

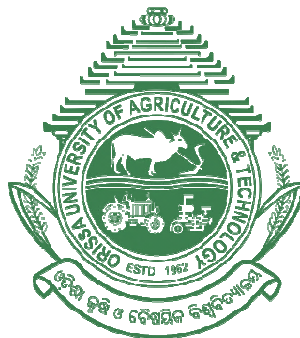
**Effect of weather on population built up of
major insects and natural enemies of aromatic
rice under staggered planting**

*A Thesis submitted to the
Orissa University of Agriculture and Technology
in Partial fulfilment of the Requirements for the degree of
Master of Science in Agriculture
(Agrometeorology)*

By

DEBASHREE SARKAR

Adm. No. 08/AM/16



**DEPARTMENT OF AGRICULTURAL METEOROLOGY
COLLEGE OF AGRICULTURE
ORISSA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
BHUBANESWAR
2018**



**ORISSA UNIVERSITY OF AGRICULTURE & TECHNOLOGY
DEPARTMENT OF AGRICULTURAL METEOROLOGY
COLLEGE OF AGRICULTURE
BHUBANESWAR**

Dr. (Mrs.) Anupama Baliarsingh
Associate Professor
Agrometeorologist
College of Agriculture
Orissa University of Agriculture & Technology

CERTIFICATE - I

This is to certify that the thesis entitled “**Effect of weather on population built up of major insects and natural enemies of aromatic rice under staggered planting**” submitted in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE (AGRICULTURAL METEOROLOGY)** to the Orissa University of Agriculture and Technology is a faithful record of *bona fide* and original research work carried out by **DEBASHREE SARKAR** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received by her from various sources during the course of investigation has been duly acknowledged.


13/6/18
Chairman
Advisory committee



**ORISSA UNIVERSITY OF AGRICULTURE & TECHNOLOGY
DEPARTMENT OF AGRICULTURAL METEOROLOGY
COLLEGE OF AGRICULTURE
BHUBANESWAR**

CERTIFICATE II

This is to certify that the thesis entitled “Effect of weather on population built up of major insects and natural enemies of aromatic rice under staggered planting” submitted by **DEBASHREE SARKAR** to the Orissa University of Agriculture and Technology, Bhubaneswar, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (AGRICULTURAL METEOROLOGY)** has been approved by the student’s advisory Committee and the external examiner.

Advisory Committee

Chairman: **Dr. Anupama Baliarsingh**
Agrometeorologist
Department of Agricultural Meteorology
College of Agriculture,
O.U.A.T, Bhubaneswar

Members:

1. **Dr. B. S. RATH**
Professor & Head
Dept. of Agricultural Meteorology
CA, OUAT, Bhubaneswar

2. **Dr. H. P. Mishra**
Professor
Department of Entomology
College of Agriculture
O.U.A.T, Bhubaneswar

External examiner

20/6/18

(Name and Designation)

PROFESSOR, BCKV
Mohampur.

ACKNOWLEDGEMENT

I deem it unique opportunity to express my profound sense infinitum gratitude, indebtness and reverence to the chairman of my Advisory Committee Dr. A. Baliarsingh, Associate Professor, Agrometeorologist, Department of Agricultural Meteorology, College of Agriculture, O.U.A.T., Bhubaneswar for her sustained interest. Persistent guidance, ceaseless encouragement and pensive remarks throughout the study to take this endeavour a reality.

I feel also indebted to Dr. B. S. Rath, Professor & Head Department of Agricultural Meteorology, College of Agriculture, O.U.A.T., Bhubaneswar for his co-operation, love and parental help for this.

I profess my heartfelt gratefulness and sincere esteem to Dr. H. P. Misha, Associate Professor, Department of Entomology, College of Agriculture, O.U.A.T., Bhubaneswar for his valuable insinuation, constructive suggestion and noble guidance during the course of my investigation.

I also express my deep sense of gratitude and reverence to Dr. A.K.B. Mohapatra, Associate Professor, College of Agriculture, O.U.A.T., Bhubaneswar.

It will be a matter of regret, if I fail to acknowledge the love; accelerating inspiration and help I got from Dr. A. Baliarsingh, Associate Professor, Department of Agricultural Meteorology, Dr. H. P. Mishra, Professor of Department of Entomology, College of Agriculture, O.U.A.T., Bhubaneswar during my post graduation thesis work.

I sprightly acknowledge all the staff members of Department of Agricultural Meteorology for the help rendered by them all through the thesis work specially Ashutosh Nanda bhai, Gouri bhai, Biswa bhai, Ambika bhai, Jaisankar bhai, Jairam bhai, Satya bhai and Suryakanti mam for the help during my thesis work.

I also wish to place on record my sincere and heartiest feelings to my classmates Sunita, Deepanjali, snigdha, Manjari, Padmanav, Debasish and Jagadeesh for their good will and steady encouragement.

I am unable to express in words, the inspiration and blessings I got from my father, Mr Tarun Ku. Sarkar, and mother Smt. Sumitra Sarkar, my living god, who made me to stand in the society.

I extend my special and hearty thanks to Monalisha, Banani, Sudipta, Sangyan, Bani, Lopa, Shalini, Krupali, Lina, Reeta, Mou, Lipi, Suraj, Deepayan, Basant, Ghasi bhai, Pravu bhai, and my roommate kiran for their consistent love, help, co-operation and encouragement during my entire studentship in this institution and completion of thesis.

It will be my preposterousness to verbalise deep sense of exaltation for my vulnerable parents, Deba daa, Sumitra boudi, Sparsh , Biswa mama, Sabitri masi, Sankar meso, Mangal meso, Choto masi, Bado pisi, Anurag daa, Pinky boudi, Sada sir for their inviolable sacrifice solicitous contrivance and blissful blessing which have made me so today.

Finally I solicit the benediction of omnipresent scared divine for the progress and prosperity in the every sphere of my life.

Bhubaneswar
Dated. 13.06.2018.

Debashree Sarkar.
(DEBASHREE SARKAR)
Adm.No.08 AM/16.

ABSTRACT

Globally rice is one of the most important cereal crop. With growing demand for aromatic rice in the local and international market in recent years, many of them found to be susceptible to insect pests therefore discarded by the farmers. About 300 species of insects have been reported attacking rice crop in India, out of which 20 are considered as the major pests. Present investigation was carried out to study the effect of weather parameters on infestation of major insects and natural enemies under staggered planting with 12 dates starting from 16th July 2017 to 1st January 2018 at 15 days interval and three varieties such as Geetanjali, Poornabhog and Pusa Sugandh-II. The experiment was conducted in Agrometeorology field, Central Research Farm, Orissa University of Agriculture and Technology Bhubaneswar during 2017-2018. The crop was infested with major insects such as Brown Plant Hopper (BPH), White Backed Plant Hopper (WBPH), Green Leaf Hopper (GLH), Whorl Maggot (WM), Yellow Stem borer (YSB), Gundhi bug (GB) and Predators namely Spider, Dragon Fly and Ladybird Beetle, during entire crop growing period. BPH occurrence was more in 1st August and 16th November planting dates, which was positively correlated with rainfall (0.55-0.78). WBPH occurrence was found most of the planting dates and it was positively correlated with maximum temperature (0.56), minimum temperature (0.58-0.67) and rainfall (0.61). Peak occurrence of WM was found in 1st week of December and 1st week of November planting dates, which was positively correlated with rainfall (0.68) and relative humidity (0.58). YSB was found in every planting dates and was positively correlated with both maximum (0.57) and minimum temperatures (0.55-0.65). GB was found in 1st September and 1st January, was negatively correlated with RH. Among predators, spider was found in all dates of planting and significantly correlated with Minimum temperature, RH and negatively correlated with BSH. Dragon fly and Damselfly were found in 16th September and 1st November dates, and were positively correlated with maximum temperature (0.51) and negatively correlated with relative humidity (-0.52). Ladybird Beetle was found in 1st August planting date and was significantly negatively correlated with maximum temperature (-0.67) and negatively correlated with bright sunshine hour (-0.53). The peak occurrence of BPH, GLH and GB was observed at maximum temperature range of 32-34^o C, minimum temperature 24-27^oC with high humidity 91-95%, weekly cumulative rainfall of >60 mm under low sunshine hour (3-4 hour). The peak occurrence of WBPH and YSB infestation was found at maximum temperature range of 33-35^oC, minimum temperature 15-22^oC under dry condition.

CONTENTS

CHAPTER	TITLE	PAGENO
I	INTRODUCTION	1-4
II	REVIEW OF LITERATURE	5-22
III	MATERIALS AND METHODS	23-35
IV	RESULTS	36-65
V	DISCUSSION	66-70
VI	SUMMARY AND CONCLUSION	71-73
	REFERENCES	i-vii
	APPENDICES	viii-xii

LIST OF TABLES

TABLE	PARTICULARS	PAGE
3.1	Weekly Weather data of Central Research Farm, OUAT, Bhubaneswar from June 2017 to April 2018	24
3.2	Cropping history of experimental field	25
3.3	Calendar of operation	30
4.1	Weekly BPH Population Per Hill	36
4.2	Correlation studies of BPH population density with weather parameters in different planting dates	37
4.3	Weekly WBPH Population Per Hill	39
4.4	Correlation studies of WBPH population density with weather parameters	41
4.5	Weekly GLH Population Per Hill	42
4.6	Correlation studies of GLH population density with weather parameters	44
4.7	Weekly WM Infestations in Percentage	45
4.8	Correlation studies of WM infestation with weather parameters	47
4.9	Weekly Occurrence of DH in Percentage	48
4.10	Weekly Occurrence of WEH in Percentage	48
4.11	Correlation studies of occurrence of DH with weather parameters	51
4.12	Correlation studies of occurrence of WEH with weather parameters.	52
4.13	Weekly GB Population Per Hill	53
4.14	Correlation studies of population density of GB with weather parameters	55
4.15	Weekly Spider Population Per Hill	56
4.16	Correlation studies of population density of Spider with weather parameters	57
4.17	Weekly Dragon fly and damselfly (DFLY) Population Per m ²	59
4.18	Correlation studies of population density of DFLY with weather parameters	60
4.19	Weekly Lady bird beetle Population Per m ²	62
4.20	Correlation studies of population density of LBB with weather parameters	64
4.21	Response of variety towards population built up of Insects and Natural enemies	64

LIST OF FIGURES

FIGURE	PARTICULAR	PAGE
3.1	Layout plan of experimental field	26
3.2	Experimental plot	32
3.3	Field observation	32
3.4	Brown plant hopper	33
3.5	Green leaf hopper	33
3.6	White ear head	34
3.7	Dead heart	34
3.8	Whorl maggot infestation	34
3.9	Gundhi bug	34
3.10	Spider	35
3.11	Dragonfly	35
3.12	Damselfly	35
3.13	Lady bird beetle	35
4.1	Favourable weather parameters for BPH population	38
4.2	Favourable weather parameters for WBPH population	40
4.3	Favourable weather parameters for Green leaf Hopper population	43
4.4	Favourable weather parameters for whorl maggot infestation	46
4.5	Favourable weather parameters for dead heart occurrence	49
4.6	Favourable weather parameters for white ear head occurrence	50
4.7	Favourable weather parameters for gundhi bug population	54
4.8	Favourable weather parameters for spider population	58
4.9	Favourable weather parameters for DFLy population	61
4.10	Favourable weather parameters for lady bird beetle population	63

ABBREVIATIONS USED

@	:	At the rate
%	:	Percentage
cm	:	Centimeter
m	:	Metre
g	:	Gram
Kg	:	Kilogram
t	:	Tonne
cm ²	:	Square centimetre
m ²	:	Square metre
ha	:	Hectare
kg ha ⁻¹	:	Kilogram per hectare
t ha ⁻¹	:	Tonne per hectare
DAT	:	Days after transplanting
et al.	:	And others
Panicle ⁻¹	:	Per panicle
hrs	:	hours
i.e.	:	that is
Tmax	:	Maximum temperature
Tmin	:	Minimum temperature
°C	:	Degree Celsius
RF	:	Rain fall
Temp.	:	Temperature
RH1	:	Morning Relative Humidity
FYM	:	Farm yard Manure
RH2	:	Afternoon Relative Humidity
etc.	:	And so on
PI	:	panicle initiation
BSH	:	Bright sunshine hours
kmph	:	Kilometre per hour
mm	:	Milimetre
BPH	:	Brown plant hopper
WBPH	:	White Backed plant hopper
GLH	:	Green leaf hopper
WM	:	Whorl maggot
YSB	:	Yellowstem borer
GB	:	Gundhi bug
Dfly	:	Dragonfly and damselfly
LBB	:	Lady bird beetle
CV	:	Cultivar

INTRODUCTION

Rice (*Oryza sativa L.*) is one of the important cereal crops of the world and forms the staple food for more than 65 per cent of the world population and is known as king of cereals. Nearly 90 per cent of the area, production and consumption of rice are confined to South East Asian countries. It is a unique creation of crop plant domestication. It is unique in having cultivars of maturity duration varying from less than 80 days to more than 180 days and showing adaptability to a wide range of land types and water regimes, including conditions of water stagnation where no other crop could possibly be grown.

Domestication of rice might have started before 3000 B.C. and possibly at a number of locations in South and Southeast Asia. In Odisha, rice is synonymous with food. Agriculture in Odisha to a considerable extent means growing rice. Age-old social customs and festivals in Odisha have strong relevance to different phases of rice cultivation: Akhyatrutiya in May-June marks the seeding of rice, Rajasankranti in mid-June marks the completion of sowing, Garbhanasankranti in October symbolizes the reproductive phase of rice, while Nuakhaee and Laxmipuja coincide with the harvesting of upland and lowland rice, respectively. Makarsankranti in mid-January is celebrated as Chaita Parabhy the tribal people as by this time rice is threshed and brought to the granary. Rice covers about 69% of the cultivated area and is the major crop, covering about 63% of the total area under food grains. It is the staple food of almost the entire population of Odisha; therefore, the state economy is directly linked with improvements in production and productivity of rice in the state. In Odisha rice production is 5857 thousand tonnes and in India rice production is 93880 thousand tonnes. Different types of rice cultivars are grown in India. Among all Basmati rice cultivars are characterized by extra long superfine slender grains and pleasant aroma after cooking (Bhattacharjee *et al.*, 2002). India produces about 70% of the world's basmati production and nearly two third of the total production is exported to other countries. With growing demand for aromatic rice in the local and international market, high

emphasis has been laid on development and improvement of basmati types. In spite of high quality traditional basmati varieties in India, the research is continued for the development of many new basmati and hybrid varieties of rice with better quality and agronomic traits to meet the consumer and farmers demand (Joshi and Behera, 2006).

Climatic factors e.g., rainfall, temperature and humidity are the key factors for development of any rice insect pest and their natural enemies (friendly arthropods). Global warming is predicted to increase frequency of precipitation/rainfall, intensity of drought and solar-radiation/UV -B radiation which might affect the intensity and severity of rice pests in one hand, but also change in other friendly arthropods on the other hand. Climate change may influence the pest-plant and pest-natural enemy, finally ecological relationship, resulting in positive or negative influence on intensity and outbreak of pests. Climate change along with other intervention such as crop diversity, variety, irrigation, cropping intensity, fertilization in rice production systems affect the in density and severity of pests and natural enemies in the ecosystem.

The rice ecosystem is bestowed with a lot of pests and natural enemies complex. Insect pests constitute the major yield limiting biotic stresses throughout the rice growing countries. About 300 species of insects have been reported to attack rice crop in India, out of which 20 are considered as the major pests. Among the insect pests, yellow stem borer (*Scirpophaga incertulas* Wik.), brown plant hopper (*Nilaparvata lugens* Stal.), green leaf hopper (*Nephotettix spp.*), ear head bug (*Leptocorisa oratorius* Fabricius), leaf folder (*Cnaphalocrocis medinalis* Gn.) and case worm (*Nymphula depunctalis* Guenee) are predominant. These pests infest the crop at all stages of plant growth and cause a variety of damage to the plant such as tissue boring, sap sucking, defoliation and leaf scrapping. Among the biotic stresses insect pests cause about 10-15% yield losses.

Paddy crop in the field is attacked by numerous guilds of insect pests, but few causes significant losses. Losses caused by the insect pests are the main constraint in achieving high yield of rice. Five species of stem borers are distributed throughout India.

Among these, YSB is the most widespread, dominant and destructive pests. It causes damage to rice throughout the crop growth period. At tillering stage, the stem borer larva enters in the tiller and feeds inside resulting in dead heart. Where in the central leaf whorl does not unfold, turns brownish and dries out although the lower leaves remain green and healthy. The affected tillers do not bear panicles. At reproductive stage, the damage is characterized by conspicuous whitish empty panicles which are called white ears. Yellow stem borer (YSB) *S.incertulas* of rice has been given the status of major pest of Odisha. Green leaf hopper (GLH) causes damage by direct feeding as well as by acting as vector of diseases. Both nymphs and adults suck the sap from leaves and cause yellowing of the crop. Tungro and yellow dwarf diseases were transmitted by this pest. White backed plant hopper (WBPH) damage the crop from seedling stage to tillering stage. Large yellow patches develop in the fields which are spectacular from a distance, they spread in concentric rings. The BPH (*N.lugens*) cause direct damage to rice plant by sucking the plant sap. In addition to the feeding damage, it also transmit grassy stunt and wilted stunt virus diseases of rice. Heavy damage caused by brown plant hopper can be identified by the development of circular patches in the field, which is termed as hopper burn. Brown plant hopper (BPH) is the most important sucking pest of rice growing tracts of India. The caterpillar pests of rice such as case worm and leaf folder are of minor importance but sometimes cause considerable losses to rice.

Rice ecosystem is conducive for proliferation of insect-pests is also equally congenial for multiplication of the natural enemies of these pests. The populations of almost all the insect-pests of rice are influenced by their natural enemies. However, the extent of their influence on insect-pests can be judged only by simultaneously monitoring the population of both the pest as well as their natural enemies. Conservation of the natural enemy fauna in situ for suppressing the pest population seems to be a very good alternative. In case of leaf and plant hoppers, predators are more important regulating factors. The important ones are the mirid bug, coccinellid beetle, *staphylinid* beetles, spiders, dragonfly and damselfly.

Insect pests causes heavy loss in yield which varies from place to place. Therefore there is need to carry the statistical study to minimize the losses in crop yield due to weather and insect pests. A systematic study on the effect of weather on population built up of major insects and natural enemies is necessary in Odisha and information pertaining to screening of rice varieties for this region is yet to be generated. Hence, the topic **“Effect of weather on population built up of major insects and natural enemies of aromatic rice under staggered planting”** has been proposed with the following objectives;

1. To study about population built up of major insects and natural enemies in aromatic rice under staggered planting.
2. To know the peak period of major insects incidence during aromatic rice growth period.
3. To find out the correlation between major insect population and natural enemies of aromatic rice with different weather parameters under staggered planting.



REVIEW AND LITERATURE

From a survey of literatures on various aspects pertaining to the present investigation, it reveals that not much literature available on Effect of weather on population built up of major insects and natural enemies of aromatic rice under staggered planting. However, the present review of literature is an attempt to trace out work made earlier within and outside India with a view to presenting critical evaluation of different aspects viz. to study the economic status of major insect contributing loss to the rice production, to ascertain the population dynamics and peak period of major insect and natural enemies, to study the correlation between weather and insect population. The scattered reports of relevance, based on works done else where in India and abroad, have been reviewed under the following heads.

2.1 Population built up of major insects of rice

Total 12 insect pests feeding on paddy crop. Out of these, the brown plant hopper (*Nilaparvata lugens*), white backed plant hopper (*Sogatella furcifera*), followed by the leaf folder (*Cnaphalocrocis medinalis*) in isolated patches, were recorded as major pests of this crop, whereas the green-horned caterpillar (*Melanitis leda ismene [M. ismene]*), skipper (*Parnara guttatus*), stem borer (*Chilo suppressalis*), thrips, green leafhopper (*Nephotettix* sp.), hispa (*Dicladispa armigera*), grasshopper (*Oxya yezoensis*) and caseworm (*Parapoinx stagnalis*) were recorded as minor pests. The yellow stem borer infestation ranged from 0.86 to 1.22% dead hearts during the vegetative stage (October) and 1.84% white ears at harvest (December). Among the sucking pests, the population of green leafhoppers was found throughout the crop growth with a slight increase during the first fortnight of November (1.38/hill). The paddy horned caterpillar was active at the tillering stage of the crop (November) and declined with the advancement in the crop stage (Kumar and Patil, 2004).

Kalita *et al.* (2015) studied that whorl maggot started infestation at the initial stage of the crop and damaged maximum (22.25 -24.25 damaged leaves/10 hills) in the second fortnight of July. Stem borer infestation was found maximum during August-

September (6.82–7.62% dead heart). They also attacked the rice crop at reproductive stage which resulted in white ear head. The maximum white ear head% was recorded in the second fortnight of October. The leaf folder population was found maximum in the last part of August and first part of September (14.50 -16.75 damaged leaves/10 hills). Gundhi bug population was found maximum when the crop attained the milky stage in the first fortnight of October (14.80-16.40 gundhi bug/10 hills).

2.1.1 Yellow stem borer/stem borer

The rice stem borer, *Scirpophaga incertulas* Wlk. is one of the most important pests of rice in India and the yield losses ranged from 3 to 65 per cent (Ghose *et al.*, 1960)

Chen *et al.* (1968) concluded that weather conditions are factors affecting population outbreaks of the yellow rice borer in China and Abraham *et al.* (1972), through correlation studies, found that there was a joint influence of rainfall, relative humidity, and mean minimum temperature on stem borer infestation while In India, Kalode (1974) cited high rainfall and very high or low temperatures as being unfavorable for population increase.

Yellow stem borer has been occurring as one of the major pest in certain endemic pockets and causing up to 20% tiller damage particularly on summer rice, on kharif season crop the incidence of this pest being observed from 2% to 5% tiller damage (Gangarade *et al.*, 1978).

Manjunath (1982), showed 3 peaks for activity of *Scirpophaga incertulas* (Walk.): a low peak in February (the winter generation), a moderate peak in May (the summer generation) and a high peak in November (kharif generation). The pest causes most damage about 2 weeks after the winter-generation adults emerge and a month before the summer and kharif generations.

Stem borer damage occurrence as below the economic threshold (5%) on crops planted in September and from December to June (Saroja, 1982).

Isahaque and Rahman (1983), observed the seasonal abundance of *Scirpophaga incertulas* (Walk.) at Titabar in Assam, India, by means of light-trap

catches. The adult activity occurred throughout the year, with one peak in April and a smaller one in August. Although a high positive correlation was found between moth abundance and temperature, rainfall and relative humidity, hours of sunshine appeared to have no significant effect on *Scirpophaga* populations.

The influence of weather factors such as maximum relative humidity and Sunshine hours on YSB population showed positive correlation as well as coefficient of determination was 71 per cent. Rainfall showed the negative influence on the catches of YSB (Rai *et al.*,2002).

The percentage yield loss due to stem borer infestation was found highest as 27.09, 24.54, 25.32, 36.26, 17.74 and 22.19 per cent by *C. polychrysus*, *C. suppressalis*, *C. partellus*, *S. incertulas*, *S. innotata* and *S. inferens*, respectively on the variety, BR31 and lowest as 11.17, 10.18, 10.54, 8.77, 8.10, and 7.07 per cent by *C. polychrysus*, *C. suppressalis*, *C. partellus*, *S. incertulas*, *S. innotata* and *S. inferens*, respectively on the variety, Bansphul. Yield loss was found positively correlated with 'dead heart' and/or 'white earhead' infestations of vegetative, reproductive and mature phases of the crop (Rahman *et al.*,2004).

Mukherjee *et al.*, (2005) conducted a field experiment to assess the effects of bright sunshine, rain, air temperature, humidity, wind speed, and morning and daytime vapour pressure on the population dynamics of rice stem borer (*S. incertulas*). The stem borer population has highly significant and positive correlation with minimum air temperature, morning vapour pressure and their mean, and negative correlation with wind velocity.

Adiroubane and Raja (2005) revealed that the high pest incidence of rice stem borer during months of March (Navarai – Rabi, 2005), August- September (Kuruvai – Kharif, 2006) and October- November (Samba – Rabi, 2006). The favourable weather conditions for high stem borer incidence were 27.6°C, 30.1°C, 26.1°C as mean temperatures and relative humidity per cent ranged between 95.9 and 65.7, 82.2 and 54.5, 95.3 and 82.8 pertaining to the Navarai, Kuruvai and Samba seasons, respectively.

The maximum infestations of yellow stem borer 7.8 white ears per 5 hills and maximum spider population of 13.3 spiders' per m² were observed during the crop growth. Weather parameters accounted for 98 and 95 percent of total variations in the yellow stem borer incidence (White ears) and spider population, respectively (Arif *et al.*, 2005).

Maximum 4.25% of dead hearts and 4.91% white ear heads due to stem borer incidence in RAU 869-5-14-1, whereas the minimum incidence of stem borer in respect to dead hearts and white ear heads were recorded in Dhanlaxmi followed by Prabhat. The maximum 5.43 and minimum 1.76% white ear head recorded in Gautam and Dhanlaxmi between 75 and 90 days after transplanting, respectively. The minimum number of dead hearts per 5 hills was 2.8% during the 11th standard week of March and 6.2% peak in Gautam during the 20th standard week of May 2002. Whereas, the minimum number of spiders (4.6 -2) recorded in the 11th standard week showed 2 peaks (10.6 and 10.2) in the 16th and 19th standard week, respectively. The impact of weather parameters were positive influence of rain on spider population. Yellow stem borer is the key pest of rice in Bihar (Misra *et al.*, 2005).

