, apricot, cherry, citrus, pear and plum and many others.

Karczmarz (2010) compared numbers of *Chromaphis juglandicola* on common walnut in Lublin town and revealed that aphids appear in spring and disappear in autumn and found that pests are significantly affected by course of weather conditions. He further revealed that their development was enhanced by a

warm spring with not very intense precipitation; an air temperature above 30 °C and heavy rain in summer limits their numbers.

Richard *et al*. (2011) reported that the apricot, walnut almond, apple, citrus, cherry, hazelnut, pear, plum, quince, ash, brick, live oak, California buckeye, elm, poplar, rose and other plants are all attacked by the fruit tree leaf roller, *Arachips argyrospila*.

Uwais *et al.* (2013) while studying the species of insect pests and their seasonal population dynamics on walnut trees in China reported four main insect pests viz., *Chromaphis juglandicola* (Kaltenbach), *Apocheima cinerarius* (Erschoff), *Eulecanium gigantean* (Shinji) and *Eulecanium kuwanai* with their seasonal peaks appeared in late-May to late-June, mid-May late-July and early-May to late-June.

Ahmad and Tariq (2014) during a survey of different orchards in the Kashmir valley revealed that *Chromaphis juglandicola* and *Panaphis juglandicola* do not grow together, and that orchards infested with one species have less or no population of the other species. They also found that high populations of aphids may cause leaf drop and exposing more nuts to sunburn. Due to this, the large populations of the season (i.e. > 15 aphids per walnut leaflet) being uncontrolled for as little as 14 days, nut quality is lowered and coupled with a significant reduction in the crop.

Khairmode and Sathe (2014) while studying the seasonal abundance of weevils viz., *Myllocerus discolor* and *Myllocerus viridanus* on mulberry garden in Kolhapur region reported that both species were found throughout the year and were more abundant from July to October.

Magnussen and Hansen (2014) examined in orchards of Norway that the nymphs of *Chromaphis* species were scattered on the underside of the leaves and more abundant than *Panaphis* species. They further revealed that these aphids not only attack *Juglans regia* but also other species like *Juglans ailanthifolia, Juglans cinerea* and *Juglans mandshurica*.

Akkopru *et al.* (2015) while conducting research on English walnut trees in Turkey reported that walnut aphid, *Chromaphis juglandicola* is a serious pest of English walnut and further revealed that feeding reduces tree vigor, nut size, yield and quality. They further reported that while feeding, it produces honey dew and due to these honey secretions secondary attack of mould fungus occur which reduces light penetration into the leaf surface and reduces photosynthetic activity.

Chireceanu *et al.* (2015) reported high infestations of gall pests viz., *Aceria tristriata* and *Aceria erinea* on walnut trees in Southern Romania. They further reported that the galls of *Aceria tristriata* present on the upper surface of walnut leaves and galls of *Aceria erinea* on the lower side of leaves inducing a characteristic discolored blister like swollen formation on the upper side of leaves which later turn brown near blister zones and found severe infestations may result in the malformations of young fruits.

Mace and Mills (2015) examined that in walnut orchards of California, aphid population growth was tied to foliar nitrogen in walnuts. Because nitrogen is often limiting factor for insects, the nitrogen content can play an important role in population dynamics of insects and it leads to increase or decrease of insect pest populations.

Balaji and Hariprasad (2016) during research at Annamalai University Chidambaram, Tamil Nadu, found a positive correlation between the population of coconut mite, *Aceria guerreronis* in the coconut palm, *Cocos nucifera* L., and temperature and wind velocity, as well as a negative correlation with relative humidity, rainfall and sunshine hours.

Haldhar *et al.* (2016) found that in fruits of ber in arid regions of Rajasthan, the activity of grey weevils were more active from June to September.

Khan *et al.* (2016) observed that the walnut blister mite is seen in walnut orchards on a rare basis and does not cause major damage. And also found that plants can sustain high populations of blister mites, which feed on the lower

surface of leaflets and cause characteristic blister-like swellings on the top surface.

Devi *et al*. (2017) while studying the seasonal incidence of the *Aceria mangiferae* on mango at the Department of Agricultural Entomology TNAU, Coimbotore found that maximum population of *Aceria mangiferae* was in May and June and further revealed that during May and June, 33.30 and 37.5 mites per leaf respectively were recorded. They also found that *A.mangiferae* population showed positive correlation with maximum temperature and minimum temperature, while rainfall and relative humidity showed negative correlation.

Khan and Khundoo (2018) reported that the aphids and chafer beetle infest the nursery, stem borer infests the tree trunk, shot hole borer infests branches, gypsy moth and tortix moth defoliate leaves, mite causes blisters and husk fly destroys the husk diminishes output and market value of the fruit.

Anderson & Mills (2018) found in walnut orchards of California, dusky aphid is an invasive species of walnuts which is active from March until early December.

Gull *et al.* (2018 a) reported that *Megacoelum stramineum*, a capsid bug was identified in walnut orchards in Central Kashmir for the first time. Both nymphs and adults have been observed feeding on the undersides of leaves, developing buds, and fruits. They further revealed that the outbreak began in April, with the peak population occurring in July.

Gull *et al.* (2018b) while assessing the abundance and type of damage caused by various Hemipteran insect pests in walnut orchards of Central Kashmir, namely district Srinagar, Budgam, and Ganderbal revealed that *Chromaphis juglandicola* and *Prionailorus cingalensis* had the highest average values of 225.23±141.63 and 93.00±20.37, respectively in Srinagar with significant difference between three districts.

Iranipout *et al.* (2018) while assessing the population fluctuations of the small walnut aphid, *Chromaphis juglandicola* in Meaghan walnut orchards of East Azerbaijan Province, Iran revealed that vertical canopy divisions (upper and

lower half), geographical canopy orientations (at four levels), and branch elongation (basal and distal ends) were three factors impacting population density of the small walnut aphid and also reported that the *Chromaphis juglandicola* were found in early May and in mid-May, there was a sharp increase in population and in early June a peak of 40 aphids per leaf was observed, following by a sharp fall in late July and a minor peak in early October.

Sauro *et al.* (2018) observed apple rust mite, *Aculus schlechtendali* (Acari: Eriophyidae) in an experimental field of apple trees in northern Italy and revealed that the seasonal abundance of apple rust mite first appeared in mid-summer and that mite populations were low in May, started to increase in June, and peaked in July. They also found a significant and positive correlation between the apple rust mite and temperature and a highly negative and significant correlation with rainfall.

Baidya and Chatterjee (2019) while studying different insect pests of mulberry in the Terai agro-ecological region in the mulberry garden of the Department of Agricultural Entomology, West Bengal, India from January 2017 to March 2018 found that the incidence of grey weevil was first recorded on the crop during the third week of May which continued to the second week of August, with the peak population recorded on the 4^{th} week of June. However, it had a non-significant and positive correlation with maximum temperature, maximum RH, and evaporation, and also a negative correlation with rainfall and wind speed.

Devi *et al.* (2019) observed important mite pests of temperate and subtropical fruits, such as apple and pear, peach, plum, apricot and cherry, walnut, hazelnut and pistachio nut, mango, litchi, citrus, guava, sapota and pomegranate and also found that eriophyid mites have a unique relationship with their host plant and are typically found on its fleshy tissues.

Gull *et al.* (2019) reported in walnut trees in Kashmir valley that the infestation of walnut aphids remain active from April to October and attained its peak in the month of June and also found that the infestation of dusky-veined

aphids remain active from April to October and attained its peak in the month of July.

Qadir and Qamar (2019) while carrying survey in two apple orchards of central region of Jammu and Kashmir to ascertain the prevalence of different types of pests infesting the orchards found that the severity of damage of mites is from April to Mid June and also reported 24.8% and 16% mite infested leaves in two orchards .

Chapter-3

MATERIALS AND METHODS

The investigations on "Studies on Pest Complex and Seasonal Incidence of Major Pests on Walnut (*Juglans regia* L.)" were carried out at Faculty of Agriculture, SKUAST-K Wadura, situated at an altitude of 1,610 meters above mean sea level between 34°20 North Latitude and 74°24 East Longitude on nine year old established walnut orchard during cropping season 2020 (Plate 1). The detail of materials and methodologies followed during the course of investigation is as under:

3.1 To identify pest complex and natural enemies on walnut

The experiment was carried out on the Walnut plantation comprised of different selections at Faculty of Agriculture, SKUAST-K, Wadura. Different pests and natural enemies were recorded for which field visits were carried at weekly intervals on 10 randomly selected plants from the first week of April to the last week of October, 2020. The pests and natural enemies noticed were collected, processed to get their correct identification. For identification purposes, immature stages of pests and natural enemies were also reared in cages under laboratory conditions until adults emerged. The identification was carried out by two taxonomist's viz., Dr. Md. Jamal Ahmad & Dr. Zakir Hussain Khan, Professors in Division of Entomology, Faculty of Horticulture, SKUAST-Kashmir, Shalimar.

3.2 To study the seasonal incidence of major pests and their relationship with weather parameters

The experiment was carried out on the Walnut plantation located at Faculty of Agriculture, Wadura. The visits were carried out at weekly intervals from first week of April to last week of October, 2020. During each visit, 10 plants were randomly selected; monitored and examined for current status of major pests viz., blister mite, walnut aphid, dusky-veined aphid and grey weevil (Plate 2).

3.2.1. To study the seasonal incidence of blister mites

Incidence of blister mites was carried out by counting the number of blisters from 20 randomly selected leaves per plant at three different heights in all the four directions. The average of the data generated from 20 leaves was considered as number of blisters per leaf.

3.2.2. Severity index

Severity was recorded by observing the number of blisters/leaf from the same plants and leaves for which incidence was computed. The categorization for severity was done on the basis of score/grade system per leaf per plant developed by (McKinny, 1923)

Scale

Description	Score assigned / Grade
No blisters	0
1-4 blisters	1
5-8 blisters	2
9-12 blisters	3
.> 12 blisters	4

Per cent Severity Index (PSI):

$$\mathbf{PSI} = \frac{\text{Sum of numerical ratings}}{\text{Max. Grades Value} \times \text{Total No. of leaves observed}} \times 100$$

Sum of numerical ratings = 1N+2N+3N+4N

Where 1,2,3,4 are grades

(N) Is the number of leaves showing respective grades or scores

3.2.3. Walnut aphids

Incidence of aphids was recorded by counting the number of aphids from 20 sub terminal randomly selected leaves/tree from lower, middle and top canopy in each direction (East, West, North and South).

3.2.4. Dusky-veined aphids

Incidence of aphids was recorded by counting the number of aphids from 20 sub terminal randomly selected leaves/tree from lower, middle and top canopy in each direction (East, West, North and South).

3.2.5. Leaf defoliator (Grey weevil)

Incidence of grey weevil was recorded by counting randomly the number of grey weevils per 20 leaves /tree selected from top, middle and bottom.

