BIOLOGY OF PADDY BROWN PLANTHOPPER

Nilaparvata lugens Stal. IN NAGPUR REGION

THESIS

Submitted to
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
in partial fulfilment of the requirements
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IN

AGRICULTURE
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By

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Enrolment No. EE-37 **2012**

DECLARATION OF STUDENT

I hereby declare that, the experimental work and its interpretation of the thesis entitled **"BIOLOGY OF PADDY BROWN PLANT HOPPER** *Nilaparvata lugens* Stal. **IN NAGPUR REGION "** or part thereof has neither been submitted for any other degree or diploma of any University, nor have the data been derived from any thesis / publication of any University or scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged.

Place: Nagpur
Date: 31 5 12

(WANKHEDE GULSHAN BHIMRAO)
Enrolment No. EE/37

CERTIFICATE

This is to certify that thesis entitled **"BIOLOGY OF PADDY BROWN PLANT HOPPER** *Nilaparvata lugens* Stal. **IN NAGPUR REGION"** submitted in partial fulfilment of the requirement for the degree of **"Master of Science in Agriculture (Agricultural Entomology)"** of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **Wankhede Gulshan Bhimrao** under my guidance and supervision.

The subject of the thesis has been approved by the Student's Advisory Committee.

Place: Nagpur
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THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE INCLUDING EXTERNAL EXAMINER (AFTER VIVA-VOCE)

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Place: Nagpur

Date: 31.5.2012

(Wankhede Gulshan Bhimrao)

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(A) List of Tables

(B) List of Plates

(C) Abbreviations

mm	:	Milimeter
cm	:	Centimeter
DAT	:	Days after treatment
^{0}C	:	Degree Celsus
etc	:	Et cetra
et al.	:	et alia (and associates)
Fig	:	Figure
ha.	:	Hectare
Hrs.	:	Hours
i.e.	:	That is
m	:	Meter
M.S.	:	Maharashtra State
No.	:	Number (s)
/	:	Per
%	:	Per cent
R.H	:	Relative humidity
Viz	:	Namely

(D) Thesis Abstract

a)	Title of Thesis	:	**"BIOLOGY OF PADDY BROWN PLANTHOPPER** *Nilaparvata lugens* Stal. **IN NAGPUR REGION"**
b)	Full name of student	:	**WANKHEDE GULSHAN BHIMRAO**
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Abstract

An experiment entitled "Biology of Paddy Brown Planthopper *Nilaparvata lugens* Stal. in Nagpur region" was carried out during kharif season of the year 2011-2012 at the Insectory Premises of Entomology Section, College of Agriculture, Nagpur with following objectives-

1. To study the life cycle of paddy brown planthopper under laboratory conditions.

Different parameters of the biology of brown planthopper were studied. Eggs were inserted in groups in a straight line in midrib of leaf sheaths. The egg laying sites appear as brownish streaks. The egg was cylindrical slightly curved. Eggs were hatch into tiny nymphs within 7-9 days. Average number of eggs laid by a female were 72.2 and 86.8 from brachypterous and macropterous female respectively.

Nymphs undergo four moults and passed through five instars in about 14 to 20 days. The pre-oviposition period was 2 to 3 days for macropterous females and 2 to 4 days for brachypterous female. The male adults survived for 6 to 11 days while macropterous females and brachypterous female survived for 11 to 15 and 13 to 19 days respectively. The oviposition period lasted for 11 to 14 days for brachypterous female while for macropterous it was 7 to 9 days. The life cycle of BPH was completed in range of 21 to 29 days.

Chapter I

INTRODUCTION

1.1 Background information

Rice (*Oryza sativa* L.) is the most important and staple food crop for more than two thirds of the population of India and more than 65 per cent of the world population (Mathur *et al.*, 1999). It plays a vital role in our national food security and is a means of livelihood for millions of rural households. In India, rice is grown over an area of 45.54 m ha with production of 99.18 MT (Anonymous 2009). In Maharashtra rice is the second important crop of the people, which is grown over an area of 14.99 lakh hectares with an annual rice production of 32.37 lakh tones. The average productivity of the state is 2.01 t/ha. Maharashtra ranks 13th place in rice production in the country. The average productivity of the Maharashtra state is low as compared to other rice growing states *viz.* Panjab, Tamil Nadu, Haryana, Andhra Pradesh, West Bengal etc. The area (7.32 lakh ha) of rice crop is more in Vidarbha region. (Thaware, B. L.*et al.*, 2008)

Because of high rainfall in Kokan region and high irrigation potential and Vidarbha region of Maharashtra, utilization of high yielding varieties of rice are also more in both the season for getting higher yields but the ample food and shelter are provided to the insect pests throughout the year. This cropping pattern and crop ecology offered an opportunity for major insect pest to multiply rapidly. Amongst the important insect pest of rice in Eastern Vidarbha zone, the *Nilparvata lugens* Stal. is one of the major insect pest of rice which occur epidemic in kharif and summer season.

1.2 Importance of the study

Among the biotic stresses insect pests caused about 10-15% yield losses. The average yield losses in rice have been estimated to 21-51 per cent. Yellow stem borer, brown planthopper and gall midge

are 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%). (Krishnaiahya, 1993.)

Among various constraints of rice production, damage due to insect pests is substantial and needs regular attention. Large-scale cultivation of high yielding varieties, monocropping, close planting, water regime, excessive use of nitrogenous fertilizers and misuse of agrochemicals have further aggravated the pest incidence. Over 1400 insect species attack standing and stored rice in the world (Grist and Lever, 1969), while (Kalode and Pasalu, 1986) reported that more than 100 species of insect pests attack rice crop at different stages of growth.

N. lugens is one of the major serious insect pest of rice in Asia. Its feeding causes plant wilt and dry symptom called 'hopperburn'. It also transmits grassy stunt and ragged stunt virus diseases (Reissig *et al.*, 1985).