Parwez *et al.* (2005) concluded that, at Pusa, Bihar the maximum infestation of yellow stem borer to the tune of 7.8 white ears per 5 hills during the crop growth of boro rice while Parwez *et al.* (2006) studied that, at Pusa, Bihar, the critical infestation of the stem borer occurred during vegetative and panicle stages of boro rice and reported that the maximum infestation by stem borer was 6.2 deadhearts per 5 hills.

Arif *et al.*, (2006) concluded that maximum infestation of stem borer (6.2 dead hearts/5 hills) and maximum spider population (10.6 spider/m²) were recorded during the cropping period. Weather parameters accounted for 93 and 57% of total variations in the stem borer incidence (dead hearts) and spider population respectively.

During Kharif 2005, borer infestation attained its peak activity when the crop was 60 days old, while in Rabi 2006, the peak activity was noticed at 75 days after sowing. Weather parameters showed a significant negative correlation with minimum temperature

and afternoon relative humidity but showed non-significant and negative correlation with maximum temperature, morning relative humidity and rainfall and had significant positive correlation with sunshine hours in Kharif. While in Rabi season, per cent dead heart or white ear head showed significant positive correlation with morning and afternoon relative humidity and non-significant positive correlation with the mean sunshine hours per day (Hugar *et al.*,2009).

Stem borers moth population decreased from May to mid-August (20-60 moths per week) and the population increased (238-515 moths per week) from mid-August to mid October as reflected from the moth population of light trap catches at study site. This population in turn caused borer incidence in terms of white ear head (8.1-13.6%) and 68.9-89.1% stem damage at crop maturity stage (Prabal-Saikia,2009).

Yang *et al.*, (2009) studied the meteorological conditions affecting the population dynamics. They reported the significant relationships between the population dynamics of paddy stem borer and meteorological factors the average minimum temperature per month and relative humidity (RH) were most influencing parameters.

Manikandan *et al.*, (2013) conducted an experiment in Coimbatore, TamilNadu and the results revealed that the number of eggs laid by YSB increased at higher temperatures while egg hatching was reduced. Egg hatching was higher (90.6%) at 30.6°C in different stages. YSB inverse relationship has been found with development time and incubation temperature level .

Infestation of rice yellow stem borer was found during August - September and December - February, reaching the peak in January - February, and without any infestation in other months. They correlated incidences of rice yellow stem borer with weather parameters and found a significant positive correlation with relative humidity and negative correlation with minimum temperature and rainfall (Justin and Preetha,2013).

2.1.2 Brown plant hopper

Lin (1970) also measured the temperature and relative humidity within the crop canopy, and concluded that the theoretically optimum niche for breeding and multiplication of plant hoppers was at about 10 cm above the water surface, where both factors of the microclimate are high, and shade formed by foliage is most effective.

The plant hopper population was significantly influenced by climatic factors especially rainfall in association with high relative humidity and high temperatures (Nair *et al.*, 1980).

Relative humidity had a significant and negative effect on populations of *Nilaparvata lugens* (Stal.) (Reddy *et al.*, 1983).

Adult BPH were first to appear in mid-September and reached peak numbers in November coinciding with flowering dough and grain formation stages in Maharashtra (Khaire and Dumber, 1984).

Chaudhary *et al.*, (2014) conducted experiments during the kharif season of 2011-12, at the Agricultural Research Farm, BHU Varanasi. The incidence of BPH in the beginning was very low. As soon as the rain stopped in last week of September then the population increased with the vegetative stage of crop and reached highest in third week of October. The incidence of the pest was severe in the last September to last October. The result showed that population of BPH was positively correlated to temperature and relative humidity whereas negative correlation was found with rainfall.

2.1.3 White backed plant hopper

Temperature around 27-28°C is favourable for the development of WBPH and higher temperature (above 30°C) for long time does not appear to be suitable. The population appeared in the 1st week of August following slight (2.0 mm) rainfall on July 26. Few showers of rainfall from mid to end August seems to favour the WBPH population indirectly by considerably decreasing the temperature (Sunega, 1963).

During 1982 serious outbreak of white backed plant hopper was reported in Haryana. Since then every year its attack is increasing in the state due to excessive use of nitrogen, close spacing and conditions submerged conditions (Kushwaha *et al.*,1982).

Reddy *et al.* (1983) revealed significant and negative relationship between relative humidity and population of WBPH at Hyderabad, (AP).

Kushwaha and Singh,(1986). Concluded severe outbreak of WBPH was noticed in Haryana during 1984 and 1985, wherein 60 of the 85 villages surveyed had more than 70 per cent infestation and 15 villages had 18 per cent infestation and WBPH population varied from 100 – 2000 per hill

Naganagoud *et al.*(1999) reported the peak catches of WBPH during second fortnight of October during kharif season in Tungabhadra Project Area of Karnataka.

Nephotettix virescens (GLH) and *Sogatella furcifera* (WBPH) are the serious pests of kharif paddy all over the world causing extensive losses. The population dynamics of Green leaf hopper and white backed plant hopper for ten consecutive years (1994 to 2004) except for 1997 were correlated with the weather parameters like maximum and minimum temperature, rainfall, relative humidity and bright sunshine hours had a positive significant correlation ($r=0.166$) with the population dynamics of GLH. The correlation between WBPH peak population and bright sunshine hours also showed positive significant correlation ($r=0.269$), while maximum temperature, minimum temperature, rainfall and relative humidity showed non-significant effect on population build up of both GLH and WBPH. Green leaf hopper attained peak population during 43rd standard meteorological week; whereas white backed plant hopper reached peak population during 39th standard meteorological week and decreased considerably thereafter (Shamim *et al.*,2009).

Rajendra *et al.*, (2010) conducted a study to know the incidence of white backed plant hopper (WBPH), *Sogatella furcifera* (Horvath) and its predators during kharif in different paddy ecosystem of Uttara Kannada district (Karnataka).The WBPH predating spider and mired population reached maximum

during the month of November. The correlation studies made on WBPH population revealed negative and significant relationship with maximum temperature while positive and significant relationship with minimum temperature, morning and evening relative humidity.

2.1.4 Green leaf hopper

Data from surveys of pests and diseases in northeast India suggested that light rainfall favors the development of green leafhoppers, but that either no rainfall or heavy rainfall was detrimental to population increase. Lack of rain may cause nymphal desiccation, and heavy rains and floods may wash the nymphs from the plants (Lowe, 1970; Lowe and Nandi, 1972).

Work in the Philippines appeared to support some of these conclusions, that for green leaf hoppers were more abundant on a wet-season than on a dry-season crop (data for 1 year) (Hsieh, 1972).

Anuj and saxena (1999) revealed that GLH had a significant correlation with bright sunshine hours and maximum temperature while negative correlation with minimum temperature, evening relative humidity and rainfall.

Bhowmik, *et al.*, (2005) showed that GLH population is significantly positive correlation (0.86) with the maximum temperature and significantly negative correlation (-0.73) with the maximum relative humidity.

Sabale *et al.*, (2010) revealed that the influence of weather factors on light trap catches of green leaf hopper for two species, namely, *Nephotettix nigropictus* (Nn) and *Nephotettix virescens* (Nv) at Pattambi, Kerala. The first peak was observed for both the species during 38th to 41st standard meteorological week, the second peak was observed during 45th standard week and the third peak was observed during 52nd to 2nd std. week. The correlation studies between light trap and net sweep collection with weather parameters that lower minimum temperature, low rainfall and abundant sunshine had major impact on population build up of green leaf hopper.

In rice ecosystem, insect pest GLH and predator LBB shows a positive correlation but not with other predator SPIDER. Maximum temperature and rainfall has positive effect on BPH population but minimum temperature has negative effect, showing that the temperature range have influence. Different insect pests and natural enemies show different types and numbers of peak abundance per year over 10 year time span although the time span is not a sufficient range. This peak or abundance depends on arthropods life cycle, number of generation per year and other ecological factors (Ahmed *et al.*, 2014).

2.1.5 Rice leaf folder

Leaf folder incidence was more in late transplanted crop than early transplanted crop as experimented by Kushwaha and Sharma (1983).

Kraker *et al.*, (1999) examined the populations of rice leaf folders and their natural enemies in eight crops of irrigated rice in Laguna Province, Philippines. The rice leaf folder complex consisted of three species: *Cnaphalocrocis medinalis* (Guenée), *Marasmia patnalis* Bradley and *M. exigua* Butler. Leaf folder population dynamics were characterized by an egg peak at maximum tillering and a broad larval peak around booting stage. Peak densities ranged from 0.2 to 2.0 larvae per hill. Forty natural enemy taxa (24 predator and 16 parasitoid) that may attack rice leaf folders were identified from suction and sweep net samples.

Ram *et al.*, (2014) opined that the larval population of rice leaf folder, *Cnaphalocrocis medinalis* (Guenee) in basmati rice was low during July to fourth week of August and the pest population increased from end of August to start of September and reached its peak (5.10 larvae/hill) during 38th standard week i.e. second fortnight of September negative correlation with larval population such as maximum ($r=-0.0909$), minimum ($r=-0.3796$) temperature. They found relative humidity ($r=-0.1146$) and rainfall ($r=-0.5108$) during crop season.

The seasonal occurrence of rice leaf folder, *Cnaphalocrocis medinalis* (Guenee) peak level reached during 4th week of September (39th SMW) when leaf

damage due to leaf folder was 2.30% under conventional method and 2.66% under SRI method. The correlation results under conventional and SRI method indicated that the weather parameters had less impact on leaf folder damage(Kakde and Patel,2015).

2.1.6 Rice gall midge

Peak period of gall midge emergence is between July to October in kharif season . The average maximum temperature ranging from 18 to 24°C with 73.3 to 97% relative humidity were reported to be optimum for the peak emergence of the gall midge Kalode and kasi (1976).

Asian rice gall midge. *Orseolia oryzae* (Diptera: cecidomyiidae), is an important pest of paddy in many Asian countries including India. In southern India, it is reported to cause about 0.8% loss in the total production(Ramaswamy *et al.*,1996).

2.3.7. Ear head bug :

The infestation is severe from October to mid November, when the temperature varies from 27-28°C and the relative humidity 80-82.1 per cent (Israel and Rao,1961).

Singh and Chandra (1967) were able to find a positive correlation between the peak population of *Leptocorisa acuta* (Tbunberg) each year and higher relative humidity and higher rainfall at a specific time of year.

2.2 Population built up of natural enemies of rice

The population of natural enemies like coccinellid, and spiders were host dependent (Khan and Ramamurthy,2004) .

Most common and dominant predators of rice ecosystem as spiders, coccinellids, staphylinids, mirids, damsel flies and dragon flies (Kumar *et al.*,2008) .

Madhukar, F. J. (2011) concluded that in both kharif (wet) and rabi (dry) seasons a predatory natural enemy complex of 23 insects including spiders predated on various stages of insect pests belonging to 7 orders and 18 families was

prominently recorded and identified. Among the 23 predators, dragonflies, *Crocothemis servilia* (Drury) and *Orthetrum sabina* (Drury), damselfly, *Agriocnemis femina*, lady bird beetles, *Micraspis* (=Verania) *discolor* and *Hormonia octamaculata*, rove beetle, *Paederus fuscipes* and ground beetle, *Ophionia indica* were found to be abundantly predating on immature and mature stages of major and minor pests. Out of the 4 species of spiders recorded as non-insect predators, *Lycosa pseudoannulata* was found to be predominant species predating on all types of pests. The abundance of dragonflies, *M. discolor* and *P. fuscipes* was more in rabi than in kharif season whereas spiders and ground beetle, *O. indica* were dominant during kharif season.

Most of the insect pests of rice in Malaysia are kept at low populations by their natural enemies such as damselflies, dragonflies, spiders and mirid predators. Indeed, such predators reduce the risk of outbreaks of rice pests and their presence indicates the health of the rice field. The use of chemical insecticides may remove the general predators and damage this rich ecosystem (Ooi, 2015).

Kalita *et al.* (2015) stated that among the natural enemies the population of spiders, *Apanteles* and dragon flies was recorded during August and September but the lady bird beetle population was found maximum during the last fortnight of September. The correlation study revealed that the population build-up of different pests and their natural enemies was influenced by the weather parameters.

A large number of insect species associated with rice production, portends to be a potential danger to rice production, as many of the species found have been identified as important pests elsewhere. However, the large number of natural enemies species (parasitoids and predators) found in this study, some natural enemies were found throughout the crop growing period, some were more during the vegetative stage of the crop and reproductive stage of the crop. All the recorded predator and parasitoids are known to be directly related to their prey population. It is suggested that important biological control agents can be exploited in the management of the major insect pests of rice (Parasappa *et al.*, 2017).

2.2.1 Spider

Spider population growth is positively correlated with BPH population density and a consequent negative relationship between nymphal survival and spider density (Kenmore *et al.*,1984) .

The spider fauna peaked in the 32nd and 42nd standard week, along with the preferred preys, i.e. green leafhopper (*Nephotettix virescens*), brown plant hopper (*Nilaparvata lugens*) and white backed plant hopper (*Sogatella furcifera*). The period of bright sunshine free from rainfall was highly conducive for both the prey and predator density, while the relative humidity showed negative impact on population build-up. The populations of both the spiders and hoppers were negatively correlated with temperature. The correlation matrix of spiders with hoppers exhibited highly significant positive relationship, indicating increase in spider density with the increase in prey density (Khan *et al.*,2003)..

Patel *et al.*, (2005) concluded that spider population had significant positive correlation with maximum temperature, average temperature and sunshine hours; significant negative correlation with minimum relative humidity, average relative humidity, rainfall and rainy days; and negative correlation with minimum temperature and maximum relative humidity. The spider population also exhibited positive correlation with all three insect pests i.e. green leaf hopper (*Nephotettix* sp.), brown plant hopper (*Nilaparvata lugens*) and rice leaf folder (*Cnaphalocrocis medinalis*).

Singh *et al.*, (2005) indicated that the rice spiders were dominant over the other predators. Correlation studies showed that predator population had a positive correlation with crop age and insect pest population (green leafhopper [*Nephotettix virescens*]) and negative correlation with maximum and minimum temperature, rainfall. The spider fauna occurred and peaked in the 32nd and 42nd standard week, respectively, along with the preferred preys, i.e. green leafhopper (*Nephotettix virescens*), brown leafhopper (*Nilaparvata lugens*) and white backed plant hopper (*Sogatella furcifera*). The period of bright sunshine free from rainfall was highly conducive for both the

prey and predator density, while the relative humidity showed negative impact on population build-up. The populations of both the spiders and hoppers were negatively correlated with temperature. The correlation matrix of spiders with hoppers exhibited highly significant positive relationship, indicating increase in spider density with the increase in prey density.

2.2.2. Dragonfly and damselfly:

The plant hopper populations in Muda agro-ecosystem in Malaysia were probably held in check by a combination of natural arthropod predators (mainly dragonflies and spiders) (Abdullah,1998) .

Parasappa *et al.*(2017) concluded that the population of yellow stem borer was significantly positively correlated to Odonata and Staphylinids, whereas BPH is positively correlated with mirids ($r=+0.770^{**}$), spider spider ($r=+440^*$), odonatan ($r=+0.700^{**}$), coccinellids ($r=+0.476^*$), carabids ($r=+0.779^{**}$) and cicindelids ($r=+0.417^*$). In the same way white backed plant hopper, skipper, caseworm, hispa, blue beetle & grass hopper recorded positive significant and positive non-significant with the predators and parasitoids.

2.2.3. Coccinellids

Coccinellid beetles are important members of arthropod communities in paddy fields where they play a valuable role in the biological control of insect pests of rice. Sasaji (1968) studied the fauna of oriental coccinellids in paddy fields and 33 species were recorded, seven of which were recorded as predators of BPH.

Yasumatsu *et al.*(1975) revealed that six species of coccinellids in the rice fields of Thailand. Among them *Micropis discolor* Fabr. and *M. vincta* Gorh. Were abundant *M. discolor* was also dominant in Malaysia.

Abraham *et al.*(1973) stated that *Coccinella arcuata*(Fabricius) to be a potential predator against BPH in Kerala and a grown up adult consumed 20 nymphs per day. Manjunath *et al.*(1978) also observed *C. arcuata* predating on the BPH in Karnataka.

C. arcuata active predator of the BPH occurring in large numbers towards the end of the BPH outbreak in Malaysia (Ooi,1980)

Parasuraman,(1989). Conducted survey at farm in Madurai, Tamil Nadu, India for predatory coccinellids. Eight species of predatory coccinellids were found feeding on BPH, WBPH and leaf hoppers in rice. Of the coccinellids, *Menochilus sexmaculata*(Fab.) accounted 43 per cent, *Stoicholotis substriata* L. for 25 per cent and *Scymnus*spp (Fab.) for 10 per cent .

2.3 Effect of weather parameters on population dynamics of insects of rice:

The seasonal effects of weather and ongoing changes in climatic conditions will directly lead to modifications in dispersal and development of insect species. Weather parameters viz., Temperature, rainfall, relative humidity, sunshine hours and wind speed are the major weather elements determining the insect pests' occurrence. The changes in surrounding temperature regimes certainly involve alterations in development rates, voltinism and survival of insects and subsequently act upon size, density.

The maximum and minimum temperatures and relative humidity were important factors influencing insects. Activity peaks occurred in late October and, to a lesser extent, in late April. The trap data were useful in determining the times of initial infestation, peak infestation and reductions in the population (Roy *et al.*,1985)

The population build up of green leafhopper *Nephotettix virescens* Dist (Cicadellidae, Hemiptera), plant hoppers *Cofana spectra* Dist (Delphacidae, Hemiptera) and rice gundhi bug *Leptocoriza acuta* Thunberg (Alydidae, Hemiptera) in rice growing season and concluded that the meteorological factors have significant effect on the population build up of *Nephotettix virescens* Dist in the month of October. In the case of *Leptocoriza acuta* Thunberg, no other factor but rainfall had positive correlation and population build up in the fourth week of September (Sharma *et al.*,2004).

The populations of major pests associated with rice ecosystem were recorded at weekly intervals during kharif 2002, using sweep nets, in Kangra Valley and the results revealed that the main insects included the stem borer (*Scirpophaga innotata*), leaf folder (*Cnaphalocrocis medinalis*) and rice hispa (*Dicladispa*

armigera), all of which appeared during the first week of July, with initial mean populations of 11.33, 1.00 and 1.67, respectively. Mean maximum population of these pests were observed as 42.66, 51.67 and 59.33 during August to September which coincided with the vegetative stage of the plant (Dogra and Choudhary,2005) .

Shukla *et al.*, (2008) conducted an experiment on Raipur and the basis of fifteen year`s trend of rice insect opined, that maximum gall midge infestation on rice was found during fourth week of September. Stem borer infest the crop at tillering and panicle stage particularly in the month of October. Peak population of WBPH, BPH and GLH were observed during August-September, September-October and October November respectively .Peak activity of caseworm and leaf folder infestation was observed during the month of September and October respectively. Intensity of gundhi bug was observed during the month of November coincide with the milking stage of the crop.

Sastri *et al.*, (2008) studied the relation between the weather parameters and insects (YSB and GM) incidence. They found that, in the case of yellow stem borer (YSB), there were significant relation of weather parameters like maximum temperature, minimum temperature, relative humidity I and relative humidity II with the yellow stem borer population.

Karuppaiah and Sujayanad (2012) showed that, declined survival rate of brown plant hopper *Nilaparvatha lugens*(Stal) and rice leaf folder, *Cnaphalocrocis medinalis* (Guen) at higher temperature indicates the impacts of rising temperature could do the changes in the pest population dynamics of rice ecosystem. Climate change would result in changes in the population dynamics of insect pests. Thus temperature rise plays a pivotal role in insect population dynamics.

Singh *et al.*, (2012) studied the effect of various meteorological parameters on population dynamic under Punjab. The maximum number (percent) of insect pest damage samples received at Plant Clinic were for plant hopper (44%) followed by leaf folder (30%) and stem borer (29%). The weather conditions conducive for the build up of rice pest population were cloudy weather. They observed during the 8 high pest

infestation years (pest samples >200) a well distributed (more number of rainy days) near or above normal rainfall was received during June to October.

Ramya *et al.*, (2012) conducted an experiment at Agro Climate Research Centre, Tamil Nadu Agricultural University, India to understand the Pest dynamics at elevated temperature. Climate change resulting in increased temperature could impact crop insect-pest populations in several complex ways. Although some climate change temperature effects might tend to depress insect populations, most researchers seem to agree that warmer temperatures in temperate climates will result in more types and higher populations of insects. The population growth of the important insect-pests such as yellow stem borer (*Scirpophaga incertulas*) and brown plant hopper (*Nilaparvata lugens*) of rice. The results revealed that there was an inverse correlation between temperature and total life span, developmental time and also fecundity. However there was a positive correlation between temperature and development rate.

Twenty six insect-pests and natural enemies of crop plants, belonging to 9 different orders (including Acarina group) were recorded in the rice (*Oryza sativa* L.) agro ecosystem. The maximum percentage of insect-pests and natural enemies were recorded in the order Coleoptera (23.10%), followed by Lepidoptera (15.40%), Homoptera, Isoptera and Thysanoptera. Insect pests viz., yellow stem borer, green leaf hopper and gundhi bug were highest in proportion, whereas rest others were found to be medium or low in proportion. Among natural enemies and predators, rove beetles, tiger beetles, carabid beetles, damsel flies and dragon flies were recorded from the rice agro-ecosystem (Kumar *et al.*,2013).

Nirala *et al.*, (2015) conducted an experiment at research farm of Indira Gandhi Krishi Vishwa Vidyalaya, Raipur Observed maximum adult of rice case worm (CW) and grasshopper were on 41th SMW of October with 416.0 adult/weeks 12 and 73.0 adult/week respectively and adult population gradually decreased as the crop departing towards maturity stage. The results revealed that Case worm showed non-significant negative correlation with average rainfall (mm) ($r = -0.342$), RH-I ($r = -0.135$), RH-II ($r = -0.024$), Average RH ($r = -0.042$) while non significant

positive correlation with maximum temperature ($r = + 0.166$), minimum temperature ($r = + 0.095$), average temperature ($r = + 0.118$) and sun shine (hours) ($r = + 0.109$). Grasshopper showed significant negative correlation with RH-I ($r = - 0.455^*$) and non-significant negative correlation with average rainfall (mm) ($r = - 0.135$), sun shine (hours) ($r = - 0.174$) whereas non-significant positive correlation with maximum temperature ($r = + 0.078$), minimum temperature ($r = + 0.157$), average temperature ($r = + 0.151$), RH-II ($r = + 0.152$) and average RH ($r = + 0.074$) at 1 and 5 per cent level of significance.

A field experiment at Central Research Farm of Orissa University of Agriculture and Technology, Bhubaneswar during summer 2014-15 and kharif- 2015 was conducted to study the effect of weather parameters on population dynamics of paddy pests. Temperature and relative humidity favours stem borer, leaf folder, whorl maggot and green leaf hopper, brown plant hopper and white backed plant hopper, but relative humidity was not ideal for leaf folder and whorl maggot. Rainfall discourages stem borer, leaf folder, whorl maggot and green leaf hopper but encourage brown plant hopper and white backed plant hopper (G. Madhuri *et al.*,2017) .

2.4 . Economic status of major insects

The major insect pests of National significance today are, rice yellow stem borer, brown plant hopper, white backed plant hopper, leaf folder, gall midge, green leaf hopper and gundhi bug. Seven out of 20 major challenges in rice production are insect pest and diseases.

Among the biotic stresses insect pests cause about 10-15% yield losses. The average yield losses in rice have been estimated to vary between 21-51 per cent. Yellow stem borer, brown planthopper and gall midge were the key pests in rice causing 25-30%, 10-70% and 15-60% yield losses, respectively. At National level, stem borers accounted for 30% of the losses while planthoppers (20%), gall midge (15%), leaf folder (10%) and other pests (25%).

The economic threshold of yellow stem borer (*Scirpophaga incertulas*) consists of the two levels viz. 5 per cent yield loss at admitted level and 7 per cent yield loss of economic importance (Monastyrskii and Sugonyaev,2001).

Insect pests such as rice hispa, case worm, grass hopper, leaf folder, whorl maggot, gall midge army worm, gundhi bug were of major economic significance and caused major extent of damage to rice crop in the plateau region of Ranchi(Prasad and Prasad,2006) .

An experiment based on 770 experimental units from 28 years coordinated data projected yield loss of 2.5%, 4.0%, and 6.4% yield loss, respectively due to 1% dead heart or white ear head, or at both phases of stem borer damage. In terms of grain production loss over ecosystems, 1% dead heart, or white ear head, or both phases of stem borer damage would be 108, 174 and 278 kg/ha, respectively. In irrigated ecosystem, 1% dead heart resulted in 0.3% or 12 kg/ha loss whereas, 1% white ear head caused 4.2% or 183 kg/ha loss in grain yields; the loss due to 1% infestation in both phases of stem borer damage was 4.6% or 201 kg/ha. In rain fed lowlands, for 1% dead heart or dead heart and white ear head caused 2.3% or 76 kg/ha yield loss. The authors opined that even at levels below the currently used economic threshold considerable losses can occur. The yield loss in different centers varied from 11.2% to 40.1% due to dead hearts and 27.6 to 71.7% due to white ears (Muralidharan and Pasalu, 2006) .

