

Insect Pest Complex of Wheat (*Triticum aestivum* L.) in Kashmir

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(2016-A-1105-M)**



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Technology of Kashmir**

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**Umer Bin Farook
(2016-A-1105-M)**



Thesis

Submitted to

**The Faculty of Agriculture
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In partial fulfilment of requirement for the award of the degree of

**Master of Science in Agriculture
(Entomology)**

2018



Dedicated
To my
Beloved Parents

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

Certificate – I

This is to certify that the thesis entitled “**Insect Pest Complex of Wheat (*Triticum aestivum* L.) in Kashmir**” 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. Umer Bin Farook (Regd. No. 2016-A-1105-M)** 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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ABSTRACT

Wheat (*Triticum aestivum* L.) is the most important cereal crop for the majority of world's population. It is the most important staple food of about two billion people (36% of the world population) and is in increasing demand in countries undergoing urbanization and industrialization. It has an immense yield potential. However, the productivity is limited by a large number of abiotic and biotic constraints. Among the biotic constraints, insect pests cause considerable loss in yield and change their status over time. So, keeping in mind these constraints, the present investigation was carried out to ascertain the status of insect pests on wheat and to screen different wheat genotypes for their relative resistance against cereal leaf beetle in Kashmir. Investigation revealed that the crop was infested by 15, 15, 11, 17, 17, 13, 15, 13, 12 insect species at different phenological stages at Wadura, Drusu, Imberzalwari, Sk-bala, Odina, Munglu, Wakura, Manigam, and Akhal respectively. Cereal leaf beetle, *Oulema melanopus*, Aphid, *Rhopalosiphum maidis* and Army worm, *Mythimna separata* appeared as major insect pests at all above locations. A total of 33 genotypes viz: AJANTA, GW-496, AKW-381, AKW-1071, C-306, CHOTTI LERMA, OPAN-1796, OPAN-3004, DBW-16, DL-784-3, DL-803, GW-190, HD-1925, HD-208, GW-503, GW-322, GW-273, GW-173,

GW-120, GW-89, GW-40, GW-10, DWR-195, DWR-39, DWR-16, DURGAPURA-65, DL-788-2, DL-153-2, DBW-14, D-134, VL-22, SW-1 and SW-2 were screened for relative resistance against cereal leaf beetle. Very low damages were reported on the Indian wheat varieties namely Ajanta (7%) followed by GW-496 (9%). The highest damage (37 %) was found on the cultivar HB-208, it was closely followed by GW-120, GW-322, DL-788-2 and GW-173 with leaf damage of 36.9, 35, 35, and 34.6 per-cent respectively. The results obtained from percentage of leaf area damaged revealed that 2 genotypes viz: Ajanta and GW-496 genotype were resistant ; cultivars AKW-381, AKW-1071, C-306, CHHOTI LERMA, OPAN-1796, OPAN 3004, DBW-16, DL-784-3, DL-803, and gw-190 were categorised as Moderately resistant; SW-1, SW-2, VL-22, HD-1925, HD-208, GW-503, GW-322, GW-273, GW-173, GW-120, GW-89, GW-40, GW-10, DWR-195, DWR-39, DWR-16, DURGAPURA-65, DL-788-2, DL-153-2, DBW-14 and D-134 as Moderately susceptible while as no genotype with susceptibility was found. Degree of damage was observed to be significant and negatively correlated with trichome density and trichome length.

Key words: cereal leaf beetle, Insect pests, Screening, wheat.

Signature of Student

Signature of Major Advisor

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Place: Wadura, Sopore

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Chapter- 1

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most important cereal among the field crops, not because of its antiquity but due to being an excellent food for mankind. Wheat is accorded a premier place among cereals due to its vast acreage attributed to civilization, high nutritive value and association with some of the earliest and most important civilizations of the world. It is the most important staple food of about two billion people (36% of the world population), which provides nearly 55% of the carbohydrates and 20% of the food calories consumed globally (Breiman and Graur, 1995). If rice is the staple food of half of the world, wheat is the chief sustenance for the other half (Kundu *et al.*, 2006). The cultivation of wheat is so widely distributed across the world that the crop is being harvested in one country or the other all the year round (Tiwari and Sharma, 2011). Globally, it is grown on 220.4 mha area with total production of 749 million tons (Anonymous, 2016). World trade in wheat is greater than all other crops combined. Wheat cultivation in India started 5000 years ago (Feldman, 2001). It is the second most important cereal in India after rice and is grown on an area of 31.781 million hectares with total annual production of 96.64 million tons (Anonymous, 2016). India is today the second largest wheat producer in the whole world. Wheat cultivation in India has been traditionally dominated by the northern region of India and major wheat producing states are Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar, Maharashtra, Gujarat, Karnataka, West Bengal, Uttarakhand, Himachal Pradesh, and Jammu & Kashmir. Out of these states Punjab and Haryana have been prolific wheat producers.

As far as the Jammu and Kashmir is concerned, wheat is the staple food in the Jammu Plain, generally wheat seed is sown in autumn, and it can withstand the cold of the severe winter months and resumes growth with the advent of warm spring and summer. In Jammu and Kashmir division, it is sown in the months of

October and November, while as in Ladakh (Sum and Nubra valleys) it is sown in the month of May (Kharif crop), and harvested in the middle of August. Important wheat producing areas of Jammu are Kathua, Ranbirsinghpora, Samba and Reasi. Wheat is grown in J&K on an area of 321 thousand hectares with production of 3143 thousand quintals with an average yield of 9.79 qt/ha (Anonymous, 2015 a). In Kashmir province wheat crop is grown on a meagre area of 494 hectares with a production of 7000 quintals in some pocket sites as Pulwama and Budgam (Anonymous, 2015 b).

Various arthropods causes considerable damage to wheat (*Triticum aestivum* L.) plants throughout their life and no stage of the crop is free from damage. Pests of wheat are either polyphagous (damaging a wide range of plants) or oligophagous (feeding on only a few plant species) and it is very rare, any insect found to be monophagous to wheat crop. In India, wheat is ravaged by a number of insect pests viz., Termites, *Odontotermes obesus* (Ramb); shoot fly, *Atherigona naqvii* (Steyskal); Brown wheat mite, *Petrobia latens* (Muller); Armyworm, *Mythimna separata* (Walker); Cutworms, *Agrotis ipsilon* (Hufnagel) and Aphid, *Sitobion avenae* (Fabricius) (Deol, 1982). Several insect pests has also been reported from J&k that causes considerable damage to wheat crop viz., armyworm, *Mythimna separate*, white grub, *Holotricha longipennis*, *Adoretas spp.*, *Brahmina spp.*: aphid, *Sitobion avenae* (Anonymous, 2011). It has been estimated that global yield losses due to insect pests in the pre-green revolution era were about 5.1%, however, the losses increased to 9.3% in the post-green revolution in 1990s (Dhaliwal *et al.*, 2010). Insect pests are dynamic and highly adaptable. Changes in environmental temperature can modify their physiology, behavior, voltinism and distribution. It has also been proven that aphids can modify their behavior in response to either high or low temperature stress (Ma and Ma, 2012; Alford *et al.*, 2014), enabling them to adapt in adverse condition presence of natural selection if genetic variation exists for such traits. While the

work on disease resistance has tremendously contributed to protect wheat yields, control of arthropod pests has largely depended on the use of chemicals.

In order to fix the priorities and for evolving suitable pest management practices, continuous review of the pest complex of wheat crop under agro climatic conditions of Kashmir is need of the day which has not been carried systematically so far. Considering the growing need and yield losses in grain as well as fodder, it is imperative to devise an effective pest management tactics which is lacking in this region, further it is necessary to understand the variability of host plant varieties/genotypes in response of source of resistance through morphological traits. Hence, the present work entitled “**Insect pest complex of wheat (*Triticum aestivum* L.) in Kashmir**” has been undertaken for investigation with following objectives:

1. To study the insect pest complex of wheat.
2. To screen different wheat genotypes for relative resistance against Cereal leaf beetle (*Oulema melanopus* L.).

Chapter-2

REVIEW OF LITERATURE

The pertinent information related to the present investigation entitled “Insect pest complex of wheat (*Triticum aestivum* L.) In Kashmir” has been reproduced and presented under the following headings:-

2.1 To study the insect pest complex of wheat

2.2 To screen different wheat genotypes for relative resistance against cereal leaf beetle (*Oulema melanopus* L.)

2.1 Insect pests of wheat

International

Chaudhry *et al.* (1972) conducted a survey in Pakistan and Bangladesh and survey 4000 colonies of termites were collected from 84 sites in Pakistan and 28 sites in Bangladesh. Among 89 identified species of termite, *Anacanthotermes vagans* (Hagen) and *Microtermes mycophagus* (Desn.) were preponderant in Pakistan, while *Odontotermes feae* (Wasm.) was found dominating in Bangladesh. The termite species viz., *Coptotermes heimi* (Wasm.), *Heterotermes indicola* (Wasm.), *O. obesus*, *M. obesi* and *M. unicolor* were considered to be an economic importance.

Anon (1987) reported 100 per cent loss in grain production due to aphid outbreak. Fifty and seventy per-cent loss in grain weight per year in winter and spring wheat, respectively were reported by kuroli *et al.* (1987).

Miller (1994) stated that Aphid infestations in both Egypt and Sudan are commonly controlled by one or more applications of chemical insecticides. Field scouts monitor aphid populations and recommend spraying when densities exceed 30 per-cent infested plants in Egypt and 35 per-cent infested plants in Sudan. Several common aphid species attack wheat along the length of the Nile River. El Heneidy *et al.* (1991) reported that a number of hymenopteran parasitoids aphids

are present in or near wheat fields in Egypt while several predators were naturally present in both Egypt and Sudan.

Macrae (1998) observed a number of insect pests on wheat in Minnesota but not all of them were problem in the region every year. An exception, perhaps, are aphids and Orange Wheat Blossom Midge (OWBM), both should be scouted for every year. Other occasional common insect pests in wheat include grasshoppers, thrips, wheat stem maggot, common stalk borer, wheat stem sawfly, and wireworms.

Ulrich *et al.* (2004) found that grain yield reduction caused by cereal leaf beetle (*Oulema melanopus*) in Europe ranged from 3 to 8% in Poland to 95% in The Netherlands (Daamen and Stol 1993) and 70% in central Europe (Stilmant 1995; Dimitrijević *et al.* 2001). In North America, yield losses of 55% in spring wheat, 23% in winter wheat, and 38 to 75% in oat and barley have been documented due to *O. melanopus* infestations (Webster and Smith 1979; Royce 2000).

Duyn (2005) reported number of insects are present in wheat ecosystem. Some feed upon the living wheat plants, others prey upon the plant feeding insects, while others may feed on dead organic matter or weeds. The following insects became abundant enough to significantly damage the wheat crop in North Carolina: aphids (several species), cereal leaf beetle, Hessian fly, and armyworm (sometimes called true armyworm). Other plant-feeding insects occasionally damage wheat, such as grasshoppers, chinch bug, or fall armyworm.

Larsson (2005) studies revealed that thrips larvae and adults cause partial or complete discoloration of the ears, known as the white ear effect, drying of the flag leaf, partial ear fertilization, and incomplete grain filling. Grain weight losses is about 5-7% in mildly damaged grain, but can reach 15-31% or more in severely damaged grain.

Langham *et al.* (2005) stated that Cereal aphids (Homoptera: Aphididae) *Rhopalosiphum padi* L., bird cherry-oat aphid, were the most abundant cereal aphid

at the Brookings site, whereas *Schizaphis graminum* (Rondani), greenbug, predominated at Highmore. Aphid were greater in early versus late plantings. Their abundance in middle plantings is attributed to prevalent species and geographical location.

Mound (2005) and Moritz (2006) observed that thrips cause evident damage to winter wheat. The common thrips species are *Limothrips denticornis* (Hal.), *L. cerealium* (Hal.) and *Haplothrips aculeatus* (Fab.) Both adults and larvae impact winter wheat development, the latter being more destructive by affecting partial or complete white ear effect, drying of flag leaf, partial ear fertilization, and incomplete grain filling (Volkmar *et al.* 2009 and Gaafar 2010).

Knodel (2008) reported that wheat midge primarily infests wheat, which is seeded in the spring and harvested in late summer northern Great Plains. The wheat midge is a seed feeder and infests a wheat plant during heading through early flowering. Crop injury is caused only by the larval stage. After hatching, wheat midge larvae crawl down to feed on the developing wheat kernel. They feed by exuding enzymes that break down cell walls and convert starch to simple sugars. This causes the wheat kernel to shrivel, crack and become deformed. Wheat kernels may be partially damaged or entirely aborted.

Roberts (2008) found that armyworm caterpillars can be a troublesome pest in cereal grains grown in the Pacific Northwest states. These caterpillars, from the genus *Faronta*, have caused crop damage in Umatilla County, Oregon since 2007. In 2007 and 2008 the pest caused damage to crops in Lincoln County, Washington. Researchers also noted a 35% yield loss due to the insect in 2007 and 2008 in spring wheat trials conducted by Washington State University (WSU) near Davenport, Washington.

Gaafar *et al.* (2009) revealed that the productivity of wheat, which is one of the commercially important cereal crops, is seriously affected by wheat blossom midge (WBM) infestation as well as thrips. Orange wheat blossom midge

(OWBM), *Sitodiplosis mosellana*, and yellow wheat blossom midge (YWBM), *Contarinia tritici* (Diptera: Cecidomyiidae), are among the major pests of wheat ears of spring and winter wheat in temperate climate zones in North America and Europe.

Rondon *et al.* (2009) reported that true WHA (White Headed Army worm) larvae feed on wheat and various other grain and grass crops. The genus also includes *Faronta terrapictalis* which scientists at Oregon State University (OSU) referred to as “false” wheat head armyworm during the 2009 growing season. *F. terrapictalis* is native to the western United States. Its host range and pest status are not known. All *Faronta* larvae and moths look similar, which can cause confusion as to which species has been found feeding on wheat, grains or grass.