With reduced land availability and increased demand for enhanced production, attention is turning towards intensification through higher fertilizer inputs and cropping. Such efforts in turn increased pest intensities (Heong, 1996) and losses caused by pests remained an important constraint to achieving high rice yields (Waddington *et al.*, 2010).

BPH damages rice crops every year in many Asian countries, with estimated annual losses of 2–3 million tons across the region. The pest not only brings viral diseases but also sucks the rice plant to death. Brown planthoppers pierce the plant stem and suck out the sap, carrying the plant food from the phloem cells, causing the rice plant to dry out, wither, and die. Serious infestation causes hopper burn in rice fields and often results in complete yield loss. (Merlicel, 2012)

1.3 Objective of study

Taking into consideration of the seriousness of this pest, the experiment is formulated on "Biology of paddy Brown plant hopper *Nilparvata lugens* Stal. in Nagpur region" with following objective.

1. To study the biology of Paddy brown plant hopper, *Nilaparvata lugens* Stal. under laboratory condition.

1.4 Hypothesis

Few workers have worked on the biology of paddy brown planthopper, *Nilparvata lugens* Stal. in the past (Manjunath 1977, San San Win et. al. 2011, Kalode 1976, Mishra and Israel 1968 and 1970, Khaire and Dumbre 1981)

Manjunath (1977) recorded the average pre-ovipostion period, oviposition period, longevity and fecundity of the macropterous and brachypterous females of the rice brown planthopper, *Nilaparvata lugens* Stal, 2·9 to 3·0 days; 8·4 to 9·2 days; 10·5 to 16·5 days; and 421·8 to 485·8 eggs, respectively.

San San Win *et. al.* (2011) reported that the females lived for a maximum of 20 days. The trend of oviposition showed a peak at around the tenth day of the female life. The highest number of eggs produced per female per day was 9.63.

Kalode (1976) reported five instar of BPH within 14 to 21 days

Mishra B. C. and Israel P. (1968) noted that a maximum of 681 eggs were laid by a BPH female and the duration of coitus, ranged from 50 to 60 minutes.

Mishra and Israel (1970) observed that an incubation period was 6.5, 13,5 and 12.6 days during June, October and November, respectively.

Khaire, V.A. and Dumbre, R.B. (1981) found that mating took place between 5.30 a.m. and 6.30 a.m. A female laid eggs in masses each containing 2 to 16 eggs in leaf sheath or inside the stem. Incubation period varied from 9 to 11 days with a mean of 10 days. Nymphs passed through five instars in 17 to 23 days. A life cycle was 54 to 62 days with a mean of 57 days.

1.5 Scope and limitations

Very few workers worked on biology of paddy brown planthopper, *Nilparvata lugens* Stal. in the past. However, efforts were being required to study the biology of Brown planthopper. The biological study of the insects plays important role for the management of insect at their damaging stage to avoid damage.

Beside good scope there were some limitations that the area of the experimental field were in city, therefore the population of BPH did not developed and self perpetuated in experimental field. In Insectory premises, therefore the population of the brown planthopper collected from Agriculture Research Station, Sakoli and Sindhewahi and released them in potted plant for multiplication. Varied life cycle of BPH have been reported by different workers at different places in different ecological condition, therefore to find out vulnerable or weakening stage and developmental period of BPH for imparting control measures for this pest in Nagpur region the studies were carried out.

CHAPTER II

REVIEW AND LITERATURE

During the present investigation efforts were made for study the biology of brown planthopper *Nilaparvata lugens* Stal. in Nagpur region.

After going through the literature, it was found that little information are available on the biology of brown planthopper. The work carried out by various scientists on this aspect during past few year are summarized below.

3.1 Taxonomy of Brown Planthopper.

Nomenclature of the brown planthopper, *Nilaparvata lugens* Stal. (Richards and Davies, 1997)

Phylum - Arthopoda
Class - Insecta
Order - Hemiptera
Suborder – Homoptera
Division – Auchenorrhyncha
Superfamily - Fulgoroidea
Family - Delphacidae
Genus - *Nilaparvata*
Species – *lugens*

3.2 Outbreak of *Nilaparvata lugens* Stal.

Chelliah and Subramanian (1972) reported the occurrence of BPH in epidemic form once every few years in Tamil Nadu and causes extensive damage.

Kulshreshtha *et al.* (1974) recorded the losses in grain yield ranged from 10% in moderately affected fields to 70% in those severely affected by brown planthopper.

Velusamy *et al.* (1975) reported in Coimbatore district, about 200 ha of rice fields was severely infested, and some hopperburn occurred in wet season.

Prakasa Rao *et al.* (1976) mentioned about 200 ha was hopperburned and 3,250 ha was severely infested by BPH during dry season in East Godavari district of Andhra Pradesh.

Heinrichs and Mochida (1984) in the beginning of 1960 the brown planthopper rise from the status of a secondary pest to a major yield constraint.

Reissing *et al.* (1986) reported that BPH damages the rice plant directly by feeding and also indirectly by transmitting the grassy stunt virus and the ragged stunt virus diseases.

Du *et al.* (2007) reported more than 485,000 ha rice production area in southern Vietnam were severely affected by viral diseases seemingly spread by BPH, resulting in the loss of 828,000 tons of rice valued at US$120 million.

3.3 Life History of *Nilaparvata lugens* Stal.

Tirumala Rao V. (1950) observed that the pest is a fulgorid bug, which lays eggs in the midribs of paddy leaves, and the nymphs which emerge therefrom, as well as the adult bugs, hide between the leaves of the top shoots and suck the plant sap.

Mochida (1964) reported that when the population of adults was high, eggs were found in the upper part of the plants.

Kisimoto (1965) observed the pre-ovipositional period of macropterous females of Japanese *N. lugens* ranged mostly from 5 to

12 days after eclosion with an great individual variation, which was being influenced by growth stage and quality of rice.