Sachan *et al.* (2006) opined that survey during the crop seasons of 2000-02 to determine the insect fauna associated with basmati rice, along with their nature of damage, seasonal incidence and economic importance, in Tarai region of Uttar Pradesh, India. A total of 28 insect species were recorded. The yellow stem borer, *Scirpophaga incertulas* (July-October), leaf-folder, *Cnaphalocrocis medinalis* (August-September), and brown plant hopper, *Nilaparvata lugens*(August-September), were found as major pests. The striped stalk borer, *Chilo suppressalis* (July-October), gundhi bug, *Leptocorisa acuta* (September-October), white-backed plant hopper, *Sogatella furcifera* (August-September), green leafhopper, *Nephotettix virescens* (August-September), grasshoppers, *Hieroglyphus banian* and *Atractomorpha crenulata* (August-October), and root weevil, *Echinocnemus oryzae* (July-September), were found moderately damaging the crop. The other insect pests recorded on the crop were of less economic importance.



MATERIALS AND METHODS

This chapter deals with the concise description of soil, weather conditions, materials used and techniques adopted during the course of investigation. The present study entitled “Effect of weather on population built up of major insect pest of rice under staggered planting” was carried out during kharif 2017 and rabi season of 2017-2018 at Research farm of College of Agriculture, Orissa University of Agriculture and Technology, Bhubaneswar, situated at an elevation of 25.9 m above mean sea level at 20° 15' N latitude and 85° 52' E longitude and East & South East Coastal Plain of Odisha.

3.1 Climate

The general climatic condition of Bhubaneswar is hot and humid. The annual mean maximum temperature of 2017 is 35.3 °C and annual mean minimum temperature is 22.6 °C. Summer season (March to June) is hot and humid, with temperatures ranging 26.4-35.7 °C. Winter season (December and January) is cold and dry with temperature ranging 15–28 °C. May is the hottest month, when daily temperatures range from 32–42 °C. January, the coolest month, has temperatures varying from 15–28 °C. The highest recorded temperature is 45 °C and the lowest is 12 °C.

3.2 Weather conditions during crop growth season

The weekly mean of maximum temperature, minimum temperature, relative humidity (RH) and bright sunshine hour (BSH) along with total weekly rainfall, number of rainy days during the crop growth season (July 2017 to April 2018) is presented in Table 3.1.

The weekly maximum temperature during the crop growth period ranged from 26.5 to 39.5 °C, with a weekly average of 33 °C, whereas, the monthly mean minimum temperature varied from 11 to 28.1 °C, with a weekly average of 21.5 °C. The 1st and 16th October, date of planting were experiencing low temperature (<12°C), which induced high percentage of sterility, so we have eliminated these dates of planting into analysis.

The mean morning relative humidity during the crop growth varied from 82 to 96 %, while the mean afternoon relative humidity varied from 44 to 84%. The mean bright sunshine hour received during the crop growth period varied from 4.4 to 8 hours, with a weekly average of 6.2 hours. The total rainfall received during the crop growth period was 1604 mm.

The weekly mean of maximum temperature, minimum temperature, relative humidity (RH) and bright sunshine hour (BSH) along with total weekly rainfall, number of rainy days during the crop growth season (July 2017 to April 2018) is presented in Table

Table 3.1 Weekly Weather data of Central Research Farm, OUAT, Bhubaneswar from June 2017 to April 2018.

Week No	Days	Rainfall (mm)	Temp(°C)		RH(%)		BSH (hrs)	Wind speed (kmph)	Evap (mm)
			Max	Min	7hrs	14 hrs			
25	18-24 Jun	14.5	35.3	26.6	86	59	6.2	5.7	38.8
26	25 Jun-1 Jul	83	31.1	25.9	94	75	0.4	2.7	25.7
27	2-8 Jul	46.5	31.3	25.8	90	75	0.8	3.2	23.9
28	9-15 Jul	145.4	32	25.4	94	76	1.6	2.7	21.9
29	16-22 Jul	164.3	31.7	26.1	93	85	2.8	5.8	18.3
30	23-29 Jul	34.3	31.8	26.3	92	78	2.7	3.4	23.9
31	30 Jul - 5 Aug	56	33.8	26.1	91	71	3.7	2.6	20.7
32	6-12 Aug	85.1	33.1	25.6	90	77	6.1	3.8	20.2
33	12-19 Aug	76.9	32.4	25.8	91	79	3.6	2.7	19
34	20-26 Aug	63.2	33.6	26	87	71	7.3	2.4	20.1
35	27 Aug-2 sep	161.4	32.1	25.3	96	78	3.3	2.1	16.1
36	3-9Sep	24.4	33.6	26	92	74	5.7	2.5	24.1
37	10-16 Sep	77.9	34.4	25.7	90	65	6.6	3.2	20.8
38	17-23 Sep	45.1	32.6	25.8	92	71	3.1	1.7	23
39	24-30Sep	33.7	33.7	25.5	92	69	3.4	2.1	23.5
40	1-7 Oct	77.7	30.7	25.1	94	79	2.3	1.8	21.7
41	8-14 Oct	24.6	33.3	25.4	94	64	6.1	2.3	23.8
42	15-21 Oct	102.2	31.5	24.8	93	72	5.3	4.8	19.9
43	22-28 Oct	0	33.5	23.2	92	63	8.8	1.7	24.5
44	29 Oct-4 Nov	0	31.1	20.6	90	62	8.2	1.9	24.3
45	5-11 Nov	0	31.4	19.5	86	52	9.3	2.3	24.4
46	12-18 Nov	55.2	27.3	20.7	87	66	3.5	5.9	21.2
47	19-25 Nov	0	29.6	18.7	91	56	6.5	1.9	22.8
48	26 Nov-2 Dec	0	29.4	13.9	92	40	8.4	1.3	24.3
49	3-9 Dec	36.3	27.1	14	88	49	5.6	3.1	23
50	10-16 Dec	0	29.5	18.3	94	59	6.3	1.7	24.2
51	17-23 Dec	0	28	13.6	92	43	7.8	1.3	24.7
52	23-31 Dec	0	28	12.5	93	43	7.8	1.8	24.7
1	1-7 Jan	0	26.5	12.6	91	38	6.6	2.1	24.9
2	8-14 Jan	0	28	11.2	91	34	7	2.4	25.6
3	15-21 Jan	0	27.6	11	95	35	7.8	1.3	25.2
4	22-28 Jan	0	29.1	13.4	93	35	7.2	1.4	26.4
5	29 Jan-4 Feb	0	31.1	12	91	24	8.9	2.5	27.8
6	5-11 Feb	0	33.5	17.1	93	31	7.7	2.3	29
7	12-18 Feb	0	31.6	15	90	33	7.8	1.9	28.9
8	19-25 Feb	0	35.2	16.5	94	29	8.8	2.8	30.7
9	26Feb-4 Mar	0	37.4	19.6	93	27	8.5	2.3	32.5
10	5-11 Mar	0	36.4	20.4	89	31	7.2	2.5	35.7
11	12-18 Mar	0	36.3	21.3	91	27	5.3	3.6	36.7
12	19-25 Mar	0	37.6	23.2	94	34	6.9	3.5	38.5
13	26 Mar-1 Apr	0	37	25.7	91	47	6.2	7	44.5
14	2-8 Apr	26.7	35.3	22.6	87	52	7.5	6	42.9
15	9-15 Apr	10.3	36.5	24	86	48	8.4	5.1	43.7
16	16-22 Apr	0	39.2	26.8	85	42	9.3	8.4	55.6
17	23-29 Apr	6.9	38.5	25.3	89	43	9	8.6	57.5

3.3 Experimental site

The field trial were conducted at Agrometeorological field, Central Research Farm, Orissa University of Agriculture and Technology, Bhubaneswar located at a latitude of 20° 15' N and longitude of 85° 52' E with an altitude of 25.9 m above the MSL. The soil of the experimental plot was sandy loam and acidic with a pH of 5.9. Bhubaneswar comes under subtropical climate of Odisha.

The cropping history during the preceding year is summarized in table 3.2

Table 3.2 Cropping history of experimental field

Year	Kharif	Rabi
2012	Rice	Rice
2013	Rice	Rice
2014	Rice	Rice
2015	Rice	Rice
2016	Rice	Rice
2017	Rice	Rice

3.4 Experiment Details:

The field experiment was conducted during kharif and Rabi season of 2017 & 2018 to find out the growth, development , yield and quality of aromatic rice of three varieties under staggered planting.

3.4.1 Design and layout

The experiment was laid out in a split plot design with dates of planting in main plots and different varieties in sub plots. The dimension of the experimental area was 57m X 48m(2736 m²) with each plot dimension of 7m X 4m(28 m²). The experimental plot was provided with irrigation channels as shown in the layout plan and the individual plots were demarcated with bunds. The layout plan of the experiment is depicted in Fig.3.3

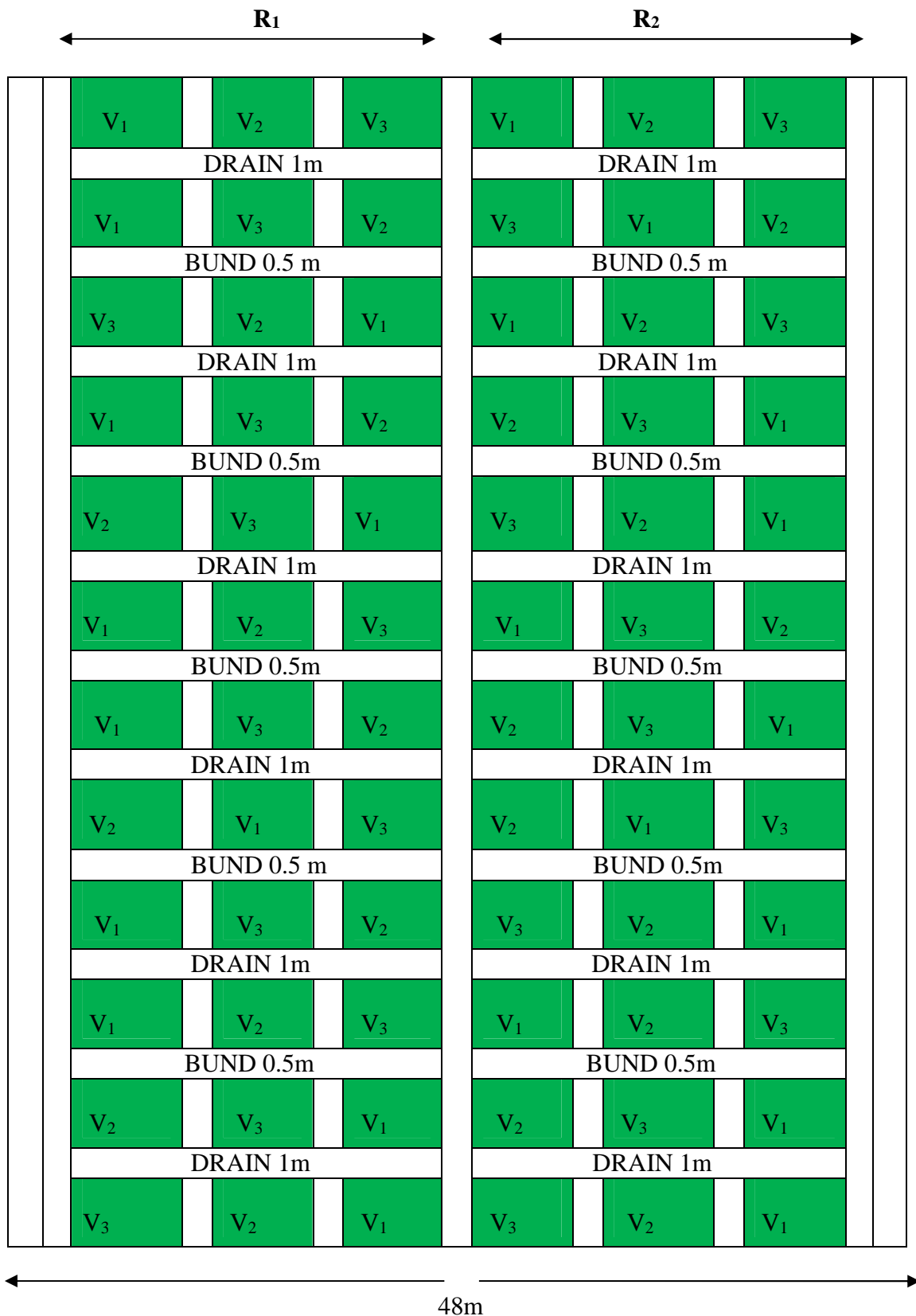


Fig. 3.1 Layout of experimental plot

Treatment Details	Spacing between
Design: split plot Replication: 2 Experimental area: 2736 m ² No. of plots: 72 Plot size: 28m ² No. of rows in plot: No. of column in plot:	Replications: 1m Main plots: 1m Sub plots: 0.5m Rows: 0.2m Plants: 0.1m

3.4.2 Treatment details

There were 36 treatment combinations consisting of twelve dates of planting in the main plot and three varieties in the sub plots. The details of the treatment combinations are given and experimental lay out is shown in figure 3.3

3.4.3 Main plot : Dates of transplanting (12)

16.7.2017
 1.8.2017
 16.8.2017
 1.9.2017
 16.9.2017
 1.10.2017
 16.10.2017
 1.11.2017
 16.11.2017
 1.12.2017
 16.12.2017
 1.1.2018

3.4.4 Subplot : varieties (3)

V₁ Geetanjali
 V₂ Purnabhog
 V₃ Pusa Sugandh -II

3.5 Cultivation details

3.5.1 Land preparation

The field was ploughed twice with a tractor drawn cultivator followed by rotavator to attain fine tilth and then divided into plots as per the layout. During land preparation, Farmyard manure @ 2 t/ha was applied.

3.5.2 Cultivar details

Geetanjali (IET-18008) is released in the year 2006, maturity occurs in 140 days in Kharif and 120-125 days in Rabi, suitable for irrigated land, plant height 110-115 cm, long and slender grains with resistant to neck blast, gall midge, moderate resistance to brown spot. Average grain yield 4000-4500kg/ha in Kharif and 4500-5000 kg/ha in Rabi . It is one of the highly adaptable rice cultivars of Odisha.

Poornabhog (CR Basna Dhan 902) is released in the year 2012, maturity occurs in 140 days, suitable for shallow lowlands, plant height 110 cm, long and slender grains with resistant to neck blast, gall midge, moderate resistance to sheath rot and stem borer. Average grain yield is 4500-5000 kg/ha . It is one of the highly adaptable rice cultivars of Odisha.

Pusa Sugandh-II is released in the year 2001, maturity occurs in 120-125 days, suitable for irrigated lands, highly adaptable in Punjab, Haryana, Delhi, Western Uttar Pradesh and Uttarakhand. A semi dwarf high yielding aromatic rice variety possessing basmati grain quality traits. It has extra –long slender grains with strong aroma, almost twice elongation on cooking, soft texture, good mouth feel and appealing taste. Average grain yield is 5000-5500 kg/ha .

3.5.3 Seed rate

A seed rate of 2.5g/ m² was used for nursery raising of the crop..

3.5.4 Nursery Sowing

Nursery raising of seedlings were done by wet bed method. Well pulverized raised nursery beds were prepared. The size of each nursery bed was 1 m wide and conventional length Drainage channel of 30 cm width was provided between the beds. The pre-soaked seeds were sown in the raised nursery bed by broadcasting method using 2.5g seeds /m² or 75g seeds per plot per variety. Light and frequent irrigations were given during dry spells until the seedlings were ready for transplanting.

3.5.5 Transplanting

After puddling and leveling operation FYM was applied at the rate of 10 kg per plot . Finally transplanting of seedlings were carried out. Fifteen days old

seedlings were transplanted in the field at 1 seedlings per hill .Flexible wire rope and coloured cloth strips were used at specific interval as per the desirable spacing for maintaining the distance between plant and rows during transplanting operation.

3.5.6 Fertilizer application

The recommended dose of fertilizer is 80:40:40 kg N P₂O and K₂O /ha was applied in the form of Urea, DAP and Muriate of Potash (MOP). One-third dose of nitrogen, entire dose of phosphorus and half of the potash were applied as basal, remaining nitrogen was applied in equal splits during active tillering (30 DAT) and panicle initiation stage (65 DAT), respectively and the remaining half of potash was applied during panicle initiation stage.

3.5.7 Irrigation

The field was irrigated to maintain the upper limit of field capacity near saturation conditions to overcome the water stress, especially during the critical crop growth stages.

3.5.8 Weeding

Butachlor was sprayed @ 2ml/l of water two days after transplanting the crop in the main field, followed by hand weeding at 20 and 35 DAT to keep the experimental plots weed free during the critical crop growth stages.

3.5.9 Harvesting and Threshing

The crop was harvested on different dates as per maturity of the respective varieties. After harvesting the produce was sun dried for couple of days and threshing was done by paddy thresher followed by winnowing manually for cleaning of grains.

3.6 Calendar of operation:

Details of calendar of operation are given in table 3.3.

Table 3.3 Calendar of operation

Date of Transplanting	Soaking	Nursery sowing	Field Preparation	Transplanting	Fertilizer Application		Weeding		Irrigation	Harvesting
					Basal	1 st TD	1 st	2 nd		
16 July	28.6.17	01.7.17	10.7.17	16.7.17	03.8.17	03.9.17	18.8.17	03.9.17		01.11.17 (V1 & V3) 18.11.17 (V2)
1 August	13.7.17	16.7.17	29.7.17	01.8.17	19.8.17	18.9.17	19.8.17	18.9.17		18.11.17 (V1 & V3) 08.12.17 (V2)
16 August	29.7.17	01.8.17	13.8.17	16.8.17	04.9.17	03.10.17	18.9.17	03.10.17		03.11.17 (V1 & V3) 15.12.17 (V2)
1 September	13.8.17	16.8.17	29.8.17	01.9.17	19.9.17	18.10.17	03.10.17	18.10.17		16.12.17 (V1 & V3) 13.12.17 (V2)
16 September	29.8.17	01.9.17	13.9.17	16.9.17	04.10.17	04.11.17	18.10.18	03.11.17		10.1.18 (V1 & V3) 25.1.18 (V2)
1 November	13.10.17	16.10.17	29.10.17	01.11.17	19.11.17	10.1.18	03.12.17	18.12.17	16.11.17 26.11.17 5.12.17 25.12.17 05.1.18 16.1.18 25.1.18 05.2.18 25.2.18 05.3.18	20.03.18 (V1 & V3) 30.3.18 (V2)
16 November	29.10.17	1.11.17	13.11.17	16.11.17	4.12.17	25.1.18	18.12.17	03.1.18	26.11.17 5.12.17 25.12.17 05.1.18 16.1.18 25.1.18 5.2.18 20.2.18 02.3.18 05.3.18 15.3.18 25.3.18	10.4.18 (V1 & V3) 25.4.18 (V2)

Date of Transplanting	Soaking	Nursery sowing	Field Preparation	Transplanting	Fertilizer Application		Weeding		Irrigation	Harvesting
1 December	13.11.17	16.11.17	28.11.17	1.12.17	19.12.17		3.1.18	18.1.18	10.12.17 21.12.17 4.1.18 16.1.18 25.1.18 5.2.18 25.2.18 5.3.18 15.3.18 25.3.18 5.4.18	9.4.18 (V1 & V3) 15.4.18 (V2)
16 December	28.11.17	1.12.17	13.12.17	16.12.17	4.1.18	4.2.18	18.1.18	3.2.18	21.12.17 4.1.18 16.1.18 25.1.18 5.2.18 16.2.18 25.2.18 5.3.18 15.3.18 25.3.18 5.4.18 15.4.18	10.4.18 (V1 & V3) 20.4.18 (V2)
1 January	13.12.17	16.12.17	29.12.17	1.1.18	19.1.18	19.2.18	19.2.18	3.2.18	4.11.17 16.1.18 25.1.18 5.2.18 16.2.18 25.2.18 5.3.18 25.3.18 5.4.18	15.4.18 (V1 & V3) 25.4.18 (V2)

3.9 Statistical analysis

The weekly total count of rice insect-pest and weekly average weather parameters were taken. The correlation between weekly count of insect-pest and meteorological parameters were worked out and the significance of correlation was tested at five per cent and one percent probability levels by using statistical analysis programme like SAS, Pearson Correlation Coefficient.

3.10 Observation on tagged plant

The observations on insect pests and predators occurrence was recorded in 5 tagged hill of each plot and averaged to per hill basis for expression. The insects and predators were counted by shaking the plant and observation of the crop basal region very minutely.

Biometric Observations such as plant height in cm, number of Tillers/per hill, Total number of leaves, number of Leaves in main shoot, panicle length in cm, No. of sterile and fertile grain per panicle, test weight were taken.



Fig. 3.2 Experimental plot



Fig.3.3 Field observation

3.10.1 Plant hopper and leaf hopper species:

Leaf and plant hopper samples were counted from 5 marked hills at the weekly interval.

The observations were recorded weekly from the month of July (2017) to April (2018).



Fig.3.4 Brown plant hopper



Fig. 3.5 Green leaf hopper

3.10.2 Stem borer

The infestation of yellow stem borer (*Scirpophaga incertulas* Walker) was recorded on 1m² of each plot by counting total number of tillers and “Dead hearts/White ear heads” on each plot and then the % was calculated by using following formula-

$$\text{Dead heart\%} = \frac{\text{Damaged tillers}}{\text{Total tillers (Healthy + Damage)}} \times 100$$

$$\text{White ear head \%} = \frac{\text{Damaged tillers}}{\text{Total tillers (Healthy + Damage)}} \times 100$$



Fig.3.6 White ear head



Fig.3.7 Dead heart

3.10.3 Gundhi bug

Gundhi bugs were counted and minutely observed from the 5 tagged hill.

3.10.4 Rice whorl maggot

The damaged leaf with white or transparent patches near the edge were counted.



Fig.3.8. Whorl maggot infestation



Fig.3.9 Gundhi bug

3.10.5 Natural enemies

The predatory population of Dragon fly and Damselfly and Coccinellids beetles was observed from per m² of each plot ,but spiders were counted from 5 marked tagged hill throughout the cropping period.



Fig.3.10 Spider



Fig.3.11 Dragonfly



Fig.3.12 Damselfly



Fig.3.13 Lady bird beetle



RESULTS

This chapter deals with the brief description of results obtained under different objectives of the experiment entitled, “Effect of weather on population built up of major insects and natural enemies of aromatic rice under staggered planting”.

Major insects such as Brown plant hopper (BPH), White backed plant hopper (WBPH), Green leaf hopper (GLH), Whorl Maggot (WM), Yellow stem borer (YSB), and natural enemies namely Spider, Dragonfly, Damselfly and Ladybird beetle were found during the entire crop growing period.

4.1 Population built up of Brown Plant Hopper

The BPH infestation was found in most of the planting date starting from 1st date (16th July) to 9th date of planting (16th November). The number of pest per hill varied from 0.1 to 0.9 (Table 4.1). However, the infestation of BPH was first found from 1st week of August (SMW 32) and was continued up to last week of December (SMW 52), BPH population was not found in December and January planting dates. The highest occurrence of BPH found at 2nd week of August and 2nd week of November i.e. WK4 and WK5 after planting (0.9 BPH/hill) in 16th July and 16th August dates of planting (Appendix-1 and Appendix-3). Mainly BPH infestation was occurred in vegetative stage of rice i.e. between WK3 to WK9 week after planting.

Table 4.1 Weekly BPH Population Per Hill

Week after planting	16-Jul	1-Aug	16-Aug	1-Sep	16-Sep	1-Nov	16-Nov	1-Dec	16-Dec	1-Jan
WK1	0	0.2	0.3	0	0	0	0	0	0	0
WK2	0	0.5	0	0	0	0	0	0	0	0
WK3	0.3	0.4	0.1	0	0	0	0.2	0	0	0
WK4	0.4	0.6	0.9	0	0	0	0	0	0	0
WK5	0.9	0.2	0.1	0	0.2	0	0.1	0	0	0
WK6	0.6	0.2	0	0	0	0	0.1	0	0	0
WK7	0.5	0.5	0	0.1	0.2	0.2	0	0	0	0
WK8	0.5	0	0.2	0	0.6	0.2	0	0	0	0
WK9	0.1	0	0.2	0	0	0	0	0	0	0
WK10	0	0	0.2	0	0	0	0	0	0	0
WK11	0	0	0	0	0	0	0	0	0	0
WK12	0	0	0	0	0	0	0	0	0	0
WK13	0	0	0	0	0	0	0	0	0	0
WK14	0	0	0	0	0	0	0	0	0	0

4.2 Favourable weather parameters for BPH Population built up

The BPH infestation was found at a maximum temperature ranging from 26 to 37°C but the peak was at a temperature of 32 to 34 °C. The BPH infestation was found at a minimum temperature ranging from 11 to 26°C but the peak was at a temperature of 25-27°C .The infestation was aggravated with the weekly cumulative rainfall up to 165 mm. However, the highest population was found at a weekly cumulative rainfall of 80 to 110 mm, the occurrence was seen from 82 to 96% and the peak at high morning relative humidity 91-95% and evening relative humidity 75-80% (Fig 4.1).

4.3 Correlation studies of Brown Plant Hopper with weather parameters

The correlation between BPH Population and different weather parameters revealed significant correlation only in two dates of planting viz., 1st August and 16th November out of 12 planting dates (Table 4.2). The BPH infestation was found positively correlated with rainfall with r value of (0.55) in 1st August and (0.78) in 16th November planting dates. In 16th September BPH population was negatively correlated with morning relative humidity (-0.69). It was also found positively correlated with afternoon relative humidity (0.58) in 16th November planting dates.