Khan *et al.* (2012) reported many insect pests attack wheat (*Triticum aestivum* L.) in Pakistan, severe damage is caused by aphids. Aphids cause yield losses either directly (35-40%) by sucking the sap of the plants or indirectly (20-80%) by transmitting viral and fungal diseases. Population density of aphids also depends on the abiotic factors. During spring season (February-March) aphid population is increased. The aphids are considered as serious pest of wheat crop. They can multiply very rapidly under favorable conditions on leaves, stems and 9 inflorescence. The infestation causes severe distortion of leaves and inflorescence, and can significantly decrease the yield through direct feeding.

Fengqi *et al.* (2013) observed that the English grain aphid, *Sitobion avenae* (F.), is a destructive insect pest of wheat. In his study, wheat germplasm was evaluated for resistance and tolerance to English grain aphid infestation. Except for spikelet number/spike, the 1,000-kernel weight, spike weight, grain weight/spike, and sterile spikelet number/spike of infested plants were all significantly impacted by English grain aphid infestation.

Ryan (2014) reported that wireworms (Coleoptera:Elateridae), the subterranean larval stage of the click beetle, are becoming more prevalent in many

cropping systems and posing an increasing economic threat to wheat growers in the Pacific Northwest.

Ali *et al.* (2015) conducted an experiment to study the population density of cereal aphids and their natural predators under the effect of different wheat varieties at the New Developmental Farm, Khyber Pakhtunkhwa Agricultural University, Peshawar (NDF, KP-AUP). Result indicated that Saleem-2000 appeared to be the resistant cultivar having minimum aphid infestation (4.65) before booting stage, due to maximum beetle population (0.15). However, after the booting stage, Pirsabak-2004 received the maximum aphid infestation (2.90) due to minimum beetle population plant-1 (0.08). Moreover, *Rhopalosiphum padi* and *Sitobian avenaee* are the dominant species of aphids during vegetative and reproductive crop stages, respectively. Higher grain yield losses (31.12%) under aphid infestation over the control were recorded in Ghaznavi-98 while Fakhr-e-sarhad (0.74%) showed minimal yield losses.

Macharia *et al.* (2016) conducted survey in farmers' fields in Ethiopia, Kenya and Uganda. The survey revealed that the Russian Wheat Aphid (*Diuraphis noxia kurdijimov*) was the most prevalent insect pest of wheat in Kenya and Uganda. The maximum number of Russian Wheat Aphid per tiller was 58 in Kenya and 38 in Uganda.

National

Wilson and Shade (1966) conducted a study in India where they found that the adult of cereal leaf beetles feed on young small grain plants and such their feeding typically does not affect yield. Larvae however, eat long strips of parenchyma tissue skeletonizing the leaf decreasing the plant's ability to photosynthesize.

Kishen *et al.* (1972) reported that *Tanymecus indicus* and *Microtermes obesi* were the main pests of wheat, damaging 14 and 2 per cent of the plants, respectively

in Uttar Pradesh. *Microtermes obesi* caused a significant reduction of 1.67 per cent in grain yield.

Hayat (1977) conducted a study on pests of wheat in India and reported more than 100 different pests associated with wheat crop, out of these 85 were insects, 2 mites, 12 nematodes, 7 birds and 3 mammals.

Deol (1982) conducted a study on the armyworm, *Mythimna separata* and categorized as regular pest of late sown wheat in Northern India. The intensity of attack varied from year to year, but serious outbreak occurred in March-April up to 85-100 larvae/m row length resulting in 42.2 per cent yield losses.

Singh (1998) conducted a study on insect pest complex on wheat in India, where 24 species of insect pests were reported. Major insect pests of wheat are termite, *Odontotermes obesus* (Rambur), Gujhia weevil *Tanymecus indicus* (Faust), cutworm, *Agrotis ipsylon* (Hufnagel), Brown wheat mite, *Petrobia lateens* (Muller), Armyworm, *Mythimna separata* (Walker), Thrips, *Anapothrips flavicinctus* (Karny), Aphids, *Macrosiphum granarium* (Kirby), Shoot fly, *Antherigona soccata* (Rondani), Stem borer, *Sesamia inferens* (Walker), Surface grasshopper, *Atractomorpha crenulata* (Fabrikins), Desert locust, *Schistocerca gregaria* (Forkall), Stink bug, *Aelia eostrata* (Boheman), cereal leaf beetle, *Oulema melanopus* (Linnaeus), Hessian fly, *Mayetiola destructor* (Say), wheat stem maggot, *Meromyza Americana* (Fitch), sawfly, *Cephus cinctus* (Norton), white grub, *Holotrichia consanguinea* (Blanch), wireworm, *Agroites mancus* (Say), cricket, *Grylloides sigillatus*, (Linnaeus) and stalk borer, *Chilo auricilius* (Dudgeon). Over and above these insect pests damaging the wheat crop, the non-insect pests' mollusca slugs, *Deroceras reticulatum* (Muller) and snails, *Cepaea hortensis* (Muller) also damage the crop. Of these, termite ranked first as a pest of wheat not only in India but South Asia too as per the pest ranking system developed by Natural Resource Institute, UK (Geddes and Iles, 1991).

Das *et al.* (2000) conducted a survey on outbreak of *Helicoverpa armigera* on wheat in the Maheshwar and Khargone areas of Madhya Pradesh

(India). The survey revealed that more than 50% spikes/plant were infested and there were 1-20 larvae/spike.

Verma *et al.* (2001) conducted a survey during 2000 and 2001 in Meerut, Bagpat, Ghaziabad, Bulandshar and Muzaffarnagar districts of Western Uttar Pradesh to assess the per cent incidence and yield reduction in rotation crops sugarcane, potato, pulses (mung beans and urd beans) and wheat due to termite infestation. Maximum termite incidence (49%) and yield reduction (32.6%) were observed in pulses in the Bagpat District. Potato, pulses and sugarcane were found to be more affected in Bagpat and Bulandshar districts because of scarcity of irrigated water, but in Meerut and Muzaffarnagar districts, there was less than 15 per cent Termites infestation and 19 per cent yield reduction in different crops.

Jarosik *et al.* (2003) studied aphids that pose a serious threat to wheat cultivation in India and reported complex of four species, viz., *Rhopalosiphum maidis* (Fitch), *Sitobion miscanthi* (Takahashi), *R. padi* (Linnaeus) and *S. avenae* to infest wheat crop.

Singh and Deol (2003) conducted a study on insect pests of wheat in Punjab and found that aphids caused 3.53 - 21.05 per cent yield losses in wheat.

Sharma *et al.* (2004) conducted survey to know the distribution of termite damage on wheat crop in different parts of India. A total of 1075 fields were surveyed in 11 states covering five mega wheat growing zones and found that the damage caused by termite was more severe in Rajasthan and some parts of Madhya Pradesh. Maharashtra and Karnataka were free from termite infestation. Further, they noted that the damage was lower in clay and black soil, high in sandy loam soil and severe in red soil.

Chillar *et al.* 2006 conducted a study in which 16 species of termite were found to damage the wheat crop in India, of these two species, *Odontotermes obesus* (Rambur) and *Microtermes obesi* (Holm) are found dominant, which caused 80 per cent loss of crop.

Hussain and Ahmad (2006) reported cereal leaf beetle from Kashmir (India) on oats during Rabi season 2003-2004 at SKUAST-K.

Singh *et al.* (2008) studied insect pest complex on wheat in India and found that populations exceeding 50 aphids/year has been reported to inflict 6.13 - 27.82 per cent yield losses.

Sharma *et al.* (2013) conducted study in Palampur (Himachal Pradesh), where aphid population ranging from 7.75 - 52.07 aphids/ shoot was recorded.

Dhadwal *et al.* (2014) conducted survey to assess insect pest complex of wheat in Himachal Pradesh. The survey revealed that wheat crop was found infested with aphids, termites and armyworms .Aphid, *Rhopalosiphum maidis* was found to be the dominant species infesting wheat in Himachal Pradesh.

2.2 Screening of wheat genotypes against Cereal leaf beetle International

Wilson and Shade (1966) conducted a study and found that wheat seedlings are the most prone to attack by cereal leaf beetle. They also found that both the larvae and adults are the damaging life stages, where adult feeding is characterized by uniform longitudinal incisions on cereal leaves.

Gallun *et al.* (1967) found that if the flag leaf is damaged upto 90%, yield loss is about 23%. Most of the damage is caused by larvae feeding on leaf tissue, leaving long strips on the upper leaf surface while the bottom surface remains intact (Royce and Simko, 2000). Fields seem heavily damaged and larval density of 22-26 larvae per 100 stems of winter wheat caused yield loss in the range of 0.5 to 4%.

Ruppel (1972) found that most of the wheat crop damage is caused by the late larval instars with the fourth instar alone responsible for about 70% of all damage. He also reported greater infestations in spring grains compared to fall. However, patterns of infestations change from region to region. Plant growth stage and age also influence larval and adult damage. Higher population densities of *Oulema melanopus* are recorded at the early seedling stage than at later stages (Wilson *et al.*, 1969).

Webster *et al.* (1972) conducted study during the 1963-1964 crop years, in which approximately 30, 000 wheat, oat, and barley lines were field tested for resistance to larval feeding and it resistance was found leaf surface pubescence played a role in resistance in wheat.

Gallun *et al.* (1973) conducted a study on the principal behavioural component that was non preference for oviposition and deterrence of early instar larval feeding activity. Under field conditions several highly pubescent wheat lines reduced eggs laid by 94%.

Webster *et al.* (1975) found that the intensity of the resistance is directly related to trichome length and density.

Wellso, (1976) demonstrated that cereal leaf beetle adults produced more eggs when feeding on oats than on wheat. Thus winter wheat resistance has proportionally less effect on CLB population dynamics than oat resistance. Leaf pubescence appears to be a promising management tool for CLB suppression.

Wellso (1982) reported successful control of cereal leaf beetle by implying the mechanism of host-plant resistance with the development of the moderately resistant wheat variety, “Downy”, in the United States. Papp and Masterhazy (1996) also reported 34% reduction in feeding damage on resistant wheat genotypes when compared to susceptible ones.

Dimitrijević *et al.* (2001) conducted a study and found that area of the flag leaf and its succulence influence larval feeding of *O. melanopus*. Higher larval population densities on flag leaves with large surface areas are known. Similarly, higher feeding on succulent first and second flag leaves is observed compared to third flag leaves. The flag leaf is an important site for photosynthesis and determines grain filling and the plant's adaptability to stress in cereals, besides being a rich source of nitrogen for herbivorous arthropod pests. Hence, feeding at the flag leaf stage results in high yield reduction and crop losses. Also, transformation from the

vegetative to the reproductive phase in wheat is critical to *O. melanopus* attack as this phase determines stem length and vigour (Webster *et al.*, 1972).

Buntin *et al.* (2004) conducted a study in Asia in which losses were highly variable by cereal leaf beetles on wheat which depend on infestation levels as well as the crop and the region with maximum losses of 40 per cent.

Livia (2007) reported that the larvae of cereal leaf beetle are more damaging than adults and have been reported to consume plant biomass upto 10 times their body weight. Larval feeding leads to significant losses in crop quantity and quality due to reduced photosynthetic activity (Haynes and Gage 1981; Kostov 2001), and the flag leaf stage is the most susceptible stage to the damage.

Piesik *et al.* (2010) found that wheat plants respond to the mechanical injury caused by adult feeding damage of *Oulema melanopus* and *Oulema cyanella* by production of green leaf volatiles such as linalool and a terpene compound, β -carophyllene. *O. melanopus* and *O. cyanella* adults are attracted to plant volatiles such as (Z)-3-hexanal and (Z)-3-hexanyl acetate from wheat at low concentrations that incite feeding; however, higher concentrations of these compounds mixed with linalool result in deterrence. Further research indicated that such a response of production of volatile compounds was not limited to wheat alone but also observed in oat and barley (Piesik *et al.* 2011). Barley and wheat both produced higher concentrations of β -linalool oxide compared to oat. The array of other volatile compounds produced as a response to *O. melanopus* adult feeding damage included compounds such as: (Z)-3-hexenal, (E)-2-hexenal, (E)-2-hexenol, (Z)-3-hexenyl acetate and (Z)-1-hexenyl acetate, and (E)- β -farnesene (Piesik *et al.*, 2011). However, these compounds were produced in different amounts. The release of these volatile compounds from infested plants due to herbivore injury induces production of volatiles from neighbouring uninfested plants as a defense mechanism (Piesik *et al.*, 2010). The extent of volatile production by undamaged plants depends on their distance from injured plants (the greater the distance the less the production). A recent report indicates that *O. melanopus* adults are repelled

by production of high concentrations of *cis*-jasmones, terpenes and indoles (Delaney *et al.*, 2013).

Rouag *et al.* (2012) conducted a study on the abundance of cereal leaf beetle on six durum wheat varieties (*Triticum durum* Desf.) and the influence of leaf flags infestation on grain yield per spike. The results showed the existence of two species of beetle at the experimental site (ITGC, Sétif), namely *Oulema melanopus* and *Oulema hoffmannseggii*. The study also showed, that varieties tested were infested at different rates and there is a negative effect between the infestation rate of the flag leaf and grain weight per ear.

Micu *et al.* (2013) conducted a study to identify the most sensitive wheat varieties to the attack of *Oulema melanopus* L. The study was conducted on 16 wheat varieties of which: 8 awned species and 8 unawned. The study revealed that the Calango and Soisson (awned type) and Coronelium and Fenny (unawned type) were more resistant to attack of *Oulema melanopus* L.

Koleva *et al.* (2015) conducted a study to evaluate the antixenosis resistance to cereal leaf beetle against 54 genotypes of wheat in Bulgaria. The study showed that the lowest density of cereal leaf beetles was observed in cultivar Enola (1.2 ind/m²), breeding lines *NQ* 301 (1.3 ind/m²) and Sofia *NQ* 312 (2.8 ind/m²), while the highest was found in cultivar Nedan (22 ind/m²).