Mishra B. C. and Israel P. (1968) observed the planthopper lay eggs in masses in the midrib of leaves, leaf sheath and leaf blade. At first they make an incision by the ovipositor and lay eggs, eggs cap being directed toward outside. Anatomical studies indicate that they puncture the lower epidermis of the midrib of both the leaf sheath and leaf blade and place the eggs in the air cavities of the midrib, sometimes the eggs extend from one air cavity to the other by breaking the separating thin parenchymatous strands.

Mishra B. C. and Israel P. (1968) noted that a maximum of 681 eggs were laid by one BPH female and the duration of coitus, ranged from 50 to 60 minutes.

Mishra and Israel (1970) observed that eggs incubation period was 6.5, 13.5 and 12.6 days during June, October and November, respectively.

Takeda (1974) observed that ability of BPH to copulate increases up to 5 days after emergence and then decreases.

Nalinakumari and Mamen (1975) reported that oviposition period of BPH lasted from 10 to 28 days, and incubation period was 8.1 days.

Butani and Jothwani (1976) found the transparent eggs of BPH laid in clusters with anterior ends attached to one another, and incubation period was 8 to 9 days.

Kalode (1976) observed five instar of BPH within 14 to 21 days.

Oh (1979) reported If *N. lugens,* individuals were very low and scattered, mates was limiting. Under these conditions single matings compared to multiple matings resulting reduced in fecundity.

Khaire and Dumbre (1981) found that mating took place between 5.30 a.m. and 6.30 a.m. A female laid eggs in masses each containing 2 to 16 eggs per mass in leaf sheath or inside the stem. Incubation period varied from 9 to 11 days with a mean of 10 days. Nymphs passed through five instars in 17 to 23 days. A life cycle was completed between 54 to 62 days with a mean of 57 days.

Van Der Laan (1981) reported that the single female lay eggs from 100 to 500 eggs and it depends on the stage of growth of the rice plant.

Claridge *et al.* (1984) reported the evidence of BPH that rice variety-associated populations of *N. lugens* prefer to ovi-posit on their natal host plant, on which offspring performance is best.

Zaheruddeen *et al.* (1985) reported the eggs group of Brown planthopper deposited usually on the external surface of leaf lamina in a groups of 7-12 per batch in an exposed manner and hatching period were 6-11 days.

Heinrichs *et al.* (1986) observed that usually there are three generations on the modern high yielding intermediate duration varieties in the tropics.

Ooi P.A.C. (1992) reported the eggs of BPH laid inside rice stems, took about seven days to develop into nymphs.

Dupo and Barrion (2009) In most cases, the eggs are thrust in a straight host plant along the mid-region of the leaf sheath, though sometimes eggs are laid in clusters of 4-10 in longitudinal rows within

the leaf midribs.The different instars can be distinguished on the basis of shape of mesonotum and body size. The eggs are crescent-shaped and less pointed.

3.4 Ecology of the pest.

Kisimoto (1957) recorded the number of eggs laid by a female was highly correlated to her life span, renewing the food plant at different intervals and using several chemicals, he found that deterioration in quality and quantity of food accelerated the increase in relative numbers of the macropterous insects of both sexes. He also noted that, in *N. lugens* the nymphal period was shorter for the brachypterous form than for the macropterous in both sexes, and that even at high densities, the nymphal period of the brachypterous insect was fairly constant, whereas that of the macropterous insect was longer by higher density.

Suenaga (1963) in his studies said fourth- and fifth-instar nymphs are normally active between 12 and 31°C temperature. The temperature range for normal behavior is 9 to 30°C in the macropterous male and 10 to 32°C in the macropterous female.

Mochida (1964) studied the five generations of *N. lugens* on a single rice crop in southern Japan, and observed the temperature to which the nymph was exposed affect the adult female's longevity and oviposition. Adult longevity was curtailed as temperature rises in the range of 20 to 33°C further he mentioned the temperature conditions in the nymphal stage affect the longevity and oviposition of adult hoppers. The preoviposition period of macropters is extended at cool temperatures and yet remains the same for brachypters across an wide range of temperatures.

The incidence of brown planthopper was noticed in the month of October to November (Anonymous 1972).

Hirao, J. (1972) observed that Brown planthopper population reached its peak in the month of September or early October.

Kisimoto (1977) noticed that the eggs of BPH were very sensitive to desication and soon shriveled when the host plant started wilting.

Dyck *et al.* (1979) showed that the number of nymphsof BPH/tiller were similar in sparse and dense plantings of rice. At the time of colonization, the macropterous forms dominate in a rice field under tropical conditions.

Saxena *et al.* (1981) shown signifcant increased in macropterous forms among progenies reared on senescent and hopper burned rice plants.

Khaire and Dumbre (1984) reported that incidence of Brown planthopper began from the second week of September thereafter it increased progressively and peaked in November when maximum temperature and humidity were 30.1^0 C and 71.8 percent respectively, the peak of incidence during flowering, dough and grain formation stages of the crop.

Vijaykumar and Patil (2004) carried out field surveys during kharif, 2001 in Tungbhadra districts of Karnataka and indicated that, the incidence of BPH appearing in the month of October and continued it till the harvest of the crop.

Wada *et al.* (2006) demonstrated that macropters originating in temperate and subtropical East Asia had a longer pre-ovipositional period, which was presumably beneficial for pre-reproductive long-distance migration.

Varma *et al.* (2008) predicted that, BPH population in September was low, when cumulative rainfall in August was <100mm, and it moderate rainfall received about 200mm. The outbreak of BPH was noticed when rainfall received >300-400mm.

Bambawale *et al.* (2009) reported that Brown plant-hopper, *Nilaparvata lugens* (Stal) on basmati rice in Haryana and Western Uttar Pradesh noticed during September- October 2008 mainly due to favourable prevailing weather conditions.

Win *et al.* (2010) reported that the population fluctuations of the hoppers in rainy season is depend of the rainfall and the humidity and in dry season, it depend of the temperature.