Table 4.2 Correlation studies of BPH population density with weather parameters in different planting dates

WP	16 th Jul	1 st Aug	16 th Aug	1 st Sep	16 th Sep	1 st Nov	16 th Nov	16 th Dec
TX	0.23197	0.40878	-0.1234	-0.1205	0.11943	-0.2902	-0.4391	-0.3958
	0.4249	0.1467	0.6741	0.6815	0.6716	0.228	0.0599	0.1442
TN	0.2256	0.40843	0.28114	0.16464	0.06006	-0.3081	-0.1712	-0.281
	0.438	0.1471	0.3302	0.5738	0.8316	0.1993	0.4832	0.3102
RH1	-0.3538	-0.4253	0.30468	0.24425	-0.6961	0.27723	-0.2156	-0.0921
	0.2146	0.1295	0.2895	0.4	0.0039	0.2505	0.3752	0.7439
RH2	0.21151	-0.0491	0.41402	0.41258	-0.0337	0.11586	0.58519	0.12039
	0.4679	0.8676	0.1411	0.1426	0.905	0.6367	0.0085	0.6691
RF	0.09671	0.55895	0.50996	0.01369	-0.0214	-0.1149	0.78444	-0.0714
	0.7422	0.0377	0.0625	0.963	0.9396	0.6394	<.0001	0.8003
SS	0.2649	0.70355	-0.3867	-0.4544	0.30782	0.09422	-0.4488	-0.3145
	0.36	0.005	0.1719	0.1026	0.2644	0.7012	0.0539	0.2535

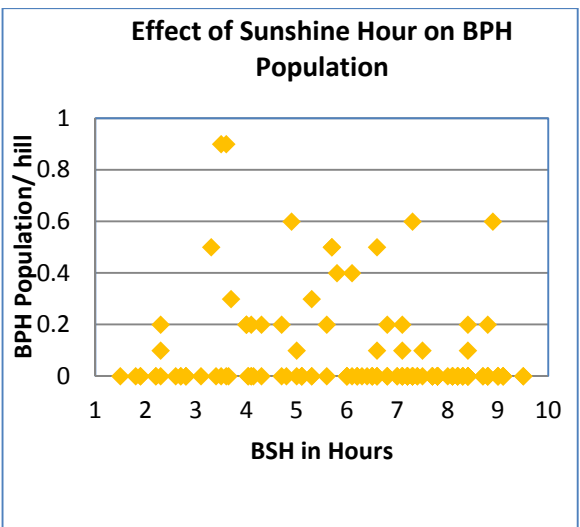
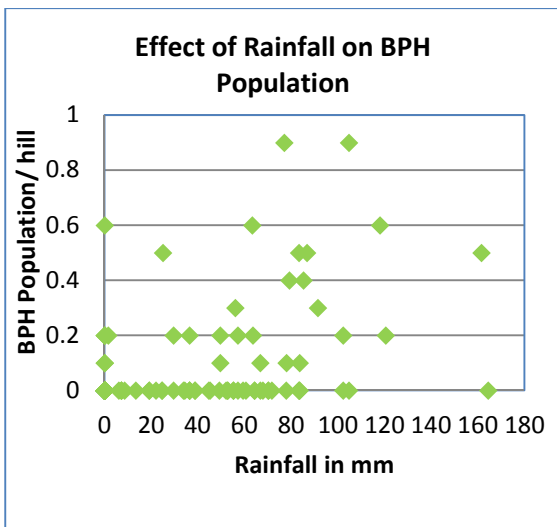
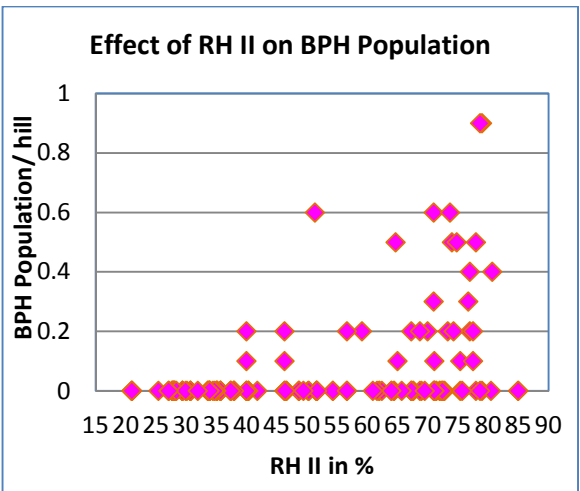
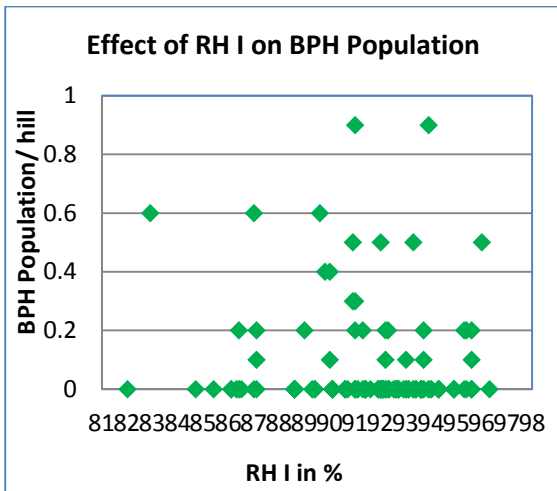
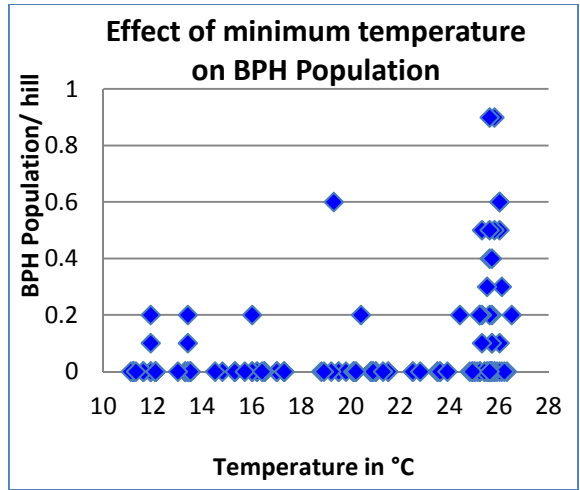
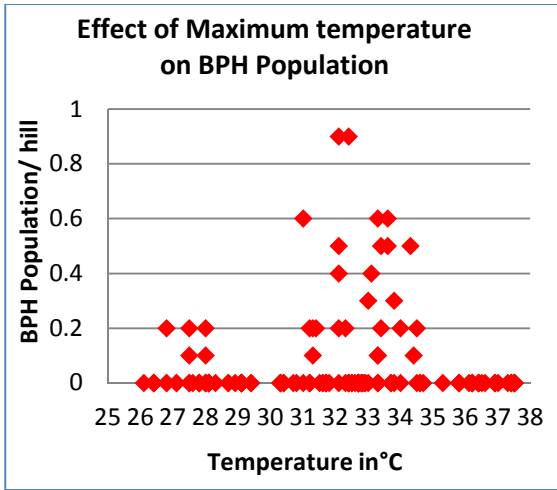


Fig 4.1 Favourable weather parameters for BPH population

4.4 Population built up of White Backed Plant Hopper

The WBPH infestation was found most planting date starting from 1st date (16th July) to 11th date of planting (16th December). The number of pest per hill varied from 0.1 to 1.7 (Table 4.3). However, the infestation of WBPH was first found from 2nd week of August (SMW 33) and was continued up to second week of January (SMW 1). Though the population of WBPH was built up from August to January, but the highest occurrence was observed during second week of November i.e. WK6 after planting (1.7 WBPH/hill) in 1st August date of planting and second peak occurrence was observed during 3rd week of September in 1st September date of planting (Appendix-2).

Table 4.3 Weekly WBPH Population Per Hill

Week after planting	16-Jul	1-Aug	16-Aug	1-Sep	16-Sep	1-Nov	16-Nov	1-Dec	16-Dec	1-Jan
WK1	0	0	0	0	0	0	0	0.2	0	0
WK2	0	0	0	0.7	0	0	0	0.2	0	0
WK3	0	0.1	0.5	1.1	0	0.2	0.2	0.2	0.2	0
WK4	0	0.1	0.5	0.6	0	0	0.2	0	0	0
WK5	0.2	0.2	0.3	0.2	0.2	0	0.2	0	0	0
WK6	0.3	1.7	0.7	0.3	0	0.2	0.2	0.1	0	0
WK7	0.1	0.6	0.7	0.3	0.2	0.2	0	0	0	0
WK8	0.9	0.4	0.3	0.2	0.6	0.1	0	0	0	0
WK9	0.2	0.1	0.4	0	0	0.3	0	0	0	0
WK10	0	0	0.3	0	0	0.3	0	0	0	0
WK11	0	0	0	0	0	0	0	0	0	0
WK12	0	0	0	0	0	0	0	0	0	0
WK13	0	0	0	0	0	0	0	0	0	0
WK14	0	0	0	0	0	0	0	0	0	0

4.5 Favourable weather parameters for WBPH Population built up

The WBPH infestation was found at a range of maximum temperature from (27-37°C), minimum temperature (11-26°C), relative humidity at morning (82-96%), relative humidity at afternoon of (20-85%), rain fall (0-160mm), with 2-10 hours of sunshine. The WBPH infestation was highest at low rainfall with weekly cumulative rainfall of 0 to 10mm and aggravated by maximum temperature (33-35°C), minimum temperature (22-27°C), high morning relative humidity 90-92% and evening relative humidity 70-75%, with 6-8 sunshine hours (Fig4.2).

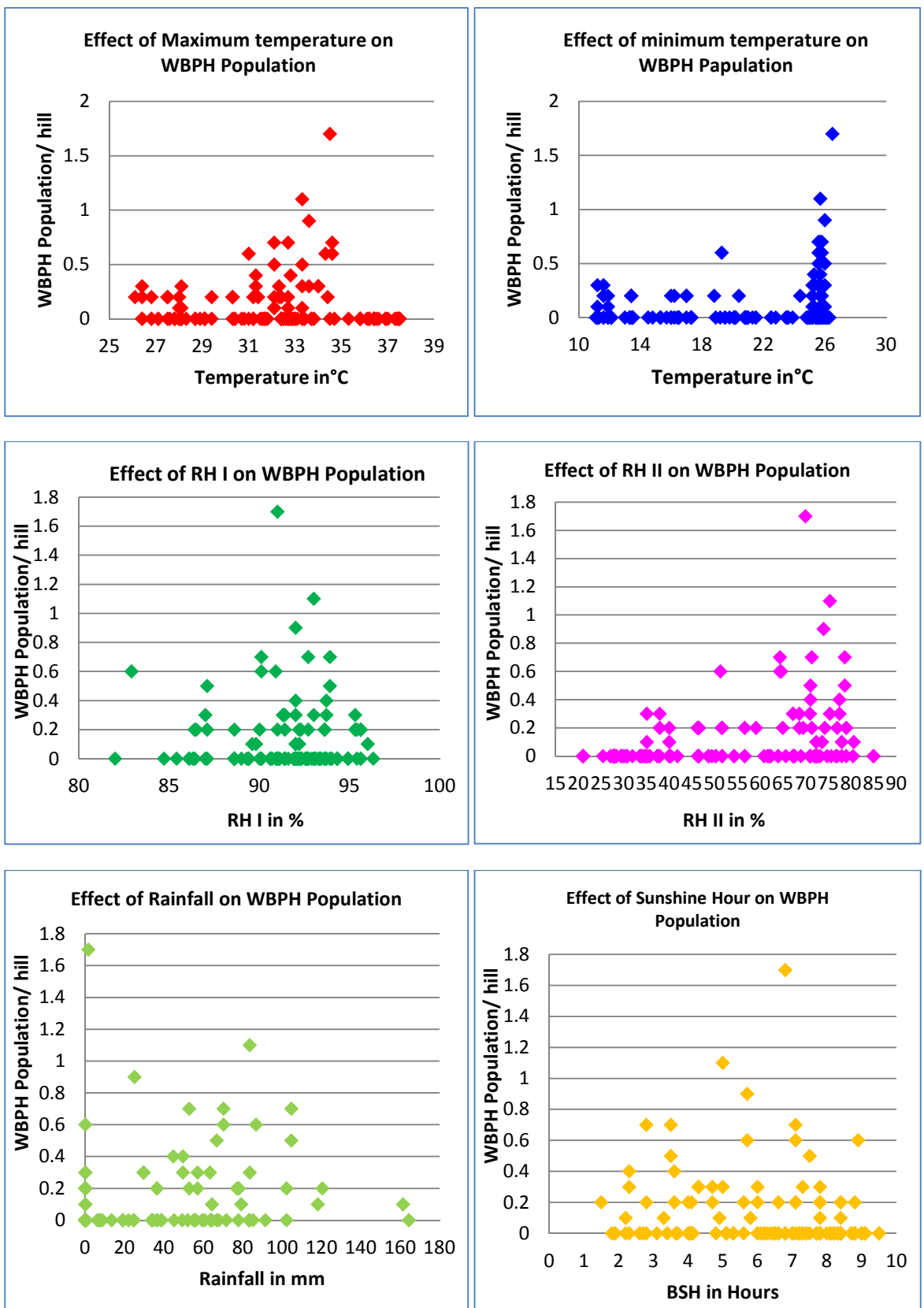


Fig. 4.2 Favourable weather parameters for WBPH population

4.6 Correlation studies of White Backed Plant Hopper with weather parameters

The correlation between WBPH Population and different weather parameters revealed significant correlation in most of the planting date starting from 1st August to 1st December except 16th December and 1st January dates of planting (Table 4.12). The WBPH infestation was found positively correlated with both maximum temperature and minimum temperature and sunshine hour with r value of (0.56), (0.67) and (0.51) in 1st August planting date. In 16th August date of planting WBPH was positively correlated with correlated minimum r value of (0.52). In 1st September date of planting WBPH was positively correlated with minimum temperature, evening relative humidity and rainfall with r value (0.53), (0.58), (0.61). In 16th September date of planting WBPH was negatively correlated (-0.69) with morning relative humidity. In 1st November and 1st December dates of planting it was negatively correlated with maximum temperature of r value (-0.46) and (-0.49). In 1st December date of transplanting WBPH was positively correlated with evening relative humidity and rain fall with rainfall (0.74) and (0.48). In 16th November date of transplanting WBPH was positively correlated with evening relative humidity with r value (0.67) at 1% significance.

Table 4.4 Correlation studies of WBPH population density with weather parameters.

WP	16 th Jul	1st Aug	16 th Aug	1 st Sep	16 th Sep	1 st Nov	16 th Nov	1 st Dec	16 th Dec
TX	0.3623	0.56784	0.39493	0.44088	0.11943	-0.4644	-0.4454	-0.4981	-0.3958
	0.203	0.0342	0.1623	0.1146	0.6716	0.0451	0.056	0.0419	0.1442
TN	0.27778	0.67971	0.5288	0.53972	0.06006	-0.4414	-0.1876	-0.101	-0.281
	0.3363	0.0075	0.0519	0.0464	0.8316	0.0585	0.4418	0.6997	0.3102
RH1	-0.22846	-0.1912	0.05666	0.40566	-0.6961	0.16199	0.07677	0.02258	-0.0921
	0.4321	0.5126	0.8474	0.1501	0.0039	0.5076	0.7547	0.9314	0.7439
RH2	-0.04992	-0.4349	0.12586	0.58855	-0.0337	0.16101	0.67506	0.74012	0.12039
	0.8654	0.1201	0.6681	0.0268	0.905	0.5102	0.0015	0.0007	0.6691
RF	-0.25379	-0.503	0.31953	0.61669	-0.0214	-0.2125	0.4291	0.48525	-0.0714
	0.3813	0.0667	0.2654	0.0188	0.9396	0.3823	0.0668	0.0483	0.8003
SS	0.40467	0.51715	-0.3512	-0.3727	0.30782	0.05702	-0.2086	-0.3955	-0.3145
	0.1512	0.0583	0.2182	0.1893	0.2644	0.8166	0.3912	0.116	0.2535

4.7 Population built up of Green Leaf Hopper

The GLH infestation was found most planting date starting from 1st date (16th July) to 11th date of planting (16th December). The number of pest per hill varied from 0.1 to 0.7 (Table 4.5). However, the infestation of GLH was first found from 2nd week of August (SMW 33) and was continued up to last week of January (SMW 4). Though the population of GLH was built up from August to January, but the highest occurrence was observed during last week of October and 1st week of November in 16th September date of planting i.e. (0.7GLH/hill) (Appendix-5).

Table 4.5 Weekly GLH Population Per Hill

Week after planting	16-Jul	1-Aug	16-Aug	1-Sep	16-Sep	1-Nov	16-Nov	1-Dec	16-Dec	1-Jan
WK1	0	0	0	0	0	0	0	0.1	0	0
WK2	0	0	0.1	0.5	0	0	0.2	0.2	0.1	0
WK3	0	0	0.1	0.2	0.3	0.2	0.5	0.3	0.2	0
WK4	0	0	0.6	0.5	0.2	0.2	0.3	0.1	0	0
WK5	0.2	0.3	0.2	0.3	0.5	0	0.2	0.1	0	0
WK6	0.2	0.1	0.3	0.3	0.7	0.4	0	0.3	0.2	0
WK7	0.3	0.1	1	0.4	0.7	0.2	0	0	0	0
WK8	0.2	0.3	0.2	0.1	0.2	0.8	0	0	0	0
WK9	0.3	0.2	0.3	0	0	0.1	0	0.2	0	0
WK10	0	0	0.3	0	0	0.1	0	0	0	0
WK11	0	0	0	0	0	0	0	0	0	0
WK12	0	0	0	0	0	0	0	0	0	0
WK13	0	0	0	0	0	0	0	0	0	0
WK14	0	0	0	0	0	0	0	0	0	0

4.8 Favourable weather parameters for GLH Population built up

The GLH infestation was found at a range of maximum temperature from (26-38°C), minimum temperature (11- 26°C), relative humidity at morning (82-96%), relative humidity at afternoon of (20-85%),rain fall (0-160mm),with 1-10 hours of sunshine. The peak occurrence of GLH was observed at maximum temperature (32-34⁰c), minimum temperature (24-26⁰c), high morning relative humidity 90-95% and evening relative humidity 60-95%, 2-4 sunshine hours, with 40-60 mm rainfall prevailing the pest population (Fig 4.3).

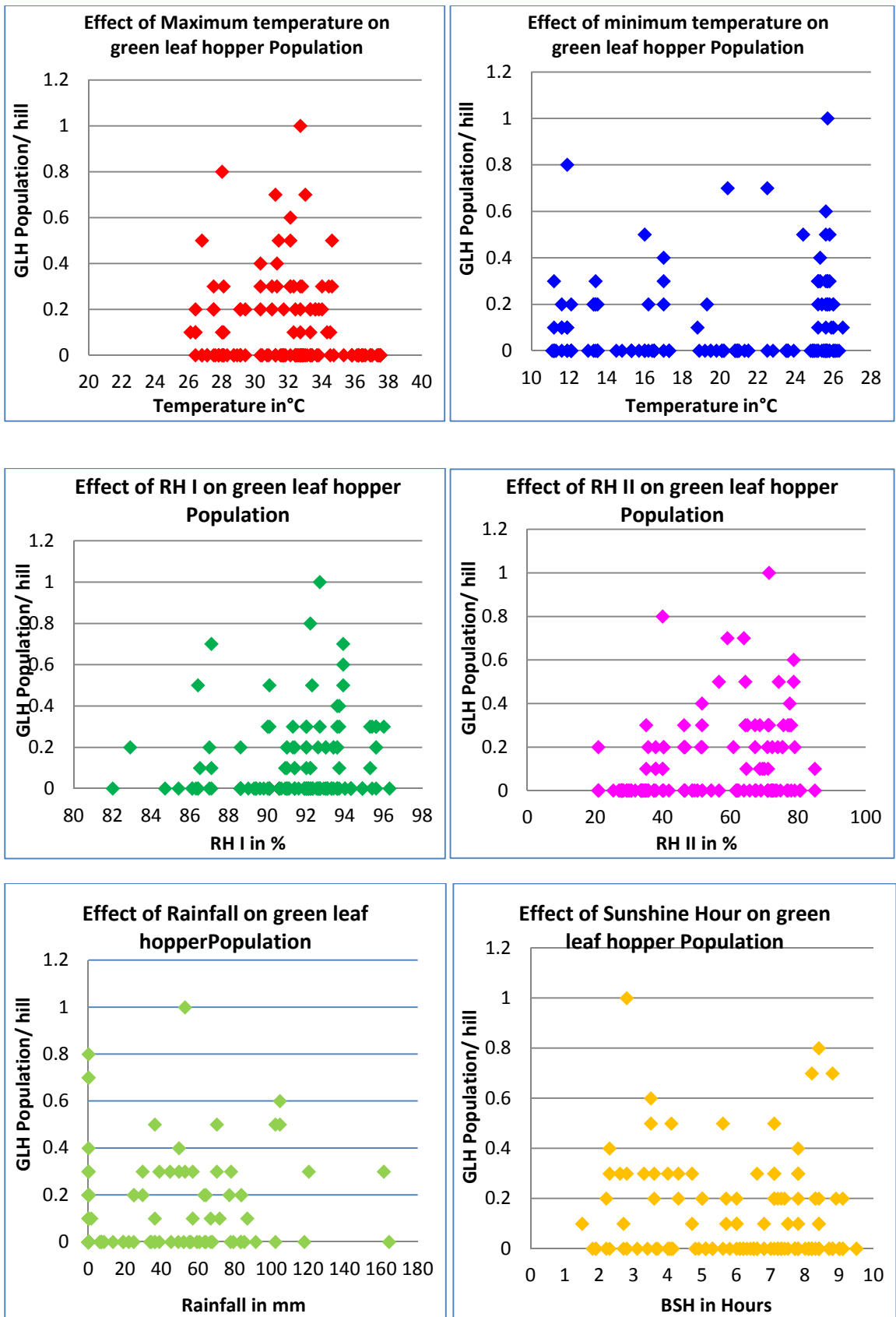


Fig. 4.3 Favourable weather parameters for Green leaf Hopper population

4.9 Correlation studies of Green Leaf Hopper with weather parameters

The correlation between GLH Population and different weather parameters revealed significant correlation in many planting viz., 1st September, 16th November, 1st December and 16th December out of 12 planting dates (Table 4.6). The GLH population was found positively correlated with minimum temperature and evening relative humidity with r value of (0.61) and (0.57) and negatively correlated with bright sunshine hour(-0.57) in 1st September date of planting. In 16th November date of planting it was positively correlated with evening relative humidity and rainfall with r value (0.73) and (0.73). In 1st December date of planting GLH was negatively correlated with maximum temperature and minimum temperature with r value (-0.57) and (-0.51). In 16th December date of planting it was negatively correlated with maximum temperature with r value (-0.53).

Table 4.6 Correlation studies of GLH population density with weather parameters

WP	16 th Jul	1st Aug	16 th Aug	1 st Sep	16 th Sep	1 st Nov	16 th Nov	1 st Dec	16 th Dec
TX	0.34221	0.00778	0.05591	0.4447	0.41808	-0.3255	-0.4017	-0.571	-0.5384
	0.2311	0.9789	0.8494	0.1111	0.121	0.1739	0.0882	0.0165	0.0384
TN	0.0672	-0.2291	0.40132	0.6138	0.3929	-0.3357	-0.0804	-0.511	-0.415
	0.8193	0.4306	0.155	0.0195	0.1474	0.16	0.7435	0.0357	0.124
RH1	-0.14839	0.28109	0.36348	0.4177	-0.0664	0.20117	-0.117	0.2060	0.07984
	0.6127	0.3303	0.2014	0.1372	0.8141	0.4089	0.6332	0.4276	0.7773
RH2	-0.08965	-0.1724	0.25398	0.5798	0.37713	0.1878	0.73472	0.2561	0.18575
	0.7605	0.5556	0.3809	0.0297	0.1658	0.4414	0.0003	0.3211	0.5075
RF	0.23344	0.08972	0.26763	0.5157	0.09138	-0.18	0.73729	0.0201	-0.1274
	0.4218	0.7604	0.3549	0.0591	0.746	0.4608	0.0003	0.939	0.6509
SS	0.36419	-0.1811	-0.6036	-0.5763	0.21539	0.21878	-0.4136	0.0611	-0.1726
	0.2005	0.5353	0.0223	0.031	0.4407	0.3682	0.0783	0.8158	0.5383

4.10 Population built up of Whorl Maggot

The WM infestation was found in planting date starting from 1st date (16th July) to 9th date of planting (16th Nov). The pest infestation was varied from 0.5 to 26.4 percent (Table 4.7). But not found during 16th September, 1st December, 16th December and 1st January dates of transplanting. However, the infestation of WM was first found from 3rd week of August (SMW 34) and was continued up to last week of December (SMW 52). Though the population of WM was built up from August to

December, but the highest infestation was observed during 1st week of December in 1st week of November date of planting. Mainly whorl maggots are infesting the rice crop in the early stage of growth (Appendix-6).

Table 4.7 Weekly WM Infestations in Percentage

Week after planting	16-Jul	1-Aug	16-Aug	1-Sep	16-Sep	1-Nov	16-Nov	1-Dec	16-Dec	1-Jan
WK1	0	1.5	0	0	0	0	0	0	0	0
WK2	0	0.54	5	0	0	0	0	0	0	0
WK3	0	3.3	0	0.8	0	0	0	0	0	0
WK4	0	6.8	0	0.6	0	3.6	0	0	0	0
WK5	3.5	18.1	0	1.1	0	26.4	0	0	0	0
WK6	0.5	0	0	3	0	0	5.76	0	0	0
WK7	0	0	0	0	0	0	0	0	0	0
WK8	0.7	0	0	0	0	0	0	0	0	0
WK9	0	0	0	0	0	0	0	0	0	0
WK10	0	0	0	0	0	0	0	0	0	0
WK11	0	0	0	0	0	0	0	0	0	0
WK12	0	0	0	0	0	0	0	0	0	0
WK13	0	0	0	0	0	0	0	0	0	0
WK14	0	0	0	0	0	0	0	0	0	0

4.11 Favourable weather parameters for Whorl Maggot Population built up

The WM infestation was aggravated with low weekly cumulative rainfall of 20 to 40 mm and low sunshine hours of 3 to 5 hrs. The peak occurrence of WM infestation was observed at maximum temperature (26-28^oc), minimum temperature (14-16^oc), morning relative humidity 84-88% and evening relative humidity 55-60%, 2-4 sunshine hours, while WM infestation was found at a range of maximum temperature from(26- 38°C), minimum temperature (11- 27°C), relative humidity at morning (82-96%), relative humidity at afternoon of (20-85%),rain fall (0-170mm),with 1-10 hours of sunshine (Fig 4.4).