3.2.6. Statistical Analysis

Data thus collected was subjected to standard statistical methods (Gomez and Goomez, 1984). For linear association among the various factors, weekly mean population of incidence of pest populations was subjected to correlation with Minimum temperature, Maximum temperature, Rainfall and Relative Humidity.

Plate1. General overview of experimental field at FoA, Wadura

Plate 2. Monitoring of Pests on Walnut at experimental field

Chapter-4

EXPERIMENTAL FINDINGS

The present investigation "Studies on Pest Complex and Seasonal Incidence of Major Pests on Walnut (*Juglans regia* L)" was conducted at Faculty of Agriculture, SKUAST-K Wadura. To achieve the objectives under these studies, the investigations were planned under the following segments and the results are presented as under:

4.1 To identify pest complex and natural enemies on walnut

4.1.1. Pest complex of walnut

Different walnut pests in compact/regular orchard at FoA, Wadura were recorded for which field visits were carried at weekly intervals on 10 randomly selected plants from April to October. The results clearly indicated that the walnut orchard was infested by the insect pests/mites at different growth stages. The observations on various pests associated with walnut presented in Table-1 revealed that eight insect pest species and one non-insect pest species infested walnut crop at Faculty of Agriculture, Wadura during 2020. Among eight insect pest species, four insect pests viz., walnut aphid (*Chromaphis juglandicola*), dusky-veined aphid (*Panaphis juglandis*), capsid bug (*Megacoelum stramineum*), and stink bug (*Apodiphus pilipes*) were sucking pests, out of which three insect pests (walnut aphid, dusky-veined aphid and capsid bug) belong to order Hemiptera, family Aphidae, one insect pest (stink bug) belong to order Hemiptera, family Pentatomidae; four insect pests viz., grey weevil (*Myllocerus viridanus*), green leaf weevil (*Polydrusus formosus*), flea beetle (*Altica himensis*) and walnut blue butterfly (*Chaetoprocta odata*) were defoliators, among them three (grey weevil, green leaf weevil and flea beetle) belong to order Coleoptera, family Curculionidae, one insect pest (walnut blue butterfly) belong to order Lepidoptera, family Lycaenidae; one non-insect pest viz., blister mite (*Eriophyes erinea*) was reported as sucking pest belonging to order Acari, family Eriophyidae. During

present studies, three insect pests viz., walnut aphid (*Chromaphis juglandicola),* dusky-veined aphid (*Panaphis juglandis*), grey weevil (*Myllocerus viridanus*) and one non-insect pest blister mite (*Eriophyes erinea*) were found as major pests causing serious damage to the walnut foliage, while as the other five insect pests viz., capsid bug (*Megacoelum stramineum*), stink bug (*Apodiphus pilipes*), green leaf weevil (*Polydrusus formosus*), walnut blue butterfly (*Chaetoprocta odata*) and flea beetle (*Altica himensis*) were recorded as minor pests (Plate 3 and 4).

4.1.2. Natural enemies associated with walnut pests

For recording natural enemies, field visits were carried out at weekly intervals from April to October on 10 randomly selected plants. The data presented in Table-2 revealed the presence of nine species of natural enemies (predators) viz., pink ladybird beetle (*Coleomegilla maculata*), seven-spotted lady beetle (*Coccinella septempunctata*), two spotted lady beetle (*Adalia bipunctata*), spotted lady beetle (*Coleomegilla maculata*), convergent lady beetle (*Hippodamia convergens*), multi colored Asian lady beetle (*Harmonia axyridis*), green lacewing (*Chrysoperla carnea*), syrphid fly (*Sphaerophoria philanthus*) and predatory mite (*Phytoseiulos* sp) associated with walnut pests. Among them, six natural enemies (predators) viz., pink ladybird beetle (*Coleomegilla maculata*), seven-spotted lady beetle (*Coccinella septempunctata*), two spotted lady beetle (*Adalia bipunctata*), spotted lady beetle (*Coleomegilla maculata*), convergent lady beetle (*Hippodamia convergens*), multi colored asian lady beetle (*Harmonia axyridis*) belong to order Coleoptera, family Coccinellidae; two natural enemies viz green lacewing (*Chrysoperla carnea*) and syrphid fly (*Sphaerophoria philanthus*) belong to order Hemiptera, family Miridae and order Diptera, family Syrphidae, respectively; one predatory mite, *Phytoseiulos* sp. belong to order Acari, family Phytoseiidae (Plate 5). The results further revealed that among all the recorded natural enemies, the most diverse species of lady bird beetles were found.

Table – 1 Different pests observed on walnut (*Juglans regia* L.)

S. No.	Common name	Scientific name	Order: Family	Period of activity
	Sucking pest			
1	Walnut aphid	*Chromaphis juglandicola*	Hemiptera: Aphidae	Apr- Oct
2	Dusky-veined walnut aphid	*Panaphis juglandis*	Hemiptera: Aphidae	Apr- Oct
3	Capsid bug	*Megacoelum stramineum*	Hemiptera: Miridae	Apr- Oct
4	Stink bug	*Apodiphus pilipes*	Hemiptera: Pentatomidae	Apr- Oct
	Defoliators			
5	Grey weevil	*Myllocerus viridanus*	Coleoptera: Curculionidae	May –Aug
6	Green leaf weevil	*Polydrusus formosus*	Coleoptera: Curculionidae	May –Aug
7	Flea beetle	*Altica himensis*	Coleoptera :Chrysomelidae	May –Aug
8	Walnut blue butterfly	*Chaetoprocta odata*	Lepidoptera: Lycaenidae	May –Aug
	Non insect pest			
9	Blister mite	*Eriophyes erinea*	Acari: Eriophyidae	Apr-Oct

Table-2 Different natural enemies associated with walnut (*Juglans regia* L.) pests

S. No.	Common name	Scientific name	Order : Family
1	Pink ladybird beetle	*Coleomegilla maculata*	Coleoptera: Coccinellidae
2	Seven-spotted ladybeetle	*Coccinella septempunctata*	Coleoptera :Coccinellidae
3	Two-spotted lady beetle	*Adalia bipunctata*	Coleoptera: Coccinellidae
4	Spotted lady beetle	*Coleomegilla maculata*	Coleoptera: Coccinellidae
5	Multi colored Asian lady beetle	*Harmonia axyridis*	Coleoptera: Coccinellidae
6	Convergent ladybeetle	*Hippodamia convergens*	Coleoptera :Coccinellidae
7	Green lacewing	*Chrysoperla carnea*	Hemiptera: Miridae
8	Syrphid fly	*Sphaerophoria philanthus*	Diptera: Syrphidae
9	Predatory mite	*Phytoseiulos* sp.	Acari : Phytoseiidae

A

B

C

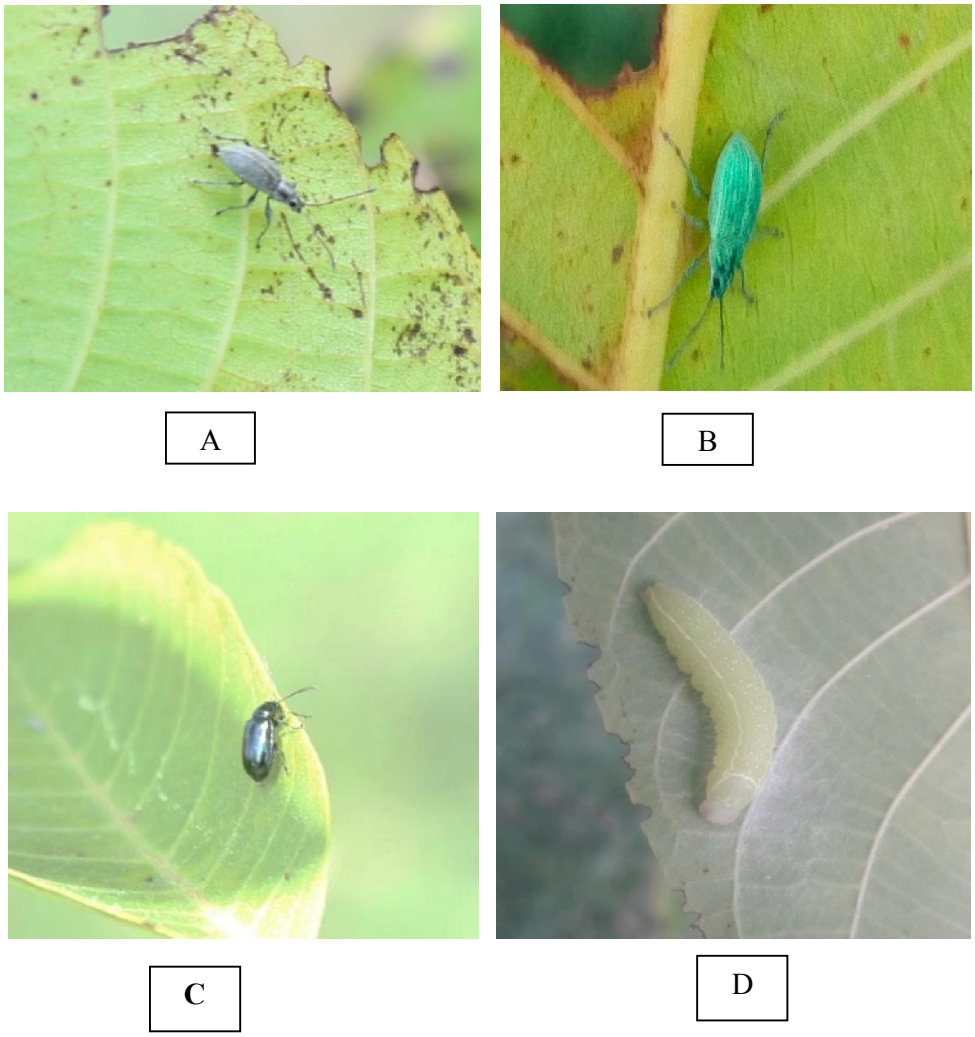
D

E

F

Plate 3 Sucking pests of walnut

A. Galls caused by blister mites B. Microscopic view of blister mite, *Eriophyes erinea* C. Walnut aphid, *Chromaphis juglandicola* D. Dusky-veined aphid, *Panaphis juglandis* E. Capsid bug, *Megacoelum stramineum* F. Stink bug, *Apodiphus pilipes*



A B C D

Plate 4. Leaf defoliators of walnut

A. Grey weevil, *Myllocerus viridanus* B. Green weevil, *Myllocerus discolor* C. Flea beetle, *Altica himensis* D. Larva of Walnut blue butterfly, *Chaetoprocta odata*