Jadhao M.F. and Khurad A.M. (2011) reported that the incidence of *N. lugens* and *S. furcifera* during rabi season were much lower as compared to the kharif season. The infestation of *S. furcifera* was noticed at an early stage of the crop growth whereas the BPH appeared in appreciable number at the grain filling stage of crop.

3.5 Cultural factors governing pest population.

Sogawa (1971) laboratory studies shown that the hoppers prefer and feed more on plants receiving higher nitrogen rates and lay more eggs.

Mochida *et al.* (1979) noticed intensification of rice production through continuous irrigation favors outbreaks of brown planthopper.

Chelliah and Heinrichs (1980) resurgence of the brown planthopper, *Nilaparvata lugens* (Stål) on rice was induced by applications of decamethrin, methyl parathion, and diazinon. Differential mortality of predators and hoppers did not appear to be the primary factor for resurgence. Hoppers appeared due to methyl

parathion and decamethrin treated plants because of plant growth. Improved plant growth however did not compensate for the increased feeding of the insecticide-treated hopper population, and plants treated with resurgence-causing insecticides succumbed to feeding injury earlier than untreated plants. Population increases were due in part to stimulation of reproduction of the hopper, either by contact action of the insecticides or through increased plant growth. Reduction in the length of the nymphal stage and increased adult longevity resulting in a shortened life cycle and longer oviposition period respectively, were additional factors contributing to resurgence.

Heinrichs and Mochida (1984) found that insecticides have been suggested as the major factor involved in brown planthopper outbreaks due to the poor control and reproductive stimulation of the hopper at sublethal rates and destruction of natural enemies.

Kenmore *et al.* (1984) reported that widespread misuse of insecticides, outbreaks of BPH have been occurred, thus killing natural enemies that normally play a key role in suppressing planthopper populations in rice.

Gallagher *et al.* (1994) reported that when brown planthoppers were introduced to treated resistant rice varieties, the resistant varieties lost their effectiveness, causing a density increase in the BPH population.

Preap *et al.* (2001) reported birth and survival rates of BPH were higher in susceptible plants with high fertilizer rate used. The experiment indicated that natural enemies have played an important role to manage the BPH population. The fecundity and survival of BPH was higher in susceptible host plant variety with high rate of NPK fertilizer used.

Preap *et al.* (2002) tested the hypothesis that early-planted seedbeds of rice were heavily infested with brown planthopper (BPH) than later seedbeds, and the transplanted plants with BPH was a source of subsequent population increase and possible outbreaks. For hypothetical study, the experiments were conducted at CARDI and Takeo province in wet season 2000 and early wet season 2001. BPH at 0, 25, 50, 100, 200 /m^2 were infested onto plants with low and high fertilizer treatments. Rice seeds of varieties moderately and highly susceptible to BPH were sown at 3 weeks early, 2 weeks early, at normal time, and later than normal (5 weeks) and treated with low and high fertilizer rates. At Takeo, the 3 weeks early seedbeds were infested by BPH migration, and both varieties with high fertilizer caught more immigrant insects and subsequently caused outbreak of BPH in the third generation. At CARDI, no seedbeds were infested with immigrant BPH. Seedbeds in areas with continuous cropping of rice have a high risk of BPH attack. Seedlings infested with 200, 100, and 50 BPH/m^2 resulted in death of the plant. Plants with 100 and 200 BPH/m^2 were killed sooner. With 25 BPH/m^2plants were not killed, but subsequent population increase caused yield reduction. Yield loss was high in high fertilizer treated plants.

Lu *et al.* (2004) found that ecological fitness characters of the BPH increased proportionally with increasing nitrogen content of the rice plants.

Gudem (2006) noticed factors that contributed the BPH outbreaks in rice due to the continuous cultivation of susceptible rice varieties, high use of nitrogenous fertilizers, favorable microclimatic conditions for the development of winged black-colored macropterous forms, widespread migration in endemic areas and new areas, closer planting, and imbalance use of N and K fertilizers etc.

Chapter III

MATERIAL AND METHODS

Nilparvata lugens Stal., commonly known as brown planthopper, is one of the serious pests of Rice throughout the world.

With the introduction and cultivation of rice as a second crop during kharif and summer, the severity of various insect pests like gall migde, stemborer, leaf folder, case worm, leafhopper, planthopper, gundhi bug have been in serious proportions. So as for as brown planthopper is concerned, it has shown its existence in sporadic form, but with the introduction of new improved varieties of rice and hybrid rice in larger area in both the season it wide spread and assumes the status of an important insect pest, causing heavy reductions in the crop yields.

Considering the imminent danger of rice crop due to brown planthopper, it was very essential to study the various aspect of its biology from its management point of view.

Therefore, the present study was conducted on **"Biology of paddy Brown plant hopper** *Nilparvata lugens* Stal. **in Nagpur region"** with following objective.

1. To study the biology of Paddy brown plant hopper, *Nilaparvata lugens* Stal. under laboratory condition.

The experiment was carried out in insectory, Entomology section, College of Agriculture, Nagpur during Kharif 2011-12. The material used and methods adopted during the period of investigation are explained below.

3.1 MATERIAL

For carrying out present investigation materials like seed of HMT rice variety, fertilizers, glass wares, goglets, earthen pots, iron hoods

with muslin cloth net, curtain, magnifying glass, needle, lenses, microscope, polythene bags, petridishes, stage micrometer etc. were used.