4.12 Correlation studies of Whorl Maggot with weather parameters

The correlation between WM infestation and different weather parameters revealed significant correlation only in three dates of planting viz., 1st August, 16th August and 1st November out of 12 planting dates (Table 4.8). The WM infestation was found positively correlated with rainfall (0.68) in 1st August and (0.50) in 1st November planting dates. It was also found positively correlated with afternoon relative humidity at r value (0.53) in 16th August planting date.

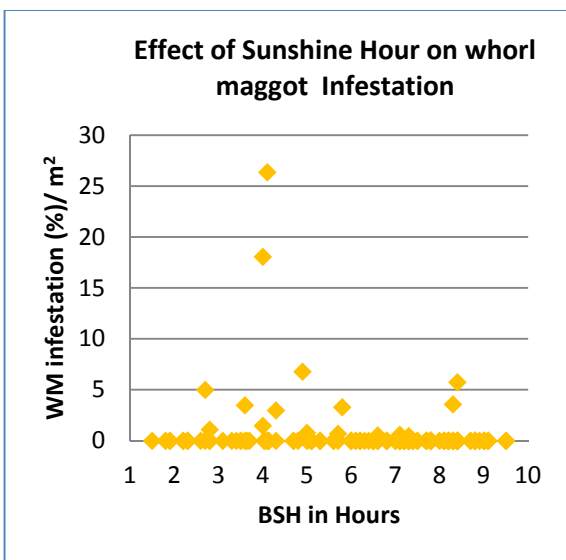
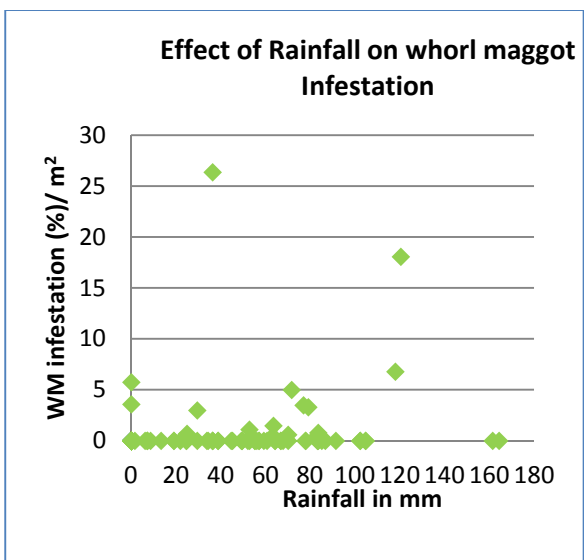
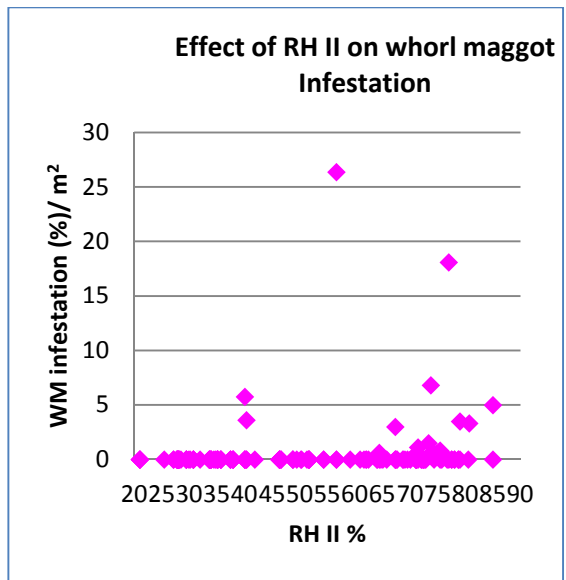
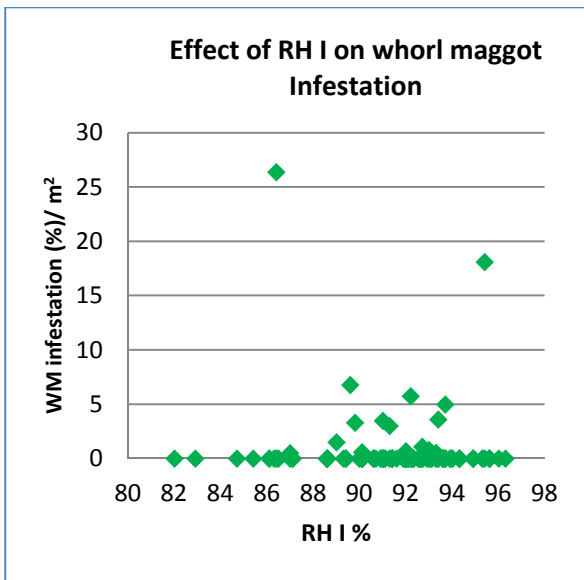
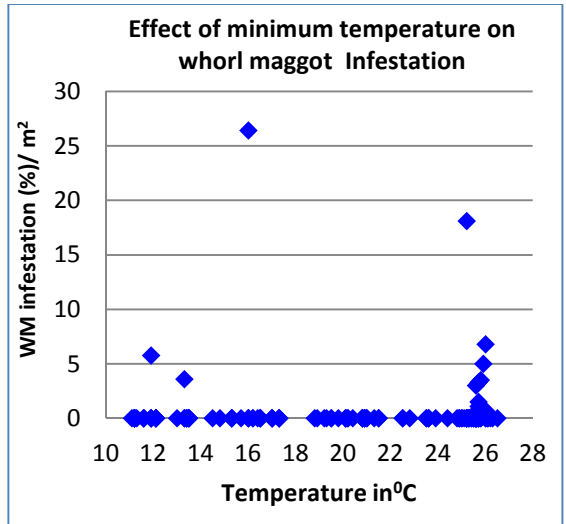
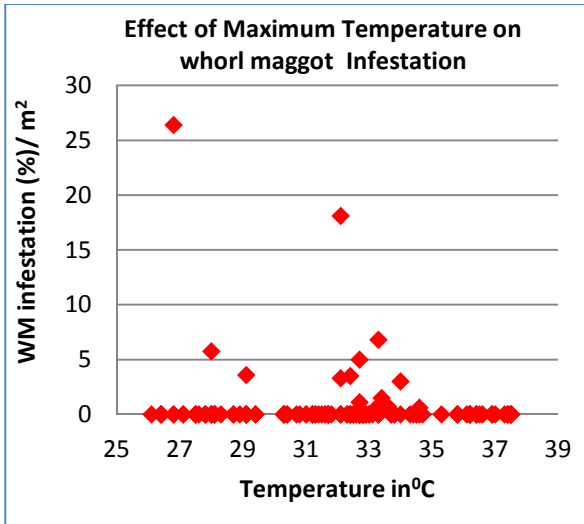


Fig. 4.4 Favourable weather parameters for whorl maggot infestation

Table 4.8 Correlation studies of WM infestation with weather parameters

WP	16 th Jul	1st Aug	16 th Aug	1 st Sep	1 st Nov	16 th Nov
TX	-0.01056	-0.1983	0.00853	0.46822	-0.2781	-0.2123
	0.9714	0.4968	0.9769	0.0913	0.2489	0.3827
TN	0.15676	-0.2271	0.17878	0.36135	-0.0047	-0.2384
	0.5925	0.4348	0.5409	0.2043	0.9847	0.3255
RH1	-0.21481	0.27264	0.22467	0.10142	-0.3477	0.05738
	0.4608	0.3456	0.44	0.7301	0.1446	0.8155
RH2	0.23776	0.34567	0.53292	0.0862	0.34933	0.07879
	0.4131	0.2261	0.0497	0.7695	0.1427	0.7485
RF	-0.04895	0.68341	0.13976	-0.023	0.50473	-0.0658
	0.868	0.007	0.6337	0.9375	0.0275	0.7887
SS	-0.02817	0.02574	-0.3568	-0.2948	-0.3911	0.18387
	0.9238	0.9304	0.2104	0.3062	0.0977	0.4511

4.13 Population built up of Yellow stem borer

The YSB infestation was found in every dates of planting starting from 1st date (16th July) to 12th date of planting (1st January), The pest infestation was varied from 0.1 to 2.9 percent in early stages of crop growth but in reproductive stage infestation was varied from 0.2 to 7.56 percent (Table 4.9 and Table 4.10). However, the infestation of YSB was first found from 3rd week of September and was continued up to last week of March and YSB infestation was not found in November planting dates. Though the population of YSB was built up from July to January, the highest infestation of YSB at early stages (DH) was found in 3rd week of February (2.9%/m²) in 1st January planting date (Appendix-10). The YSB infestation at reproductive stage of crop was found highest in 2nd week of March i.e. (7.56%/m²) in 16th December planting date (Appendix-9).

Table 4.9 Weekly Occurrence of DH in Percentage

Week after planting	16-Jul	1-Aug	16-Aug	1-Sep	16-Sep	1-Nov	16-Nov	1-Dec	16-Dec	1-Jan
WK1	0	0	0	0	0	0	0	0	0	0
WK2	0	0	0	0	0	0	0	0	0	0
WK3	0	0	0	0	0	0	0	0	0	2.01
WK4	0	0	0	0	0	0	0	0	0	0.73
WK5	0	0	0	0	0	0	0	0	0	0.97
WK6	0	0	0.1	0	0	0	0	0	0	0.33
WK7	0	0	0	0	0.25	0	0	0	0	2.9
WK8	0	0	0	0	0	0	0	0	0.74	0
WK9	0	0	0	0	0	0	0	0	0	0
WK10	0	0	0	0	0	0	0	0	0	0
WK11	0	0	0	0	0	0	0	0	0	0
WK12	0	0	0	0	0	0	0	0	0	0
WK13	0	0	0	0	0	0	0	0	0	0
WK14	0	0	0	0	0	0	0	0	0	0

Table 4.10 Weekly Occurrence of WEH in Percentage

Week after planting	16-Jul	1-Aug	16-Aug	1-Sep	16-Sep	1-Nov	16-Nov	1-Dec	16-Dec	1-Jan
WK1	0	0	0	0	0	0	0	0	0	0
WK2	0	0	0	0	0	0	0	0	0	0
WK3	0	0	0	0	0	0	0	0	0	0
WK4	0	0	0	0	0	0	0	0	0	0
WK5	0	0	0	0	0	0	0	0	0	0
WK6	0	0	0	0	0	0	0	0	0	0.32
WK7	0	0	0	0	0	0	0	0	0	1.26
WK8	0	0	0	0	0	0	0	0	2.98	6.4
WK9	0.16	2.5	0	0.2	0.13	0	0	0	2.31	5.4
WK10	0.32	0.83	1	0.2	2.4	0	0	0	5.1	6.56
WK11	0.35	0.41	3	1.9	1	0	0	1.6	2.41	1.28
WK12	0.63	0.68	0	0.8	2	0	0	1.4	7.56	1.61
WK13	0.31	0	0	1.1	0	0	0	3	2.5	0
WK14	0	0	0	0	0	0	0	2.61	0	0

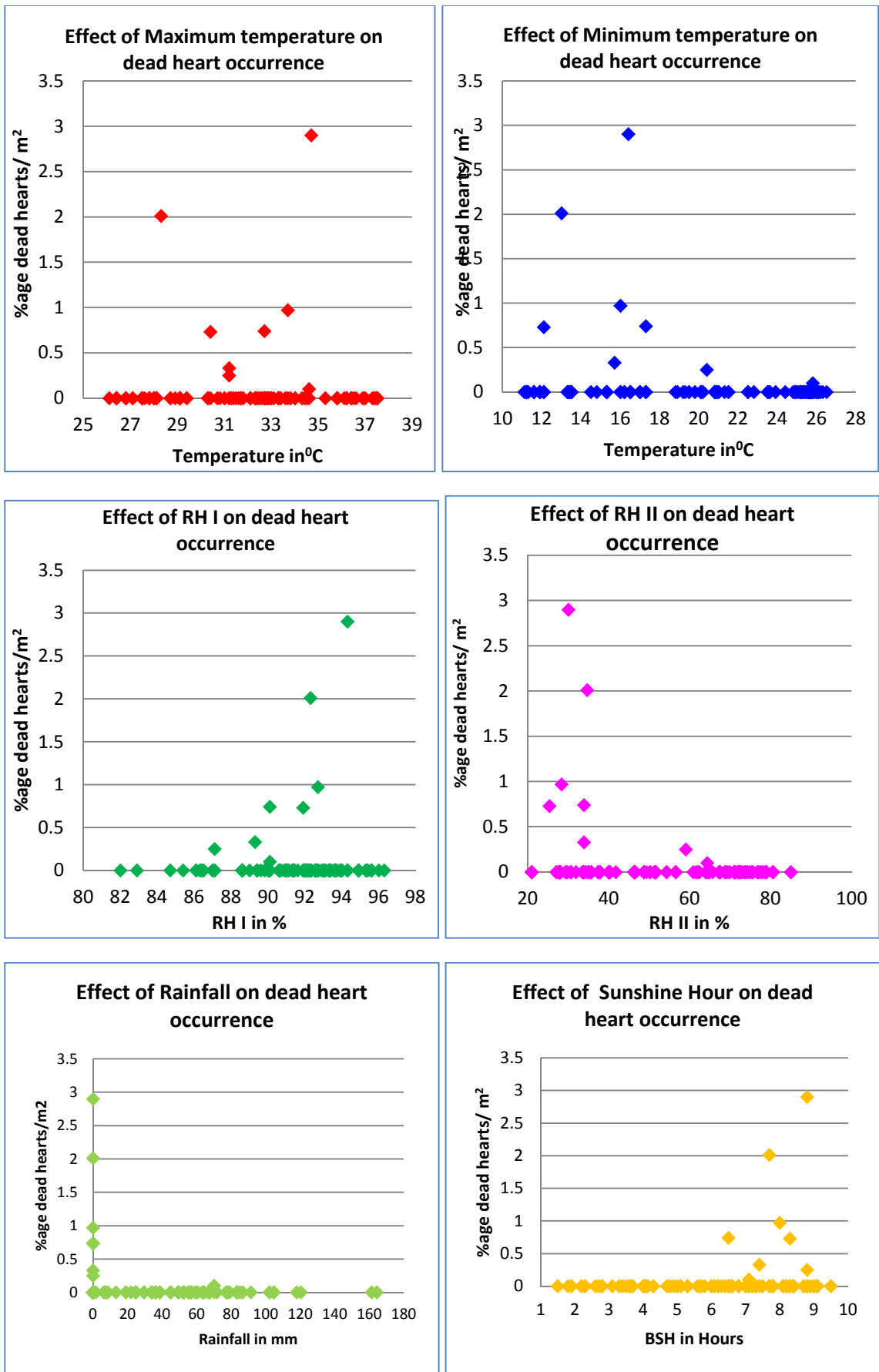


Fig. 4.5 Favourable weather parameters for dead heart occurrence

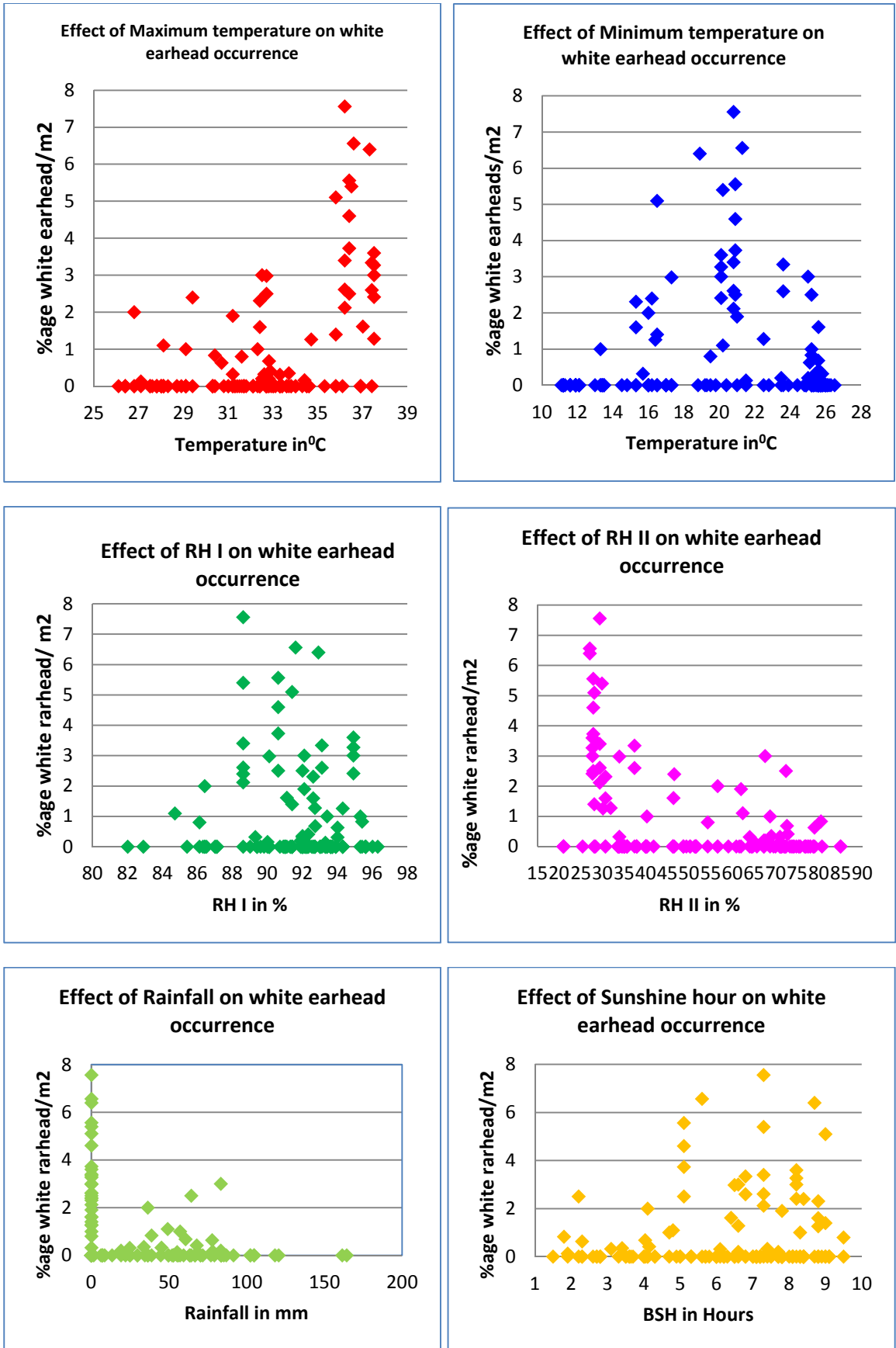


Fig. 4.6 Favourable weather parameters for white ear head occurrence

4.14 Favourable weather parameters for Yellow stem borer

Maximum infestation of YSB was found at prevailing weather conditions such as maximum temperature (30-38⁰c), minimum temperature (16-22⁰c), morning relative humidity 88-96% and evening relative humidity 25-35%, ample sunshine hours and dry conditions found favourable for pest population, while YSB infestation was found at a range of maximum temperature from(26- 37°C), minimum temperature (11- 27°C), relative humidity at morning (82-96%), relative humidity at afternoon of (20- 85%),rain fall (0-170mm),with 1-10 hours of sunshine (Fig 4.5 and 4.6).

4.15 Correlation studies of Yellow stem borer infestation with weather parameters

The correlation between YSB Population and different weather parameters revealed significant correlation in many dates of planting viz., 1st August, 16th August, 1st November, 16th November, 1st December, 16th December, 1st January out of 12 planting dates (Table 4.11 and Table 4.12). The YSB infestation at seedling stage(DH) is positively correlated with maximum temperature in 16th August date of planting with r value (0.57) and YSB infestation at reproductive stage (WEH) is negatively correlated with bright sunshine with r value (-0.59). WEH found positive correlation with maximum temperature and minimum temperature in 1st November, 16th November and 1st December date of planting with r value(0.73),(0.69),(0.69), (0.60),(0.65),(0.55). In 16th December date of planting and 1st January date of planting WEH was positively correlated with only maximum temperature with r value (0.53) and (0.58).

Table 4.11 Correlation studies of occurrence of DH with weather parameters

WP	16 th Aug	16 th Sep	16 th Dec	1 st Jan
TX	0.57563	0.0846	0.02683	-0.2514
	0.0312	0.7644	0.9244	0.3859
TN	0.16431	0.03016	0.05551	-0.3644
	0.5746	0.915	0.8442	0.2001
RH1	-0.1811	-0.3265	-0.2633	0.42732
	0.5353	0.2349	0.343	0.1275
RH2	-0.2256	0.01615	-0.0209	-0.2641
	0.4379	0.9545	0.9409	0.3615
RF	0.12664	-0.1932	-0.0714	-0.2249
	0.6662	0.4901	0.8003	0.4394
SS	0.20677	0.25836	-0.2011	0.47943
	0.4782	0.3525	0.4722	0.0828

Table 4.12 Correlation studies of occurrence of WEH with weather parameters.

WM	16th Jul	1st Aug	16th Aug	1st Sep	16th Sep	1st Nov	16th Nov	1st Dec	16th Dec	1st Jan
TX	-0.19643	-0.287	-0.0856	-0.4551	-0.43	0.7391	0.6993	0.699	0.536	0.5835
	0.5009	0.3205	0.7711	0.102	0.1092	0.0003	0.0009	0.001	0.039	0.0285
TN	-0.42684	-0.488	0.07227	-0.6743	-0.417	0.6091	0.6512	0.55171	0.3633	0.351
	0.128	0.077	0.806	0.0082	0.1219	0.0056	0.0025	0.0217	0.1833	0.2185
RH1	0.29969	0.196	0.17417	-0.3771	-0.356	0.00012	0.0958	-0.0316	-0.469	0.05
	0.2979	0.5019	0.5515	0.1837	0.1925	0.9996	0.6966	0.904	0.0779	0.8652
RH2	-0.24374	0.0686	-0.1265	-0.5577	-0.361	-0.3922	-0.364	-0.4215	-0.453	-0.4138
	0.4011	0.8157	0.6664	0.0382	0.1863	0.0967	0.1259	0.0919	0.0903	0.1413
RF	-0.29735	-0.128	0.23825	-0.5146	-0.12	-0.143	-0.141	-0.187	-0.18	-0.266
	0.3019	0.6635	0.4121	0.0597	0.67	0.5577	0.5646	0.471	0.514	0.3576
SS	-0.28979	-0.60	0.10606	0.43718	0.0451	-0.129	-0.245	-0.061	0.112	-0.245
	0.3149	0.0235	0.7182	0.118	0.8732	0.5983	0.3121	0.814	0.689	0.3975

4.16 Population built up of Gundhi Bug

The Gundhi bug occurrence was found most of the planting date starting from 1st date (16th July) to 12th date of planting (1st January), except 16th August, 1st November, 16th November, 16th December date of planting. The number of pest per hill varied from 0.1 to 1.8 (Table 4.13). However, the infestation of GB was first found from 3rd week of September (SMW 38) and was continued up to 2nd week of April (SMW 45). Though the population of GB was built up from September to April, but the highest occurrence was observed during last week of November in 1st September date of transplanting (Appendix-4), and gundhi bug was not found in November and December dates of planting.

Table 4.13 Weekly GB Population Per Hill

Week after planting	16-Jul	1-Aug	16-Aug	1-Sep	16-Sep	1-Nov	16-Nov	1-Dec	16-Dec	1-Jan
WK1	0	0	0	0	0	0	0	0	0	0
WK2	0	0	0	0	0	0	0	0	0	0
WK3	0	0	0	0	0	0	0	0	0	0
WK4	0	0	0	0	0	0	0	0	0	0
WK5	0	0	0	0	0	0	0	0	0	0.2
WK6	0	0	0	0	0	0	0	0	0	0
WK7	0	0	0	0	0	0	0	0	0	0
WK8	0	0.1	0	0	0	0	0	0	0	0
WK9	0.2	0.2	0	0	0.3	0	0	0	0	0
WK10	0.5	0	0	0	0.1	0	0	0	0	0
WK11	0.1	0	0	0	0	0	0	0	0	0
WK12	0	0.1	0	1.8	0	0	0	0	0	0
WK13	0	0	0	0	0	0	0	0	0	0.4
WK14	0	0	0	0	0	0	0	0	0	0.3

4.17 Favourable weather parameters for Gundhi Bug Population

The GB population was highest when the following conditions were prevailed as maximum temperature (30-34⁰c), minimum temperature (18-20⁰c), morning relative humidity 85-88% and evening relative humidity 50-55%, ample sunshine hours of (9-10hr), with dry conditions found favourable for pest population, while the GB population was found at a range of maximum temperature from(26- 37°C), minimum temperature (11- 26°C),relative humidity at morning (82-96%), relative humidity at afternoon of (20-85%),rain fall (0-160mm),with 1-10hours of sunshine (Fig 4.7).