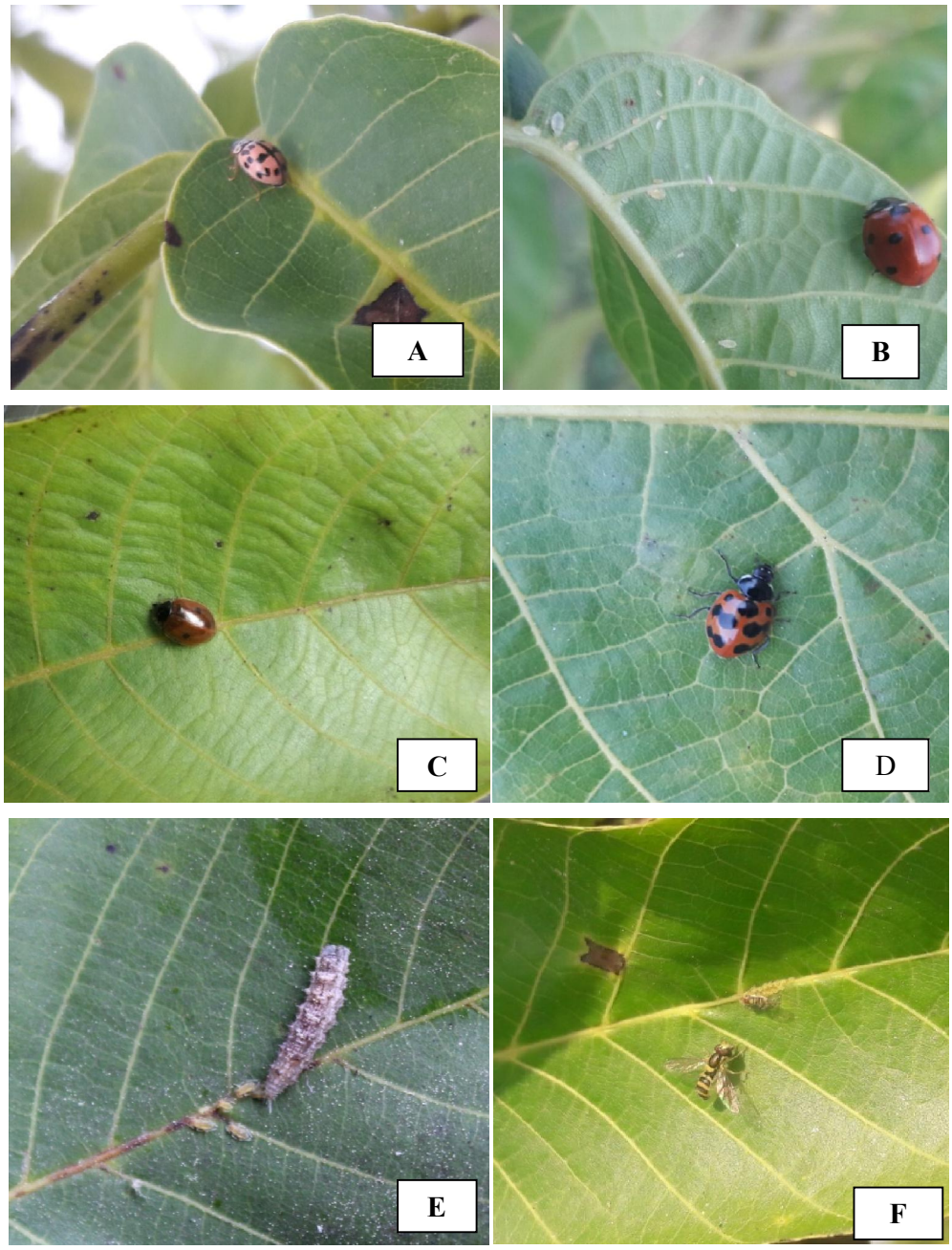
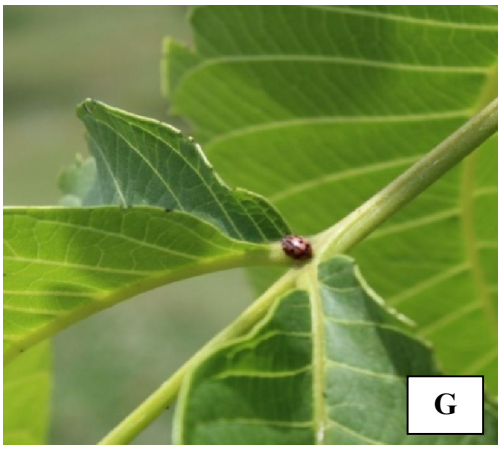


Plate 5. Natural enemies of walnut pests

A. Pink ladybird beetle, *Coleomegilla maculate* B. Seven-spotted lady beetle C. Two- spotted lady beetle**,** *Adalia bipunctata* D. Spotted lady beetle, *Coleomegilla maculate* E. Syrphid fly larva F. Adult syrphid fly, *Sphaerophoria scripta* G. Convergent ladybird beetle, *Hippodamia convergens* H. Multi colored Asian lady beetle, *Harmonia axyridis* I. Larva of green lacewing, *Chrysoperla carnea* J. Adult of green lacewing, *Chrysoperla carnea* K. Predatory mite, *Phytoseiulos* sp.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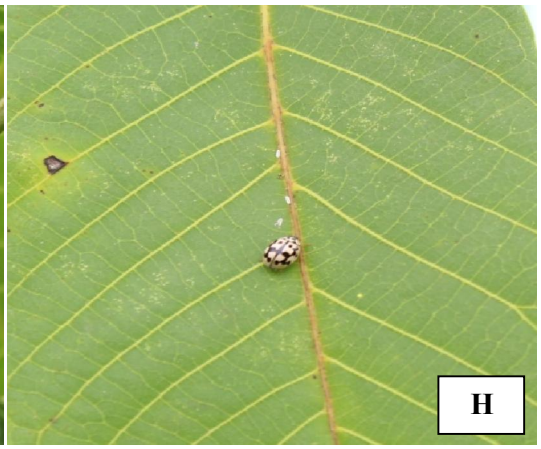
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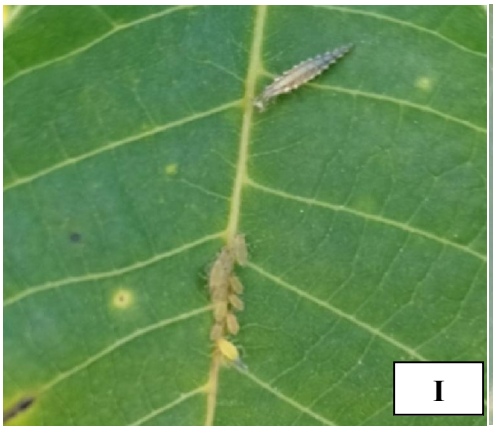
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4.2 To study the seasonal incidence of major pests and their relationship with weather parameters.

Seasonal incidence of insect pests/mites was monitored throughout the growing season for which field visits were carried out at weekly intervals from April to October on ten randomly selected walnut trees of walnut orchard established at FoA, Wadura during 2020. The results indicated that the walnut orchards under study were infested by different insect pests/ mites at different growth stages. The incidence of various pests recorded during field visits presented in various tables is described as under:

4.2.1. Incidence of blister mite on walnut

The data on incidence of blister mite (*Eriophyes erinea*) on walnut is presented in Table-3 and illustrated by Figure I. The perusal of data revealed that activity of blister mite commenced from 13th standard meteorological week (SMW) with mean incidence (1.2 blisters per leaf) was observed in this meteorological week. Thereafter, there was gradual increase in the pest incidence which reached to its peak (22.7 blisters per leaf) in 30th SMW from where it started declining and reached to minimum (0.8 blister per leaf) in 43rd SMW. The mean number of blister/ leaf was found highest (18.64±1.62) in the month of July and lowest (1.25±0.2) in the month of October. Coefficient of variance (CV) was recorded highest (40%) in the month of October and lowest (2.26%) in the month of June.

4.2.2. Correlation of blister mite with important weather parameters

The data on correlation of blister mite (*Eriophyes erinea*) on walnut with temperature (°C), humidity (%) and rainfall (mm) from 13th to 43th standard meteorological week under field conditions presented in Table-4 revealed that among the different weather parameters, maximum temperature had a significant and positive correlation (r=0.787) with blister mite, and negative and significant correlation (r=- 0.397) with rainfall and morning and evening relative humidity (r=-0.332 and -0.330). Minimum temperature had a non-significant and positive correlation (r=0.681) with it.

4.2.3. Regression studies of blister mite with weather parameters:

The data presented in Table-5 indicated the regression between populations of blister mite with the weather parameters. The regression analysis showed that the weather parameters have a significant effect on the population density of blister mite. From the regression equation, R^2 value (0.73) suggested that all the weather parameters jointly contributed 73 per cent variation in population indicating higher dependence of population on weather parameters.

4.2.4. Severity of blister mite on walnut

The data on mean per cent severity of blister mite/leaf presented in Table-6 revealed that blister formation on leaves is directly related to the pest population. A scale (1-4) was used to determine the mean pest severity. The data presented in the Table-6 showed increased trend of severity from 13th standard meteorological week (SMW) till 43rd SMW. The maximum severity (28.5%) was observed in 30th SMW from where it started declining and reached to minimum (1.5%) in 43rd SMW.The mean per cent severity was recorded highest (24.84%) in the month of July and lowest (2.50 %) in the month of October.