3.2 METHOD

3.2.1 Raising the crop for natural multiplication of *Nilparvata lugens* Stal. :

Field collection of the desired stage of BPH was necessary to start with the life history of the brown plant hopper. For this purpose susceptible variety of rice PKV HMT was grown and transplanted in an area of about 200 m^2 in the insectory premises College of Agricultural, Nagpur especially for studying the natural multiplication and population fluctuations under field condition. The seed was raised in nursery on 19th July 2011. Healthy seedlings were transplanted on maintaining the spacing of 20 cm between rows and 15 cm between plant. The crop was raised by adopting the recommended agronomic practices and irrigated them as and when required. However, pest control measures were not undertaken throughout the crop season in order to allow the natural multiplication of pest and parasite. (Plate No.1)

3.2.2 Collection of the pest:

While surveying the paddy pests in Bhandara district incidence of *Nilparvata lugens* Stal. was spotted out in the field of Agriculture Research Station, Sakoli. Adults and nymphs were collected in large number with the help of aspirator. In addition to it about 15 infested hills were also uprooted and brought to Nagpur. The infested hills were replanted in 25 cm diameter pots which were then kept adjacent to the rice field in the insectory premises. The nymphal stages develop on this infested potted plant and migrated towards the adjacent transplanted rice field on 15th September 2011. Approximately 11 days

Plate No. 1 Transplanting of Paddy seedlings in field

Plate No. 2 Potted paddy seedlings under bell jar

Plate No. 3 Brown plant hopper infestation

after the introduction of infested plant. Similarly, the adult and nymph were collected separately and released them on the hooded seedlings which were already raised in the pots of same size. Thus, the pest was allowed to multiply in the field and this field culture was then utilized for studying the life history studies.

3.2.3 Life history:

The life history of the pest was under taken in the laboratory condition at the prevailing room temperature as well as under field condition.

3.2.4 Collection of newly formed Adults:

With a view to obtained fresh adults almost fully developed nymphs of *N. lugens* Stal. were released on the potted plant which was already covered with bell jar and as soon as the nymphs were released the opening of the top of bell jar was covered with muslin cloth for the development of nymph into adult. Released populations were frequently observed in the bell jarred plants and as soon as the adult noticed, they were collected in specimen examining their sex under binocular microscope. Then male and female pairs were separated for further study.

The adult of smaller size having dark brownish and blunt abdominal end were considered as male, while large size adults having tapering abdominal end with an ovipositor, were considered as females.

The females separated in this way were observed for the development of their wings. Macropterous and brachtypterous female then seperated.

3.2.5 Life history studies under laboratory conditions:

The life history of *Nilparvata lugens* Stal. was studied under laboratory conditions at the prevailing room temperature during October 2011. The paddy seedlings of PKV HMT variety were raised simultaneously and seedlings of 10 to 15 cm height were used as food. Test tubes, about 10 to 15 cm long and 2.5 to 3.0 cm in diameter were used for studying the various aspects of the life history of the test insect one young seedlings was inserted in a test tube containing water at the level of 2.5 cm so as to keep the root system of the seedlings dipped under water. Two to three numbers of urea granules were added to the water in the test tube to meet the nutritional requirement. Such seedlings in the test tubes were used as a source of food for the study of different developmental stages of BPH.

3.2.6 Mating Period:

In an experiment to study the mating behaviour, a newly emerged pair of a male and a female was confined to a test tube containing a fresh seedlings and the mating behavior and copulation period was studied.

3.2.7 Pre-oviposition and oviposition period and longevity of Adult:

One newly emerged brachypterous female and a male were paired together and released in a test tube containing paddy seedlings. The open mouth of the test tube was closed by cotton swab. Thus the pair was confined to the test tube and at the same time normal aeration was restored. Similarly in another test tube, a pair of macropterous female and male was released. Five such sets were prepared immediately after their emergence and kept under study.

With a view to study the pre-oviposition as well as oviposition period of both macropterous and brachypterous females pairs were

withdrawn from the test tubes daily and released into new test tube containing seedling. In this way a pair was shifted to new test tube till the death of the gravid female occurred. Thus a pair was allowed to remain in each test tube for a day only. The seedling in each test tube was regularly observed for the hatching of the eggs. The pre-oviposition period was determined between the day of release of a pair of adults and the day of first egg deposition. Similarly the period of oviposition was determined by observing the period of first egg laying to the last in all test tubes, containing seedlings exposed to the pair for oviposition. The observations were continued till the death of adult. The longevity of the adult was also determined.

3.2.8 Fecundity Study:

With a view to study the egg laying capacity, a female from a released pair was allowed to lay the eggs on fresh plants till they died. The total number of eggs laid per female was determined. Five such sets of a pair of male and female were released from both macropterous and brachypterous forms.

3.2.9 Incubation Period:

For this study the eggs laying seedlings were dissected to know the size and colour of the freshly laid egg as well as counted the incubation period of eggs upto hatching.

3.2.10 Nymphal Period:

Young seedlings about 15 cm tall were inserted in the test tubes about 10 to 15 cm long and 2.5 to 3.0 cm in diameter. The freshly emerged nymphs were individually confined to seedlings in the test tubes and development was closely and regularly observed to determine the number of instars and the time required for completing each instar. Fresh food in the form of healthy seedlings was supplied to the nymphs every day. In this way the one successive generation was studied under laboratory conditions from October to December 2011.

Chapter VI

Results and Discussion

Nilaparvata lugens Stal. A well known serious pest of paddy is spreading to the new areas wherever more than one paddy crops are being cultivated within a year. Bhandara, Gondia, Chandrapur, Gadchiroli and some part of Nagpur districts in Vidarbha region of Maharashtra state are known as an potential rice growing districts. The appearance of BPH in these potential paddy growing districts of Maharashtra in the recent past as a sporadic pest and is likely to spread and assume a status of serious pest due to the intensive cultivation of rice.

Keeping in view the impending danger of this pest studies on some of the following aspects of biology of this insect was therefore planned and carried out during the course of these investigation.

4.1 Life history under laboratory condition:

Under laboratory condition mating behaviour and copulation period, pre-ovipositon period, oviposition period, fecundity, longevity of adults, eggs and incubation period, nymphs and adults was thoroughly studied.