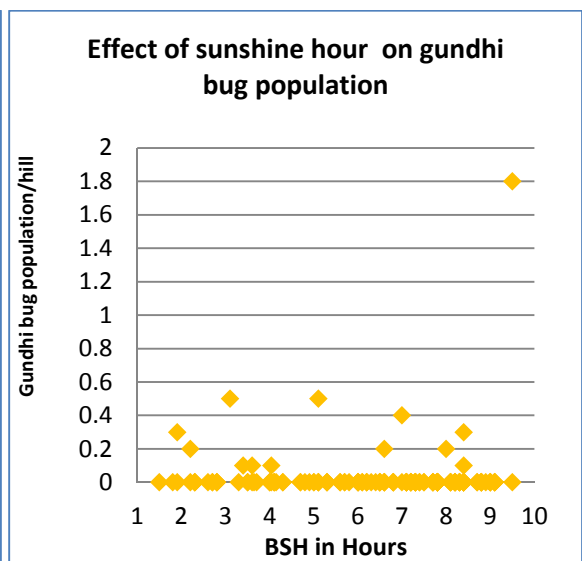
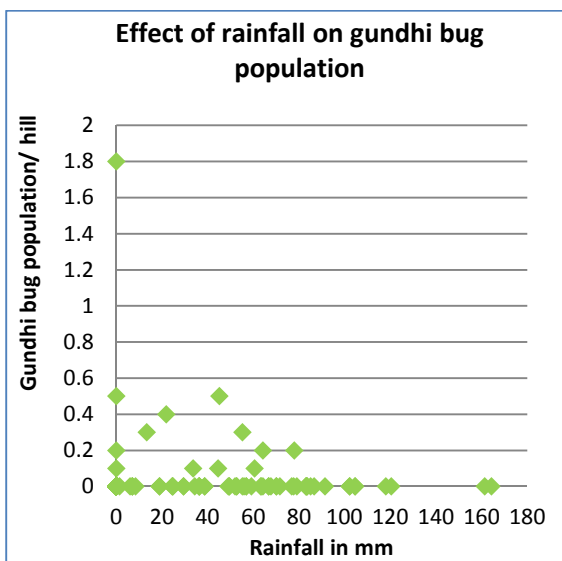
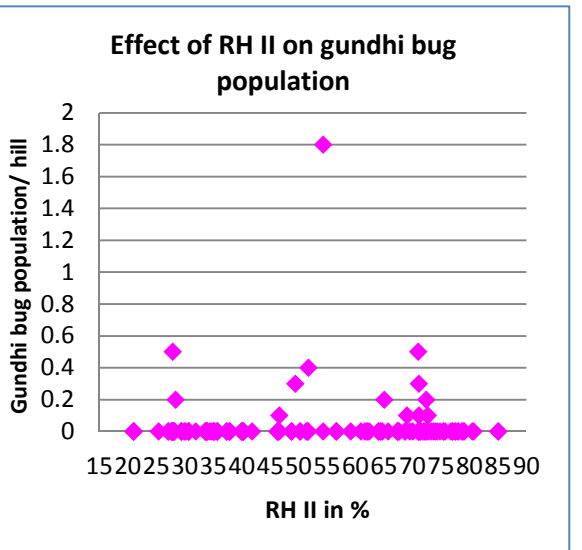
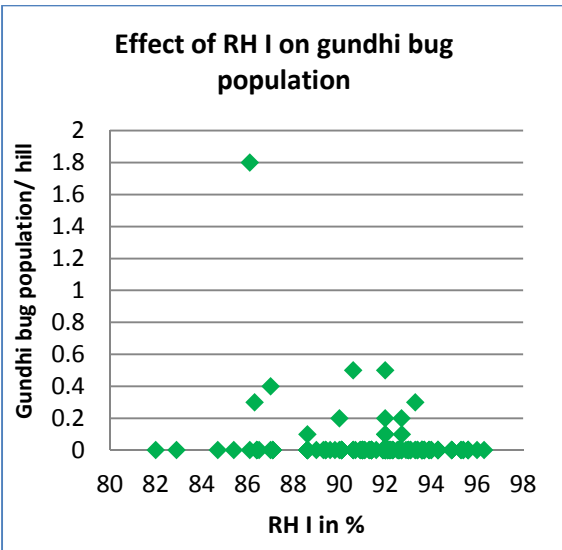
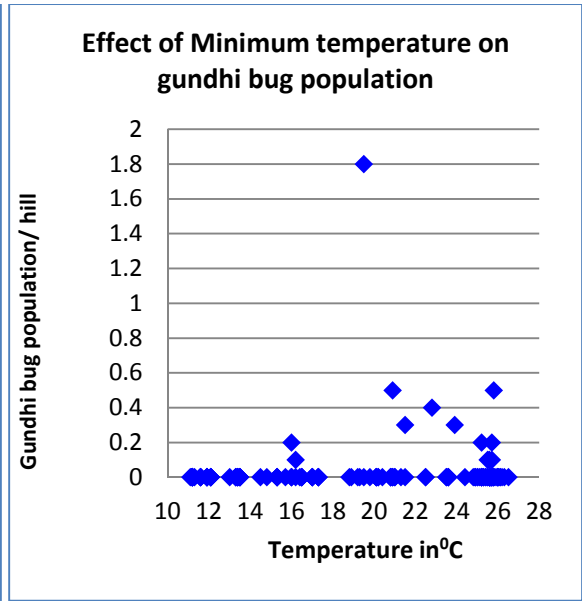
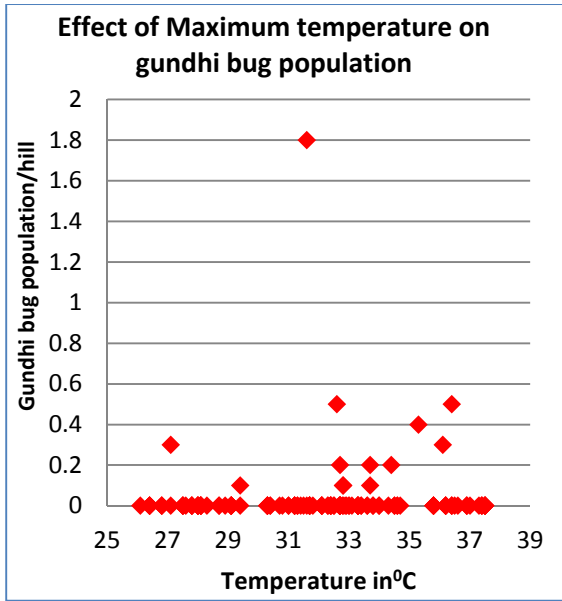


Fig. 4.7 Favourable weather parameters for gundhi bug population

4.18 Correlation studies of Gundhi Bug with weather parameters

The correlation between GB Population and different weather parameters revealed significant correlation only in two dates of planting viz., 1st September and 1st January out of 12 planting dates (Table 4.14). The GB was negatively correlated with afternoon relative humidity with r value (-0.57) in 1st September date of planting. In 1st January date of planting GB was negatively correlated with morning relative humidity with r value (-0.66) and positively correlated with evening relative humidity and rainfall with r value (0.67) and (0.91).

Table 4.14 Correlation studies of population density of GB with weather parameters

WP	16 th Jul	1 st Aug	1 st Sep	16 th Sep	1 st Dec	1 st Jan
TX	0.18548	-0.0652	-0.0723	-0.407	0.28376	0.22418
	0.5255	0.8247	0.8059	0.1322	0.2697	0.441
TN	0.06107	-0.311	-0.4939	0.02275	0.25541	0.39285
	0.8357	0.2791	0.0726	0.9359	0.3225	0.1647
RH1	-0.0871	0.04231	-0.4638	0.07737	-0.1332	-0.6683
	0.7672	0.8858	0.0948	0.784	0.6101	0.009
RH2	-0.33983	-0.1599	-0.5778	0.19442	-0.21	0.67656
	0.2345	0.5849	0.0304	0.4875	0.4174	0.0079
RF	-0.21128	-0.1433	-0.4174	0.22076	-0.0742	0.91329
	0.4684	0.625	0.1375	0.4291	0.7771	<.0001
SS	-0.10939	-0.4671	0.52641	-0.4147	-0.2841	0.10269
	0.7097	0.0921	0.0531	0.1243	0.269	0.7268

4.19 Population built up of Spider

The Spider population was found in every planting date starting from 1st date (16th July) to 12th date of planting (1st January). The number of predators per hill varied from 0.1 to 3 (Table 4.15). However, the peak population was observed during 3rd week of February in 1st November date of planting (Appendix-6).

Table 4.15 Weekly Spider Population Per Hill

Week after planting	16-Jul	1-Aug	16-Aug	1-Sep	16-Sep	1-Nov	16-Nov	1-Dec	16-Dec	1-Jan
WK1	0.2	0.1	0.3	0	0.1	0.1	0.1	0.2	0.3	0.3
WK2	0.2	0.2	0.1	0.2	0.1	0.2	0.3	0.2	0.2	0.4
WK3	0.1	0.1	0.2	0.4	0.4	0.2	0.4	0.3	0.4	0.6
WK4	0.2	0.1	0.7	0.5	0.3	0.3	0.2	0.5	0.3	0.7
WK5	0.3	1.7	0.5	0.4	0.3	0.2	0.3	0.2	0.2	1
WK6	0.4	0.4	0.4	0.1	0.4	0.4	0.4	0.1	0.4	0.1
WK7	0.4	0.6	0.5	0.3	0.7	0.4	0.5	0.5	0.3	0.25
WK8	0.3	0.5	0.5	0.5	0.4	0.8	0.2	0.4	0.5	0.2
WK9	0.3	0	0.4	0.1	0.5	0.5	0.5	0	0.4	0.1
WK10	0.1	0.3	0.7	0.1	0	0.4	0.3	0.6	0.3	0.3
WK11	0	0.1	0.2	0.2	0.1	0.4	0.3	0.8	0	0.2
WK12	0.1	0.1	0.1	1	0.3	0.2	0.2	0.5	0.1	0
WK13	0.1	0.1	0	0.2	0.4	0.2	0.5	0	0	0.2
WK14	0	0.1	0	0.2	0.4	0.3	0.3	0.1	0	0.2
WK15	0	0	0	0	0.1	0.3	0.5	0.2	0.2	0
WK16	0	0	0	0	0	3	0.2	0.1	0	0

4.20 Favourable weather parameters for Spider Population built up

The spider population was highest when the following conditions were prevailed as maximum temperature (34-36⁰c), minimum temperature (16-18⁰c), high morning relative humidity of 90-95% and evening relative humidity 20-40% with ample sunshine hours of (8-10hr), with dry conditions found favourable for Spider population, while it was found at a range of maximum temperature from(26- 38°C), minimum temperature (11- 26°C),relative humidity at morning (82-97%), relative humidity at afternoon of (20-85%),rain fall (0-160mm),with 1-10hours of sunshine (Fig 4.8).

4.21 Correlation studies of Spider with weather parameters

The correlation between Spider Population and different weather parameters revealed significant correlation only in three dates of planting viz., 16^t h August, 16^t h December,1st January out of 12 planting dates (Table4.16).In 16th August date of planting spider was positively correlated with minimum temperature, morning relative humidity, rainfall with r value (0.62),(0.54),(0.53) and was negatively correlated with bright sunshine hour at 5% significance with r value (-0.61).In 16th December date of planting was negatively correlated with maximum temperature and minimum temperature at 5% significance with r value (-0.59),(-0.58).In 1st January date of planting spider was negatively correlated with minimum temperature(-0.55).

Table 4.16 Correlation studies of population density of Spider with weather parameters

WP	16 th Jul	1st Aug	16 th Aug	1 st Sep	16 th Sep	1 st Nov	16 th Nov	1 st Dec	16 th Dec	1 st Jan
TX	0.20189	-0.0898	0.25657	0.03717	-0.0774	0.20692	-0.2475	-0.2053	-0.597	-0.4413
	0.4888	0.7602	0.3759	0.8996	0.7839	0.3953	0.307	0.4293	0.0187	0.1142
TN	0.37905	-0.2362	0.62625	-0.2734	0.15416	-0.1191	-0.3836	-0.2908	-0.585	-0.5578
	0.1814	0.4162	0.0166	0.3443	0.5833	0.6273	0.105	0.2574	0.022	0.0382
RH1	-0.26946	0.49368	0.54438	-0.1421	-0.0609	0.0947	0.45254	0.11433	-0.047	0.37552
	0.3515	0.0728	0.0441	0.6281	0.8292	0.6998	0.0517	0.6622	0.8682	0.1858
RH2	0.22473	0.04603	0.35498	-0.4008	0.28375	-0.2045	-0.1839	-0.0397	0.1284	-0.4162
	0.4399	0.8758	0.213	0.1555	0.3054	0.401	0.451	0.8798	0.6484	0.1388
RF	0.29371	0.36047	0.53721	-0.2133	0.00444	-0.1268	0.09999	-0.1194	-0.069	-0.189
	0.3081	0.2055	0.0476	0.4641	0.9875	0.605	0.6838	0.648	0.8059	0.5175
SS	0.30902	0.0524	-0.6123	0.24062	-0.051	0.26578	0.11409	0.20645	0.1425	0.31051
	0.2824	0.8588	0.0199	0.4073	0.8568	0.2714	0.6419	0.4266	0.6124	0.2799

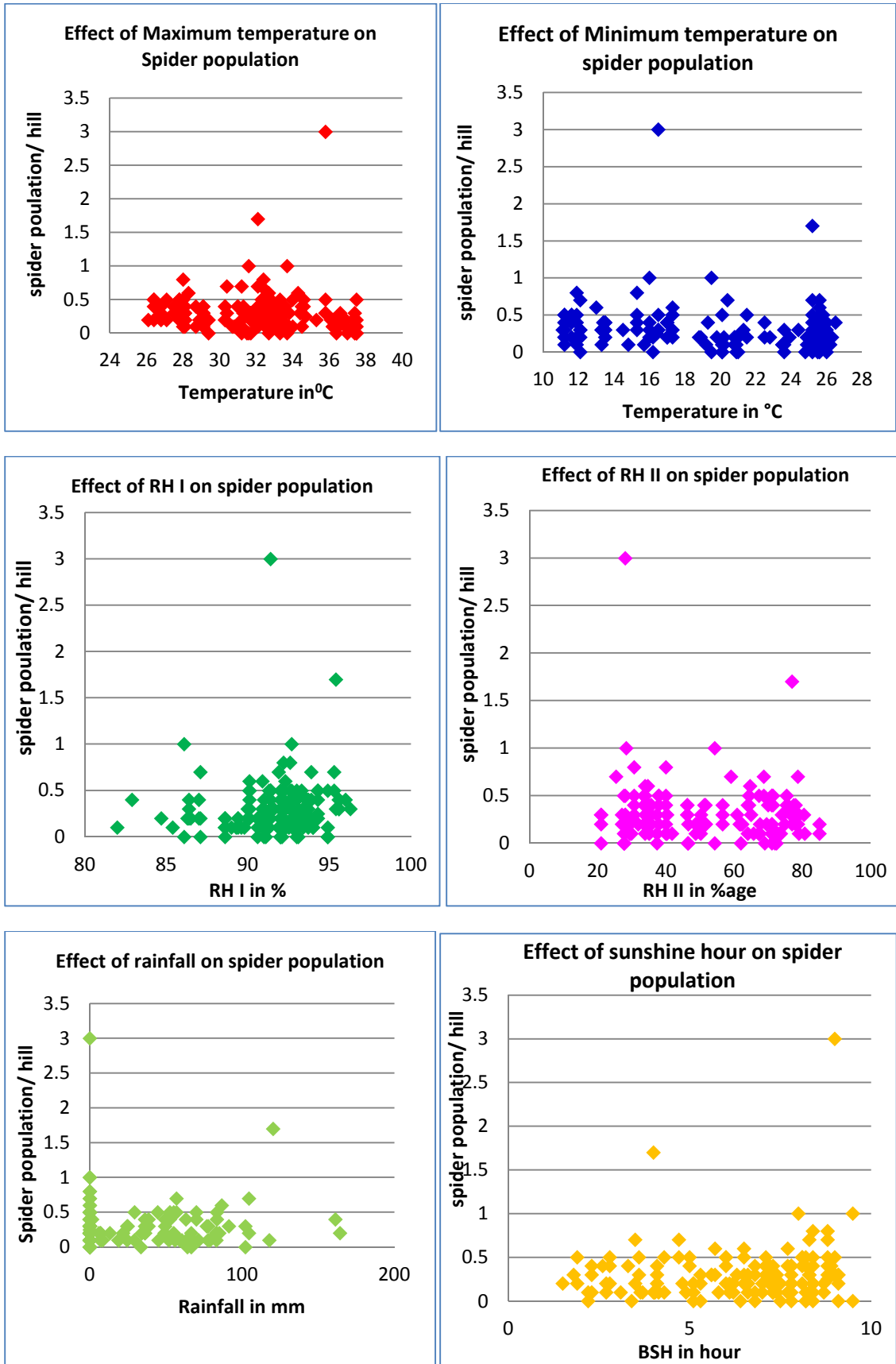


Fig. 4.8 Favourable weather parameters for spider population

4.22 Population built up of Dragon fly and damselfly (DFLY)

The Dragonfly and Damselfly population were found in most of the planting date starting from 1st date (16th July) to 12th date of planting (1st January). The number of predators per square meter varied from 0.5 to 2.5 (Table 4.17). However, the peak occurrence was observed during 2nd week of November and second highest population was observed during last week of October in 1st September planting (Appendix-4).

Table 4.17 Weekly Dragon fly and damselfly (DFLY) Population Per m²

Week after planting	16-Jul	1-Aug	16-Aug	1-Sep	16-Sep	1-Nov	16-Nov	1-Dec	16-Dec	1-Jan
WK1	0	5	1	1	0.5	1	0	0.5	0	0
WK2	0	0.5	0	1.5	0	0.5	0	0.5	0	0
WK3	0	0.5	1	1.5	0	1	0	0	0.5	0
WK4	0	1	0.5	1	0	0	0	0	0	0
WK5	0.5	2	1.5	1.5	0.5	0	0	0	0	0
WK6	1	1	1.5	0.5	0.5	0	0	0.5	0	0.5
WK7	1.5	1	0	0.5	0	0	0	0	0	0
WK8	1	0	0.5	1.5	0.5	0	0	0	0	1
WK9	1	0	1	1.5	0	0	0	0	0	0
WK10	3	1.5	0	0	0	0	0	1	0	0
WK11	0	2	1	2.5	0	0	0	0	0	0
WK12	0.5	2	0	0	0	0	0.5	0	0	0
WK13	0.5	1	0.5	0	0	0	0.5	0	0	0
WK14	0.5	1	0	0	0	0.5	0	0	0	0

4.23 Favourable weather parameters for Dragon fly and damselfly (DFLY)

Population built up

The highest occurrence of dragonfly and damselfly was observed when maximum temperature (32-36⁰c), minimum temperature (24-26⁰c), high morning relative humidity 88-90% and evening relative humidity 70-75%, with rainfall of (60-80mm) and less sunshine hours of 3-5hrs, found favourable, while the predators population were found at a range of maximum temperature from(26- 38°C), minimum temperature (11- 26°C), relative humidity at morning (82-97%), relative humidity at afternoon of (20-85%), rain fall (0-160mm), with 1-10hours of sunshine (Fig 4.9).

4.24 Correlation studies of Dragon fly and damselfly (DFLY) with weather parameters

The correlation between Dragonfly and Damselfly Population and different weather parameters revealed significant correlation only two dates of planting viz., 16th September, 1st November out of 12 planting dates (Table4.18). In 16th September date of planting dragon fly and damselfly were positively correlated with maximum temperature at 5% significance with r value (0.51).In 1st November date of planting they were negative correlated with morning relative humidity at 5% significance with r value (-0.52).

Table 4.18 Correlation studies of population density of DFLY with weather parameters

WP	16 th Jul	1st Aug	16 th Aug	1 st Sep	16 th Sep	1 st Nov	16 th Nov	1 st Dec	16 th Dec	1 st Jan
TX	0.04454	0.02459	0.41145	0.3438	0.51684	0.1273	0.3634	-0.2284	-0.3958	0.1786
	0.8798	0.9335	0.1438	0.2288	0.0485	0.6035	0.1262	0.3778	0.1442	0.5413
TN	-0.07627	-0.038	0.37942	0.408	0.40834	0.3421	0.2083	-0.0186	-0.281	-0.007
	0.7955	0.8973	0.1809	0.1476	0.1308	0.1517	0.3922	0.9434	0.3102	0.9823
RH1	0.07248	-0.1775	-0.1295	0.5239	-0.2422	-0.521	0.2401	-0.3065	-0.0921	0.0772
	0.8055	0.5438	0.659	0.0545	0.3843	0.0222	0.3222	0.2314	0.7439	0.7931
RH2	-0.22227	0.06341	0.12472	0.3468	0.28001	0.2471	-0.3207	0.34451	0.12039	-0.249
	0.445	0.8295	0.671	0.2245	0.3121	0.3079	0.1806	0.1757	0.6691	0.3904
RF	-0.02713	0.06046	0.48124	0.3718	0.11298	0.0816	-0.112	0.28227	-0.0714	-0.152
	0.9267	0.8373	0.0815	0.1905	0.6885	0.7397	0.6453	0.2723	0.8003	0.6049
SS	0.02394	-0.1105	0.06235	-0.092	0.24234	0.1002	0.1686	-0.3181	-0.3145	0.3302
	0.9353	0.7068	0.8323	0.7555	0.3842	0.6831	0.4903	0.2134	0.2535	0.2489

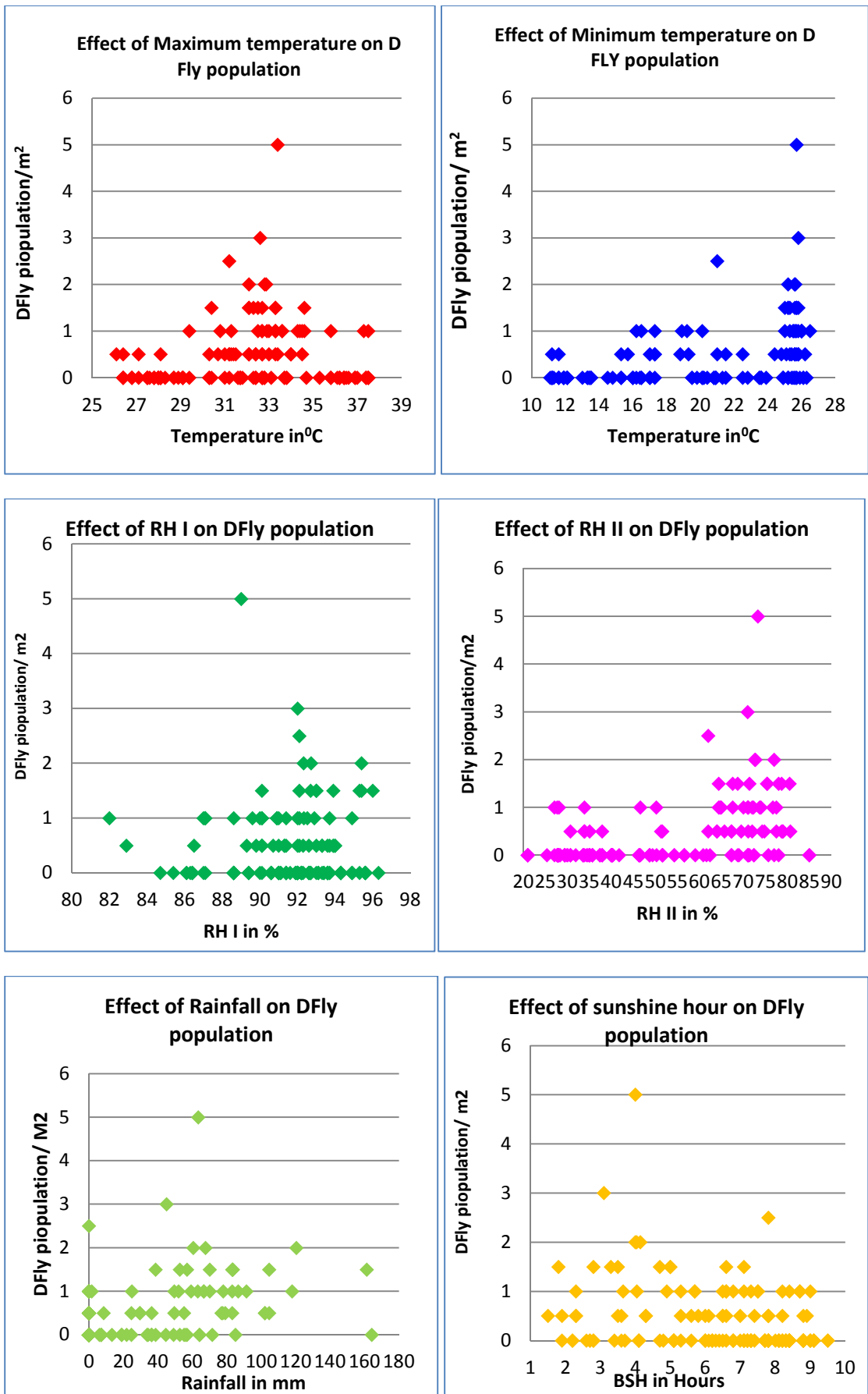


Fig. 4.9 Favourable weather parameters for DFLY population

4.25 Population built up of Lady bird beetle (LBB)

The LBB population was found in most of the planting date starting from 1st date (16th July) to 12th date of planting. The number of predators per square meter varied from 0.5 to 4.5 (1st January) except 1st September date of planting (Table 4.19). However, the peak occurrence was observed during last week of November (47 SMW) in 16th September date of planting (Appendix-5).