Table-3 Incidence of blister mite, *Eriophyes erinea* on walnut

Month	SMW	*Mean No. blisters /leaf	Confidence interval	
			Lower limit	Upper limit
April	13th	1.20	0.95	1.45
	14th	1.20	0.95	1.45
	15th	1.60	1.13	2.25
	16th	1.80	1.39	2.07
	17th	2.00	1.35	2.65
	Mean	**1.56**	**1.15**	**1.96**
	SE (Mean)	**0.16**		
	CV (%)	**22.93**		
May	18th	4.40	3.76	5.04
	19th	5.20	4.25	6.15
	20th	8.00	7.08	9.92
	21st	8.80	7.60	10.0
	Mean	**6.60**	**5.67**	**7.77**
	SE(Mean)	**1.06**		
	CV (%)	**32.26**		
June	22nd	12.60	7.10	18.1
	23rd	13.00	6.50	19.5
	24th	13.10	12.00	14.2
	25th	13.30	12.10	14.5
	Mean	**13.00**	**11.78**	**20.71**
	SE(Mean)	**0.14**		
	CV (%)	**2.26**		
July	26th	**13.7**	**10.50**	**16.0**
	27th	16.5	14.70	18.5
	28th	19.0	15.50	22.5
	29th	21.3	17.00	25.6
	30th	22.7	18.10	27.3
	Mean	**18.64**	**15.16**	**21.98**
	SE(Mean)	**1.62**		
	CV (%)	**19.46**		
August	3I st	11.30	10.09	12.51
	32nd	10.70	8.00	12.0
	33rd	9.50	8.50	10.5
	34th	9.40	8.00	10.4
	Mean	**10.25**	**8.64**	**11.35**
	SE(Mean)	**0.46**		
	CV (%)	**9.08**		
September	35th	5.20	4.43	5.97
	36th	4.80	4.29	5.31
	37th	5.00	4.23	5.77
	38th	4.20	3.49	4.91
	39th	2.00	1.31	2.69
	Mean	**4.24**	**3.55**	4.93
	SE(Mean)	**0.58**		
	CV (%)	**30.82**		
October	40th	1.60	1.2 0	2.0
	4I st	1.40	1.00	1.8
	42nd	1.20	1.00	1.4
	43rd	0.80	0.60	1
	Mean	**1.25**	**0.95**	**1.55**
	SE(Mean)	**0.20**		
	CV (%)	**40.00**		

SMW = Standard meteorological week
***Mean of 200 leaves per 10 plants taken in one Standard week**
SE = Standard Error
CV = Coefficient of Variance

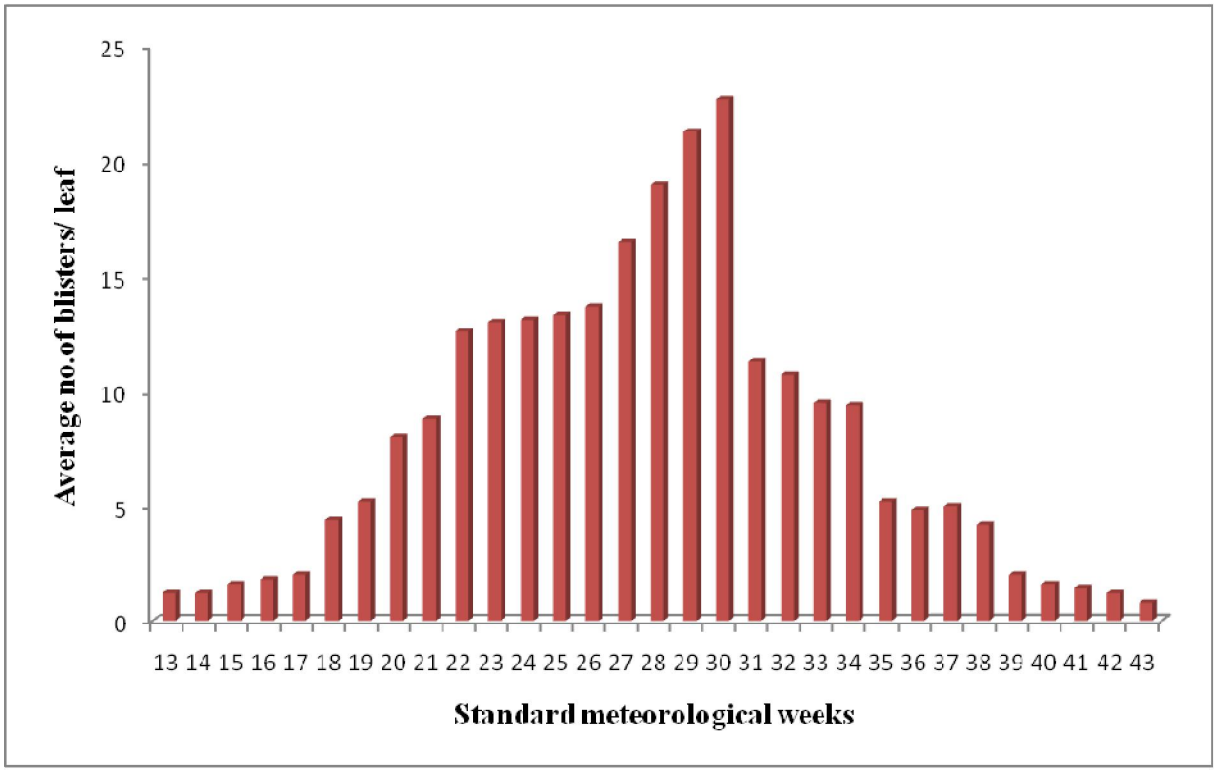

Figure I: Incidence of blister mites (*Eriophyes erinea*) on walnut

Table-4 **Correlation between blister mite (*Eriophyes erinea*), walnut aphid (*Chromaphis juglandicola*), dusky-veined aphid (*Panaphis juglandis*) and grey weevil (*Myllocerus viridanus*) with weather parameters on walnut (*Juglans regia* L.)**

Weather parameters	Correlation coefficient (r)			
	Blister mite	**Walnut aphid**	**Dusky-veined aphid**	**Grey weevil**
Max. Temperature (^{o}C)	0.787 (0.001)**	0.881 (0.001)**	0.784 (0.001)**	0.808 (0.001)**
Min. temperature (^{o}C)	0.681 (0.48)	0.191 (0.689)	0.264 (0.140)	0.589 (0.240)
Relative humidity (Morning)	-0.332 (.04)*	0.266 (.01)*	0.320 (.03)*	0.381 (0.02)*
Relative humidity (Evening)	-0.330 (.03)	0.294 (.10)	0.272 (.13)	0.309 (.09)
Rainfall (mm)	- 0.397 (.04)*	- 0.425 (.01)*	- 0.425 (.01)*	-0.395 (.02)*

****Correlation is significant at 0.05 level**

***Correlation is significant at 0.01 level**

Values in parenthesis are p values

Table-5 Regression between incidence of blister mite (*Eriophyes erinea*) with weather parameters on walnut (*Juglans regia* L.)

Weather parameters	*Eriophyes erinea*			
	Coefficients	**Standard Error**	**"t" value**	**"p" value**
Intercept	-18.939	12.616	-1.501	0.146
Max temperature (^{o}C)	0.581	0.281	2.06	0.01
Min temperature (^{o}C)	0.435	0.267	1.63	0.90
Rainfall (mm)	-0.190	0.185	-1.09	0.02
Relative humidity (Morning)	-0.144	0.118	-1.12	0.04
Relative humidity (Evening)	-0.099	0.055	-1.79	0.05
Coefficient of Determination (R^2)	**0.738**			
Regression Equation	**$Y = -18.939 + 0.58x_1 + 0.43x_2 - 0.19x_3 + 0.14x_4 + 0.099x_5$**			

Table-6 Percent severity index of blister mite (*Eriophyes erinea*) on walnut

Month	SMW	Mean severity index (%)	*Grade
April	13th	4.00	1
	14th	4.00	1
	15th	4.50	1
	16th	7.00	2
	17th	9.00	3
	Mean	**5.70**	
May	18th	11.00	3
	19th	12.50	4
	20th	14.00	4
	21st	14.70	4
	Mean	**13.05**	
June	22nd	16.20	4
	23rd	17.40	4
	24th	18.50	4
	25th	19.00	4
	Mean	**17.77**	
July	26th	21.00	4
	27th	23.00	4
	28th	25.00	4
	29th	26.70	4
	30th	28.50	4
	Mean	**24.84**	
August	3Ist	24.00	4
	32nd	22.00	4
	33rd	21.50	4
	34th	18.00	4
	Mean	**21.37**	
September	35th	15.50	4
	36th	12.40	4
	37th	11.20	3
	38th	11.00	3
	39th	7.00	2
	Mean	**11.42**	
October	40th	5.50	2
	4Ist	1.50	1
	42nd	1.50	1
	43rd	1.50	1
	Mean	**2.50**	

SMW= Standard meteorological week

***Grade 0 = No blisters**

Grade 1= 1-4 blisters

Grade 2= 5-8 blisters

Grade 3= 9-5 blisters

Grade 4 = > 12 blisters

4.2.5. Incidence of walnut aphid on walnut

The data on seasonal incidence of walnut aphid, *Chromaphis juglandicola* on walnut is presented in Table-7 and illustrated by Figure -II. The perusal of data revealed that activity of walnut aphid commenced from 13th standard meteorological week (SMW) with mean incidence (1.4 walnut aphids per leaf) was observed in this SMW. Thereafter, there was increase in the pest incidence which reached to its peak (28.3 aphids per leaf) in 25th SMW, from where it started declining and reached to minimum (1.2 aphids per leaf) in 43rd SMW. The mean number of walnut aphids was found highest (24.72±1.47) in the month of June and lowest (1.85±0.23) in the month of October. Coefficient of variance (CV) was highest (43.57%) in the month of May and lowest (9.45%) in the month of July.

4.2.6. Correlation of walnut aphid with important weather parameters

The data on correlation of walnut aphid (*Chromaphis juglandicola)* on walnut with temperature (°C), humidity (%) and rainfall (mm) from 13th to 43th standard week under field conditions presented in Table-4 revealed that the different weather parameters like maximum temperature and relative humidity (morning) had a significant and positive correlation (r=0.881 and 0.266) with walnut aphid while as rainfall showed a significant and negative correlation (r=-0.425) with it. Minimum temperature and relative humidity (evening) had a non-significant and positive correlation (r=0.191 and 0.294) with it.

4.2.7. Regression studies of walnut aphid with weather parameters

The data presented in Table-8 indicated the regression between populations of walnut aphid with the weather parameters. The regression analysis revealed that the weather parameters showed a significant effect on the population density of walnut aphid. From the regression equation, R^2 value (0.79) suggested that all the weather parameters jointly contributed 79 per cent variation in population indicating higher dependence of population on weather parameters.