4.1.1 Mating behaviour and copulation period:

During the study of experiment, the mating behaviour of newly emerged pair of male and female was confined to a test tube containing a fresh seedlings and it was observed that the male usually showed the sexual excitement first and tried to approach the female. It jump from one place to another in search of female and tried to stablilize near the female till it responded favourably. When female responded, it show the movement of valvulae and ovipositor. A male approached the female and caught her by sitting on the back

(abdomen). The male hold the female firmly by means of the legs, it bent the tip of the abdomen so as to reach the level of female genitalia, and aedeagus was then inserted into its genital aperture. During copulation period, the pair moved actively. The mating continued for about 6 minutes as observed during October under laboratory condition. Tirumala Rao (1950), Mishra and Israel (1968) and Khaire and Dumbre (1981) observed that mating began 2 days after emergence of 5th instar and on leaf sheath or stem, with a marked preference for leaf sheath.

4.1.2 Pre-oviposition period.

The observation revealed that pre-oviposition period were in range of 2 to 3 days with an average of 2.4 days in case of macropterous female while it was 2 to 4 days in case of brachypterous female during October (Table 1). Khaire and Dumbre (1981) also found an average of two days as pre-oviposition period which support the data.

Table 1. Pre-oviposition period of *Nilaparvata lugens* Stal.

Sr. No.	Macropterous (Days)	Brachypterous (Days)
1	2	2
2	2	3
3	3	4
4	2	3
5	3	4
Range	2-3	2-4
Average	2.4	3.2

4.1.3. Oviposition period.

Table 2. Oviposition period of *Nilaparvata lugens* Stal.

Sr. No.	Macropterous (Days)	Brachypterous (Days)
1	9	11
2	8	13
3	8	14
4	7	11
5	9	14
Range	7-9	11-14
Average	8.2	12.6

When the female was ready for oviposition it moved on the plant surface to select the suitable site. Leaf sheath and midrib of leaf lamina were preferred and used for depositing the eggs. The gravid female made a vertical slit with the help of its strong ovipositor and through it, placed the eggs either inside leaf sheath or the midrib. Although the fresh site of ovipositon was not visible to the naked eye, it could be easily located under microscope in the form of an incision.

It is worth mentioning that both the types of females continued to lay eggs till their death occurred. During October although the eggs laying commenced 4 to 5 days after the 5th instar stage, in case of macropterous, it continued till it survived for 7 to 9 days. Thus the oviposition spread over a period of 7 to 9 days with an average of 8.2 days. In case of brachypterous females the oviposition period, however, extended over a period of 11 to 14 days with an average of 12.6 days. Manjunath (1977) reported the oviposition period of 8.2 days for macropterous female. Nalinakumari and Mammen (1975) reported the oviposition period within a range of 10 to 28 days. Thus

the above findings are analogus to the findings of present investigation and support the data.

4.1.4. Eggs:

The female made an incision with the help of an ovipositor, carved out a cavity in the lower epidermis of a midrib of a leaf or a leafsheath of rice plant and inserted the egg masses in a single row in it. The eggs mostly remained hidden within this incised space. The eggs were inserted in such a way that the egg caps were always directed towards the outside opening of the cavity. It helped in easy hatching of the eggs and emergence of the young nymphs. It was very convenient to spot out the site of oviposition as the incised tissues of the leaf turned brownish or blackish due to tissue injury.

4.1.5. Shape of the eggs:

The eggs were somewhat cylindrical, slightly curved in the middle, broader at the base and somewhat tapering towards the mycropyle end which protruded from the leaf tissues. (Plate No.4)

Although the freshly laid eggs were snowwhite in colour, they turned yellowish on aging and two distinct red spots appeared when the eggs were about three days old. These spots subsequently turned out to be the eyes of the nymphs.

4.1.6 Incubation period:

The incubation period of the eggs laid during different growth period of the crop varied greatly. The incubation period observed during October was 7 to 9 days. (Table 3)

Similar incubation period of BPH reported by Nalinakumari and Mammen (1975), Butani and Jothwani (1976) and Manjunath (1977) was in the range of 6 to 9 days and support the data.

Table 3. Incubation period and hatching percentage of *Nilaparvata lugens* Stal.

Sr. No.	No. of Eggs observed	Number hatched			Total eggs hatched	Percent hatching
		7^{th} Day	8^{th} Day	9^{th} Day		
1	20	6	7	4	17	85
2	20	4	9	3	16	80
3	20	5	8	1	14	70
4	20	4	12	2	18	90
5	20	3	8	2	13	65
Total	100	22	44	12	78	78

4.1.7 Hatching of the eggs:

At the time of the emergence of the young nymphs from the eggs, the head was directed towards the eggs cap while the abdominal end was towards the base of the eggs shell. When the egg was about to hatch the younger nymph alternately expansion and contraction of their body pushed the eggs cap which was detached from the egg shell and through this opening the younger nymph emerged out.

The hatching of the egg was completed and the young nymph came out. Total 78 percent hatching of eggs observed during investigation.

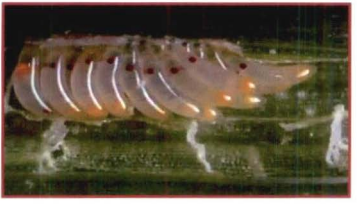
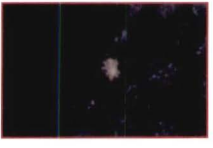
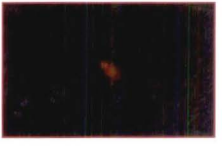


Plate No. 4 Eggs of Brown Planthohher



Ist Instar



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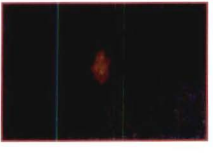
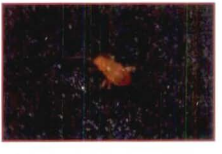


IIIrd Instar



IVth Instar

Instar Vth

Plate No.5 Nymphal stages of Brown planthopper

4.2 Nymphs:

Freshly hatched nymphs were creamy coloured with well developed eyes. Their colour turned to dull white after about half an hour. Then delicate nymph stabilized near the site of oviposition for few minutes. Then it moved in search of a suitable site for feeding and stabilized for a while to suck the plant sap. (Plate No.5)

Nymphs of all instars were somewhat oval shaped dorsoventrally flattened. The measurement of width and length of a body for 3rd to 5th instar nymph and adults were given in Table 4.