National

Since no work has been done so far on the screening of wheat varieties against Cereal leaf beetle in India. Thus no literature has been included.

Chapter-3

MATERIALS AND METHODS

3.1 To study the insect pest complex of wheat

The present research was carried out in three districts viz; Baramulla, Bandipora and Ganderbal. Three locations at different altitude (High, Medium and Low) in each district were surveyed (Table 1).

Table 1: Details of the locations selected for recording insect- pests on wheat

| S. No. | Districts | Locations | Altitude | Geographic coordinates | |
|--------|------------|--------------|----------|------------------------|---------------|
| | | | | Latitude | longitude |
| 1 | Baramullah | Wadura | 1510 | 34°21'00.6" N | 74°23'47.3" E |
| | | Drusu | 1590 | 34°22' 06.44" N | 74°24'32.4" E |
| | | Imberzalwari | 2120 | 34°24'11.0"N | 74°25'02.4" E |
| 2 | Bandipora | Sk-bala | 1590 | 34°18'06"N | 74°39'32" E |
| | | Odina | 1640 | 34°24'54.8"N | 74°44'89.6" E |
| | | Munglu | 2110 | 34°26'34.6"N | 74°48'66.9" E |
| 3 | Ganderbal | Wakura | 1590 | 34°10'46"N | 74°41'52" E |
| | | Manigam | 1650 | 34°16'57"N | 74°48'27" E |
| | | Akhal | 1810 | 34°15'27"N | 74°53'59" E |

The crop was observed under free choice conditions at fortnightly intervals during the cropping season in the experimental plots to know the status of the various insect pests attacking the crop. Pest population were observed during the growing season by square meter method. Trapping of insect pests was done by using light and yellow sticky traps (Yadav *et al.*, 2007). The insect pests collected from the catch were preserved at laboratory of Division of Entomology, FOA, wadura for proper identification and documentation.

3.1.1 Various methods of estimation are discussed here under on the basis of the pest habitat

3.1.1.1 Soil borne Insect Pests

Pests hiding in the soil debris (soil arthropods *viz.* white grubs, wireworms etc.) were quantified by digging pits of different dimensions in the crop field which are described below:

- (i) White grubs : (20 x 20 x 21) cm
- (ii) Wireworm : (20 x 20 x 21) cm

Three samples for white grub and wireworm were taken by excavating 8400 cm² area (20cm x 20cm) of 21cm deep soil in the field.

3.1.1.2 Sucking insects

Aphids, thrips, hoppers and bugs were counted on plant basis. Fortnightly observations were recorded from randomly selected plants in the experimental plot.

Per cent plant infestation by aphids was calculated by using the following formula

$$\text{Per-cent infestation (\%)} = \frac{\text{Number of infested plants}}{\text{Total number of plants observed}} \times 100$$

3.1.1.3 Foliage feeders

Caterpillars, beetles, grasshoppers, feeding on foliage of the crop, were observed by square meter method and the damage was worked out given as under

$$\text{Damage percentage} = \frac{\text{No. of damaged plants}}{\text{Total number of plants}} \times 100$$

3.2 To screen different wheat genotypes for relative resistance against cereal leaf beetle (*Oulema melanopus* L.)

Present study was carried out at FOA SKUAST-K Wadura during Rabi season (2017-18). Sowing was done on 7th of November 2017. A set of 30 wheat genotypes (released wheat varieties/advanced breeding lines/germplasm lines) with 3 check varieties were screened for their resistance against cereal leaf beetle. The cultivars were sown in Augmented Block Design with genotype to genotype spacing of 50 cm and plant to plant spacing of 10 cm. The packages of practices were followed as per recommendations of SKUAST-K. However, no insecticidal treatment was given to experimental plots. The genotypes were screened under natural infestation in the field.

The relative resistance of wheat genotypes against Cereal leaf beetle *Oulema melanopus* was recorded on 3 plants per entry of each genotype. The degree of damage was determined during the phase of flowering (BBCH 61-69) after the development of the larvae and was defined as a percentage of leaf area damaged by cereal leaf beetles over the entire surface of the leaf flag. The percentage of flag leaf damaged was evaluated on a scale ranging from 1 to 5 (Rouag *et al.*, 2012) on the basis of which varieties were classified as resistant, moderately resistant, moderately susceptible and Susceptible. (Table-2)

Table-2: Scale for scoring intensity of flag leaf damaged by cereal leaf beetle

| Scale | Percentage of flag leaf damaged | Grade |
|-------|---------------------------------|----------------------------------|
| 1-2 | <10% | Resistant varieties |
| 2-3 | 10-20% | Moderately Resistant varieties |
| 3-4 | 20-40% | Moderately Susceptible varieties |
| 4-5 | >40% | Susceptible varieties. |

Rouag *et al.*, 2012

3.3 Comparison of Morphological characters of genotypes

The genotypes were also compared with each other with regard to following Morphological characters:

- a) **Leaf trichome density (mm^2):** Three comparative plants from each genotype were taken randomly at boot leaf immediately after spike emergence for recording the average trichome density. Trichome density count was done by cutting the leaf ($1\text{mm} \times 1\text{mm}$) and the number of trichome hairs was counted under a dissecting microscope.
- b) **Leaf trichome length (mm):** Three comparative plants from each genotype were taken at boot leaf immediately after spike emergence for recording the average trichome length. Trichome length was measured by using an ocular micrometer calibrated with stage micrometer.
- c) **Plant height (cm):** Height of the plant measured at maturity from surface of the ground to tip of the spike excluding awn length averaged from three comparative plants.
- d) **Number of tillers per plant:** Three comparative plants from each genotype were selected at tillering stage to determine the average number of tillers per plant.
- e) **Flag leaf length (cm):** The flag leaf size was determined by using measuring scale at flowering stage.
- f) **Flag leaf area (cm^2):** The area was determined by using Leaf Area Meter.
- g) **Flag leaf width (cm):** The flag leaf width was measured using a measuring scale at flowering stage.

Statistical analysis

Data obtained from the experiments have been analyzed using standard statistical procedures.

Chapter – 4

Experimental findings

The findings of the present investigation “Insect Pest complex of Wheat (*Triticum aestivum* L.) In Kashmir” are presented as under:

4.1 Assessment of insect pests of wheat at district Baramulla

The observations presented in the Table 3a revealed that 15, 15 and 11 insect pest species, infesting the wheat crop at different phenological stages, were recorded at Faculty of Agriculture, Wadura, Drusu and Imberzalwari respectively.

At FOA, Wadura, out of 15 insect pest species, 4 were found belonging to order Lepidoptera; 4 to order Coeloptera; 5 to order Hemiptera and 2 to order Orthoptera representing 10 families in total with a share of 27 per cent of insect pests to Lepidoptera and Coeloptera each, 13 per cent to Orthoptera and 33 per cent to Hemiptera (Figure 1a).

At Drusu, out of 15 insect pest species, 4 were found belonging to order Lepidoptera; 4 to order Coeloptera ; 5 to order Hemiptera and 2 to order Orthopteran representing 10 families in total with a share of 27 per-cent of insect pests to Lepidoptera and Coeloptera each, 13 per cent to Orthopteran and 33 per cent to Hemipteran (figure 1a).

At Imberzalwari out of 11 insect pest species, 4 were found belonging to order Coeloptera; 4 to order Hemipteran; 2 to Lepidoptera and 1 to order Orthopteran representing 9 families in total with a share of 37 per cent of insects to Coeloptera and Hemipteran each, 18 per cent to Lepidoptera and 8 per cent to Orthoptera (figure 1a). The major insect pests were *Oulema melonopus* (Linnaeus) *Rhopalosiphum maidis* (Fitch) and *Mythimna separata* (Walker) while the minor ones were *Holotrichia longipennis* (Hope), *Helicoverpa armigera* (Hubner), *Carpocoris purpureipennis* (De Geer), *Agriotes* spp., *Aloa lactinea* (Cramer), *Chrotogonus trachypterus* (Blanchard), *Macrosteles quadrilineatus* (Forbes) , *Agrotis ipsylon* (Hufnagel) and *Oxya japonica* (Thunberg). Two pests viz. *Aphis fabae* (Scopoli) and *Altica himensis* (Shukla) were recorded as secondary and stray insect pests respectively.

Table-3a: Insect pest complex of wheat at Baramulla

| S. No | Common name | Scientific name | Family/ Order | Nature of damage | Crop stage infested | Period of prevalence and peak incidence | Status | Locations | | |
|-------|---------------------|--|---------------------------|---|---------------------|--|--------|-----------|-------|---------------|
| | | | | | | | | Wadura | Drusu | Imberzal wari |
| 01 | Cereal leaf beetle | <i>Oulema melanopus</i> (Linnaeus) | Chrysomelidae; Coleoptera | Both Adults and larvae feed on the chlorophyllous tissue leaving leaf lamina only intact. | BBCH 31-89 | 1 st week of April – Last week of July; 1 st fortnight of June | Major | + | + | + |
| 02 | Green leaf Aphids | <i>Rhopalosiphum maidis</i> (Fitch). | Aphididae; Hemiptera | Nymphs and adults suck sap from leaves | BBCH 29-85 | 3 rd week of FEB – 1 st week of June; 1 st week of April | Major | + | + | + |
| 03 | Armyworm | <i>Mythimna separata</i> (Walker) | Noctuidae; Lepidoptera | Larvae feed on foliage of plant. | BBCH 61-89 | Last week of April – last week of July; 2 nd fortnight of May | Major | + | + | + |
| 04 | Brown stink bug | <i>Carpocoris purpureipennis</i> (De Geer) | Pentatomidae; Hemiptera | Nymph and adults infesting foliage, leaves, ears and grain. | BBCH 61-77 | 2 nd fortnight of April- August; 2 nd fortnight of May | Minor | + | + | + |
| 05 | Surface grasshopper | <i>Chrotogonus trachypterus</i> (Blanchard). | Acrididae; Orthoptera | Nymphs and adults nibble at the leaves giving irregular lateral cuts. | BBCH 51-77 | 3 rd week of April – Last week of June; 1 st fortnight of June | Minor | + | + | + |
| 06 | Rice grasshopper | <i>Oxya japonica</i> (Thunberg) | Acrididae; Orthoptera | Nymphs and adults nibble at the foliage in a zig-zag fashion laterally. | BBCH 71-89 | 3 rd week of May – 2 nd week of July; 1 st week of June | Minor | + | + | - |
| 07 | Gram pod borer | <i>Helicoverpa armigera</i> (Hubner) | Noctuidae; Lepidoptera | Larvae feed on grains of plant. | BBCH 71-89 | 1 st week of May – 1 st week of July; 1 st fortnight of June | Minor | + | + | - |

| | | | | | | | | | | |
|----|-----------------------|--|---------------------------|--|------------|---|------------|---|---|---|
| 08 | White grub | <i>Holotrichia longipennis</i> (Hope) | Scarabaeidae; Coleoptera | Grubs feed on root system of seedlings and adults feed on foliage of plants. | BBCH-51-89 | 1 st week of April - last week of September; Last week of May (grubs) and last week of June (adults). | Minor | + | + | + |
| 09 | Wireworm | <i>Agriotes</i> spp. | Elateridae; Coleoptera | Grubs feed on root system of seedlings and weaken the whole plant. | BBCH 51-69 | 1 st week of April – last week of June; 1 st fortnight of May | Minor | + | + | + |
| 10 | Cut worm | <i>Agrotis ipsylon</i> (Hufnagel) | Noctuidae; Lepidoptera | Larvae cut the seedling horizontally at the ground surface. | BBCH 29-69 | 2 nd fortnight of March; 1 st fortnight of June | Minor | + | + | + |
| 11 | Black bean aphid | <i>Aphis fabae</i> (Scopoli) | Aphididae; Hemiptera | Adults and nymphs suck sap from foliage. | BBCH 51-89 | 2 nd fortnight of May; 1 st week of June | Stray pest | + | + | + |
| 12 | Flea beetle | <i>Altica himensis</i> (Shukla) | Chrysomelidae; Coleoptera | Adults scrap chlorophyllous tissues and leave behind epidermis. | BBCH 51-89 | 2 nd week of May – July; 1 st fortnight of June | Stray pest | + | + | + |
| 13 | Aster leaf hopper | <i>Macrostelus quadrilineatus</i> (Forbes) | Cicadellidae; Hemiptera | Nymphs and adults suck sap from the plant. | BBCH 51-77 | Last week of April – last week of July ;1 st week of June | Minor | + | + | - |
| 14 | Broad headed bug | <i>Camptopus lateralis</i> (Germar) | Alydidae; Hemiptera | Nymph infesting foliage, sucking sap | BBCH 61-85 | 1 st week of May – 3 rd week of June; 1 st fortnight of June | Minor | + | + | + |
| 15 | Red hairy caterpillar | <i>Aloa lactinea</i> (Cramer) | Eribidae ; Lepidoptera | Larvae feed on foliage of plants. | BBCH 61-85 | 1 st week of May – 3 rd week of June; 1 st fortnight of June | Minor | + | + | - |

