3.1. Study Area

Jammu and Kashmir is the Northern most region of India. (Fig. 2b). It lies in between 32°17’ and 36°58’ North latitude and 73°26’ and 80°30’ East longitude. It comprises of beautiful scenic beauty. It encompasses total area of 2,22,236 sq. kms, of which 78,114 sq. kms has been illegally occupied by Pakistan and 42,685 sq. kms is under China. The state has international boundaries with Tibet in east, China and Afghanistan in the north and Pakistan in the west, Punjab and Himachal Pradesh lies to its south. More than 90 percent of the state is mountainous and height from sea level varies between 1,000 feet to 28,500 feet. From Southwest to Northeast, the region contains fertile Jammu and Poonch plains, the sub Himalayan foothills from 2,000 to 7,000 feet, heavily glaciated Pir Panjal range at 12,500 feet, the valley of Kashmir at 5,300 feet, the Great Himalayan ranges above 20,000 feet, the upper Indus river valley at 11,000 feet, the barren plateau of Ladakh and the remote Karakoram range. The state has number of lakes, rivers, rivulets and glacial regions. From geographical point of view, Jammu and Kashmir State consists of four major zones;

1. Sub- mountain and Semi- mountain plain known as Kandi or dry belt.

2. The Shivaliks

3. The high mountain zone mainly constituting the Kashmir valley, Pir Panjal range and its off-shoots. This includes Doda, Kishtwar, Poonch and Rajouri districts and part of Kathua and Udhampur districts.

4. The Great Himalayas comprises Tibetan tract of Ladakh and Kargil consisting of middle run of the Indus river.

Jammu Division

Jammu Division is situated between longitude 74°91’ east and latitude 32°67’ north and varies from nearly 1000 feet to 1200 feet above sea level. Jammu division has plain areas as well as mountainous region including valleys and river basins of which, 24 lakh hectares form agricultural land. Plains areas of this region which are continuous with
Punjab have the tropical heat and share with it the periodical rainfall. Due to these extreme variations within a limited distance there is a marked difference in climate. Jammu division is divided into 10 districts i.e. Jammu, Kathua, Sambha, Udhampur, Doda, Kishtwar, Poonch, Reasi, Rajouri, and Ramban.

The present investigator has carried out this work in District Kishtwar of Jammu Division.

District Kishtwar

The plateau of Kishtwar lies at latitude 32° 53’ and 34°21’ N and longitude 75°1’ and 76° 47’E and is 1638 meters or 5300 feet above sea level. It is about 240 kilometres from the winter capital of the state. (Plate-5b, 6a) Kishtwar district is a newly formed district of Jammu and Kashmir. It has been curved out of Erstwhile Doda district in the year 2007 and started functioning as independent administrative unit on 01-04-2007.

It is situated on the bank of river Chenab. A project on Chenab named Dul Hasti hydroelectric power project (390 MW) is located in Kishtwar which is an ample source of hydroelectric energy to the state and nation thus earning good revenue for the state. However, a number of new hydropower projects are in the list for approval and initiation.

Popularly known as the Land of Sapphire and Saffron, it has been endowed by nature with rich vigour. Kishtwar has the honour of being amongst the world’s few places where quality Saffron (Crocus sativus), Black zeera (Bunium bulbocastanum), Gucchi (Morchela esculants), Chilgoza (Pinus gerardiana) are cultivated. Forests of deodar, pine and fir are timber treasure of the area.

Net cultivated area of Jammu region is estimated at 3.9 lakh Hectare and area covered under Pulses production is equal to 33.26 ('000 Hectare). (Directorate of Agriculture, Jammu)

Total geographical area of Kishtwar is 160384 hectare. Gross cultivated area is 25078 hectare and net sown area is 19064 Hectare. The area covered under pulse
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cultivation is **1045 hectare** (Directorate of Agriculture, Jammu). Agriculture is the main occupation for people in Kishtwar and earns livelihood to them.

Amongst vegetarian cousine, Rajma chawal holds a respected place. Rajma grown in Kishtwar area are renowned and in demand throughout India for its best taste and aroma. Moreover, it acts as ready cash to the growing farmers as they earn money by selling it to the markets. The lush green foliage of host plant acts as a potent host for many insect pests and so, a number of insects pests gets attracted to the standing crop in search of food as well as shelter. In this process of procuring food, these insects cause significant damage to the viability of the host plant thus decreasing its annual yields.

An extensive survey of the district was done so as to know about the various rajma producing areas. After the survey, five stations were selected for doing detailed practical investigations, covering five large tehsils i.e. Kishtwar (**Galighar** at Altitude- **1630 meters** above Sea level) (Plate-5d, 6b), Padder (**Atholi** at Altitude- **1940 meters** above Sea level) (Plate-5d, 6c), Chatroo (**Dangar Nallah** at Altitude- **3330 meters** above Sea level) (Plate-5d, 6d), Nagseni (**Padhyarna** at Altitude- **1645 meters** above Sea level) (Plate-5d, 6e) and Marwah (at Altitude- **3500 meters** above Sea level) (Plate-5d, 6f).