Although the nymphs did not remain stationary throughout their nymphal period, they changed their site of feeding as least as possible only for the search of better feeding site. First three instars of the nymphs were comparatively less active than the 4th and 5th instar nymphs which exhibited sharp reflexes on slightest disturbance and jumped quickly. The nymphs were never found on the older leaves and hard shoots of the plants. They always preferred to fed on the tender shoots. The nymphs appeared to be sensitive to bright light and therefore, mostly confined themselves to the shaded base of the plant above the water level. Whereas during evening hours when the light intensity diminished, the grown up nymphs migrated to the upper tender shoots.

4.2.1 Newly hatched (First instar):

These are cottony white and turn purple-brown within an hour. First instar nymph was moult within 2 to 3 days (Table 5). Demarcation between the thorax and abdomen was clear. The junction was narrow, with brown pigmentation at the vertex.

4.2.2 Second instar:

Second instar nymph was moult within 2 to 4 days (Table 5). Their colour was brownish white, with eyes slightly red. The abdomen was uniformly brownish white and the thorax was brownish.

4.2.3 Third instar:

Body length of 3rd instar nymph of BPH was in the range of 1.42 to 1.46 mm with an average of 1.44 mm while abdominal width ranges from 0.62 to 0.66 mm with an average width of 0.64 mm (Table 4). Third instar nymph was moult within 3 to 4 days (Table 5). They had a brownish colour with red eyes. There was a longitudinal midline from base of vertex to the tip of the metathorax and also, the wing rudiments make their appearance.

4.2.4 Fourth instar:

The body length was between 1.88 to 1.92 mm with an average of 1.90 mm while abdominal width ranges from 0.76 to 0.80 mm with an average width of 0.78 mm (Table 4). Fourth instar nymph was moult within 4 to 5 days (Table 5). In this case, the nymphs were brown with red eyes. The longitudinal midline extends from the base of the vertex to the end of the metathorax with the rudiment wings covering the first two abdominal segments.

4.2.5 Fifth instar:

The body length ranges from 2.88 to 2.92 mm with an average of 2.90 mm while abdominal width ranges from 1.11 to 1.15 mm with an average width of 1.13 mm (Table 4). Fifth instar nymph was moult within 3 to 4 days (Table 5). The body colour was brownish black, with grayish blue eyes. Also, the midline appears as a prominent median

Plate No.6 Macropterous (long wing) female of Brown Planthopper

Plate No.7 Brachypterous (short wing) female adult of Brown Planthopper

Plate No.8 Male adult of Brown Planthopper

line from the base of the vertex to the end of the metathorax, where it was the widest, this crosses at right-angles to the partition line between the pro and mesothorax. At this stage, the developing wings cover the first three abdominal segments.

4.3 Adult:

The newly formed adult was greyish, subsequently turning to yellowish brown. The male was 3.85 to 4.12 mm (including tegmina) in length, whereas the length of macropterous and brachypterous female was 4.28 to 4.70 mm and 3.31 to 3.73 mm respectively (Table 4). (Plate No. 6, 7 and 8)

The head yellowish white with large compound eyes, the antennae yellowish brown and inserted near the lower margin of the eyes.

The wing sloping over the sides of the body, apical marginal veins brown, on the terminal a dark elongated spot and the hind wings was broader.

Abdomen 8 segmented, in male it was black, the margins of the segments yellowish white. In female it was above black and beneath yellow.

Table 4. Measurement on nymphs adults *Nilaparvata lugens* Stal. (mm)

Stages	Abdominal width (mm)	Mean	Body length (mm)	Mean
Ist Instar				
IInd Instar				
IIIrd Instar	0.62-0.66	0.64	1.42-1.46	1.44
IVth Instar	0.76-0.80	0.78	1.88-1.92	1.90
Vth Instar	1.11-1.15	1.13	2.88-2.92	2.90
Adult Macropterous female	1.05-1.10	1.08	4.28-4.70	4.48
Adult Brachypterous female	1.02-1.06	1.04	3.31-3.73	3.54
Adult male	0.83-0.87	0.85	3.87-3.91	3.89

Table 5. Duration of various nymphal stages of *Nilaparvata lugens* Stal. (Days)

	Duration (Days)		
Instar	Maximum	Minimum	Average
I	3	2	2.5
II	4	2	3
III	4	3	3.5
IV	5	4	4.5
V	4	3	3.5

4.4 Adult Longevity:

Although the males survived comparatively less than the females, the trend of variation in their longevity was same as that of females during different periods. The males survived for an average of 8.4 days during October (Table 6). This study was carried out during the month of October revealed that the average longevity of male about 8.4 days. The macropterous female survived for an average of 12.4 days while brachypterous female survived for an average of 16 days.

Manjunath (1977) reported that macropterous and brachypterous female survived in a range of 11 to 17 and 13 to 21 days respectively while male survived upto the range of 6 to 15 days. These results are in agreement with the findings of present investigation and support the data.

Table 6. Longevity of adult *Nilaparvata lugens* Stal.

Sr. No.	Macropterous female (Days)	Brachypterous female (Days)	Male (Days)
1	11	13	8
2	13	19	6
3	15	16	11
4	11	15	8
5	12	17	9
Range	11-15	13-19	6-11
Average	12.4	16	8.4

4.5 Fecundity

The fecundity of female BPH studied in laboratory condition on potted plants and observed its oviposition at 2 to 3 spots of the plant.

The average 72.2 eggs were laid by a macropterous female and 86.8 eggs laid by a brachypterous female in 9.2 and 11.2 masses respectively during October (Table 7). The slight decrease as well as increase in the fecundity was directly correlated with the oviposition period.

But these findings could not be compared due to unavailability of literature.

Table 7. Fecundity of *Nilaparvata lugens* Stal.