BBCH

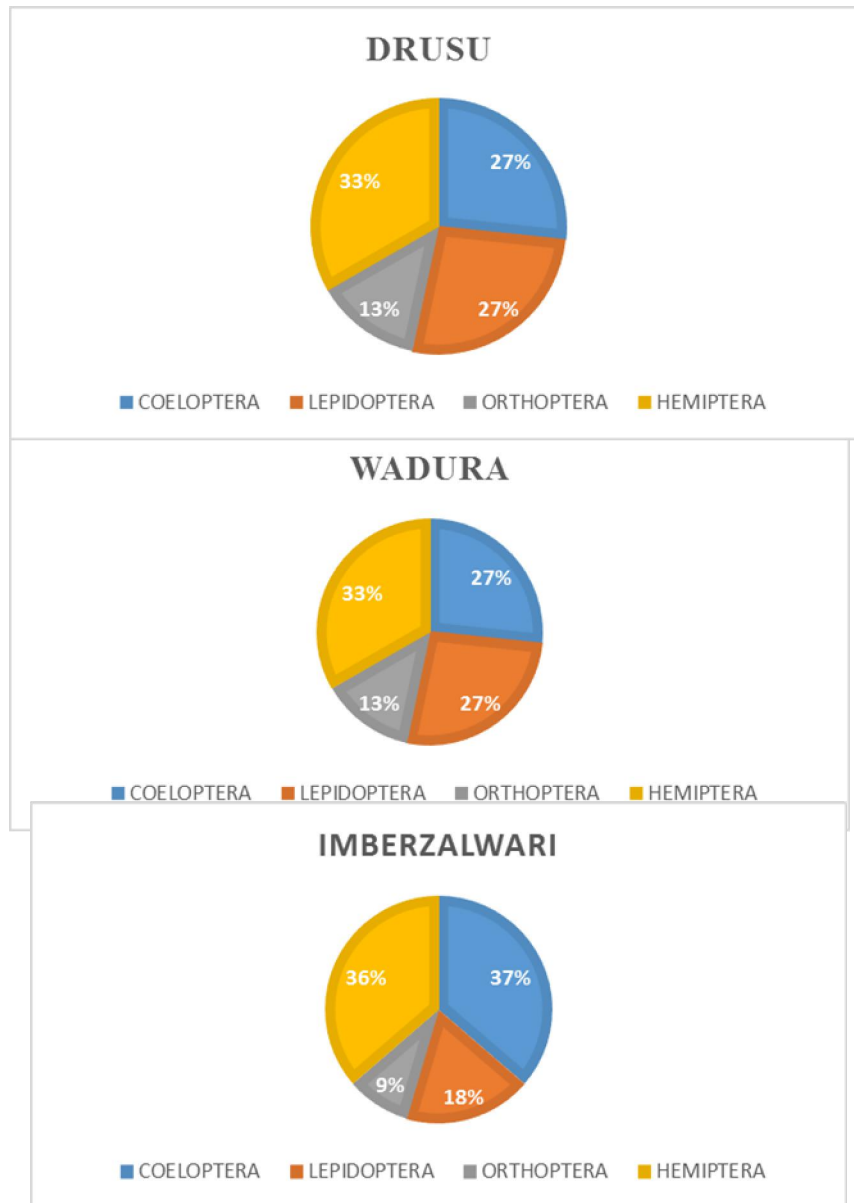


FIGURE 1: Order-wise per cent relative abundance of insect pests of wheat at

4.1.1 Infestation of major insect pests of wheat (*Triticum aestivum* L.) at Baramulla

The major insect pests were *Oulema melanopus*, *Rhopalosiphum maidis* and *Mythimna separate*. Their infestation is presented in table 3b, 3c and 3d respectively.

Table-3b: Infestation of Cereal leaf beetle *Oulema melanopus* L. on wheat at Baramulla

| Standard Meteorological week | % infestation at different locations of Baramulla | | |
|-------------------------------------|---|--------------|-----------|
| | Wadura | Imberzalwari | Drusu |
| 11 th - 12 th | 14 ± 2.3 | 9 ± 2.2 | 11 ± 3.0 |
| 13 th - 14 th | 16 ± 8.2 | 10 ± 1.9 | 14 ± 5.9 |
| 15 th - 16 th | 22 ± 2.1 | 14 ± 5.2 | 18 ± 8.4 |
| 17 th - 18 th | 27 ± 16.2 | 19 ± 5.9 | 23 ± 10.1 |
| 19 th - 20 th | 30 ± 17.2 | 22 ± 6.8 | 27 ± 13.7 |
| 21 th - 22 nd | 31 ± 7.1 | 25 ± 9.6 | 27 ± 2.7 |
| 23 th - 24 th | 34 ± 9.3 | 30 ± 13.5 | 32 ± 12.0 |
| 25 th - 26 th | 26 ± 5.6 | 27 ± 7.2 | 24 ± 9.0 |
| 27 th - 28 th | 0 | 10 ± 3.2 | 8 ± 2.1 |

Values are mean of 10 replications ± SD

4.1.2 Infestation of cereal leaf beetle (*Oulema melanopus* L.) on wheat at Baramulla

The cereal leaf beetle (*Oulema melanopus* L.) was found to be infesting wheat crop from the first week of April to last week of June with the peak incidence period of first fortnight of June, 2018 at all the locations of district Baramulla. The highest infestation was recorded from Wadura (34%) followed by Imberzalwari (32%) and Drusu (30%). Both Adults and larvae feed on the chlorophyllous tissue leaving leaf lamina only intact (Plate 2). The damaged leaves turns whitish and the plants takes on the appearance of frost damage.

Table-3c: Infestation of Armyworm *Mythimna separata* on wheat at Baramulla

| Standard Meteorological week | % infestation at different locations of Baramulla | | |
|------------------------------------|---|--------------|-----------|
| | Wadura | Imberzalwari | Drusu |
| 12 th -13 th | 0 | 0 | 0 |
| 14 th -15 th | 7 ± 3.0 | 5 ± 1.3 | 8 ± 0.1 |
| 16 th -17 th | 11 ± 5.5 | 9 ± 5.9 | 10 ± 4.2 |
| 18 th -19 th | 17 ± 1.8 | 19 ± 4.8 | 20 ± 13.5 |
| 20 th -21 st | 30 ± 16.3 | 22 ± 11.2 | 29 ± 2.7 |
| 22 th -23 th | 29 ± 9.6 | 20 ± 10.6 | 22 ± 14.3 |
| 24 th 25 th | 16 ± 5.6 | 3 ± 1.9 | 7 ± 1.5 |
| 26 th -27 th | 4 ± 1.3 | 0 | 0 |

value are mean of 10 replications ± SD

4.1.3 Infestation of Armyworm *Mythimna separata* on wheat at Baramulla

Mythimna separata: Commonly known as Armyworm, the larvae of the insect feed on foliage, resulting in tattered lamina of the leaves, sometimes leaving veins intact. The central whorl of the infested plant is filled with frass and a careful examination of the inner whorls revealed the presence of the larvae (Plate 3). The peak per cent infestation of armyworm was recorded during the second fortnight of May, 2018 at all the locations of district Baramulla. The highest infestation was recorded from Wadura (30%) followed by Imberzalwari (29%) and Drusu (22%).

Table-3d: Infestation of *Rhopalosiphum maidis* on wheat at Baramulla

| Standard Meteorological week | % infestation at different locations of Baramulla | | |
|-------------------------------------|---|--------------|-----------|
| | Wadura | Imberzalwari | Drusu |
| 6 th -7 th | 0 | 0 | 0 |
| 8 th 9 th | 9 ± 2.0 | 0 | 5 ± 3.8 |
| 10 th -11 th | 18 ± 2.5 | 9 ± 1.2 | 15 ± 9.5 |
| 12 th -13 th | 22 ± 9.3 | 15 ± 4.7 | 17 ± 13.4 |
| 14 th -15 th | 44 ± 17.6 | 37 ± 16.8 | 41 ± 17.6 |
| 16 th -17 th | 38 ± 13.2 | 28 ± 8.3 | 33 ± 11.5 |
| 18 th -19 th | 30 ± 11.5 | 20 ± 12.8 | 23 ± 8.4 |
| 19 th – 20 th | 26 ± 8.6 | 15 ± 5.2 | 17 ± 4.7 |

Value are mean of 10 replications ± SD

4.1.4 Infestation of *Rhopalosiphum maidis* on wheat at Baramulla

The Aphids cause severe damage in cereal crops, particularly wheat, *Triticum aestivum*, by direct feeding (sucking plant sap from the phloem) and by transmitting plant pathogenic viruses such as barley yellow dwarf virus (BYDV) (Mann *et al.*1996, Thackeray *et al.* 2009). They hinder the development in the early stages of the crop result in 19-31% yield loss; later infestation reduces the yield loss to up to 20% (Voss et al. 1997). During our studies the aphid was found to be a major insect pest of wheat throughout the season with peak per cent infestation recorded during the first fortnight of April, 2018 at all the locations of district Baramulla (Table 3d). The highest infestation was recorded from Wadura (44%) followed by Imberzalwari (41%) and Drusu (37%).

4.2 Assessment of insect pests of wheat at district Bandipora

The data presented in the Table 4a revealed that 17, 17 and 13 insect pest species, infesting the wheat crop at different phenological stages, were recorded at Sk-bala, Odina and Munglu respectively.

At Sk-bala, out of 17 insect pest species, 5 were found belonging to order Lepidoptera; 4 to order Coeloptera; 5 to order Hemiptera; 2 to order Orthoptera and 1 to order Trombidiformis representing 11 families in total with a share of 29 per cent of insect pests to Lepidoptera and Hemiptera each, 24 per cent to Coeloptera; 12 per cent to Orthoptera and 1 per cent to Trombidiformis (Fig. 2).

At Odina out of 17 insect pest species, 5 were found belonging to order Lepidoptera; 4 to order Coeloptera; 5 to order Hemiptera; 2 to order Orthoptera and 1 to order Trombidiformis representing 11 families in total with a share of 29 per cent of insect pests to Lepidoptera and Hemiptera each, 24 per cent to Coeloptera; 12 per cent to Orthoptera and 1 per cent to Trombidiformis (Fig. 2).

At Munglu out of 13 insect pest species, 4 were found belonging to order Coeloptera; 5 to order Hemipteran; 3 to Lepidoptera and 1 to order Orthopteran representing 9 families in total with a share of 31 per cent of insects to Coeloptera; 38 per cent of insects to Hemipteran, 23 per cent to Lepidoptera and 8 per cent to Orthoptera (figure 2).

The major insect pests were *Oulema melonopus* (Linnaeus) *Rhopalosiphum maidis* (Fitch) and *Mythimna separata* (Walker) while the minor ones were *Holotrichia longipennis* (Hope), *Helicoverpa armigera* (Hubner), *Carpocoris* spp., *Agriotes* spp., *Aloa lactinea* (Cramer), *Chrotogonus trachypterus* (Blanchard), *Chaetocnema pulicaria*, *Agrotis ipsylon* (Hufnagel), *Macrostoteles quadrilineatus* (Forbes), *Oxya japonica* (Thunberg), *Spodoptera litura* (Fabricus) and *Petrobia latens* (Muller) 2 pests viz. *Aphis fabae* (Scopoli) and *Altica himensis* (Shukla) were recorded as secondary and stray insect pests respectively.

Table -4a: Insect pest complex of wheat at Bandipora

| S. No. | Common name | Scientific name | Family /Order | Nature of damage | Crop stage infested | Period of prevalence and peak incidence | Status | Locations | | |
|--------|---------------------|---|------------------------------|---|---------------------|---|--------|-----------|-------|--------|
| | | | | | | | | Sk-bala | Odina | Munglu |
| 01 | Cereal leaf beetle | <i>Oulema melanopus</i> (Linnaeus) | Chrysomelidae; Coleoptera | Adults feed on the chlorophyllous tissue leaving leaf lamina only intact. | BBCH 31-89 | 1 st fortnight of April – Last week of July; 2nd fortnight of May. | Major | + | + | + |
| 02 | Green leaf Aphids | <i>Rhopalosiphum maidis</i> (Fitch). | Aphididae; Hemiptera | Nymphs and adults suck sap from leaves | BBCH 29-85 | 2 nd week of FEB – 3 rd week of May; 1st fortnight of April. | Major | + | + | + |
| 03 | Armyworm | <i>Mythimna separata</i> (Walker) | Noctuidae; Lepidoptera | Larvae feed on foliage of plant. | BBCH 61-89 | 2 nd fortnight of April – 1 st fortnight of July; 1 st fortnight of June | Major | + | + | + |
| 04 | Brown stink bug | <i>Carpocoris purpureipennis</i> (De Geer) | Pentatomidae; Hemiptera | Nymph and adults infesting foliage, leaves, ears and grain. | BBCH 61-77 | April- august; 2 nd fort night of May | Minor | + | + | + |
| 05 | Surface grasshopper | <i>Chrotogonus trachypterus</i> (Blanchard). | Acrididae; Orthoptera | Nymphs and adults nibble at the leaves giving irregular lateral cuts. | BBCH 51-77 | 3 rd week of April - Last week of June; 1 st fortnight of June | Minor | + | + | + |
| 06 | Rice grasshopper | <i>Oxya japonica</i> (Thunberg) | Acrididae; Orthoptera | Nymphs and adults nibble at the foliage in a zig-zag fashion laterally. | BBCH 71-89 | 3 rd week of May - 2 nd week of July; 1 st week of June | Minor | + | + | - |
| 07 | Gram pod borer | <i>Helicoverpa armigera</i> (Hubner) | Noctuidae; Lepidoptera | Larvae feed on grains of plant. | BBCH 71-89 | 1 st week of May -1 st week of July; 1 st fortnight of June | Minor | + | + | + |

| | | | | | | | | | | |
|----|-------------------------|--|-------------------------------|--|------------|---|------------|---|---|---|
| 08 | White grub | <i>Holotrichia longipennis</i> (Hope) | Scarabaeidae; Coleoptera | Grubs feed on root system of seedlings and adults feed on foliage of plants. | BBCH-51-89 | 1 st week of April - last week of September; Last week of May (grubs) and last week of June (adults). | Minor | + | + | + |
| 09 | Wireworm | <i>Agriotes</i> spp. | Elateridae; Coleoptera | Grubs feed on root system of seedlings and weaken the whole plant. | BBCH 51-69 | 1 st week of April – last week of June; 1 st fortnight of May | Minor | + | + | + |
| 10 | Cut worm | <i>Agrotis ipsylon</i> (Hufnagel) | Noctuidae; Lepidoptera | Larvae cut the seedling horizontally at the ground surface. | BBCH 29-69 | 2 nd fortnight of March; 1 st fortnight of June | Minor | + | + | + |
| 11 | Black bean aphid | <i>Aphis fabae</i> (Scopoli) | Aphididae; Hemiptera | Adults and nymphs suck sap from foliage. | BBCH 51-89 | 2 nd fortnight of may; 1 st week of June | Stray pest | + | + | + |
| 12 | Flea beetle | <i>Altica himensis</i> (Shukla) | Chrysomelidae; Coleoptera | Adults scrap chlorophyllous tissues and leave behind epidermis. | BBCH 51-89 | 2 nd week of May – July; 2 nd fortnight of June | Stray pest | + | + | + |
| 13 | Aster leaf hopper | <i>Macrostelus quadrilineatus</i> (Forbes) | Cicadellidae; Hemiptera | Nymphs and adults suck sap from the plant. | BBCH 51-77 | Last week of April – Last week of July ; 1 st week of June | Minor | + | + | + |
| 14 | Broad headed bug | <i>Camptopus lateralis</i> (Germar) | Alydidae; Hemiptera | Nymph infesting foliage, sucking sap | BBCH 61-85 | 1 st week of May – 3 rd week of June; 1 st fortnight of June | Minor | + | + | + |
| 15 | Red hairy caterpillar | <i>Aloa lactinea</i> (Cramer) | Eribidae ; Lepidoptera | Larvae feed on foliage of plants. | BBCH 61-85 | 1 st week of May – 3 rd week of June; 1 st fortnight of June | Minor | + | + | - |
| 16 | Leaf eating caterpillar | <i>Spodoptera litura</i> (Fabricus) | Noctuidae; Lepidoptera | Larvae feed on foliage of plant. | BBCH 61-89 | 2 nd fortnight of April – 1 st fortnight of July; 2 nd fortnight of may | Minor | + | + | - |
| 17 | Brown wheat mite | <i>Petrobia latens</i> (Muller) | Tetranychidae; Trombidiformis | Nymphs and adults feed upon leaves and spikes of wheat plant, as a result leaves dry up. | BBCH 20-69 | 1 st week of March to 1 st fortnight of April; 1 st week of April | Minor | + | + | - |