Exhaustive and regular visits were made to the field stations with regard to the various purposes of the research including collection of diversity of insect pests associated with the host plan, pest complex formation, mode of infestation, biological studies and life table formation of major pests. However, for ecological and population dynamics studies of major pest, three stations were selected i.e. **Galighar (Kishtwar)**, **Atholi (Padder)** and **Padhyarna (Nagseni)** as it was not possible to reach remotest area Dangar Nallah (Chatroo) and Marwah on weekly basis. It is important to mention that a small plot of rajma was also grown in the kitchen garden by the present investigator so as to provide fresh food to the rearing insect pests.

The insect diversity was collected from the field plantations as well as from the stored grains so as to document total insect pest complex of Rajmash from District Kishtwar. Some insects were found causing significant damage and have been listed as
major pests. Their life cycle and biology has been studied in detail including nature, mode and extent of damage caused by larval and adult stages.

3.2. Collection and Preservation of insects

Collection

The practical was done both in the standing fields at district Kishtwar as well as in the make shift lab from April 2013 – Oct 2015. Traditional methods were used for collection of insect pests including hand picking, beating and entomological nets. The immature stages were collected using soft camel brush, needles, forceps, glass tubes, polyethene bags and plastic boxes.

In case of stored insect pest, stock of Rajma in household, shops and wholesale distributors was analysed so as to find the insect pest associated with it under stored conditions. As a good sign, many insects were not found damaging the pulse. During the present study only one insect pest; Callosobruchus chinensis was found attacking grains of Rajma during the survey of 3 years, from 2013 – 2015. The infested grains were broken using sharp razor and forceps and the interior was scanned for instars. Dissection microscope, Compound microscope and Stereo microscope were used to study the details of different larval stages.

Natural enemies were also recorded which were found attacking major insect pest of rajma. The infested larvae were reared and the parasitoids so emerged were later identified from concerned agencies.

Preservation

The collected specimens were killed with benzene or ethyl acetate vapours in the killing bottles. Killed insects were made to relax on blotting paper for some time. Then proper stretching was done on thermocol sheets after pinning. Process of pinning is different for different orders of insects i.e. the mid of mesothorax in case of Lepidopterans, Coleopterans were pinned on the right elytra, Hemipteran were pinned on triangular scutellum slightly towards right, in Orthopterans pinning was done in thorax part and carding in case of minute insects.
After pinning, the specimens were dried properly and were carefully placed in the entomological boxes. Naphthalene balls were pierced with hot paper pins and then pinned at the corners of box properly. These entomological boxes were placed carefully for further studies and identification purpose.

However, another preservation technique using a special solution known as **KAAD mixture** was used for storing immature stages of major insect pests. Larvae and pupae were dipped in this solution before storing them in the alcohol solution. Borror and DeLong (1973) proposed a procedure for making KAAD solution. It include following ingredients in the ratio of, as given:

- Ethyl Alcohol: 7 to 10 parts
- Dioxane: 1 part
- Kerosene Oil: 1 part
- Glacial Acetic Acid: 2 parts

All the ingredients were mixed properly as per their ratio. The immature stages were dipped in it for sometime up to 24 hours. After the stipulated time, they were taken out and stored in 80 – 90 % Ethyl alcohol. Importance of KAAD solution is that it keeps the colour intact which helps in identification of the insect specimen.

### 3.3. Morphological and Morphometric Studies

Morphological description of different stages of major pests as well as insects collected were made using microscope. However, for morphometric calculations of adult insects traditional methods including graph paper and use of scale were used. For measuring the developmental stages like egg and larvae, occulometer calibrated against a stage microscope was used.

### 3.4. Biological studies of Major pests

The present research work was done both in the standing field of host crop as well as in the makeshift lab. The collected material was brought to make shift lab. for further entomological investigations. Adult insects were collected using traditional methods like hand picking and entomological nets. However, the delicate eggs were shifted from field
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to the make shift lab very cautiously. As the moths lay their eggs on the leaves so the infested leaves were plucked carefully and were brought to the lab.

In the makeshift laboratory clean, large plastics boxes were used as rearing cages. The upper lid of boxes was perforated properly with the help of hot iron bars so as to ensure proper air supply. The lower bottom of boxes was covered with moist filter paper which was changed regularly during the life cycle studies. Immature stages were provided with fresh leaves every day. The faecal waste and left out leaves were changed regularly. For pupation, raw material was provided in the box including dried leaves and a pile of refined soil. Number of moults was determined on the bases of casted head capsule and skin.