Table-7 Incidence of walnut aphid (*Chromaphis juglandicola*) on walnut

Month	SMW	*Mean no. of Walnut aphids / leaf	Confidence interval	
			Lower limit	Upper limit
April	13th	1.40	1.12	1.68
	14th	1.60	1.20	2.00
	15th	1.80	1.35	2.25
	16th	2.10	1.55	2.65
	17th	2.60	2.17	3.03
	Mean	**1.90**	**1.47**	**2.32**
	SE (Mean)	**0.20**		
	CV (%)	**24.68**		
May	18th	5.80	4.12	7.48
	19th	6.10	4.27	7.93
	20th	11.30	9.89	12.71
	21st	14.10	12.97	15.23
	Mean	**9.35**	**7.81**	**10.83**
	SE(Mean)	**2.03**		
	CV (%)	**43.57**		
June	22nd	21.30	19.75	23.85
	23rd	23.80	22.50	25.10
	24th	25.50	23.80	27.20
	25th	28.30	27.20	29.40
	Mean	**24.72**	**23.31**	**26.38**
	SE(Mean)	**1.47**		
	CV (%)	**11.89**		
July	26th	20.70	19.00	22.40
	27th	23.30	21.00	25.60
	28th	25.40	23.00	27.80
	29th	26.70	24.90	28.50
	30th	24.50	21.10	27.90
	Mean	**24.12**	**21.80**	**26.44**
	SE(Mean)	**1.02**		
	CV (%)	**9.45**		
August	31st	17.20	15.10	19.30
	32nd	13.20	11.90	14.50
	33rd	10.50	9.80	11.20
	34th	9.70	7.80	11.60
	Mean	**12.65**	**28.70**	**14.15**
	SE(Mean)	**1.69**		
	CV (%)	**26.74**		
September	35th	7.50	6.00	9.00
	36th	8.10	6.50	9.70
	37th	5.20	4.70	5.70
	38th	4.10	3.80	4.40
	39th	3.50	2.80	4.20
	Mean	**5.68**	**4.76**	**6.60**
	SE(Mean)	**0.91**		
	CV (%)	**35.91**		
October	40th	2.30	2.00	2.60
	41st	2.00	1.70	2.30
	42nd	1.90	1.10	2.70
	43rd	1.20	0.90	1.50
	Mean	**1.85**	**1.42**	**2.28**
	SE(Mean)	**0.23**		
	CV (%)	**25.16**		

SMW = Standard meteorological week
***Mean of 200 leaves per 10 plants taken in one Standard Week**
SE = Standard Error
CV = Coefficient of Variance

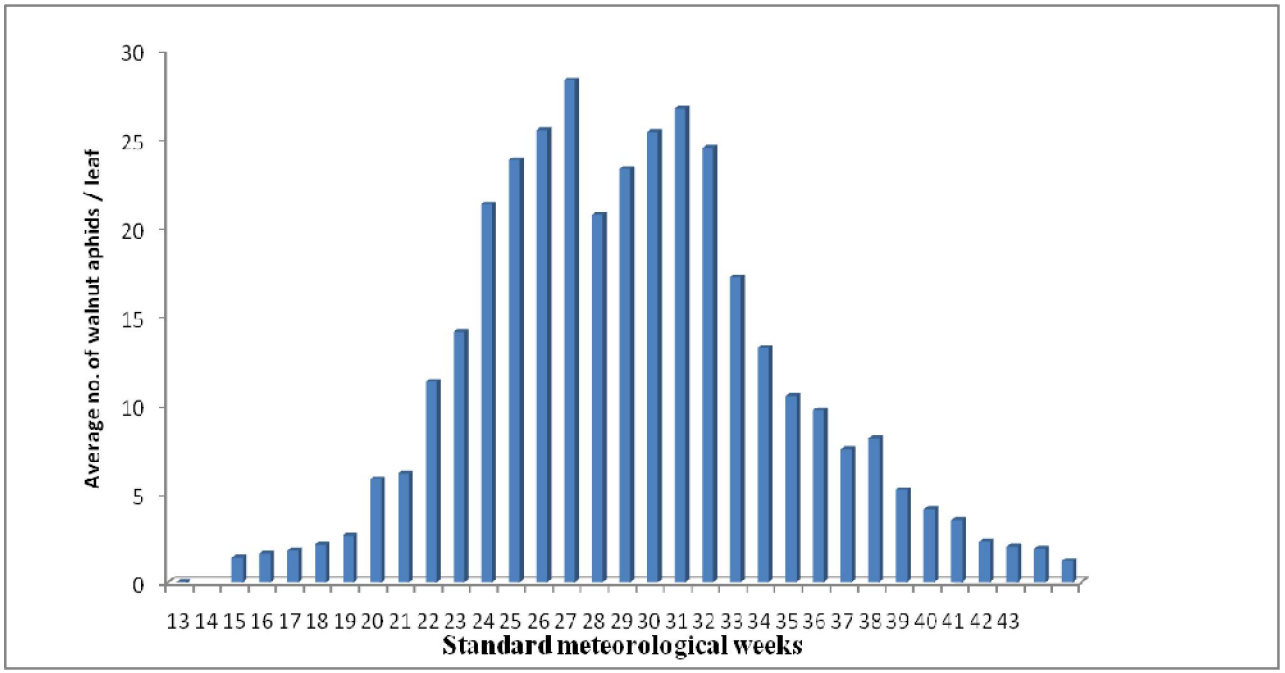

Figure-II: Incidence of Walnut aphid (*Chromaphis juglandicola*) on walnut

Table-8 **Regression between incidence of walnut aphid (*Chromaphis juglandicola*) with weather parameters on walnut (*Juglans regia* L.)**

Weather parameters	*Chromaphis juglandicola*			
	Coefficients	**Standard Error**	**"t" value**	**"p" value**
Intercept	-18.939	12.616	-1.501	0.146
Max temperature (^{o}C)	0.581	0.281	2.06	0.01
Min temperature (^{o}C)	0.435	0.267	1.63	0.01
Rainfall (mm)	-0.19	0.185	-1.02	0.02
Relative humidity (Morning)	0.144	0.118	0.12	0.905
Relative humidity (Evening)	0.099	0.055	1.79	0.486
Coefficient of Determination (R^2)	**0.798**			
Regression Equation	$\mathbf{Y = -18.939 + 0.58x_1 + 0.43x_2 - 0.19x_3 + 0.14x_4 + 0.099x_5}$			

4.2.8. Incidence of dusky-veined aphid on walnut

The data on incidence of dusky-veined aphid, *Panaphis juglandis* on walnut is presented in Table-9 and illustrated by Figure-III. The perusal of data revealed that activity of dusky-veined aphid commenced from 13th standard meteorological week (SMW) with mean incidence (3.7 dusky-veined aphids per leaf) was observed in this SMW. Thereafter, there was gradual increase in the pest incidence which reached to its peak (29.4 dusky-veined aphids per leaf) in 28th SMW. The incidence decreases thereafter and reached (1.5 dusky-veined aphids per leaf) in 43rd SMW. The mean number of dusky-veined aphids was found highest (25.4±1.20) in the month of July and lowest (1.92±0.16) in the month of October. Coefficient of variance (CV) was found highest (34.47**%**) in the month of September and lowest (6.79%) in the month of April.

4.2.9. Correlation of dusky-veined aphid with important weather parameters

The data on correlation of dusky-veined aphid, *Panaphis juglandis)* with temperature (°C), humidity (%) and rainfall (mm) from 13th to 43th standard meteorological week under field conditions presented in Table-4 revealed that among the different weather parameters, maximum temperature and relative humidity (morning) had a significant and positive correlation (r=0.784 and 0.320) with dusky-veined aphid while as rainfall showed a significant and negative correlation (r=-0.425) with it. Minimum temperature and relative humidity (evening) had a non-significant and positive correlation (r=0.264 and 0.272) with it.

4.2.10. Regression studies of dusky-veined aphid with weather parameters

The data presented in Table-10 indicated the regression between populations of dusky-veined aphid with the weather parameters on walnut. The regression analysis revealed that the weather parameters showed a significant effect on the population density of dusky-veined aphid. From the regression equation, R^2 value (0.70) suggested that all the weather parameters jointly contributed 70 per cent variation in population indicating higher dependence of population on weather parameters.

Table-9 Incidence of dusky-veined aphid (*Panaphis juglandis*) on walnut

Month	SMW	*Mean no. of dusky-veined aphids/leaf	Confidence interval	
			Lower limit	Upper limit
April	13th	3.70	3.22	4.18
	14th	4.10	3.48	4.80
	15th	3.80	3.18	4.60
	16th	3.50	2.87	4.15
	17th	4.10	3.56	4.76
	Mean	**3.84**	**3.26**	**4.49**
	SE (Mean)	**0.11**		
	CV (%)	**6.79**		
May	18th	6.40	5.68	7.26
	19th	8.40	6.31	7.51
	20th	9.10	7.66	9.20
	21st	11.50	8.68	9.64
	Mean	**7.70**	**7.08**	**8.40**
	SE(Mean)	**0.63**		
	CV (%)	**16.39**		
June	22nd	15.70	10.60	12.40
	23rd	18.00	11.70	19.70
	24th	21.00	12.60	21.00
	25th	23.30	14.10	23.70
	Mean	**16.55**	**12.25**	**19.20**
	SE(Mean)	**2.00**		
	CV (%)	**24.20**		
July	26th	20.70	15.90	25.50
	27th	25.50	18.90	27.70
	28th	29.40	20.90	29.90
	29th	26.20	22.50	30.90
	30th	22.60	23.80	32.40
	Mean	**25.40**	**20.40**	**29.28**
	SE(Mean)	**1.20**		
	CV (%)	**10.58**		
August	31st	17.20	15.10	19.30
	32nd	13.20	11.90	14.50
	33rd	10.50	9.80	11.20
	34th	9.70	7.80	11.60
	Mean	**12.65**	**28.70**	**14.15**
	SE(Mean)	**1.69**		
	CV (%)	**26.74**		
September	35th	8.30	6.00	9.00
	36th	6.00	5.10	6.90
	37th	5.30	4.70	5.90
	38th	4.10	3.80	4.40
	39th	3.50	2.80	4.20
	Mean	**5.44**	**4.48**	**6.08**
	SE(Mean)	**0.83**		
	CV (%)	**34.47**		
October	40th	2.30	2.00	2.60
	41st	2.00	1.70	2.30
	42nd	1.90	1.10	2.70
	43rd	1.50	0.90	2.10
	Mean	**1.92**	**1.42**	**2.42**
	SE(Mean)	**0.16**		
	CV (%)	**17.16**		

SMW = Standard meteorological week
***Mean of 200 leaves per 10 plants taken in one Standard Week**
SE = Standard Error
CV = Coefficient of Variance

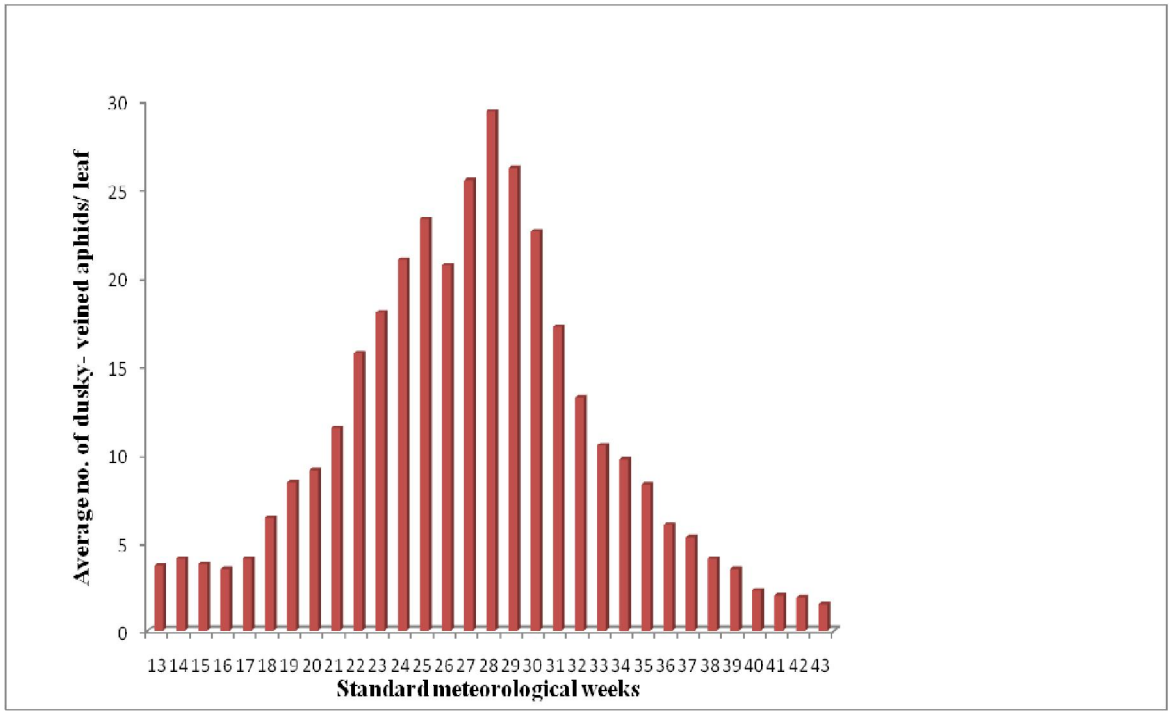

Figure-III: Incidence of dusky-veined aphid (*Panaphis juglandis*) on walnut

Table-10 Regression between incidence of dusky-veined aphid (*Panaphis juglandis*) with weather parameters on walnut (*Juglans regia* L.)