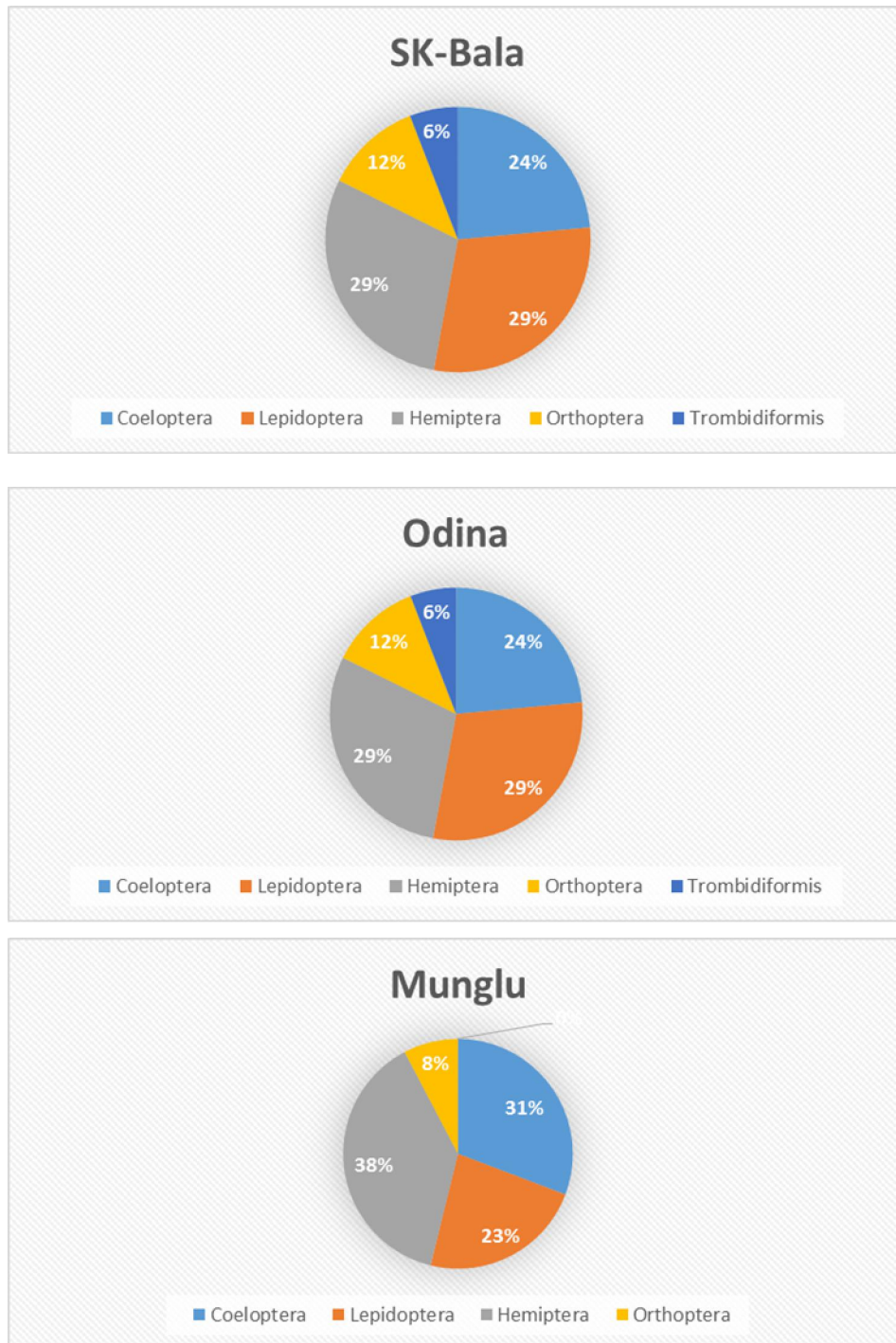


FIGURE 2: Order-wise percent relative abundance of insect pests of wheat at Bandipora

4.2.1 Infestation of major insect pests of wheat (*Triticum aestivum* L.) at Bandipora

The major insect pests were *Oulema melanopus*, *Rhopalosiphum maidis* and *Mythimna separate*. Their infestation is presented in table 4b, 4c and 4d respectively.

Table-4b: Infestation of Cereal leaf beetle (*Oulema melanopus* L.) on wheat at Bandipora

| Standard metrological week | % infestation at different locations of Bandipora | | |
|-------------------------------------|---|-----------|----------|
| | Sk-bala | Odina | Munglu |
| 9 th -10 th | 0 | 0 | 0 |
| 11 th – 12 th | 6 ± 2.1 | 7 ± 2.9 | 4 ± 0.3 |
| 13 th -14 th | 10 ± 1.2 | 11 ± 5.3 | 7 ± 1.6 |
| 15 th -16 th | 13 ± 2.6 | 13 ± 1.5 | 10 ± 6.4 |
| 17 th -18 th | 17 ± 3.6 | 18 ± 4.7 | 13 ± 2.2 |
| 19 th -20 th | 21 ± 15.6 | 22 ± 10.3 | 15 ± 0.1 |
| 21 st -22 nd | 32 ± 9.6 | 29 ± 17.6 | 27 ± 8.4 |
| 23 rd -24 th | 27 ± 11.2 | 25 ± 5.2 | 21 ± 8.2 |
| 25 th -26 th | 12 ± 1.2 | 8 ± 2.0 | 10 ± 3.7 |

value are mean of 10 replications ± SD

4.2.2 Infestation of Cereal leaf beetle *Oulema melanopus* L. on wheat at Bandipora

The data embodied in table 4b vividly revealed that Cereal leaf beetle (*Oulema melanopus* L.) was found to be one of the severe pest infesting wheat crop right from the first week of April to last week of July with the peak incidence period of second fortnight of May, 2018 at all the locations of district Bandipora. The highest infestation was recorded from Sk-bala (32%) followed by Odina (29%) and Munglu. Both Adults and larvae feed on the chlorophyllous tissue leaving leaf lamina intact (Plate 2). The damaged leaves turns whitish and the plants takes on the appearance of frost damage.

Table -4c: Infestation of Armyworm, *Mythimna separata* on wheat at Bandipora

| Metrological week | % infestation at different locations of Bandipora | | |
|------------------------------------|---|-----------|-----------|
| | Sk-bala | Odina | Munglu |
| 12 th -13 th | 0 | 0 | 0 |
| 14 th -15 th | 9 ± 1.2 | 7 ± 0.1 | 3 ± 2.2 |
| 16 th -17 th | 10 ± 3.5 | 12 ± 1.2 | 7 ± 2.5 |
| 18 th -19 th | 16 ± 4.5 | 19 ± 9.6 | 11 ± 5.6 |
| 20 th -21 st | 21 ± 5.6 | 21 ± 14.9 | 14 ± 15.6 |
| 22 nd -23 rd | 34 ± 4.6 | 29 ± 14.6 | 22 ± 18.6 |
| 24 th -25 th | 25 ± 2.6 | 26 ± 15.2 | 19 ± 7.6 |
| 26 th -27 th | 0 | 0 | 0 |

value are mean of 10 replications ± SD

4.2.3 Infestation of Armyworm, *Mythimna separata* on wheat at Bandipora

The data presented in Table 4c clearly indicates that *Mythimna separata* commonly known as Armyworm, is one of the major pest of wheat at Bandipora. The larvae of the insect feed on foliage, resulting in tattered lamina of the leaves, sometimes leaving veins intact. The central whorl of the infested plant is filled with frass and a careful examination of the inner whorls revealed the presence of the larvae (Plate 3). The peak per cent infestation of Armyworm was recorded during the first fortnight of June, 2018 at all the locations of district Bandipora. The highest infestation was recorded from Sk-bala (34%) followed by Odina (29%) and Munglu (22%).

Table-4d: Infestation of *Rhopalosiphum maidis* on wheat at Bandipora

| Standard Metrological week | % infestation at different locations of Bandipora | | |
|-------------------------------------|---|-----------|-----------|
| | Sk-bala | Odina | Munglu |
| 6 th -7 th | 0 | 0 | 0 |
| 8 th - 9 th | 15 ± 2.4 | 0 | 9 ± 2.1 |
| 10 th -11 th | 22 ±16.6 | 21 ± 5.2 | 15 ±0.1 |
| 12 th -13 th | 27 ±13.4 | 18 ±1.9 | 15 ± 2.7 |
| 14 th - 15 th | 53 ± 16.5 | 48 ± 16.8 | 45 ± 16.3 |
| 16 th -17 th | 37 ±7.1 | 36 ±12.5 | 23 ± 11.2 |
| 18 th -19 th | 30 ± 8.4 | 27 ± 13.7 | 21 ± 4.7 |

value are mean of 10 replications ± SD

4.2.4 Infestation of *Rhopalosiphum maidis* on wheat at Bandipora

The leaf aphids injure the plants by sucking sap from the phloem. They also inject a toxin into plants while feeding, causing a characteristic leaf rolling. The peak per cent infestation of Aphid was recorded during the first fortnight of April, 2018 at all the locations of district Bandipora (Table 4d). The highest infestation was recorded from Sk-bala (53%) followed by Odina (48%) and Munglu (45%).

4.3 Assessment of insect pests of wheat at district Ganderbal

The data presented in the Table 5a revealed the prevalence of 15, 13 and 12 insect pest species, infesting the wheat crop at different phenological stages at Wakura, Manigam and Akhal respectively.

At Wakura, out of 15 insect pest species, 4 belonging to order Lepidoptera; 4 of Coeloptera; maximum 5 to order Hemiptera and 2 from Orthoptera representing 10 families in total with a relative abundance of 27 per cent from Lepidoptera and Coeloptera each, 33 per cent to Hemipteran and 13 per cent to Orthoptera (Fig. 3).

At Manigam out of 13 insect pest species, 4 pest species belonging to order Lepidoptera; 4 to order Coeloptera ; 4 to order Hemiptera and 1 to order Orthoptera representing 10 families in total with a share of 31 per cent of insect pests to Lepidoptera, Coeloptera and Hemiptera each and 7 per cent to Orthopteran (Fig. 3).

At Akhal out of 12 insect pest species, 4 were found belonging to order Coeloptera; 3 to order Hemipteran; 3 to Lepidoptera and 2 to order Orthopteran representing 9 families in total with a share of 33 per cent of insects to Coeloptera; 25 per cent of insects to Hemiptera and Lepidoptera each and 17 per cent to Orthoptera (Fig. 3).

The major insect pests were Cereal leaf beetle *Oulema melanopus* (Linnaeus), Aphids *Rhopalosiphum maidis* (Fitch) and Armyworm *Mythimna*

separata (Walker) while the minor ones were *Holotrichia longipennis* (Hope), *Helicoverpa armigera* (Hubner), *Carpocoris* spp., *Agriotes* spp., *Chrotogonus trachypterus* (Blanchard), *Agrotis ipsylon* (Hufnagel), *Macrosteles quadrilineatus* (Forbes), *Oxya japonica* (Thunberg) and *Spodoptera litura* (Fabricus) 2 pests viz. *Aphis fabae* (Scopoli) and *Altica himensis* (Shukla) were recorded as secondary and stray insect pests respectively.