Table 4.19 Weekly Lady bird beetle Population Per m²

Week after planting	16-Jul	1-Aug	16-Aug	1-Sep	16-Sep	1-Nov	16-Nov	1-Dec	16-Dec	1-Jan
WK1	0	0	0	0	0	0	0	0	0	0
WK2	0	0	0	0	0	0	0	0	0	0
WK3	0	0	0	0	0	0	0	0	0	0
WK4	0	0	0	0	0	0	0.5	0	0	0
WK5	0	0	0	0	0	0	0	2	0	0
WK6	0	0	0	0	0	1	0	0.5	0	0
WK7	0	0	0	0	0	1	0	0	0	0
WK8	0	1	0	0	1.5	4.5	1.5	0	0	3
WK9	0.5	0	0	0	0	1.5	0.5	0.5	0	1.5
WK10	0	2	0	0	4.5	1	0	0.5	0	1
WK11	1	0	0.5	0	0.5	0	0	0.5	1	1.5
WK12	0	0	1	0	0.5	0	0	0	0	1
WK13	0	0	0	0	0	0	0	2.5	0	0
WK14	0	0	0	0	0	0	0	0.2	0	0.5

4.26 Favourable weather parameters for Lady bird beetle (LBB) Population

The peak occurrence of LBB was found prevailing weather condition such as maximum temperature (28-30⁰c), minimum temperature (12-16⁰c), high morning relative humidity 88-95% and evening relative humidity 40-60%, 8-9 sunshine hours, with less rainfall prevailing the beetle population, while the predators population were found at a range of maximum temperature from(26- 38°C), minimum temperature (11- 26°C),relative humidity at morning (82-97%), relative humidity at afternoon of (20-85%),rain fall (0-170mm),with 1-10hours of sunshine (Fig 4.10).

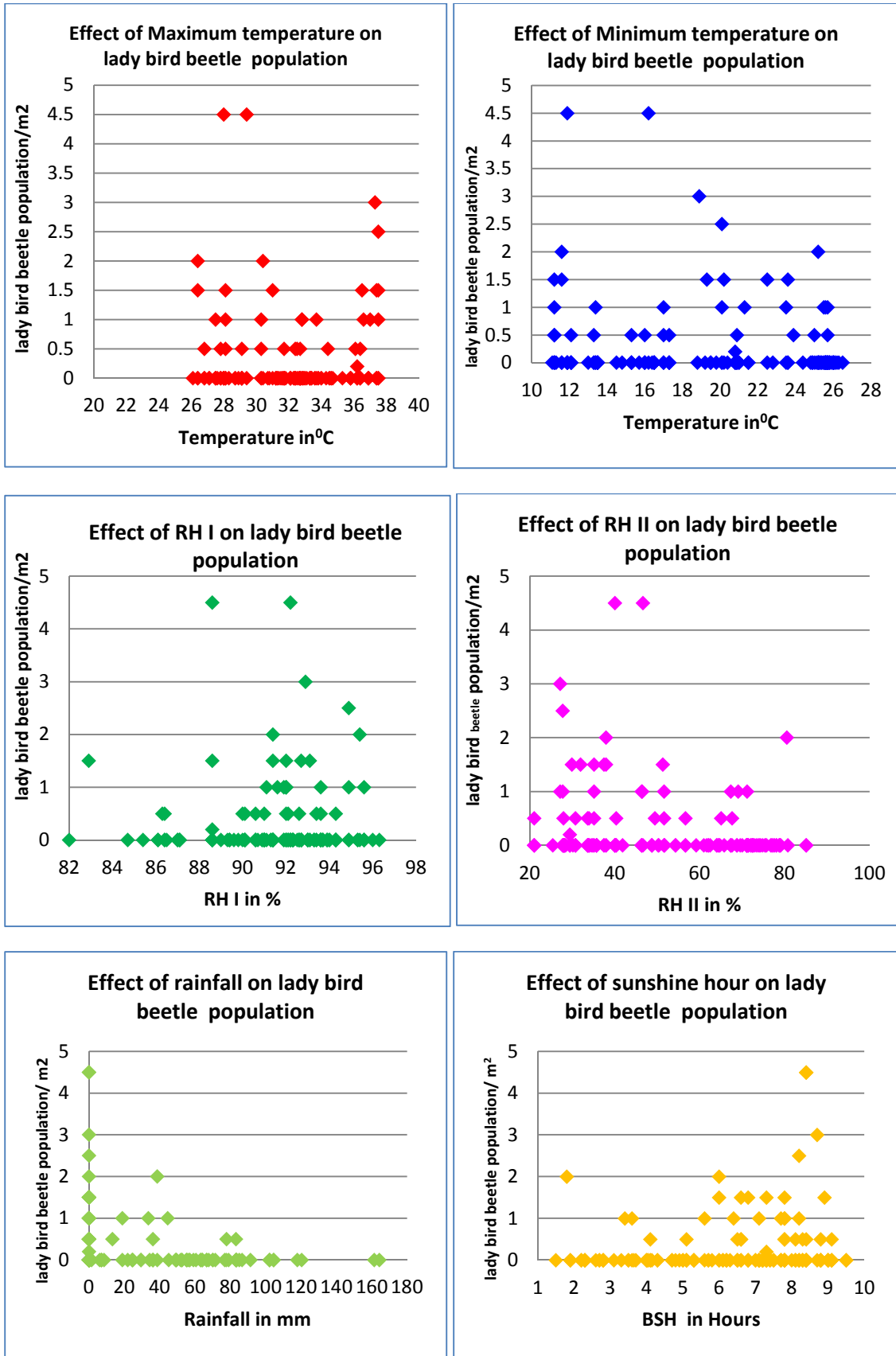


Fig. 4.10. Favourable weather parameters for lady bird beetle population

4.27 Correlation studies of Lady bird beetle (LBB) with weather parameters

The correlation between Lady bird beetle Population and different weather parameters revealed significant correlation with 1st August date of planting, out of 12 planting dates (Table4.20). LBB was negatively correlated with maximum temperature and bright sunshine hour at 5% significance with r value of (-0.67), (-0.53) in 1st August date of planting.

Table 4.20 Correlation studies of population density of LBB with weather parameters

WP	16 th Jul	1 st Aug	16 th Aug	1 st Sep	16 th Sep	1 st Nov	16 th Nov	1 st Dec	16 th Dec	1 st Jan
TX	0.44543	-0.674	0.0118	0.34375	-0.158	-0.3149	-0.287	0.22578	0.3488	0.6706
	0.1105	0.0082	0.968	0.2288	0.5732	0.1891	0.2339	0.3836	0.2025	0.0087
TN	-0.1050	-0.314	-0.133	0.408	-0.274	-0.3861	-0.332	0.1059	0.2209	0.4721
	0.7208	0.2735	0.6501	0.1476	0.3238	0.1025	0.1652	0.6858	0.429	0.0883
RH1	-0.1096	0.4695	0.0405	0.52386	-0.443	0.16961	0.1708	0.25263	0.3686	0.0386
	0.7092	0.0903	0.8906	0.0545	0.0984	0.4876	0.4845	0.3279	0.1764	0.8959
RH2	-0.4153	0.3854	-0.159	0.34678	-0.366	0.05042	0.0442	-0.2707	-0.24	-0.226
	0.1397	0.1735	0.5858	0.2245	0.1797	0.8376	0.8574	0.2933	0.3888	0.4372
RF	-0.2220	-0.343	-0.184	0.3718	-0.26	-0.1593	-0.103	-0.1907	-0.071	-0.189
	0.4455	0.2285	0.5276	0.1905	0.3503	0.5146	0.6747	0.4635	0.8003	0.5157
SS	0.00907	-0.532	0.3278	-0.0915	0.2918	0.0871	0.1355	0.08602	0.1845	-0.061
	0.9754	0.0499	0.2526	0.7555	0.2912	0.7229	0.5803	0.7427	0.5103	0.8348

Table 4.21 Response of variety towards population built up of Insects and Natural enemies

Insects and Natural enemies	Geetanjali	Poornabhog	Pusa sugandh II
BPH /hill	0.03	0.04	0.02
WBPH /hill	0.07	0.08	0.04
GLH /hill	0.06	0.07	0.06
WM/ % sq.m.	0.31	0.21	0.01
YSB/ % sq.m.	0.15	0.13	0.34
GB/hill	0.1	0.2	0.1
SPIDER /hill	0.18	0.19	0.18
DFLY/ sq.m.	0.16	0.18	0.17
LBB/sq.m.	0.21	0.26	0.23

4.4 Varieties

From above Table 4.21 it revealed that Poornabgoh variety is most susceptible to plant hopper and leaf hopper species. Whorl maggot infestation is highest in Geetanjali followed by Poornabgoh and Pusa sugandh-II.

Yellow stem borer infestation is maximum in Pusa Sugandh-II followed by Geetanjali and Poornabgoh. Gundhi bug population is maximum at the milking stage of the crop and highest population was occurred in Poornabhog variety followed by Geetanjali and Pusa sugandh-II. All the natural enemies such as spider, Dragonfly, Damselfly, and Ladybird beetle population is high in Poornabhog as compared to other two varieties.



DISCUSSION

Rice is known as king of cereal and contributing as basic food crop for more than 65% of the world population. Nearly 90 per cent of the area, production and consumption of rice are confined to South East Asian countries. Different types of rice cultivars are grown in India. Among all Basmati rice cultivars are characterized by extra long superfine slender grains and pleasant aroma after cooking. India produces about 70% of the world's basmati production and nearly two third of the total production is exported to other countries. With growing demand for aromatic rice in the local and international market, high emphasis has been laid on development and improvement of basmati types but two major factors are responsible for low yields in Basmati rice crops i.e. adverse weather and pest epidemics. The rice ecosystem is bestowed with a lot of pests and natural enemies complex. The seasonal effects of weather and ongoing changes in climatic conditions will directly lead to modifications in dispersal and development of insect species. The changes in surrounding temperature regimes certainly involve alterations in development rates, voltinism and survival of insects and subsequently act upon size, density. Weather parameters viz., Temperature, rainfall, relative humidity, sunshine hours and wind speed are the major weather elements determining the occurrence of insect pests .

The field experiment was conducted at Central Research Farm of Orissa University of Agriculture and Technology, Bhubaneswar during 2017-18 to study the effect of weather on population built up of major insects and natural enemies of aromatic rice under staggered planting, showed that Brown Plant Hopper (BPH), White Backed Plant hopper (WBPH), Green Leaf Hopper (GLH), Whorl Maggot (WM), Yellow Stem Borer (YSB), and natural enemies namely Spider, Dragonfly, Damselfly and Ladybird beetle were major insects and natural enemies found during the entire crop growing period.

Brown plant hopper (BPH)

The highest occurrence of BPH was found at 2nd week of August and 2nd week of November in 16th July and 16th planting date found positively correlated with

rainfall and relative humidity. The infestation was aggravated with the weekly cumulative rainfall up to 165 mm. However, the highest population was found at a weekly cumulative rainfall of 80 to 110 mm, with maximum temperature (32-34⁰c), minimum temperature (25-27⁰c), high morning relative humidity 91-95% and evening relative humidity 75-80%. The BPH infestation was found positively correlated with rainfall with r value of (0.55) in 1st August and (0.78) in 16th November planting dates. It was also found positively correlated with afternoon relative humidity (0.58) in 16th November planting date.

Similar findings were reported by Nair *et al.*, 1980, who found that the plant hopper population was significantly influenced by climatic factors especially rainfall in association with high relative humidity and high temperatures, and it was partially supported by the findings of Chaudhary *et al.* (2014).

White Backed Plant Hopper

The WBPH infestation was found most planting date starting from 1st date (16th July) to 11th date of planting (16th December). However, the infestation of WBPH was first found from 2nd week of August (SMW 33) and was continued up to second week of January (SMW 1). Though the population of WBPH was built up from August to January, but the peak occurrence was observed during second week of November in 1st August and second peak occurrence was observed during 3rd week of September in 1st September planting date.

The WBPH infestation was highest at low rainfall with weekly cumulative rainfall of 0 to 10 mm and was aggravated by moderate minimum temperature (22-27⁰c), high morning relative humidity (90-92%) and evening relative humidity (70-75%),

(Sunega, 1963) had also almost similar findings, that temperature around 27-28°C is favorable for the development of WBPH. The population appeared in the 1st week of August following slight (2.0 mm) rainfall. The WBPH population was indirectly depends upon decreasing the temperature.

Green Leaf Hopper

The GLH infestation was found in most of the planting date starting from 1st date (16th July) to 11th date of planting (16th December) . However, the infestation of

GLH was first found from 2nd week of August (SMW 33) and was continued up to last week of January (SMW 04). Though the population of GLH was built up from August to January, but the highest occurrence was observed during last week of October to 1st week of November in 16th September planting date and second peak occurrence was observed during 2nd week of September in 16th August planting. The peak occurrence of GLH was observed at a maximum temperature range of (32-34⁰c), minimum temperature (24-26⁰c), high morning relative humidity 90-95% and evening relative humidity 60-95%, with 40-60mm rainfall prevailing the pest population.

The GLH population was found positively correlated with minimum temperature and evening relative humidity with r value of (0.61) and (0.57) respectively, and negatively correlated with bright sunshine hour(-0.57).

Similar results were observed by Hsieh,(1972) Who concluded that green leaf hoppers were more abundant on a wet-season than on a dry-season crop.

Whorl Maggot

The population of Whorl Maggot (WM) was built up from August to December, but the highest infestation was observed during 1st week of December in 1st week of November planting date and second peak infestation was observed during 1st week of September in 1st August planting.

The correlation between WM infestation and different weather parameters revealed a significant correlation only in three dates of planting viz., 1st August, 16th August and 1st November out of 12 planting dates. The WM infestation was found positively correlated with rainfall. It was also found positively correlated with afternoon relative humidity (0.53).

Mainly whorl maggots are infesting the rice crop at early stages of growth. The WM infestation was aggravated with low weekly cumulative rainfall of 20 to 40 mm and low sunshine hours of 3 to 5 hrs. The peak occurrence of WM infestation was observed at low maximum temperature (26-28⁰c), minimum temperature (14-16⁰c), morning relative humidity 84-88% and afternoon relative humidity 55-60%, and 2-4 hours of sunshine. The findings were supported by the findings of Bhattacharya *et al.*,(2006) who developed the incidence of whorl maggot on rice crop was non-significantly negatively correlated with sunshine hours and incidence of rice whorl maggot on crop was significantly positively correlated with minimum temperature, relative humidity and rainfall.

Yellow Stem Borer

The YSB infestation was found in every dates of planting starting from 1st date (16th July) to 12th date of planting (1st January) in vegetative stage resulting dead heart and at reproductive. However, the infestation of YSB was first found from 3rd week of September and was continued up to last week of March. Though the population of WBPH was built up from July to January, the highest infestation of YSB at early stages (DH) was found in 3rd week of February and 3rd week of January in 16th December and 1st January planting dates respectively. The YSB infestation at reproductive stage of crop was found highest.

Maximum infestation of YSB was found at prevailing weather conditions such as maximum temperature (30-38⁰c), minimum temperature (16-22⁰c), morning relative humidity 88-96% and evening relative humidity 25-35%, ample sunshine hours and dry conditions found favourable for pest population.

The YSB infestation at seedling stage(DH) is positively correlated with maximum temperature in 16th August with r value (0.57) and YSB infestation at reproductive stage(WEH) is negatively correlated with bright sunshine with r value (-0.59). WEH found positive correlation with maximum temperature and minimum temperature with r value(0.73),(0.60),(0.69),(0.65),(0.65),(0.55). This findings were partially supported by the findings of Mukherjee *et al.* (2005).

Gundhi Bug

The population of WBPH was built up from September to April, but the highest occurrence was observed during last week of November in 1st September planting date and second peak occurrence was observed during 2nd week of September in 16th July date.

The GB population was highest when maximum temperature was 30-34⁰c, minimum temperature (18-20⁰c), morning relative humidity 85-88% and afternoon relative humidity 50-55%, ample sunshine hours of (9-10hr), under dry conditions found favourable for pest population.

The correlation between GB Population and different weather parameters was significant. In 1st January planting date. GB population was positively correlated with afternoon relative humidity and rainfall with r value (0.67) and (0.91) respectively.

Similar findings were reported by (Israel and Rao, 1961), that infestation is severe from October to mid-November, when the mean temperature varies from 27-28°C and the relative humidity 80-82.1 per cent.

Natural Enemies

During the experiment most commonly found natural enemies are spider, dragonfly, damselfly and Ladybird beetle. Same findings were also cited by Kumar *et al.*, (2008) Most common and dominant predators of rice ecosystem as spiders, coccinellids, staphylinids, mirids, damsel flies and dragon flies. Staphylinids, mirids were also found in the field but their population is not so high.

Spider

In (16th December) planting date the spider population was negatively correlated with maximum temperature and minimum temperature and also in (1st January) planting date.

Singh *et al.* (2005) found that the populations of spiders were negatively correlated with temperature. This was similar to the experimental findings.

Dragonfly and damselfly:

Dragonfly and damselfly are also considered as major predators for controlling the rice insect pest. The spider population was highest when the maximum temperature was 32-36^oC. Dragonfly population is positively correlated with maximum temperature and negatively correlated with relative humidity.

Lady bird beetle:

Lady bird beetle or coccinellids were also considered as another major natural enemies for controlling rice insect pest. Lady bird beetle Population and different weather parameters revealed significant correlation with 1st August planting date. LBB was negatively correlated with maximum temperature and bright sunshine hour at 5% significance with r value of (-0.67), (-0.53) in 1st August date of planting.

Parasuraman (1989) conducted survey at farm in Madurai, Tamil Nadu, India for predatory coccinellids. Eight species of predatory coccinellids were found feeding on BPH, WBPH and leaf hoppers in rice.



SUMMARY AND CONCLUSION

The present investigation entitled “ Effect of weather on population built up of major insects and natural enemies of aromatic rice under staggered planting” was carried out at the Agrometeorology field, Central Research Farm, Orissa University of Agriculture and Technology Bhubaneswar during 2017-2018. The result obtained from different objectives are summarized here-

1. BPH population was found in most of the planting dates but the highest occurrence of BPH was found at 2nd week of August (32 SMW) and 2nd week of November (45 SMW). The highest population was found at a weekly cumulative rainfall of 80 to 110 mm, at a maximum temperature range of 32-34⁰c, minimum temperature 25-27⁰c. With high relative humidity of 91-95%. It was found positively correlated with rainfall and afternoon humidity.
2. WBPH population was also found in most of the planting dates. The highest occurrence was observed at 2nd week of November and 3rd week of September. The WBPH occurrence is high at a maximum temperature 32-34⁰c, minimum 25-27⁰c with high relative humidity. WBPH population was positively correlate with maximum and minimum temperature and sunshine hour.
3. GLH population was found in almost all the planting dates except 1st January. During last week of October (43 SMW) followed by 2nd week of September (37 SMW). The maximum GLH population was found at a maximum temperature range of 33-35⁰c, minimum temperature range of 15-27⁰c with high humidity and sunshine. It was found that, GLH was correlated with all weather parameters in different dates of planting mainly positively correlated with relative humidity and rainfall and negatively correlated with temperature.
4. WM infestation was found from SMW 34 to SMW 52 and the peak occurrence of the WM was at 49 SMW mostly the infestation was occurred when the crop is at seedling to vegetative stage. The WM infestation was aggravated by maximum temperature of 26-28⁰C minimum temperature 14-16⁰C, morning relative humidity of 84-88% under cloudy weather. It was found positively correlated with rainfall and humidity.

5. The infestation of YSB was first found from 3rd week of September (SMW 38) and was continued up to last week of March (SMW 13). DH% was found highest when 3rd week of February (SMW 7) & 3rd week of January (4) and the WEH% is highest at (SMW-11). Maximum infestation of YSB was found at prevailing weather condition of maximum temperature at 30-38⁰C, minimum temperature 16-22⁰C.
6. Gundhi bug was attacked the crop at reproductive stage and was at maximum occurrence during (SMW 47) followed by (SMW 37) and was aggravated by weather condition of (30-34⁰c) maximum temperature of minimum temperature 18-20⁰C, RH1(85-88%), RH 2(0-55%) under long hours of sunshine, GB was mostly correlated with relative humidity and rainfall.
7. Spider: the spider population was seen throughout the cropping season and highest occurrence of spider seen in 3rd week of February (SMW 8) followed by last week of November (SMW 47). The spider population was found highest when the prevailed weather condition was maximum temperature (34-36⁰C), minimum temperature (16-18⁰c) with high relative humidity and ample sunshine (8-10 hr). Spider mostly correlated with maximum temperature minimum temperature rainfall, relative humidity and sunshine hour.
8. The Damselfly and dragonfly population also seen in whole cropping period with maximum population at 2nd week of November (SMW 45). Maximum temperature of 32-36⁰c, minimum temperature 24-26⁰c, with high relative humidity >70% and rainfall >60 mm with less sunshine hours found favourable for the predator population. It was positively correlated with maximum temperature and negatively correlated with relative humidity.
9. LBB occurrence, high during last week of November (47 SMW). Maximum temperature (28-30⁰c), minimum temperature (12-16⁰c) with high humidity and less rainfall prevailing the beetle population. LBB was negatively correlated with maximum temperature and bright sunshine hour.
10. Among the insects, whorl maggot and yellow stemborer infestation were crossed the economic threshold level. Whorl maggot infestation was crossed ETL during,

1st week of December (SMW 49) which was (26-4%) and (6.56%) yellow stemborrer infestation was found during 2nd week of March (SMW 10).

11. Among 3 varieties Poornabhog was most susceptible variety to BPH, WBPH, GLH and GB but moderately resistance to YSB and WM and it was found that Pusa Sugandh variety was less susceptible by insect pests. Poornabhog also good alternator of natural enemies..
12. In 16th August, 1st November, 16th November, 1st December, 16th December dates of planting were free from Gundhi bug infestation. Where as 16th December, 1st January planting dates were free from BPH population and 16th August, 16th September, 1st December, 16th December, 1st January dates of planting were free from Whorl Maggot infestation.

CONCLUSION

Basmati rice cv. Pusa Sugandh-II was resistance to insect pests and also a high yielding variety among three cultivars. Poornabhog was most susceptible variety to insect pests except YSB and WM infestation. Crop planted on 16th December 1st January were free from BPH population and crop planted after November free from Gundhi bug infestsation. Hence planting in above dates may escape the respective pest infestation. Correlation studies among the weather parameters with population dynamics of insects and natural enemies contradicting each other in some planting dates, which needs further investigation.



REFERENCES

- Adiroubane D and Raja K.2005. Influence of Weather Parameters on the Occurrence of Rice Yellow Stem Borer, *Scirpophaga incertulus* (Walker, *Journal of Rice Research* , **3** (1):5-9.
- Arif P, Mandal SK, Abdus S and Mishra AK. 2006. Population dynamics of stem borer, *Scirpophaga incertulas* Walker and spider in boro rice, *Environment and Ecology*, **24**: 152-154.
- Arif P, Mandal SK, Abdus S and Mishra AK. 2005. Activity of *Scirpophaga incertulas* and *Lycosa pseudoannulata* in boro rice as influenced by meteorological parameters, *Journal of Applied Biology*, **15** (2): 55-59.
- Bhattacharjee P and Kulkarni PR. 2000. A comparative study on the physical characteristics and cooking quality parameters of commercial brands of basmati rice, *International Journal of Food Science and Nutrition*, **51** : 295–299 .
- Bhattacharya B, Basit A, Saikia DK. Parasitoids and predators of rice insect-pests of Jorhat districts, *Journal of Biological Control*. 2006; **20**(1):37-44.
- Bhowmik P, Mukherjee A and Somchoudhury AK. 2005. Population dynamics of green leaf hopper *Nephotettix virescens* (Dist). in relation to weather parameters in rice, *Environment and Ecology*, **23**(2): 345-346.
- Chaudhary S, Raghuraman M, Kumar H. 2014. Seasonal abundance of brown plant hopper (*Nilaparvata lugens*) in Baranasi Region. *Int. J. Curr. Microbiol. App. Sci.* , **3**(7):1014-1017.
- Dogra I and Choudhary A. 2005. Some insect pests of rice, *Oryza sativa* Linn. In Kangra Valley of Himachal Pradesh, *Insect-Environment*, **11**(1): 21-22.
- Gangarade GA, Kaushik UK, Patidar DG, Shukla BC, Shrivastava SK, Deshmukh PD and Pophaly DJ. 1978. Insect pests of summer paddy in M.P, **3**(6):16.
- Ghose RLM, Ghatge MB and Subramanyan V.1960. Pests of Rice, ICAR, New Delhi, pp. 248- 257.

- Hugar SV, Venkatesh H, Hanumanthaswamy BC and Pradeep S. 2009. Influence of weather factors on the infestation of yellow stem borer, *Scirpophaga incertulas* Walker in aerobic rice, *Asian Journal of Environmental Science*, **4** (2): 151-154.
- Isahaque NMM and Rahman A.1983. Seasonal abundance of rice stem borer, *Scirpophaga incertulas* (Walk.) in Assam, *Pesticides*, **17**(1):25-27.
- Israel P and Rao. 1961. The Incidence of Gundhi bug and steps for its control. Proc. Rice Conf., Cuttack, pp. 297-99.
- Joshi RK and Behera L. 2006 Identification and differentiation of indigenous non Basmati aromatic rice genotypes of India using microsatellite markers, *African Journal of Biotechnology*, **6** (4), pp. 348-354.
- Justin C and Preetha G .2013. Seasonal incidence of rice yellow stem borer, *Scirpophaga incertulas* (Walker) in Tamil Nadu. *Indian Journal of Entomology*, **75**(2): 109-112.
- Kakde AM and Patel KG. 2015. Seasonal incidence of rice leaf folder in relation to SRI and conventional methods of planting and its correlation with weather parameters, *Plant Archives* ,**15** (1): 121-126.
- Kalode MB and Kasi VPR. 1976. Changes in relative status of insect pests in rice, *Indian J.Plant Protection*, **4**(1):79-91.
- Kalita H, Avasthe RK and Ramesh K. 2015. Effect of Weather Parameters on Population Build-up of Different Insect Pests of Rice and Their Natural Enemies, *Indian Journal of Hill Farming*, **28** (1): 69-72.
- Karuppaiah V and Sujayanad G K. 2012. Impact of Climate Change on Population Dynamics of Insect Pests, *World Journal of Agricultural Sciences*, **8** (3): 240-246.
- Kenmore PE, Carino FO, Perez CA, Dyck VA and Gutierrez AP. 1984. Population regulation of rice brown plant hopper (*Nilaparvata lugens* stal.) within rice fields in the Philippines, *Journals of Plant Protection in the Tropics*, **1**: 19-37.