Weather parameters	*Panaphis Juglandis*			
	Coefficients	**Standard Error**	**"t" value**	**"p" value**
Intercept	-16.859	18.333	-0.92	0.367
Max temperature (^{o}C)	0.9	0.408	0.2	0.01
Min temperature (^{o}C)	0.941	0.388	2.42	0.01
Rainfall (mm)	-0.313	-0.269	-1.16	0.02
Relative humidity (Morning)	0.145	0.172	3.24	0.74
Relative humidity (Evening)	0.123	0.08	1.53	0.13
Coefficient of Determination (R^2)	**0.700**			
Regression Equation	$\mathbf{Y = -16.859 + 0.90x_1 + 0.94x_2 - 0.31x_3 + 0.14x_4 + 0.12x_5}$			

4.2.11. Incidence of grey weevil on walnut

The data on incidence of grey weevil, *Myllocerus viridanus* on walnut is presented in Table-11 and illustrated by Figures-IV. The perusal of data revealed that activity of grey weevil commenced from 18th standard meteorological week (SMW) with an average incidence (7.2 grey weevils per 20 leaves) was observed in this meteorological week. Thereafter, there was gradual increase in the pest incidence which reached to its peak (23.3 grey weevils per 20 leaves) in 28th SMW from where it started declining and no incidence was recorded in 43rd standard meteorological week .The mean number of grey weevils was recorded highest (21.52±0.68) in the month of July and lowest (2.64 ±0.91) in the month of October. Coefficient of variance (CV) was highest (43.67**%**) in the month of August and lowest (6.79%) in the month of April.

4.2.12. Correlation of grey weevil with important weather parameters

The data on correlation of grey weevils, *Myllocerus viridanus* with temperature (°C), humidity (%) and rainfall (mm) from 13th to 43th standard meteorological week under field conditions presented in Table-4 revealed that among the different weather parameters, maximum temperature and relative humidity (morning) had a significant and positive correlation (0.808 and 0.381) with grey weevil while as rainfall showed a significant and negative correlation (-0.395) with it. Minimum temperature and relative humidity (evening) had a non-significant and positive correlation (0.589 and 0.309) with it.

4.2.13. Regression studies of grey weevil with weather parameters:

The data presented in Table-13 indicated the regression of grey weevil population with weather parameters. The regression analysis revealed that the weather parameters showed a significant effect on the population density of grey weevil. From the regression equation, R^2 value (0.76) suggested that all the weather parameters jointly contribute 76 per cent variation in population indicating higher dependence of population on weather parameters.

Table -11 Incidence of grey weevil (*Myllocerus viridanus*) on walnut

Month	SMW	*Mean no. of grey weevils/ 20 leaves	Confidence interval	
			Lower limit	Upper limit
April	13th	0.00	0.00	0.00
	14th	0.00	0.00	0.00
	15th	0.00	0.00	0.00
	16th	0.00	0.00	0.00
	17th	0.00	0.00	0.00
	Mean	0.00	0.00	0.00
	SE (Mean)	0.00		
	CV (%)	0.00		
May	18th	7.20	5.60	8.80
	19th	8.00	6.30	9.70
	20th	8.40	6.60	10.20
	21st	13.90	12.20	15.60
	Mean	**9.37**	**7.67**	**11.07**
	SE(Mean)	**1.52**		
	CV (%)	**32.61**		
June	22nd	19.5	12.70	26.30
	23rd	20.0	13.00	27.00
	24th	22.6	15.00	30.20
	25th	21.85	13.70	30.00
	Mean	**20.98**	**13.60**	**25.37**
	SE(Mean)	**0.66**		
	CV (%)	**6.30**		
July	26th	22.48	17.60	22.48
	27th	22.73	18.90	22.73
	28th	23.32	21.30	23.32
	29th	19.82	23.00	19.82
	30th	19.28	24.00	19.28
	Mean	**21.52**	**20.96**	**21.52**
	SE(Mean)	**0.68**		
	CV (%)	**8.54**		
August	31st	19.38	13.60	19.38
	32nd	16.55	12.40	16.55
	33rd	16.05	9.70	16.05
	34th	5.19	7.50	5.19
	Mean	**14.29**	**10.8**	**14.29**
	SE(Mean)	**3.12**		
	CV (%)	**43.67**		
September	35th	4.56	6.70	4.56
	36th	7.37	6.00	7.37
	37th	7.28	5.40	7.28
	38th	7.77	5.50	7.77
	39th	3.07	4.10	3.07
	Mean	**6.01**	**5.54**	**6.01**
	SE(Mean)	**0.93**		
	CV (%)	**34.60**		
October	40th	3.55	3.80	3.55
	41st	4.14	3.10	4.14
	42nd	2.88	1.50	2.88
	43rd	0.00	0.00	0.00
	Mean	**2.64**	**2.10**	**2.64**
	SE(Mean)	**0.91**		
	CV (%)	**69.45**		

SMW = Standard meteorological week
***Mean of 200 leaves per 10 plants taken in one Standard Week**
SE = Standard ErrorCV = Coefficient of Variance

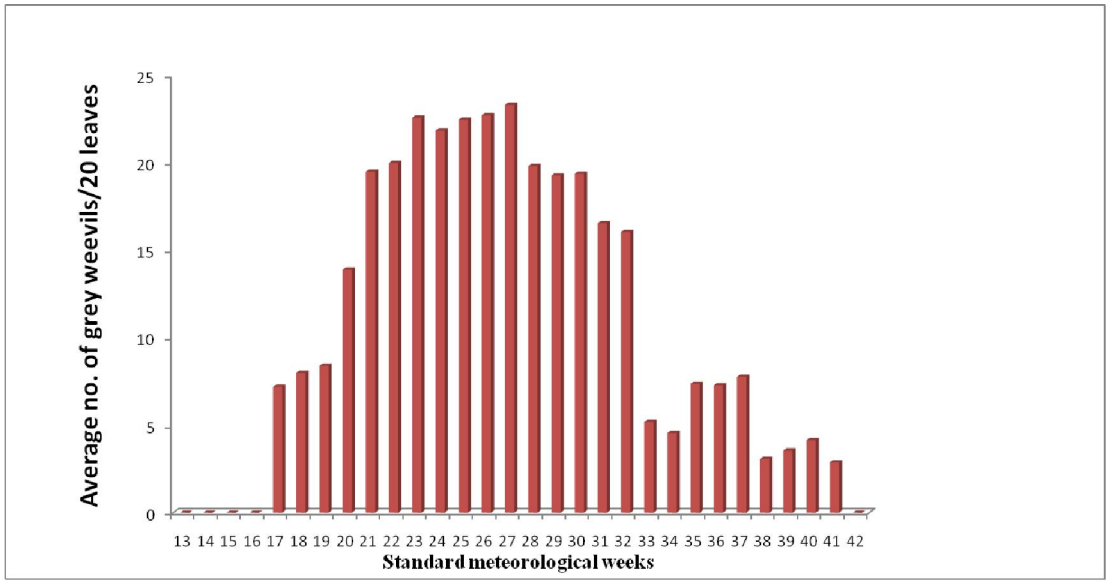

Figure-IV: Incidence of grey weevil (*Myllocerus viridanus*) on walnut

Table-12 Regression between incidence of grey weevil (*Myllocerus viridanus*) with weather parameters on walnut (*Juglans regia* L.)

Weather parameters	*Myllocerus viridanus*			
	Coefficients	**Standard Error**	**"t" value**	**"p" value**
Intercept	-39.893	15.46	-2.58	0.16
Max temperature (^{o} C)	0.581	0.281	2.06	0.01
Min temperature (^{o} C)	0.435	0.267	1.63	0.01
Rainfall (mm)	-0.19	0.185	-1.02	0.02
Relative humidity (Morning)	0.144	0.118	0.12	0.04
Relative humidity (Evening)	0.119	0.055	1.79	0.086
Coefficient of Determination (R^2)	**0.769**			
Regression Equation	$\mathbf{Y = -39.893 + 0.58x_1 + 0.43x_2 - 0.19x_3 + 0.14x_4 + 0.11x_5}$			

Chapter-5

DISCUSSION

Walnut (*Juglans regia* L.) is the most widespread tree nut in the world. Walnut demand has risen steadily throughout the years, both domestically and internationally. There are numerous insect pests associated with walnuts that have been reported from all over the world, inflicting severe harm to walnut trees and walnut products. The present study was conducted to record Pest Complex and Seasonal Incidence of Major Pests on Walnut (*Juglans regia* L) at FoA, Wadura during 2020. The experimental findings are thoroughly discussed in the light of available scientific evidences as under:

5.1 To identify pest complex and natural enemies on walnut

5.1.1. Pest complex on walnut

To record different pests and natural enemies associated with walnut, field visits were carried at weekly intervals on 10 randomly selected plants from first week of April to last week of October, 2020. During the present investigations, eight insect pest species and one non-insect pest species infesting the walnut crop were recorded. Among these eight insect pest species, four insect pests viz., walnut aphid, *C. juglandicola* (Hemiptera: Aphidae), dusky-veined aphid, *P. juglandis* (Hemiptera: Aphidae), capsid bug, *M. stramineum* (Hemiptera: Aphidae) and stink bug, *A. pilipes* (Hemiptera: Pentatomidae) were found sucking pests; four insect pests viz., grey weevil, *M. viridanus* (Coleoptera: Curculionidae), green leaf weevil, *P. formosus* (Coleoptera: Curculionidae),flea beetle, *A. himensis* (Coleoptera: Curculionidae) and walnut blue butterfly, *C. odata* (Lepidoptera: Lycaenidae) were recorded as defoliators; one non-insect viz., blister mite, *E. erinea* (Acari: Eriophyidae) was found sucking pest. The result further revealed that the three insect pests viz., *C. juglandicola, P. juglandis, M. viridanus* and one non-insect pest *E. erinea* were found as major pests causing serious damage to the walnut foliage, while as other five pests viz.,