Table-5a: Insect pest complex of wheat at Ganderbal

| S. No. | Common name | Scientific name | Family / Order | Nature of damage | Crop stage infested | Period of prevalence and peak incidence | Status | Locations | | |
|--------|---------------------|---|------------------------------|---|---------------------|--|--------|-----------|---------|-------|
| | | | | | | | | Wakura | Manigam | Akhal |
| 01 | Cereal leaf beetle | <i>Oulema melanopus</i> (Linnaeus) | Chrysomelidae; Coleoptera | Adults feed on the chlorophyllous tissue leaving leaf lamina only intact. | BBCH 31-89 | 1 st fortnight of April – Last week of July; 1 st week of June | Major | + | + | + |
| 02 | Green leaf Aphids | <i>Rhopalosiphum maidis</i> (Fitch). | Aphididae; Hemiptera | Nymphs and adults suck sap from leaves | BBCH 29-85 | 2 nd week of FEB – 1 ST week of June; 1 st fortnight of MAY | Major | + | + | + |
| 03 | Armyworm | <i>Mythimna separata</i> (Walker) | Noctuidae; Lepidoptera | Larvae feed on foliage of plant. | BBCH 61-89 | 2 nd fortnight of April – 1 st fortnight of July; 1 st fortnight of June | Major | + | + | + |
| 04 | Brown stink bug | <i>Carpocoris purpureipennis</i> (De Geer) | Pentatomidae; Hemiptera | Nymph and adults infesting foliage, leaves, ears and grain. | BBCH 61-77 | April- august; 2 nd fort night of May | Minor | + | + | + |
| 05 | Surface grasshopper | <i>Chrotogonus trachypterus</i> (Blanchard). | Acrididae; Orthoptera | Nymphs and adults nibble at the leaves giving irregular lateral cuts. | BBCH 51-77 | 3 rd week of April – Last week of June; 1 st fortnight of June | Minor | + | + | + |
| 06 | Rice grasshopper | <i>Oxya japonica</i> (Thunberg) | Acrididae; Orthoptera | Nymphs and adults nibble at the foliage in a zig-zag fashion laterally. | BBCH 71-89 | 3 rd week of May – 2 nd week of July; 1st week of June | Minor | + | - | + |
| 07 | Gram pod borer | <i>Helicoverpa armigera</i> (Hubner) | Noctuidae; Lepidoptera | Larvae feed on grains of plant. | BBCH 71-89 | 1 st week of May – 1 st week of July; 1 st fortnight of June | Minor | + | + | + |

| | | | | | | | | | | |
|----|-------------------------|--|------------------------------|--|------------|---|------------|---|---|---|
| 08 | White grub | <i>Holotrichia longipennis</i> (Hope) | Scarabaeidae; Coleoptera | Grubs feed on root system of seedlings and adults feed on foliage of plants. | BBCH-51-89 | 1 st week of April - last week of September; Last week of May (grubs) and last week of June (adults). | Minor | + | + | + |
| 09 | Wireworm | <i>Agriotes</i> spp. | Elateridae; Coleoptera | Grubs feed on root system of seedlings and weaken the whole plant. | BBCH 51-69 | 1 st week of April- last week of June; 1 st fortnight of May | Minor | + | + | + |
| 10 | Cut worm | <i>Agrotis ipsylon</i> (Hufnagel) | Noctuidae; Lepidoptera | Larvae cut the seedling horizontally at the ground surface. | BBCH 29-69 | 2 nd fortnight of March; 1 st fortnight of June | Minor | + | + | + |
| 11 | Black bean aphid | <i>Aphis fabae</i> (Scopoli) | Aphididae; Hemiptera | Adults and nymphs suck sap from foliage. | BBCH 51-89 | 2 nd fortnight of May; 1 st week of June. | Stray pest | + | + | - |
| 12 | Flea beetle | <i>Altica himensis</i> (Shukla) | Chrysomelidae; Coleoptera | Adults scrap chlorophyllous tissues and leave behind epidermis. | BBCH 51-89 | 2 nd week of May - July; 1 st fortnight of June | Stray pest | + | + | + |
| 13 | Aster leaf hopper | <i>Macrostelus quadrilineatus</i> (Forbes) | Cicadellidae; Hemiptera | Nymphs and adults suck sap from the plant. | BBCH 51-77 | Last week of April -Last week of July ; 1 st week of June | Minor | + | + | - |
| 14 | Broad headed bug | <i>Camptopus lateralis</i> (Germar) | Alydidae; Hemiptera | Nymph infesting foliage, sucking sap | BBCH 61-85 | 1 st week of May - 3 rd week of June; 1 st fortnight of June | Minor | + | - | + |
| 15 | Leaf eating caterpillar | <i>Spodoptera litura</i> (Fabricus) | Noctuidae; Lepidoptera | Larvae feed on foliage of plant. | BBCH 61-89 | 2 nd fortnight of April -1 st fortnight of July; 1 st fortnight of may | Minor | + | + | - |

BBCH 00-09—Germination: BBCH 10-19--Leaf development; BBCH 20-29--Tillering: BBCH 30-39--- Stem elongation: BBCH 41-49 ---Booting BBCH 51-59 – Inflorescence emerging Heading: BBCH 61-69 --- Flowering Anthesis: BBCH 71-79 – Development of fruit: BBCH 83-89—Ripening; (+) means presence and (-) means absence.

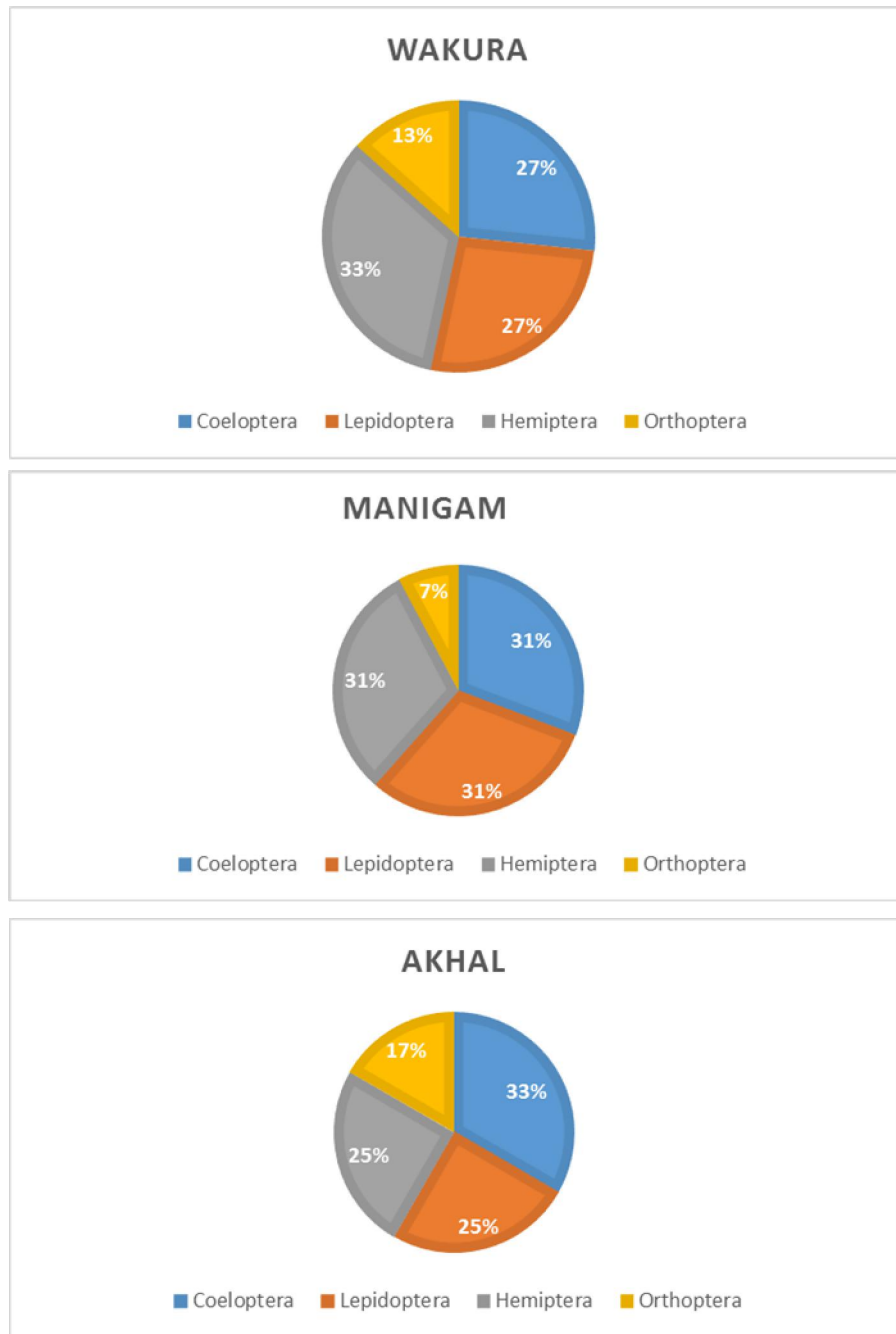


Fig. 3: Order-wise percent relative abundance of insect pests of wheat at Ganderbal

4.3.1 Infestation of major insect pests of wheat (*Triticum aestivum* L.) at Ganderbal

The major insect pests were *Oulema melanopus*, *Rhopalosiphum maidis* and *Mythimna separate*. Their infestation is presented in table 5b, 5c and 5d respectively.

Table-5b: Infestation of Cereal leaf beetle (*Oulema melanopus* L.) on wheat at Ganderbal

| Standard Meteorological week | % infestation at different locations of Ganderbal | | |
|-------------------------------------|---|-----------|-----------|
| | Wakura | Manigam | Akhal |
| 11 th -12 th | 10 ± 1.2 | 7 ± 2.4 | 7 ± 5.2 |
| 13 th -14 th | 13 ± 5.3 | 11 ± 1.7 | 9 ± 4.8 |
| 15 th -16 th | 17 ± 6.8 | 13 ± 9.4 | 10 ± 2.1 |
| 17 th -18 th | 21 ± 2.7 | 18 ± 13.4 | 15 ± 3.8 |
| 19 th -20 th | 25 ± 4.7 | 22 ± 10.5 | 21 ± 10.3 |
| 21 st -22 nd | 29 ± 12.6 | 29 ± 12.2 | 25 ± 6.7 |
| 23 rd -24 th | 32 ± 8.3 | 29 ± 12.5 | 27 ± 11.5 |
| 25 th - 26 th | 24 ± 8.2 | 20 ± 7.7 | 18 ± 6.4 |
| 27 th - 28 th | 11 ± 3.1 | 7 ± 2.3 | 8 ± 1.2 |

value are mean of 10 replications ± SD

4.3.2 Infestation of Cereal leaf beetle *Oulema melanopus* L. on wheat at Ganderbal

The data presented in table 5b clearly indicates the peak per cent infestation of Cereal leaf beetle was recorded during the first fortnight of June, 2018 at all the locations of district Ganderbal. The highest infestation was recorded from Wakura (32%) followed by Manigam (29%) and Akhal (27%).

Table 5c: Infestation of Armyworm *Mythimna separata* on wheat at Ganderbal

| Standard Meteorological week | % infestation at different locations of Ganderbal | | |
|------------------------------------|---|-----------|----------|
| | Wakura | Manigam | Akhal |
| 12 th -13 th | 0 | 0 | 0 |
| 14 th -15 th | 7 ± 3 | 3 ± 1.8 | 0 |
| 16 th -17 th | 9 ± 3.1 | 12 ± 1.5 | 7 ± 2.7 |
| 18 th -19 th | 19 ± 3.8 | 15 ± 2.7 | 11 ± 0.5 |
| 20 th -21 st | 26 ± 1.9 | 21 ± 5.2 | 14 ± 3.8 |
| 22 nd -23 rd | 34 ± 2.7 | 29 ± 18.2 | 22 ± 2.4 |
| 24 th -25 th | 26 ± 8.3 | 27 ± 16.6 | 21 ± 7.0 |
| 26 th -27 th | 0 | 0 | 0 |

value are mean of 10 replications ± SD

4.3.3 Infestation of Armyworm *Mythimna separata* on wheat at Ganderbal

The data from table 5c revealed that the peak per cent infestation of Armyworm was recorded during the first fortnight of June, 2018 at all the locations of district Ganderbal. The highest infestation was recorded from Wakura (34%) followed by Manigam (29%) and Akhal (22%).

Table-5d: Infestation of *Rhopalosiphum maidis* on wheat at Ganderbal

| Standard Meteorological week | % infestation at different locations of Ganderbal | | |
|------------------------------------|---|-----------|-----------|
| | Wakura | Manigam | Akhal |
| 6 th -7 th | 0 | 0 | 0 |
| 8 th -9 th | 9 ± 0.1 | 0 | 0 |
| 10 th -11 th | 15 ± 10.1 | 9 ± 1.5 | 0 |
| 12 th -13 th | 18 ± 1.8 | 15 ± 6.4 | 9 ± 2 |
| 14 th -15 th | 56 ± 26.0 | 53 ± 5.2 | 45 ± 13.4 |
| 16 th -17 th | 43 ± 4.8 | 41 ± 6.7 | 33 ± 15.6 |
| 18 th -19 th | 33 ± 10.3 | 30 ± 10.3 | 27 ± 4.7 |

value are mean of 10 replications± SD

4.3.4 Infestation of *Rhopalosiphum maidis* on wheat at Ganderbal

It is evident from the table 5d that the peak per cent infestation of aphid was recorded during the first fortnight of April, 2018 at all the locations of district Ganderbal. The highest infestation was recorded from Wakura (56%) followed by Manigam (53%) and Akhal (45%).

4.4 To screen different wheat genotypes for relative resistance against cereal leaf beetle (*Oulema melanopus* L.)

4.4.1 Incidence of cereal leaf beetle *Oulema melanopus* L. on different wheat genotypes

A perusal of data in figure 4 revealed that the Wheat cultivar 'HB-208 had the highest incidence of 35.55 per cent followed by GW-120 with 31.11 per cent and was found to be significantly different. The least incidence of 3.33 per cent was observed in cultivar AJANTA and hence the incidence ranged from 35.55 to 3.33 per cent and the total average for all genotypes was 18.89%.

4.4.2 Screening wheat genotypes for their relative resistance against *O. melanopus*

The degree of damage on the leaves of 33 wheat genotypes showed variation from 5 to 37% and the total average for all genotypes was 23.53%. Very low damages were reported on the Indian wheat varieties namely Ajanta (7%) followed by GW-496 (9%). The highest damage (37 %) was found on the cultivar HB-208, it was closely followed by GW-120, GW-322, DL-788-2 and GW-173 with leaf damage of 36.9, 35, 35, and 34.6 per-cent respectively.