- Khairi VA and Dumbre RB. 1984. Seasonal incidence and chemical control of brown plant hopper in Konkan region, *J. Maharashtra Agric. University*, **9**(1) : 106-107.
- Khan AA and Misra DS. (2003) Abundance of spider in relation to biotic and abiotic factors in upland rice ecosystem of Eastern Uttar Pradesh, *Plant Protection Bulletin Faridabad*, **55**(3/4): 23-29
- Khan ZH and Ramamurthy VV. 2004. Influence of weather factors on the activity of rice leaf folder, *Ann. Pl. Protec. Science*, **12**:267-270.
- Kraker JD, Huis AV, Heong KL, Lenteren JC and Rabbinge R. 1999. Population dynamics of rice leaf folders (Lepidoptera: Pyralidae) and their natural enemies in irrigated rice in the Philippines, *Bulletin of Entomological Research* , **89**: pp. 411-42.
- Kumar V, Patil BV. 2004. Occurrence of minor insect pests of paddy in Tungabhadra project area of Karnataka, *Karnataka Journal of Agricultural Sciences*, **17**(4): 825-826.
- Kumar S, Khan MA, Kumar A and Sharma K. (2008). Biodiversity of natural enemies in Paddy ecosystem and their seasonal dominance, *Ann. Pl. Protec. Science*, **16**(2): 381-383.
- Kumar D, Raghuraman M, Singh J, Waza S and Kumar K, 2013. Occurrence of insect-pests and natural enemies in rice (*Oryza sativa* L.) agro-ecosystem, *International Journal Of Plant Protection*, **6**(2):266-270.
- Kushwaha KS and Sharma SK. 1983, Relationship of date of transplanting, spacing and levels of nitrogen on incidence of rice leaf folder, *Indian J. Entomol*, **43**(3): 338-339.
- Kushwaha KS, Mrig KK and Singh R. 1982. White backed plant hopper populations on rice cultivars, *International Rice Research Newsletter*, **7**(2): 8.
- Kushwaha KS and Singh R. 1986. Resistance to white backed plant hopper (WBPH) at flowering stage, *Int. Rice Res. Newsletter*, **11**(5): 7.

- Lin KS.1974. Notes on some natural enemies of *Nephotettix cincticeps* and *Nilaparvata lugens* in Thailand, *J. Thailand Agric. Res*, **23** : 91-115.
- Madhukar FJ. 2011. A preliminary study of the predatory natural enemy complex of riceecosystem in Vidarbha region of Maharashtra, *India. International Referred Research Journal* , **2** (22):25-27.
- Madhuri G, Dash P.C ,and Rout K.K.2017. Effect of Weather Parameters on Population Dynamics of Paddy Pests *Int.J.Curr.Microbiol.App.Sci* ,**6**(10): 2049-2053
- Manikandan N, Kennedy JS and Geethalakshmi V. 2013. Effect of elevated temperature on development time of rice yellow stem borer, *Indian Journal of Science and Technology*, **6** (12): 5563–5566.
- Manjunath TM. (1982).Light trap catches of rice yellow stem borer. *International Rice Research Newsletter* 7:5.
- Manju S, Thangaraju D and David PMM. 2002. Egg parasitism in rice yellow stem borer, *Scirpophaga incertulas* (Walker), *Indian Journal of Plant Protection*,**30**(1):91.
- Misra AK, Singh SPN and Parwez A. 2005. Incidence of yellow stem borer (*S. incertulas* Wlk.) in different cultivars of boro rice (*Oryza sativa* L.) at different crop age, *Oryza* , **42**(4): 329-332.
- Mukherjee A, Bhowmik P and Chakraborty G .2005. Impact of different meteorological parameters on the population dynamics of rice stem borer (*Scirpophaga incertulus* (Walker)), *Environment and Ecology*, **23**(4): 774-775.
- Muralidharan and Pasalu .2006. Changing Insect Pest Scenario in the Rice Ecosystem, Rice Knowledge Management Portal (RKMP), pp 5-6.
- Muralidharan K and Pasalu C. 2005. Assessments of crop losses in rice ecosystems due to stem borer damage (Lepidoptera: Pyralidae), *Crop Protection*, **25**: 409-417.

- Naganagouda A, Patil BV and Sreenivas AG. 1999, Studies on light trap catches of major pests of rice in Tungabhadra project area, *Karnataka J. Agric. Science*, **12** (1-4) : 191-194.
- Nair MRGK .1986 Insects and Mites of crops in India. Pp 4-5. ICAR, New Delhi (Walker) attracted to light trap, *Andhra Agric. J*, **17**(1) : 30-32.
- Nirala YS, Ghirtlahre SK, Sahu CM, Kerketta A and Chandrakar G. 2015. Population Dynamics of Rice Case Worm, *Nymphula Depunctalis* Guenee And Rice Grasshopper, *Hieroglyphus Bania Fabricius* Relation To 64 Weather Parameters: A Light Trap Study, *International Journal of Tropical Agriculture*, **33** (2): 541-545.
- Ooi PAC.1980. Seasonal abundance of the white backed plant hopper and brown plant hopper and predators in insecticide-free rice fields in Malaysia, *Int. Rice Res. Newsletter*, **5**: 13-14.
- Parasuraman S. 1989. Predatory Coccinellids in rice fields at Agricultural college and Research Institute Madurai, *Int. Rice Res. Newslett.*, **14** : 30.
- Parwez A, Misra AK, Mandal SK and Sattar A. 2005. Activity of *Scirpophaga incertulas* and *Lycosa pseudoannulata* in boro rice as influenced by meteorological parameters, *Journal of Applied Biology*, **15**(2): 55-59
- Parwez A, Mandal SK, Sattar A and Mishra AK. 2006. Population dynamics of stem borer, *Scirpophaga incertulas* Walker and spider in boro rice: a biometeorological interaction study, *Environment and Ecology*, **24S** (Special 1): 152-154.
- Patel ML, Patel KG and Pandya HV. 2005. Correlation of spiders with weather parameter and insect pests of rice (*Oryza sativa* L.), *Insect-Environment*, **11** (1): 23-25.
- Prabal S. 2009. Prevalence and influence of paddy stem borer in deep water rice, *Annals of Plant-Protection Science*, **17** (2): 461-462.
- Parasappa HH, Reddy NG and Neelakanth. 2017. Rice insect pests and their natural enemies complex in different rice ecosystem of Cauvery command areas of Karnataka, *Journal of Entomology and Zoology Studies*, **5**(5): 335-338.

- Rahman MT, Khalequzzaman M and Khan MAR. 2004. Assessment of infestation and yield loss by stem borers on variety of rice, *Journal of Asia Pacific Entomology*, **7** (1): 89-95.
- Ramiah K, Ghose RLM. 1951. Origin and distribution of cultivated plants of South Asia: rice, *Indian Journal of Genetics and Plant Breeding*, **11**:7-13.
- Ramiah K, Rao MBVN. 1953. Rice breeding and genetics. Indian Council of Agricultural Research, New Delhi.
- Ram M, Sachan SK and Singh G. 2014. Study on population build up of rice leaf folder, *Cnaphalocrocis medinalis* (Guenee) in relation to weather factors, *International Journal of Advanced Research*, **2**(10): 75-77.
- Ramya M, Kennedy JS, Lakshmi VG, Lakshmanan A, Manikandan N and Sekhar NU. 2012. Impact of elevated temperature on major pests of rice, *Climarice technical Brief*: 1-6.
- Rai AK, Singh AK and Khan MA. 2002. Influence of weather factors on light trap catches of yellow stem borer in kharif season, *Indian J.Ent* , **64**(4):510-517.
- Ramaswamy C, Shanmugam TR and Suresh D. 1996. Yields in different rice production environment and prioritization of rice research in South India: Rice Research in Asia: Progress and Priorities, Manila, Philippines, CAB International and IRRI, pp.141-160.
- Reddy MS, Rao PK, Rao BHK and Rao GN.1983.Preliminary studies on the seasonal prevalence of certain Homoptera occurring on rice at Hyderabad,*Indian J. Entomology*, **45**(1) : 20-28.
- Roy P, Sinha PK, Regupathy A and Jayaraj S. 1985. Utility of light trap data in the control of rice stemborer, *Tryporyza incertulas* (walker), *Behavioural and physiological approaches in pest management*, **1**.92-93.
- Sabale JP, Das C and Samui RP. 2010. Influence of weather factors on light trap catches of Green leaf hopper at Pattambi, Kerala. *Journal of Agrometerology*, **12**(1):108-110.
- Saroja R, 1982, Occurrence of rice stem borers and gall midges at Tirur, Chinglepur district, India, *Int. Rice Res. Newsletter*, **7**(1): 14.

- Sharma SD, Tripathy S, Biswal J. 2000. Origin of *O. sativa* and its ecotypes. In: Nanda JS, editor. Rice breeding and genetics: research priorities and challenges. Science Publishers, Enfield and Oxford and IBH, New Delhi. p 349-369.
- Sharma MK, Pandey V, Singh RS and Singh RA. 2004. A study on light trap catches of some rice pests in relation to meteorological factor, *Ethiopia Journal of Science*, **27**(2):165–170.
- Shamim M, Shekh AM, Patel VJ, Dodia JF, Korat DM and Mehta AM. 2009. Effect of weather parameters on population dynamics of green leaf hopper and white backed plant hopper in paddy grown in middle Gujarat region, *Journal of Agrometeorology*, **11**(2):172-174.
- Shukla BC, Phoply DJ, Chandrakar HK, Gupta R, Dubey VK, Yadu YK, Rana, DK, Sharma S, Rana N and Gupta A. 2008. Souvenir of National Conference on Pest Management Strategies for Food Security, IGKV, Raipur, p.2-3.
- Singh RB, Gupta PK, Singh RA and Prasad SS. 2005. Population dynamics of predators in rainfed lowland rice, *Journal of Plant Protection and Environment*, **2**(2): 1-6.
- Suenaga H. 1963. Analytical studies on the ecology of two species of planthopper, the white backed planthopper (*Sogatia furcifera* Horvath) and the brown planthopper (*Nilaparvata lugens* Stal) with special reference to their outbreaks, *Bull. Kyushu agric. Exp. Stn.*, **3**:1-52.
- Yang L, Peng L, Zhong F and Zhang Y. 2009. A study of paddy stem borer (*Scirpophaga Incertulas*) population dynamics and its influence factors base on stepwise regress analysis, *Computer and Computing Technologies in Agriculture II*, **2**: 1519-1526.
- Yasumatsu K, Wongsiri T, S Navavichit and C Tirawat .1975. Approaches toward an integrated control of rice pests. Part 1: Survey of natural enemies of important rice pests in Thailand, *Plant Prot.* ,pp .8-9.



APPENDICES

APPENDIX-1 Weekly peak insects and natural enemies population (16th July)

O.DATE	BPH/ HILL	WBPH/ HILL	GLH/ HILL	WM%	GB/H	DH%	WEH%	SPIDER /H	DFLY /m2	LBB /m2
23.7.17	0	0	0	0	0	0	0	0.2	0	0
30.7.17	0	0	0	0	0	0	0	0.2	0	0
6.8.17	0.3	0	0	0	0	0	0	0.1	0	0
13.8.17	0.4	0	0	0	0	0	0	0.2	0	0
20.8.17	0.9	0.2	0.2	3.5	0	0	0	0.3	0.5	0
27.8.17	0.6	0.3	0.2	0.5	0	0	0	0.4	1	0
3.9.17	0.5	0.1	0.3	0	0	0	0	0.4	1.5	0
10.9.17	0.5	0.9	0.2	0.7	0	0	0	0.3	1	0
17.9.17	0.1	0.2	0.3	0	0.2	0	0.16	0.3	1	0.5
24.9.17	0	0	0	0	0.5	0	0.32	0.1	3	0
1.10.17	0	0	0	0	0.1	0	0.35	0	0	1
8.10.17	0	0	0	0	0	0	0.63	0.1	0.5	0
15.10.17	0	0	0	0	0	0	0.31	0.1	0.5	0
22.10.17	0	0	0	0	0	0	0	0	0.5	0

APPENDI-2 Weekly peak insects and natural enemies population (1st August)

O.DATE	BPH/ HILL	WBPH/ HILL	GLH/ HILL	WM%	GB/H	DH%	WEH%	SPIDER /H	DFLY /m2	LBB /m2
8.8.17	0.2	0	0	1.5	0	0	0	0.1	5	0
15.8.17	0.5	0	0	0.54	0	0	0	0.2	0.5	0
22.8.17	0.4	0.1	0	3.3	0	0	0	0.1	0.5	0
29.8.17	0.6	0.1	0	6.8	0	0	0	0.1	1	0
5.9.17	0.2	0.2	0.3	18.1	0	0	0	1.7	2	0
12.9.17	0.2	1.7	0.1	0	0	0	0	0.4	1	0
19.9.17	0.5	0.6	0.1	0	0	0	0	0.6	1	0
26.9.17	0	0.4	0.3	0	0.1	0	0	0.5	0	1
3.10.17	0	0.1	0.2	0	0.2	0	2.5	0	0	0
10.10.17	0	0	0	0	0	0	0.83	0.3	1.5	2
17.10.17	0	0	0	0	0	0	0.41	0.1	2	0
24.10.17	0	0	0	0	0.1	0	0.68	0.1	2	0
31.10.17	0	0	0	0	0	0	0	0.1	1	0
7.11.17	0	0	0	0	0	0	0	0.1	1	0

APPENDIX-3 Weekly peak insects and natural enemies population (16th August)

O.DATE	BPH/ HILL	WBPH/ HILL	GLH/ HILL	WM%	GB/H	DH%	WEH%	SPIDER /H	DFLY /m2	LBB /m2
23.8.17	0.3	0	0	0	0	0	0	0.3	1	0
30.8.17	0	0	0.1	5	0	0	0	0.1	0	0
6.9.17	0.1	0.5	0.1	0	0	0	0	0.2	1	0
13.9.17	0.9	0.5	0.6	0	0	0	0	0.7	0.5	0
20.9.17	0.1	0.3	0.2	0	0	0	0	0.5	1.5	0
27.9.17	0	0.7	0.3	0	0	0.1	0	0.4	1.5	0
4.10.17	0	0.7	1	0	0	0	0	0.5	0	0
11.10.17	0.2	0.3	0.2	0	0	0	0	0.5	0.5	0
18.10.17	0.2	0.4	0.3	0	0	0	0	0.4	1	0
25.10.17	0.2	0.3	0.3	0	0	0	1	0.7	0	0
1.11.17	0	0	0	0	0	0	3	0.2	1	0.5
8.11.17	0	0	0	0	0	0	0	0.1	0	1
15.11.17	0	0	0	0	0	0	0	0	0.5	0
22.11.17	0	0	0	0	0	0	0	0	0	0

APPENDIX-4 Weekly peak insects and natural enemies population (1st September)

O.DATE	BPH/ HILL	WBPH/ HILL	GLH/ HILL	WM%	GB/H	DH%	WEH%	SPIDER /H	DFLY /m2	LBB /m2
8.9.17	0	0	0	0	0	0	0	0	1	0
15.9.17	0	0.7	0.5	0	0	0	0	0.2	1.5	0
22.9.17	0	1.1	0.2	0.8	0	0	0	0.4	1.5	0
29.9.17	0	0.6	0.5	0.6	0	0	0	0.5	1	0
6.10.17	0	0.2	0.3	1.1	0	0	0	0.4	1.5	0
13.10.17	0	0.3	0.3	3	0	0	0	0.1	0.5	0
20.10.17	0.1	0.3	0.4	0	0	0	0	0.3	0.5	0
27.10.17	0	0.2	0.1	0	0	0	0	0.5	1.5	0
4.11.17	0	0	0	0	0	0	0.2	0.1	1.5	0
10.11.17	0	0	0	0	0	0	0.2	0.1	0	0
17.11.17	0	0	0	0	0	0	1.9	0.2	2.5	0
24.11.17	0	0	0	0	1.8	0	0.8	1	0	0
1.12.17	0	0	0	0	0	0	1.1	0.2	0	0
8.12.17	0	0	0	0	0	0	0	0.2	0	0

APPENDIX-5 Weekly peak insects and natural enemies population (16th September)

O.DATE	BPH/ HILL	WBPH/ HILL	GLH/ HILL	WM%	GB/H	DH%	WEH%	SPIDER /H	DFLY /m2	LBB /m2
23.9.17	0	0	0	0	0	0	0	0.1	0.5	0
30.9.17	0	0	0	0	0	0	0	0.1	0	0
7.10.17	0	0	0.3	0	0	0	0	0.4	0	0
14.10.17	0	0	0.2	0	0	0	0	0.3	0	0
21.10.17	0.2	0.2	0.5	0	0	0	0	0.3	0.5	0
28.10.17	0	0	0.7	0	0	0	0	0.4	0.5	0
4.11.17	0.2	0.2	0.7	0	0	0.25	0	0.7	0	0
11.11.17	0.6	0.6	0.2	0	0	0	0	0.4	0.5	1.5
18.11.17	0	0	0	0	0.3	0	0.13	0.5	0	0
25.11.17	0	0	0	0	0.1	0	2.4	0	0	4.5
2.12.17	0	0	0	0	0	0	1	0.1	0	0.5
9.12.17	0	0	0	0	0	0	2	0.3	0	0.5
16.12.17	0	0	0	0	0	0	0	0.4	0	0
23.12.17	0	0	0	0	0	0	0	0.4	0	0
30.12.17	0	0	0	0	0	0	0	0.1	0	0

APPENDIX-6 Weekly peak insects and natural enemies population (1st November)

O.DATE	BPH /HILL	WBPH /HILL	GLH /HILL	WM%	GB/H	DH%	WEH%	SPIDER /H	DFLY /m2	LBB /m2
8.11.17	0	0	0	0	0	0	0	0.1	1	0
15.11.17	0	0	0	0	0	0	0	0.2	0.5	0
22.11.17	0	0.2	0.2	0	0	0	0	0.2	1	0
29.11.17	0	0	0.2	3.6	0	0	0	0.3	0	0
6.12.17	0	0	0	26.4	0	0	0	0.2	0	0
13.12.17	0	0.2	0.4	0	0	0	0	0.4	0	1
20.12.17	0.2	0.2	0.2	0	0	0	0	0.4	0	1
27.12.17	0.2	0.1	0.8	0	0	0	0	0.8	0	4.5
3.1.18	0	0.3	0.1	0	0	0	0	0.5	0	1.5
10.1.18	0	0.3	0.1	0	0	0	0	0.4	0	1
17.1.18	0	0	0	0	0	0	0	0.4	0	0
24.1.18	0	0	0	0	0	0	0	0.2	0	0
31.1.18	0	0	0	0	0	0	0	0.2	0	0
7.2.18	0	0	0	0	0	0	0	0.3	0.5	0
14.2.18	0	0	0	0	0	0	0	0.3	0	0
21.2.18	0	0	0	0	0	0	0	3	1	0
28.2.18	0	0	0	0	0	0	3.6	0.1	0	0
7.3.18	0	0	0	0	0	0	3.4	0.2	0	0
14.3.18	0	0	0	0	0	0	4.6	0.1	0	0.5

APPENDIX-7 Weekly peak insects and natural enemies population (16th November)

O.DATE	BPH/ HILL	WBPH/ /HILL	GLH/ /HILL	WM%	GB/H	DH%	WEH%	SPIDER /H	DFLY /m2	LBB /m2
23.11.17	0	0	0	0	0	0	0	0.1	0	0
30.11.17	0	0	0.2	0	0	0	0	0.3	0	0
7.12.17	0.2	0.2	0.5	0	0	0	0	0.4	0	0
14.12.17	0	0.2	0.3	0	0	0	0	0.2	0	0.5
21.12.17	0.1	0.2	0.2	0	0	0	0	0.3	0	0
28.12.17	0.1	0.2	0	5.76	0	0	0	0.4	0	0
4.1.18	0	0	0	0	0	0	0	0.5	0	0
11.1.18	0	0	0	0	0	0	0	0.2	0	1.5
18.1.18	0	0	0	0	0	0	0	0.5	0	0.5
25.1.18	0	0	0	0	0	0	0	0.3	0	0
1.2.18	0	0	0	0	0	0	0	0.3	0	0
8.2.18	0	0	0	0	0	0	0	0.2	0.5	0
15.2.18	0	0	0	0	0	0	0	0.5	0.5	0
22.2.18	0	0	0	0	0	0	0	0.3	0	0
1.3.18	0	0	0	0	0	0	3.27	0.5	1	0
8.3.18	0	0	0	0	0	0	2.12	0.2	0	0
15.3.18	0	0	0	0	0	0	3.73	0.2	0	0
22.3.18	0	0	0	0	0	0	3.34	0.3	0	0
31.3.18	0	0	0	0	0	0	0	0.1	0	0

APPENDIX-8 Weekly peak insects and natural enemies population (1st December)

O.DATE	BPH/ HILL	WBPH/ HILL	GLH/ HILL	WM%	GB/H	DH%	WEH%	SPIDER /H	DFLY /m2	LBB /m2
8.12.17	0	0.2	0.1	0	0	0	0	0.2	0.5	0
15.12.17	0	0.2	0.2	0	0	0	0	0.2	0.5	0
22.12.17	0	0.2	0.3	0	0	0	0	0.3	0	0
29.12.17	0	0	0.1	0	0	0	0	0.5	0	0
5.1.18	0	0	0.1	0	0	0	0	0.2	0	2
12.1.18	0	0.1	0.3	0	0	0	0	0.1	0.5	0.5
19.1.18	0	0	0	0	0	0	0	0.5	0	0
26.1.18	0	0	0	0	0	0	0	0.4	0	0
2.2.18	0	0	0.2	0	0	0	0	0	0	0.5
9.2.18	0	0	0	0	0	0	0	0.6	1	0.5
16.2.18	0	0	0	0	0	0	1.6	0.8	0	0.5
23.2.18	0	0	0	0	0	0	1.4	0.5	0	0
2.3.18	0	0	0	0	0	0	3	0	0	2.5
9.3.18	0	0	0	0	0	0	2.61	0.1	0	0.2
16.3.18	0	0	0	0	0.5	0	5.56	0.2	0	0
23.3.18	0	0	0	0	0	0	2.6	0.1	0	1.5
30.3.18	0	0	0	0	0	0	0	0.2	0	0

APPENDIX-9 Weekly peak insects and natural enemies population (16th December)

O.DATE	BPH/ HILL	WBPH/ HILL	GLH/ HILL	WM%	GB/H	DH%	WEH%	SPIDER /H	DFLY /m2	LBB /m2
23.12.17	0	0	0	0	0	0	0	0.3	0	0
30.12.17	0	0	0.1	0	0	0	0	0.2	0	0
6.1.18	0	0.2	0.2	0	0	0	0	0.4	0.5	0
13.1.18	0	0	0	0	0	0	0	0.3	0	0
20.1.18	0	0	0	0	0	0	0	0.2	0	0
27.1.18	0	0	0.2	0	0	0	0	0.4	0	0
3.2.18	0	0	0	0	0	0	0	0.3	0	0
10.2.18	0	0	0	0	0	0.74	2.98	0.5	0	0
17.2.18	0	0	0	0	0	0	2.31	0.4	0	0
24.2.18	0	0	0	0	0	0	5.1	0.3	0	0
3.3.18	0	0	0	0	0	0	2.41	0	0	1
10.3.18	0	0	0	0	0	0	7.56	0.1	0	0
17.3.18	0	0	0	0	0	0	2.5	0	0	0
24.3.18	0	0	0	0	0	0	0	0	0	0
31.3.18	0	0	0	0	0	0	0	0.2	0	0

APPENDIX-10 Weekly peak insects and natural enemies population (1st January)

O.DATE	BPH/ HILL	WBPH/ HILL	GLH/ HILL	WM%	GB/H	DH%	WEH%	SPIDER /H	DFLY /m2	LBB /m2
8.1.18	0	0	0	0	0	0	0	0.3	0	0
15.1.18	0	0	0	0	0	0	0	0.4	0	0
22.1.18	0	0	0	0	0	2.01	0	0.6	0	0
29.1.18	0	0	0	0	0	0.73	0	0.7	0	0
5.2.18	0	0	0	0	0.2	0.97	0	1	0	0
12.2.18	0	0	0	0	0	0.33	0.32	0.1	0.5	0
19.2.18	0	0	0	0	0	2.9	1.26	0.25	0	0
26.2.18	0	0	0	0	0	0	6.4	0.2	1	3
5.3.18	0	0	0	0	0	0	5.4	0.1	0	1.5
12.3.18	0	0	0	0	0	0	6.56	0.3	0	1
19.3.18	0	0	0	0	0	0	1.28	0.2	0	1.5
26.3.18	0	0	0	0	0	0	1.61	0	0	1
2.4.18	0	0	0	0	0.4	0	0	0.2	0	0
9.4.18	0	0	0	0	0.3	0	0	0.2	0	0.5