In case of *Alcidodes signatus*, male and female were collected and released in the rearing boxes for further biological investigations. However, the infected twigs and stems were collected from fields so as to study the behaviour of immature, by cutting them neatly with sharp razor.

As the present study was carried out in the field as well as in the lab. so larvae of major insect pest *Thysanoplusia orichalcea, Spilarctia luteum, Callimorpha principalis* were collected from the standing fields of rajmash from five different study stations and shifted to makeshift lab. The collected larvae were shifted to the plastic boxes containing filter paper at the base and fresh leaves of the host plant. The leaves given to larvae as feed were changed daily till pupation. As the insect pest pupates in the leaf litter or debris so the dry leaves were placed in the rearing box towards the maturity of final instar.

After emergence of the adult, 10 percent honey solution dipped in cotton swabs were placed in the rearing box for recording longevity of adults. These cotton swabs were replaced daily. Camel hair brush was used for transferring eggs from old leaves to the fresh leaves.

3.5. Population Dynamics Studies of Major insect pest

For monitoring the larval population of slender burnished moth, *Thysanoplusia orichalcea* fields were selected at three study stations i.e. Galighar, Padhyarna and
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Atholi. Each rajma field was divided into five blocks i.e. four blocks from four directions and one at centre. From each field 50 plants were selected randomly from all five blocks, at weekly interval throughout the season i.e. from April to October for consecutive two years 2014 and 2015 for number of larvae. The mean population of larvae collected during 2014-2015 was correlated with weather parameters including maximum and minimum temperature, rainfall relative humidity_{morning} and relative humidity_{evening} for calculating Pearson’s coefficient and P-value.

3.6. Collection of Meteorological Data

As the population dynamics studies includes the studying the behaviour of insect pests in relation to the various weather parameters so the meteorological data was needed. Meteorological data on **weekly basis** including the following parameters was collected from The Indian Meteorological Station, Rambagh, Srinagar, for a period from March 2014 – October 2015.

01. Relative humidity (Morning and Evening)
02. Temperature (Max. and Min.)
03. Rainfall (Weekly)

3.7. Statistical Analysis of Data: The data generated during research was subjected to various statistical operations, which are enlisted as;

3.7.1. Standard Deviation (sd):

\[ SD = \sqrt{\frac{\sum d^2}{n}} \]

Where \( d \) = deviation from mean

\( N \) = the total no. of observations

3.7.2. Relative Abundance (R.A):

\[ \text{R.A of a species} = \frac{\text{No. of individual of the species}}{\text{No. of individuals of all species}} \times 100 \]
3.7.3. Ecological Indices:

3.7.3.1. Shannon – Weaver Diversity Index (H): The index takes into account both the number of species and the distribution of individuals among species. Species diversity was determined by using Shannon-Weaver Diversity Index using formula;

\[ H = -\sum_{i=1}^{S} p_i \ln(p_i) \]

Where \( H \) = information content of the sample;

\( S \) = number of Species

\( p_i \) = proportion of total no. of species belonging to \( i^{th} \) species.

Areas with high value of \( H \) are more diverse.

3.7.3.2. Simpson’s Diversity Index (D): The index measures the abundance of the commonest species rather than species richness.

\[ D = \sum_{i} n_i (n_i - 1)/N (N-1) \]

Where, \( n \) = the total number of organisms of a particular species

\( N \) = the total number of organisms of all species.

Its value ranges between 0 – 1. Bigger the value of \( D \), lower the diversity of the area.

3.7.3.3. Margalaf Richness Index (d):

Species richness is the simplest measure of biodiversity and is simply a count of the number of different species in a given area. The Margalaf diversity index was easily calculated using the formula;

\[ d = (S - 1) / \ln N \]

Where, \( S \) = number of species

\( N \) = total number of individuals in the sample.
3.7.3.4. **Pielou’s Index (J):** Also known as **Evenness index.** Evenness means measurement of the relative abundance of the different species which makes richness of an area. A community dominated by one or two species is considered to be less diverse than one in which several different species have a similar abundance.

\[
J = \frac{H}{\ln(S)}
\]

Where, \(H = \text{Shannon Weiner diversity}\)

\(S = \text{the total number of species}\)

3.8. **Identification of Insects**

The collected well preserved specimens of insects were identified by the help of Principal Scientist and experts at Entomological Division, Indian Agricultural Research Institute (IARI), New Delhi and ZSI, Solan.

3.9. **Photography**

The photography of biological stages of major insect pests was done using digital still camera **Sony DSC-TX55 Cybershot with inbuilt double macro** function. This helped in studying the minute details of the developmental stages, specially eggs and immature larval instars. Field photography as well as the photography of preserved specimens was clicked with digital still camera **Sony DSC- HX400.**