M. stramineum, A. pilipes, *P. formosus, C. odata* and *A. himensis* were recorded as minor pests. Uwais *et al*. (2013) also reported seven pest species on walnut trees in China including *Chromaphis juglandicola* (Kaltenbach), *Apocheima cinerarius* (Erschoff), *Eulecanium giganteum* (Shinji) and *Eulecanium kuwanai*. The findings of Akkopru *et al.* (2015) who reported that walnut aphid, *Chromaphis juglandicola* is a serious pest of English walnut, reducing tree vigor, nut size, yield and quality are in line with our results. The results of Khan and Khundoo (2018) who reported that the major pests of walnut in Kashmir include aphids and mites are in close conformity with our results. Gull *et al.* (2018 a) reported first time a new capsid bug, *Megacoelum stramineum* in walnut orchards of Central Kashmir which was also reported in our study. The results of Gull *et al.* (2019) who found nine different pests viz., *Apodiphus pilipes* (Horvath), *Chaetoprocta odata* (Hewitson), *Chromaphis juglandicola* (Kaltenbach), *Erschoviella musculana* (Erschoff), *Megacoelum stramineum* (Walker), *Myllocerus fotedari* (Ahmad), *Panaphis juglandis* (Goeze), *Paracopium cingalensis* (Walker) and *Scolytus nitidus* (Schedl) infesting walnut (*Juglans regia* L.) in Kashmir are largely in line with our results.

5.1.2. Natural enemies of walnut pests

During the present study, nine species of natural enemies (predators) viz., pink ladybird, beetle *C. maculata* (Coleoptera: Coccinellidae), seven-spotted ladybeetle, *C. septempunctata* (Coleoptera: Coccinellidae), two-spotted lady beetle, *A. bipunctata* (Coleoptera: Coccinellidae), spotted lady beetle *C. maculate* (Coleoptera: Coccinellidae), convergent ladybeetle, *H. convergens* (Coleoptera: Coccinellidae) and multi-coloured Asain lady beetle, *H. axyridis* (Coleoptera: Coccinellidae), green lacewing, *C. carnea* (Hemiptera: Miridae), syrphid fly, *S. philanthus* (Diptera: Syrphidae); one predatory mite, *Phytoseiulos* sp.(Acari: Phytoseiidae) were found associated with insect pests of walnut. Our findings are more or less in line with Uwais *et al*. (2013) who reported *Chrysoperla carnea* (Stephens), *Chrysopa phyllochroma* (Wesmael), *Chrysopa formosa* (Brauer), *Oenopia conglobata* L., *Coccinella undecimpunctata* Linnaeus, *Chilocorus*

geminus and spiders (Araneida) as natural enemies associated with walnut pests. During present investigations, six ladybird beetles were found associated with walnut aphid which is supported by the findings of Flint (2014) who during his investigations found that lady beetles are voracious aphid feeders. Atlihan *et al*. (2015) reported in Turkey commonly observed predators and parasitoids including *Chrysoperla carnea, Orious majuscules, Anthocoris nemorum,* and *Hemerobius humulinus* of Hemiptera, *Adalia fascioptera, Oenopia* sp., *Hippodomia variegate, Adalia bipunctata* and *Scymnus rubromaculatus* of Coloeptera as predators and *Trioxy spallidus* of Hymenoptera as parasitoid, which largely support our findings.

5.2 To study the seasonal incidence of major pests and their relationship with weather parameters

5.2.1. Incidence of blister mite on walnut

The perusal of data revealed that activity of blister mite commenced from 13th standard meteorological week (SMW) with mean incidence (1.2 blisters per leaf) was observed in this meteorological week. Thereafter, there was gradual increase in the pest incidence which reached to its peak (22.7 blisters per leaf) in 30th SMW from where it started declining and reached to minimum (0.8 blister per leaf) in 43rd SMW. The mean number of blisters was found highest (18.64±1.62) in the month of July and lowest (1.25±0.2) in the month of October. Coefficient of variance (CV) was highest (40%) in the month of October and lowest (2.26%) in the month of June. The present findings are also supported by the studies of Devi *et al*. (2017) who also reported that incidence of mango bud mite, *Aceria mangiferae* (gall mite) in mango showed increasing trend in May (33.30 per leaf) and June (37.5 per leaf). Our findings are also supported by the findings of Sauro *et al.* (2018) who reported that the apple rust mite, *Aculus schlechtendali* first appeared in mid-summer and mite populations were low in May, started to increase in June, and peaked in July as reported in our study. Our findings revealed that blister mites cause blisters (galls) on the upper surface of foliage. Weber (1980) also reported that the velvet gall mite, *Eriophyes cauliseifer*

causes a noticeable velvety red growth up to an inch long on the leaf stem in orchards of black walnut in the Eastern United States, forcing the leaf to curl or twist over on it. The results of Rather (1989) who conducted survey and found that walnut blister mite, *Eriophyes erinea* (Nelepa) occurs in epidemic form in all agro climatic zones of Jammu & Kashmir and prevails as a major acarine pest of walnut due to which affected leaves showed galls on upper surface of leaves are in consonance with our results.

5.2.2. Correlation of blister mite with important weather parameters

The data on correlation of blister mite (*Eriophyes erinea*) on walnut from 13^{th} to 43^{th} standard week with temperature (°C), humidity (%) and rainfall (mm) under field conditions revealed that among different weather parameters, maximum temperature had a significant and positive correlation (r=0.787) with blister mite, and negative and significant correlation (r=- 0.397) with rainfall and relative humidity (r=-0.332 and -0.330) and minimum temperature had a non-significant positive correlation (r=0.681) with it. The present study is in conformity with the findings of Balaji and Hariprasad (2016) who reported a positive correlation between the population of coconut mite, *Aceria guerreronis* in the coconut palm with maximum temperature and negative correlation with relative humidity, rainfall, and sunshine hours. Devi *et al*. (2017) also reported a positive correlation of population of mango bud mite, *Aceria mangiferae* in mango with maximum temperature and minimum temperature and negative correlation with rainfall and relative humidity. Sauro *et al.* (2018) also found that the apple rust mite showed a significant and positive correlation with maximum temperature and a highly negative and significant correlation with rainfall

5.2.3. Severity of blister mite in walnut

The data on mean per cent severity of blister mite revealed that blister formation on leaves is directly related to the pest population and a scale (1-4) was used to determine the mean pest severity. The present findings showed an increased trend in severity from 13th standard meteorological week (SMW) till 43th SMW. The maximum (28.5%) severity was observed in 30th SMW from where it started declining and reached to minimum (1.5%) in 43rd SMW. The mean per cent severity was highest (24.84%) in the month of July and lowest (2.62%) in the month of October. The present findings are supported by the results of Qadir and Qamar (2019) who reported that severity of damage due to mites in apple is from April to mid-June.

5.2.4. Incidence of walnut aphid on walnut

The perusal of data revealed that activity of walnut aphid commenced from 13th standard meteorological week (SMW) with mean incidence (1.4 walnut aphids per leaf) was observed in this SMW. Thereafter, there was an increase in the pest incidence which reached to its peak (28.3 aphids per leaf) in 25th SMW, from where it started declining and reached to minimum (1.2 aphids per leaf) in 43rd SMW. The mean number of walnut aphids was found highest (24.72±1.47) in the month of June and lowest (1.85±0.23) in the month of October. Coefficient of variance (CV) was highest (43.57%) in the month of May and lowest (9.45%) in the month of July. The present findings are in accordance with the studies of Hougardy and Mills (2009) who reported first appearance of walnut aphid, *Chromaphis juglandicola* in spring and attaining peak population in late June. Karczmarz (2010) who reported that walnut aphid appear in spring and disappear in autumn also support our results. Iranipout *et al.* (2018) also reported that the small walnut aphid (SWA), *Chromaphis juglandicola* was found in early May and in mid-May, thereafter there was a sharp increase in population and in early June, a peak of 40 aphids per leaf was observed, following by a sharp fall in late July and a minor peak in early October. The findings of Gull *et al*. (2019) who reported that the infestation of walnut aphids remain from

April to October and attained its peak in the month of June are in line with the findings of our study.

5.2.5. Correlation of walnut aphid with important weather parameters

The data on correlation of walnut aphid (*Chromaphis juglandicola)* with temperature (°C), humidity (%) and rainfall (mm) from 13th to 43rd standard meteorological week under field conditions revealed that among different weather parameters, maximum temperature and relative humidity (morning) had a positive and significant correlation (r=0.881 and 0.266) with walnut aphid while as rainfall showed a negative and significant correlation (r=-0.425) with it. Minimum temperature and relative humidity (evening) had positive and non-significant correlation (r=0.191 and 0.294) with it. The results of present study are in conformity with the findings of Karczmarz (2010) who reported that walnut aphids were significantly affected by course of weather conditions and found that their development is enhanced by a warm spring and air temperature above 30 (°C) while as heavy rain in summer limit their number.

5.2.6. Incidence of dusky-veined aphid on walnut

The perusal of data revealed that the activity of dusky-veined aphid commenced from 13th standard meteorological week (SMW) with mean incidence (3.7 dusky-veined aphids per leaf) was observed in this SMW. Thereafter, there was a gradual increase in the pest incidence which reached to its peak (29.4 dusky-veined aphids per leaf) in 28th SMW. The incidence decreases thereafter and reached (1.5 dusky-veined aphids per leaf) in 43rd SMW. The mean number of dusky-veined aphids was found highest (25.4±1.20) in the month of July and lowest (1.92±0.16) in the month of October. Coefficient of variance (CV) was reported highest (34.47**%**) in the month of September and lowest (6.79%) in the month of April. The findings of present study are in conformity with the findings of Masoodi *et al*. (1987) who found that the initial incidence of population of this pest was recorded in the first week of May when the day temperature was 24.8 °C and also reported that the highest population of 22.20 aphid per 10 leaves was recorded at 27.3 °C in the first week of June, thereafter population showed a declining trend and lowest mean population of

0.9 aphids per sample was recorded at 29.4 °C. Anderson and Mills (2018) reported that dusky-veined aphids, an invasive species of walnuts are active from March till early December in walnut orchards of California. The slight variation in his studies from the present findings may be due to differences in the climatic conditions at two places. Gull *et al*. (2019) also reported infestation of dusky-veined aphids from April to October with its peak in the month of July.