The results obtained from percentage of leaf damage is presented in Figure 5, revealed that there 2 genotypes viz: Ajanta and GW-496 genotype were resistant; cultivars AKW-381, AKW-1071, C-306, CHHOTI LERMA, OPAN-1796, OPAN 3004, DBW-16, DL-784-3, DL-803, and gw-190 were categorized as Moderately resistant; SW-1, SW-2, VL-22, HD-1925, HD-208, GW-503, GW-322, GW-273, GW-173, GW-120, GW-89, GW-40, GW-10, DWR-195, DWR-39, DWR-16, DURGAPURA-65, DL-788-2, DL-153-2, DBW-14 and D-134 as Moderately susceptible while as no genotype with complete susceptibility was found.

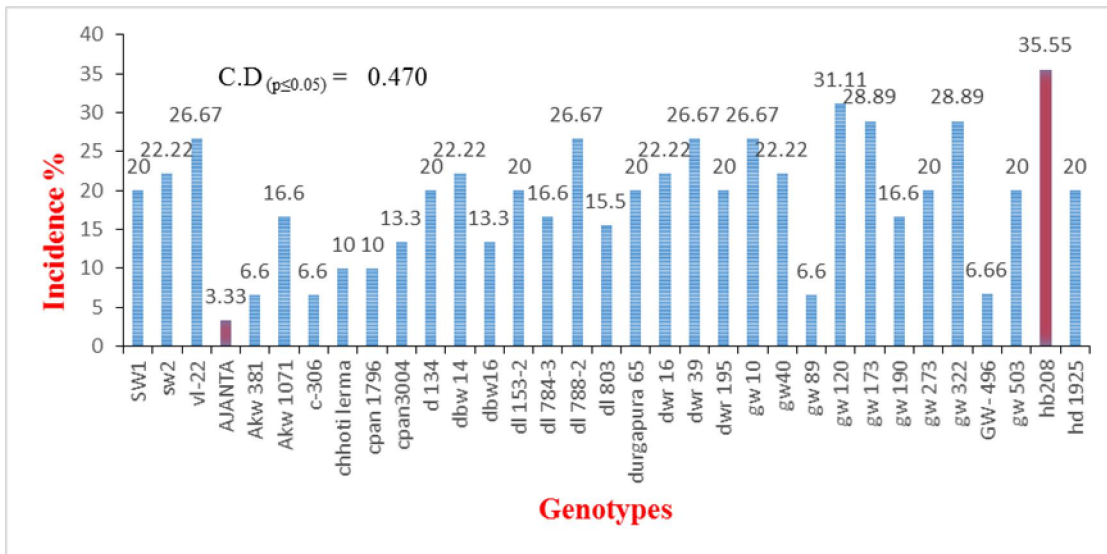


Fig. 4: Incidence of *Oulema melonopus* on different wheat genotypes

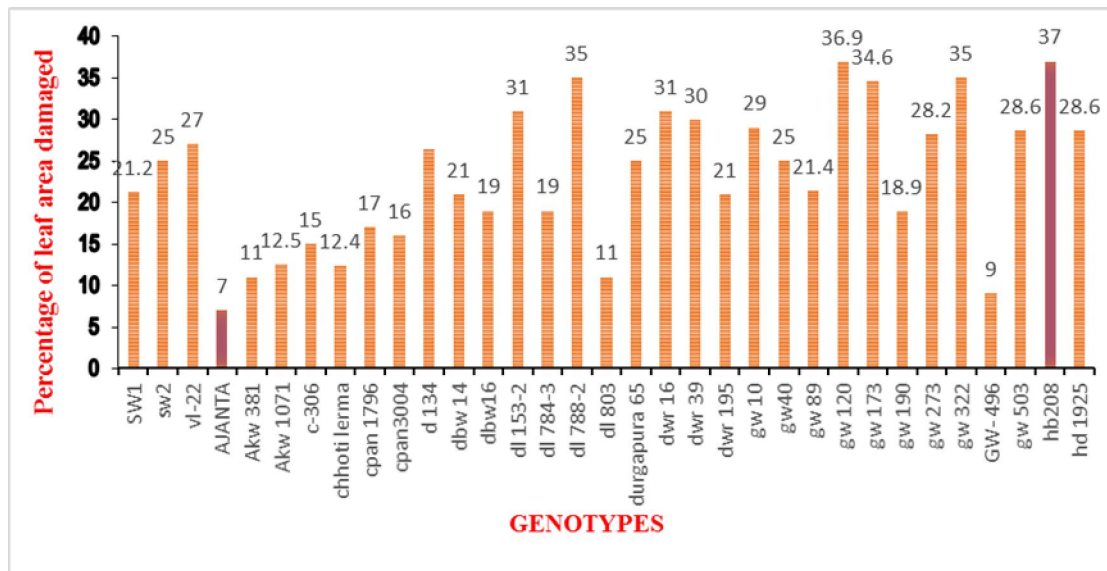


Fig. 5: Degree of damage by *Oulema melonopus* on 33 wheat genotypes



Plate-1: Different classes of infested flag leaves according to degree of attack

Table-6: Categorisation into resistant/susceptible genotype for relative resistance against *O. melonopus*

| S. no | Scale | Percentage of flag leaf damaged | Grade | Genotypes |
|--------------|--------------|--|----------------------------------|--|
| 1 | 1-2 | <10% | Resistant varieties | AJANTA, GW-496 |
| 2 | 2-3 | 10-20% | Moderately Resistant varieties | AKW-381, AKW-1071, C-306, CHOTTI LERMA, OPAN-1796, OPAN-3004, DBW-16, DL-784-3, DL-803, GW-190. |
| 3 | 3-4 | 20-40% | Moderately Susceptible varieties | HD-1925, HD-208, GW-503, GW-322, GW-273, GW-173, GW-120, GW-89, GW-40, GW-10, DWR-195, DWR-39, DWR-16, DURGAPURA-65, DL-788-2, DL-153-2, DBW-14, D-134, VL-22, SW-1, SW-2. |
| 4 | 4-5 | >40% | Susceptible varieties | --- |

(Rouag *et al.*, 2012)

Table-7: Comparison of the genotypes for various morphological characters

| S. No. | Genotypes | Incidence | Degree of damage | Plant height (cm)* | No. of tillers* | Trichome density (mm ²)* | Trichome length (mm)* | Flag leaf area (cm ²)* | Flag leaf width (cm)* | Flag leaf length (cm)* |
|--------|--------------|-----------|------------------|--------------------|-----------------|--------------------------------------|-----------------------|------------------------------------|-----------------------|------------------------|
| 1 | SW-1 | 20.00 | 21.20 | 82.30 | 10.60 | 59 | 0.63 | 10.38 | 1.80 | 17.80 |
| 2 | SW-2 | 22.22 | 25.00 | 79.70 | 10.20 | 57 | 0.57 | 10.87 | 1.86 | 17.60 |
| 3 | VL-22 | 26.67 | 27.00 | 74.93 | 11.80 | 56 | 0.55 | 10.67 | 1.89 | 17.20 |
| 4 | AJANTA | 3.33 | 3.00 | 94.80 | 10.00 | 74 | 0.76 | 11.63 | 1.53 | 23.83 |
| 5 | AKW-381 | 6.60 | 11.00 | 89.70 | 40.00 | 67 | 0.70 | 10.00 | 1.66 | 16.33 |
| 6 | AKW-1071 | 16.60 | 12.50 | 116.84 | 17.33 | 65 | 0.68 | 12.23 | 1.70 | 23.66 |
| 7 | C-306 | 6.60 | 15.00 | 90.20 | 32.00 | 63 | 0.69 | 10.01 | 1.76 | 15.50 |
| 8 | CHHOTI LERMA | 10.00 | 12.40 | 84.50 | 17.66 | 68 | 0.68 | 14.03 | 1.68 | 24.06 |
| 9 | CPAN-1796 | 10.00 | 17.00 | 89.80 | 16.33 | 66 | 0.66 | 11.87 | 1.78 | 21.16 |
| 10 | CPAN-3004 | 13.30 | 16.00 | 84.50 | 13.00 | 64 | 0.67 | 14.54 | 1.80 | 24.43 |
| 11 | D -134 | 20.00 | 27.00 | 76.20 | 13.00 | 56 | 0.56 | 15.62 | 1.86 | 25.70 |
| 12 | DBW- 14 | 22.22 | 21.00 | 72.80 | 11.00 | 58 | 0.57 | 14.88 | 1.75 | 25.56 |
| 13 | DBW-16 | 13.30 | 19.00 | 90.20 | 12.60 | 65 | 0.63 | 10.15 | 1.70 | 18.6 |
| 14 | DL 153-2 | 20.00 | 31.00 | 77.80 | 10.00 | 46 | 0.47 | 15.17 | 2.10 | 22.00 |
| 15 | DL 784-3 | 16.60 | 19.00 | 76.20 | 24.00 | 64 | 0.68 | 10.07 | 1.80 | 16.73 |
| 16 | DL 788-2 | 26.67 | 35.00 | 82.90 | 22.00 | 41 | 0.42 | 17.57 | 2.00 | 27.60 |

| | | | | | | | | | | |
|----------------------------------|---------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|--------------|-------------|
| 17 | DL -803 | 15.50 | 11.00 | 84.60 | 27.30 | 63 | 0.68 | 12.01 | 1.68 | 22.50 |
| 18 | DURGAPURA -65 | 20.00 | 25.00 | 104.90 | 6.30 | 53 | 0.56 | 13.36 | 1.88 | 24.76 |
| 19 | DWR- 16 | 22.22 | 31.00 | 84.60 | 7.00 | 48 | 0.45 | 11.33 | 2.03 | 16.90 |
| 20 | DWR- 39 | 26.67 | 30.00 | 87.20 | 13.30 | 53 | 0.52 | 13.66 | 2.00 | 20.83 |
| 21 | DWR- 195 | 20.00 | 21.00 | 87.20 | 23.30 | 55 | 0.50 | 12.05 | 1.80 | 21.03 |
| 22 | GW- 10 | 26.67 | 29.00 | 86.40 | 14.33 | 61 | 0.43 | 15.39 | 1.89 | 24.83 |
| 23 | GW-40 | 22.22 | 25.00 | 90.20 | 10.00 | 58 | 0.47 | 13.56 | 1.88 | 22.16 |
| 24 | GW- 89 | 6.60 | 21.40 | 92.20 | 12.33 | 59 | 0.50 | 15.03 | 1.80 | 25.60 |
| 25 | GW- 120 | 31.11 | 36.90 | 90.20 | 21.00 | 43 | 0.42 | 11.07 | 2.00 | 17.00 |
| 26 | GW -173 | 28.89 | 34.60 | 90.20 | 18.30 | 42 | 0.45 | 12.37 | 2.12 | 19.00 |
| 27 | GW- 190 | 16.60 | 18.90 | 84.60 | 10.30 | 61 | 0.67 | 12.62 | 1.79 | 22.60 |
| 28 | GW- 273 | 20.00 | 28.20 | 78.70 | 9.60 | 56 | 0.57 | 12.18 | 2.00 | 20.00 |
| 29 | GW- 322 | 28.89 | 37.00 | 82.80 | 15.00 | 40 | 0.42 | 12.13 | 2.03 | 19.70 |
| 30 | GW- 496 | 6.66 | 9.00 | 92.20 | 11.00 | 72 | 0.74 | 11.89 | 1.63 | 23.50 |
| 31 | GW- 503 | 20.00 | 28.60 | 83.80 | 14.00 | 57 | 0.59 | 14.67 | 2.00 | 22.60 |
| 32 | HB-208 | 35.55 | 37.00 | 88.90 | 28.60 | 43 | 0.40 | 18.26 | 2.13 | 28.00 |
| 33 | HD- 1925 | 20.00 | 28.60 | 83.80 | 12.00 | 58 | 0.60 | 14.21 | 1.90 | 23.00 |
| C.D (P _≤ 0.05) | | 0.64 | 1.02 | 0.11 | 0.70 | 0.96 | 0.06 | 0.28 | .0012 | 0.73 |

* mean of 3 replications

Table-8: Correlation of mean leaf damage and incidence of Cereal leaf beetle with genotype characters

| Character | Plant height | No. of tillers | Leaf trichome length | Leaf trichome density | Flag leaf area | Flag leaf width | Flag leaf length |
|--------------------|-----------------|-----------------|----------------------|-----------------------|-----------------|------------------|------------------|
| Cereal leaf beetle | | | | | | | |
| Incidence | -0.24 (0.17) | -0.09 (0.61) | -0.82 (0.0001) | -0.87 (0.0005) | 0.35 (0.43) | 0.81 (0.0001) | 0.05 (0.78) |
| Degree of damage | -0.29 (0.10) | -0.16 (0.37) | -0.90 (0.0001) | -0.93 (0.0005) | 0.41 (0.016) | 0.95 (0.0001) | 0.02 (0.89) |

Value in parenthesis is P-value

4.4.3.1 Leaf trichome density

Highest trichome density 74 trichomes per square millimeter of leaf blade was observed in cultivar Ajanta and a lowest 40 trichomes per square millimeter was observed in GW-496 with an average value of 57.30 trichomes per square of millimeter (Table-7). A negative correlation was observed between leaf trichome density with incidence of cereal leaf beetle and leaf damage percentage with $r = -0.87$ and -0.93 respectively (Table- 8).

4.4.3.2 Leaf trichome length

Largest trichome length of 0.76mm was found in cultivar Ajanta and smallest of 0.40 mm was found in cultivar HB-208 with an average value of 0.57 mm (table 7). A negative correlation was observed between leaf trichome length with both incidence of cereal leaf beetle and percentage of leaf area damaged with $r = -0.82$ and $r = -0.90$ respectively (Table 8).

4.4.3.3 Plant height

As it is evident from Table-7 plant height ranged from 72.8 cm in cultivar DBW-14 to 116.84 cm in cultivar AKW-1071 with an average height of 86.6 cm. The plant height was found to be negatively correlated with both incidence of cereal leaf beetle and leaf damage percentage with $r = -0.24$ and $r = -0.29$ respectively (Table -8).