5.2.7. Correlation of dusky-veined aphid with important weather parameters

The data on correlation of dusky-veined aphid (*Panaphis juglandis)* on walnut with temperature (°C), humidity (%) and rainfall (mm) from 13th to 43rd standard week under field conditions revealed that among the different weather parameters, maximum temperature and relative humidity (morning) had a positive and significant correlation (r=0.784 and 0.320) with dusky-veined aphid while as rainfall showed a negative and significant correlation (r=-0.425) with it. Minimum temperature and relative humidity (evening) had a positive and non-significant correlation (r=0.264 and 0.272) with it. The findings of Jaskiewiez and Kmiee (2007) who reported a positive correlation of population of dusky-veined aphid, *Panaphis juglandicola* in walnut with maximum temperature and relative humidity and negative correlation with rainfall are in conformity with our findings.

5.2.8. Incidence of grey weevil on walnut

The perusal of data revealed that activity of grey weevil commenced from 18th standard meteorological week (SMW) with mean incidence (7.2 grey weevils per 20 leaves) was observed in this meteorological week. Thereafter, there was a gradual increase in the pest incidence which reached to its peak (23.3 grey weevils per 20 leaves) in 28th SMW from where it started declining and no incidence of grey weevil was observed in 43rd SMW .The mean number of grey weevils was recorded highest (21.52±0.68) in the month of July and lowest (2.64 ±0.91) in the month of October. Coefficient of variance (CV) was reported highest (43.67 **%**) in the month of August and lowest (6.79%) in the month of April. The finding of present study is in conformity with the findings of Khairmode and Sathi (2014) who reported

seasonal abundance of *Myllocerus viridanus* throughout the year in mulberry garden and attaining peak in the month of July and lowest abundance in the month of October. Haldhar *et al.* (2016) also reported that activity of grey weevils in Ber were more active from June and also in September. The observations of Baidya and Chatterjee (2019) who found the incidence of grey weevil on mulberry crop from third week of May to the second week of August, with the peak population recorded on the 4th week of May are by and large in consonance with our results.

5.2. 9. Correlation of grey weevil with important weather parameters

The data on correlation of grey weevil (*Myllocerus viridanus)* on walnut with temperature (°C), humidity (%) and rainfall (mm) from 13th to 43th standard week under field conditions revealed that among the different weather parameters, maximum temperature and relative humidity (morning) had a positive and significant correlation (r=0.808 and 0.381) with Grey weevil while as rainfall showed a negative and significant correlation (r=-0.395) with it. Minimum temperature and relative humidity (evening) had a positive and non-significant correlation (r=0.589 and 0.309) with it. Present study results are more or less in conformity with Baidya and Chatterjee (2019) who found that the grey weevil incidence has a significant and positive correlation with minimum relative humidity and bright sunshine hours and negative correlation with minimum temperature and non-significant and positive correlation with maximum temperature, maximum relative humidity and evaporation while as a negative correlation with rainfall and wind speed. The slight variation in his studies from the present findings may be due to differences in the climatic conditions at two places.

Chapter-6

SUMMARY AND CONCLUSION

Walnut (*Juglans regia* L.) is the most widespread tree nut in the world. Jammu and Kashmir UT is having almost a monopoly in growing dry fruits like walnut. There is tremendous demand for walnuts produce both for domestic as well as export purposes. There are numerous insect pests associated with walnuts that have been reported from all over the world, inflicting severe harm to walnut trees and walnut products and also their attack reduce quality as well as quantity of walnuts. Keeping in view the damaging potential of various pests to walnut, the investigations on "Studies on Pest Complex and Seasonal Incidence of Major Pests on Walnut (*Juglans regia* L.)" were carried out at FoA, Wadura Sopore. The findings of the study are summarized as under:

Different walnut pests in compact/regular orchard at FoA, Wadura were recorded for which field visits were carried at weekly intervals on 10 randomly selected plants from April to October.

The results obtained revealed that nine pests including eight insect pests and one non-insect pest were found associated with walnut crop. Among these eight insect pest species, four insect pests viz., walnut aphid, *C. juglandicola* (Hemiptera: Aphidae), dusky-veined aphid, *P. juglandis* (Hemiptera: Aphidae), capsid bug, *M. stramineum* (Hemiptera: Aphidae) and stink bug, *A. pilipes* (Hemiptera: Pentatomidae) were found sucking pests; four insect pests viz., grey weevil, *M. viridanus* (Coleoptera: Curculionidae), green leaf weevil, *P. formosus* (Coleoptera: Curculionidae), flea beetle, *A. himensis* (Coleoptera: Curculionidae) and walnut blue butterfly, *C. odata* (Lepidoptera: Lycaenidae) were recorded as defoliators; one non-insect viz., blister mite, *E. erinea* (Acari: Eriophyidae) was sucking pest. The three insect pests viz., *C. juglandicola, P. juglandis, M. viridanus* and one non-insect pest *E. erinea* were found as major pests causing severe damage to the walnut foliage, while as other five pests viz., *M. stramineum, A. pilipes*, *P. formosus, C. odata* and *A. himensis* were recorded as minor pests.

The studies on natural enemies revealed that nine predators including convergent ladybeetle (*Hippodamia convergens*), pink ladybird beetle (*Coleomegilla maculata*), seven-spotted ladybird beetle (*Coccinella septempunctata*), two-spotted ladybird beetle (*Adalia bipunctata*), green lacewing (*Chrysoperla carnea*), syrphid fly (*Sphaerophoria philanthus*), multi colored Asian lady beetle (*Harmonia axyridis*), spotted lady beetle (*Coleomegilla maculata*) and predatory mite (*Phytoseiulos* sp.) were found associated with walnut pests. Most of the natural enemies were found associated with *C. juglandicola* and *P. juglandis.*

The observations recorded on the incidence of blister mite, *Eriophyes erinea* revealed that its incidence commenced from 13th standard meteorological week (SMW) of April with mean incidence (1.2 blisters per leaf) was recorded in this week, reached to its peak (22.7 blisters per leaf level) in 30th SMW of July and then decreased and reached (0.8 blisters per leaf) during 43rd SMW of October. The mean number of blister mites was highest (18.64±1.62) in the month of July and lowest (1.25±0.2) in the month of October. The investigations on severity of blister mite revealed that it was low (4.0%) in April, reached to its peak (28.5%) in the month of July. Thereafter, the severity decreased and reached (1.5%) in the month of October. The mean severity of blister mite was found highest (24.84%) in the month of July and lowest (2.50%) in the month of October

During the present study, it was found that the incidence of walnut aphid commenced from 13th standard meteorological week (SMW) of April with mean incidence (1.4 aphids per leaf) recorded, reached to its peak (27.1 aphids per leaf) during 30th SMW of July and then decreased and reached (1.2 walnut aphids per) leaf during 43rd SMW of October. The mean number of walnut aphids was found highest (24.72±1.47) in the month of June and lowest (1.85± 0.23) in the month of October

The data generated revealed that the incidence of dusky-veined aphid commenced from 13th standard meteorological week (SMW) with mean incidence (3.7 dusky–veined aphids per leaf) recorded in this week, reached to its peak (28.1 dusky-veined aphids per leaf) during 30th SMW and then decreased to 1.5 aphids per leaf during 43rd SMW. The mean number of dusky-veined aphids was recorded

highest (25.4±1.20) in the month of July and lowest (1.92 ±0.16) in the month of October.

Regarding to the incidence of grey weevil, the studies revealed that its incidence commenced from 18th standard meteorological week (SMW) of May with mean incidence of (6.4 grey weevils per 20 leaves) was observed in this SMW, reached to its peak (29.5 grey weevils per 20 leaves) during 30th SMW and no incidence was recorded during 43rd SMW. The mean number of grey weevils was found highest (21.52±0.68) in the month of July and lowest (2.64±0.91) in the month of October.

In the present study, the blister mite exhibited positive and significant correlation with maximum temperature (r=0.787), however blister mite showed negative and significant correlation with rainfall (r=- 0.397) and relative humidity (r=-0.332 and -0.330). Also blister mite showed non-significant and positive correlation (r=0.681) with minimum temperature. The walnut aphid exhibited a positive correlation with both maximum and minimum temperature (r=0.881 and 0.479), however, the walnut aphid population showed negative and significant correlation with rainfall (r=-0.425) and also its population showed a positive and non-significant correlation (r=0.266 and 0.294) with relative humidity morning and evening. The dusky-veined aphid showed a positive correlation with both maximum and minimum temperature (r=0.784 and 0.489), however, its population showed a negative and significant correlation with rainfall (r=-0.397) and a positive and non-significant correlation(r=0.320 and 0.272) with morning and evening relative humidity. The grey weevil showed a positive correlation with both maximum and minimum temperature (r=0.808 and 0.489). However, its population showed a negative and significant correlation with rainfall (r=-0.395) and a positive and non-significant correlation (r=0.381) with relative humidity morning but evening relative humidity showed a positive and significant correlation (0.309) with it.

The observations on multiple regression analysis revealed that the populations of blister mite (73.8 %), walnut aphid (79.8%), dusky-veined aphid (70%) and grey weevil (76.9%) were influenced by the metrological parameters.

CONCLUSIONS:

- Pests of walnut crop recorded were walnut aphid (*Chromaphis juglandicola*), dusky-veined aphid (*Panaphis juglandis*), grey weevil (*Myllocerus viridanus*), capsid bug (*Megacoelum stramineum*), stink bug (*Apodiphus pilipes*), green leaf weevil (*Polydrusus formosus*), walnut blue butterfly (*Chaetoprocta odata*), flea beetle (*Altica himensis*) and blister mite (*Eriophyes erinea*).
- The natural enemies of walnut pests recorded were convergent ladybeetle (*Hippodamia convergens*), seven-spotted lady beetle (*Coccinella septempunctata*), two-spotted lady beetle (*Adalia bipunctata*), pink ladybird beetle (*Coleomegilla maculata*), green lacewing (*Chrysoperla carnia*), syrphid fly (*Sphaerophoria philanthus*), multi-colored Asian lady beetle (*Harmonia axyridis*), spotted lady beetle (*Coleomegilla maculata)* and predatory mite (*Phytoseiulos* sp.).
- Mean number of blister mites, dusky-veined aphids and grey weevils were highest in the month of July while as mean number of walnut aphids was highest in the month of June. The incidence was found lowest number is in the month of October in all these pests.
- Blister mites have a significant and positive correlation with maximum temperature, a significant and negative correlation with rainfall, and a positive and non-significant correlation with minimum temperature.
- Walnut aphid, dusky-veined aphid and grey weevil showed a positive correlation with maximum temperature and relative humidity morning and have a negative and significant correlation with rainfall while as a positive and non- significant correlation with minimum temperature and relative humidity evening.
- Multiple regression analysis revealed that the populations of blister mite, walnut aphid, dusky-veined aphid and grey weevil were influenced by the metrological parameters.

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