4.4.3.4 Flag leaf area

The data embodied in Table-7, clearly indicate that the largest flag leaf area was found in Indian wheat variety HB-208 (18.26 cm^2) and the smallest in AKW-381 (10 cm^2) with an average value of 12.89 cm^2 . A positive correlation was found between flag leaf area with both incidence and degree of damage having $r = 0.35$ and 0.41 respectively (Table- 8).

4.4.3.5 Flag leaf width

Also it is evident from Table-7, flag leaf width ranged from 2.13 cm in Indian wheat variety HB-208 to 1.53 cm in AJANTA with an average flag leaf width of 1.85 cm. the flag leaf width was found positively correlated with both incidence and degree of damage with $r = 0.81$ and $r = 0.95$ respectively (Table- 8).



a) Adult cereal leaf beetle in field



b) Larvae of cereal leaf beetle damaging wheat leaves



c) Eggs of cereal leaf beetle on leaves



d) Eggs of cereal leaf beetle under simple microscope

Plate-2: Cereal leaf beetle with its damage



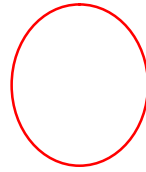
a) Armyworm larva on wheat



Plat

aves





a) Aphid on wheat leaf



b) Aphid on grains

Plate-4: Aphids on wheat leaves and grains





a) Larva of Gram pod borer (*Helicoverpa armigera* Hub.)



b) Gram bod borer damage to wheat grains



c) Adult of pod borer

Plate-5: Pod borer on wheat with its damage



a) Brown stink bug on wheat



b) Damage on wheat leaves



c) Damage on grains

Plate-6: Brown stink Bug with its damage on wheat



a) Rice grasshopper



b) Rice grasshopper damage on wheat leaves

Plate-7: Rice grasshopper with its damage on wheat leaves



a) Aster leaf hopper on wheat leaves



b) Damage on wheat leaves

Plate-8: Aster leaf hopper in wheat field and its damage



a) White grubs in wheat field



b) *Melolontha indica*



c) *Holotricha longipennis*



e) *Oryctes* sp.

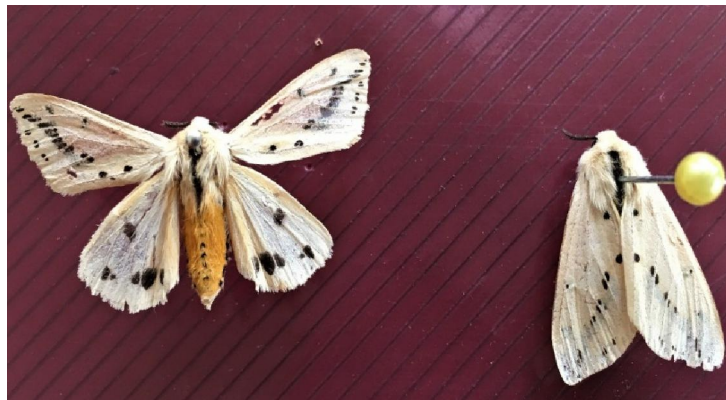
Plate-9: White grubs and its adults



a) Wire worm in wheat field



c) Broad headed bug on wheat



c) Bihar hairy caterpillar

Plate-10: Wire worm, Broad headed bug and Bihar hairy caterpillar in field



a) *Altica himensis* Shukla



b) *Phylotrata striolata* Fab

Plate-11: Flea beetle spp. observed during survey



a) Brown wheat mite on wheat leaves



b) Stippling of the leaf caused by Brown wheat mite

Plate-12: Brown wheat mite on wheat leaves with its damage

Chapter-5

DISCUSSION

The results obtained from the present investigation entitled “Insect Pest complex of Wheat in Kashmir” have been discussed in this chapter by establishing cause and effect relationship under the following headings:

5.1 Insect pest complex of wheat in Kashmir.

5.2 Screening of wheat genotypes for relative resistance against cereal leaf beetle.

5.1 Insect pest complex of wheat in Kashmir

Under the present study 17 insect pests were recorded in Sk-bala and Odina, 15 in Wadura, Drusu and Wakura, 13 in Munglu and Manigam and 12 in Akhal with variable infestation levels. The recorded insects were cereal leaf beetle, *Oulema melanopus* (Linnaeus) Aphid, *Rhopalosiphum maidis* (Fitch), Armyworm, *Mythimna separata* (Walker) Gram pod borer, *Helicoverpa armigera* (Hubner), Wireworm, *Agriotes* spp. Cutworm, *Agrotis ipsilon* (Hufnagel), White grubs, *Holotricha longipennis* (Hope), Brown stink bug *Carpocoris purpureipennis* (De Geer), Broad headed bug, *Camptopus lateralis* (Germar), Aster leaf hopper, *Macrostelus quadrilineatus* (Forbes) Brown wheat mite, *Petrobia latens* (Muller), Leaf eating caterpillar, *Spodoptera litura* (Fabricus) Rice grasshopper, *Oxya japonica* (Thunberg) Surface grasshopper, *Chrotogonus trachypterus* (Blanchard), Hairy caterpillar, *Aloa lactinea* (Cramer), Flea beetle, *Altica himensis* (Shukla) and Black bean aphids, *Aphis fabae* (Scopoli). Similar results has been found by Hayat (1977), Macrae (1998), Singh (1998), Das *et al.* (2000), Singh and Doel (2003), Duyn (2005), Singh *et al.* (2008), Ryan (2014), Sharma *et al.* (2013), Dhadwal *et al.* (2014) and Macharia *et al.* (2016).

The insect pest species recorded as major ones during present endeavor are Cereal leaf beetle, Aphid, and Armyworm. These findings are in agreement with Gallun *et al.* (1967), Ruppel (1967), Buntin *et al.* (2004), Ulrich *et al.* (2004) and

Livia (2007) who reported cereal leaf beetle as major pest of wheat. The other workers such as Anon (1987), Reed and Peek (1990), Miller (1994), Jarosik *et al.* (2003), Langham *et al.* (2005) and Ali *et al.* (2015) reported aphids as major pests of wheat, whereas Doel (1982), Roberts (2008) and Rondon *et al.* (2009) reported armyworm as predominant pest infesting wheat. The present investigations confirmed that insect pest species variation and their status completely depend on environmental conditions as Kashmir having cold climate and short cropping seasons.

5.2 Screening of wheat genotypes for relative resistance against Cereal leaf beetle

Results indicate that some of the Indian wheat genotypes selected for their relative resistance to *Oulema melanopus* have devised a mechanisms of non-preference (antixenosis) in terms of oviposition and feeding by the beetle. Lower feeding on plants of certain genotypes such as AJANTA and GW-496 are result of antixenosis. Although the genotypes involved in the trials were known to possess certain mechanisms of resistance, such mechanisms were not explored before and the current investigation helps to provide insights into possible causes of their resistance. This information is needed for more detailed studies that may result in development of commercial resistant cultivars.

Oulema melanopus did not feed actively on plants of the genotype AJANTA and GW-496. Adults feed actively when they are reproductively active and cause substantial damage to host plants (Haynes and Gage 1981; Kher *et al.* 2011); therefore, it was unusual that there was only slight feeding on AJANTA and GW-496 plants. This needs further exploration to identify plant morphological and biological characters that may be involved in hindering feeding and oviposition by adults. Other genotypes that appeared to exhibit greater antixenosis included AKW-381, AKW-1071, C-306, CHOTTI LERMA, OPAN-1796, OPAN-3004, DBW-16, DL-784-3, DL-803, GW-190. Given that strong antixenosis is absent in HD-1925, HD-208, GW-503, GW-322, GW-273, GW-173, GW-120, GW-89, GW-40,

GW-10, DWR-195, DWR-39, DWR-16, DURGAPURA-65, DL-788-2, DL-153-2, DBW-14, D-134, VL-22, SW-1 and SW-2, it is important to test whether any of these genotypes possess antibiotic characters that may hinder *O. melanopus* physiology resulting in cessation of continued feeding or death.

Most studies have indicated leaf pubescence as the main component of antixenosis in wheat for *O. melanopus* (Gallun *et al.*, 1966; Papp *et al.*, 1992); however, the phenomenon may not necessarily be restricted to pubescence, and other plant morphological characters have been reported to induce non-preference for oviposition and feeding. Wellso *et al.* (1973) pinpointed the influence of leaf width on oviposition and feeding by *O. melanopus* females, and reported an inverse relationship between leaf width and rate of oviposition. They found that plants with narrow leaves were less preferred for oviposition and suggested that leaf size characters can be considered important traits to screen for resistant germplasm. Similarly, silicaceous trichomes on leaves were noted to impart indigestibility of leaves causing antixenosis for larvae (Wellso, 1973). Narrow leaf margins between veins were deterrent for larval feeding due to the inability of larvae to accommodate their mouthparts to hold and skeletonize the leaves of certain genotypes (Shade and Wilson 1967). Hence, antixenosis in most wheat genotypes results from a variety of plant morphological and physiological characters. We have not explored what mechanisms confer antixenosis in the genotypes we studied and this warrants further research.

Mechanisms of resistance in wheat for *O. melanopus* have been widely explored (Everson *et al.*, 1966; Gallun *et al.*, 1966; Ringlund and Everson 1968; Smith *et al.*, 1971; Wallace *et al.*, 1974), and antixenosis for oviposition and feeding is regarded as the principal mechanism of resistance against the beetle in most wheat genotypes (Wellso 1973; Hoxie *et al.*, 1975). Our results concur with these studies.

Chapter- 6

SUMMARY & CONCLUSION

The present studies were undertaken to assess the insect pests of wheat crop and to screen different wheat genotypes for their relative resistance against cereal leaf beetle in Kashmir valley.

The part of the experiment pertaining to the study of insect pests of wheat in Kashmir was carried out at three different districts of Kashmir viz: Baramulla, Bandipora and Ganderbal. From each district three locations were selected on the basis of altitude viz: High, Medium and Low.

At Baramullah 15, 15 and 11 insect species from Wadura, Drusu and Imberzalwari respectively were recorded infesting wheat crop. Out of which only 3 insect pest viz: Cereal leaf beetle, Aphid and Armyworm were designated as major pest.

At Bandipora 17, 17 and 13 insect species from Sk-bala, Odina and Munglu respectively were recorded to infest wheat crop. . Out of which only 3 insect pest viz: Cereal leaf beetle, Aphid and Armyworm were designated as major pest.

Also at Ganderbal 15, 13 and 12 insect species from Wakura, Manigam and Akhal respectively were recorded to infest wheat crop. . Out of which only 3 insect pest viz: Cereal leaf beetle, Aphid and Armyworm were designated as major pest.

There were three major insect-pests viz: Cereal leaf beetle, Aphid and Armyworm recorded in Kashmir agroecosystem in wheat. The peak per cent infestation of Cereal leaf beetle (*Oulema melonopus*) was recorded during the first fortnight of June, 2018 at all the locations. The highest per cent infestation was recorded from wadura (34), sk-bala (32) and Wakura (32) of districts Baramulla, Bandipora and Ganderbal respectively.

The peak per-cent infestation of armyworm (*Mythimna separata*) was recorded during first fortnight of June, 2018 in sk-bala (34), Wakura (34) and wadura (30) of district Bandipora, Ganderbal and Baramulla respectively.

The peak per cent infestation of aphid was recorded during the first fortnight of April, 2018 in Wakura (56), Sk-bala (53) and Wadura (44) of districts Ganderbal, Bandipora and Baramulla respectively. Aphid, *Rhopalosiphum maidis* was found to be the dominant species infesting wheat in Kashmir

The part of the experiment pertaining to screening of wheat genotypes for relative resistance against cereal leaf beetle was carried out at FOA, Wadura. A total of 33 genotypes including checks were raised in Augmented Block Design with genotype to genotype spacing of 50 cm and plant to plant spacing of 10 cm. All the genotypes were evaluated for their resistance towards cereal leaf beetle under natural infestation conditions. Observations on percentage of leaf area damaged was recorded. Very low damages were reported on the Indian wheat varieties namely Ajanta (7%) followed by GW-496 (9%). While as highest damage (37 %) was found on the cultivar HB-208, it was closely followed by GW-120, GW-322, DL-788-2 and GW-173 with leaf damage of 36.9, 35, 35, and 34.6 per cent respectively. The results obtained from percentage of leaf area damaged revealed that there were 2 genotypes viz: Ajanta and GW-496 found resistant ; cultivars AKW-381, AKW-1071, C-306, CHHOTI LERMA, OPAN-1796, OPAN 3004, DBW-16, DL-784-3, DL-803, and gw-190 were categorised as Moderately resistant; SW-1, SW-2, VL-22, HD-1925, HD-208, GW-503, GW-322, GW-273, GW-173, GW-120, GW-89, GW-40, GW-10, DWR-195, DWR-39, DWR-16, DURGAPURA-65, DL-788-2, DL-153-2, DBW-14 and D-134 as Moderately susceptible while as no genotype with complete susceptibility was found. Degree of damage was observed to be significant and negatively correlated with trichome density and trichome length.

CONCLUSION

- ✚ Wheat crop was infested by many insect pests during its entire season. Under the present study 17 insect pests were recorded in Sk-bala and Odina, 15 in Wadura, Drusu and Wakura, 13 in Munglu and Manigam and 12 in Akhal with variable infestation levels.
- ✚ The major pests noticed during the surveys from all the locations were Cereal leaf beetle, Aphid and Armyworm.
- ✚ The incidence of Cereal leaf beetle was found to be highest in genotype HB-208 and lowest in genotype AJANTA.
- ✚ Differential response found in cultivars for relative resistance against cereal leaf beetle showed AJANTA and GW-496 as resistant to Cereal leaf beetle, suggesting their incorporation in breeding of Cereal leaf beetle resistant wheat varieties.
- ✚ Plant characters such as plant height, trichome density and trichome length were found to be negatively correlated with the degree of damage.

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