Sr. No.	Macropterous		Brachypterous	
	No. of groups	Total No. of eggs	No. of groups	Total No. of eggs
1	8	72	12	92
2	11	79	9	77
3	7	56	13	95
4	12	86	8	67
5	8	68	14	103
Range	8-12	56-86	8-14	67-103
Average	9.2	72.2	11.2	86.8

4.6 Life cycle:

The life history studies undertaken during October to November revealed that eggs incubation period of BPH ranged between 7 to 9 days and nymphal developmental period completed in 14 to 20 days. Although the macropterous females survived for 11 to 15 days while the brachypterous females survived for 13 to 19 days, the female started eggs laying within 24 hours after emergence of 5th instar during favourable conditions while the pre-oviposition period extended upto 4

days when the condition were not favourable. Thus a generation was completed in 23 to 33 days. The oviposition period of macropterous female was 8 to 9 days while in brachypterous female was 11 to 14 days during the peak period of infestation. It was obvious that when the conditions were favourable, one life cycle was not only completed within the shortest period of 23 days but there were overlapping generations which helped in the fast multiplication of the pest.

It is estimated that more than three generations could be conveniently completed during the growth period of rice crop and increased losses if the infestation begins in the early growth period of the crop.

Chapter V

Summary and conclusions

Brown plant hopper is considered to be the most dreaded rice pest, because it devastates the crop in concealment and when the symptoms of damage become apparent, it is absolutely futile to prevent the crop losses at this stage.

Nilaparvata lugens Stal. has now infringed the rice growing tracks of Vidarbha and it is contemplated that it might assume serious proportions due to the cultivation of rice crop in both the season. The studies on the biology of this pest were, therefore, undertaken to understand its various aspects for their appropriate utilization in the pest management programme. These investigations were carried out under laboratory conditions in the insectory premises of Entomology Section, College of Agriculture, Nagpur during October to November, 2011.

The study of biology on BPH was conducted in the month of October. The male and female adult pairs of BPH were released in a different pot containing the seedlings for observing the mating behavior and copulation. After that the macropterous female and brachypterous female released on the potted plant and the pre-oviposition period, oviposition period, fecundity and longevity were subsequently studied.

5.1 Life History:

5.1.1 Pre-oviposition period:

In the month of October, the pre-oviposition period of BPH was 2-3 days for macropterous female and 2-4 days for brachypterous female.

5.1.2 Oviposition period:

The oviposition period for macropterous females was found to be 7 to 9 days while 11 to 14 days for brachypterous female. Both the types of female were in a position to lay eggs until they survived during October.

5.1.3 Incubation period:

The crescent shaped cylindrical eggs, slightly curved in the middle were deposited either in the leaf sheath or in the lower epidermis of the midrib in longitudinal cavity incised with an ovipositor in a single row containing 6 to 15 eggs. The microscopic eggs incubated in about 7 to 9 days during October.

5.1.4 Nymphal Instar:

Nymphs passed through five instars in about 14 to 20 days during October and a generation was completed within 20 to 48 days being the shortest period (20 days) during October. Although the nymphs did not remain stationary throughout their nymphal period, they changed their site of feeding as least as possible only for the search of better feeding site. First three instars of the nymphs were comparatively less active than the 4^{th} and 5^{th} instar nymphs which exhibited sharp reflexes on slightest disturbance and jumped quickly. The nymphs were never found on the older leaves and hard shoots of the plants. They always preferred to feed on the tender shoots. The nymphs appeared to be sensitive to bright light and therefore, mostly confined themselves to the shaded base of the plant above the water level. Whereas during evening hours when the light intensity diminished, the grown up nymphs migrated to the upper tender shoots. Temperature ranging around 14.2 to 34.1^{0} C during these months coupled with adequate supply of food favoured faster breeding and

multiplication, since more than three generations could be easily completed posing a serious threat to the crop.

5.1.5 Adult:

BPH adult was brownish black with yellowish brown body. The adults exist in two forms, macropterous and brachypterous. Macropterous adults or long-winged have normal front and hind wings, where as brachypterous forms or the short-winged have reduced hind wings. These forms are the first to appear in the newly planted field and began colonization. The adults mate 24 hours after emergence and the female start laying the eggs from the day following mating. Newly formed adults, brownish in colour turning yellowish brown subsequently, measure 3.87 mm to 3.91 mm in case of males whereas macropterous and brachypterous females were 4.28 to 4.70 and 3.31 to 3.73 mm long respectively. The males survived for 6 to 11 days during October while the macropterous females lived for 11 to 15 days during these months. The brachypterous females which had a life span between 13 and 19 days.

5.1.6 Fecundity:

Average fecundity of a female ranged between 72.2 and 86.8 eggs during October. The brachypterous female oviposited large number of eggs than the macropterous female during October. Macropterous female laid eggs in the range of 56 to 86 while brachypterous female laid 67 to 103 eggs. It was apparent that irrespective of the life span, oviposition period of a concerned female had a direct bearing with its fecundity.

5.2 Conclusion:

In the biology study of BPH, the pre-oviposition period was in range of 2 to 4 days and oviposition period was in range of 7 to 14 days. Incubation period of BPH was 7 to 9 days, nymphal period 14 to 20 days and adult longevity in a range of 6 to 19 days. The average fecundity of BPH was 72.2 and 86.8 eggs for brachypterous and macropterous female respectively. The total life cycle of the BPH was in the range of 23 to 33 days. The fourth and fifth instar nymphs were more active than the other. The nymphs and adults were remain on a plant just above the water level.

CHAPTER VI

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*Original not seen.

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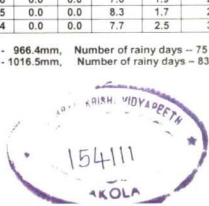
APPENDIX

Statement showing the Weekly Meteorological Data for the year 2011-12 recorded at meteorological observatory, Agriculture College Farm, Nagpur – (January – December-2011)

Date		Met Week	Temp °C		R.H. %		Total Rainfall (mm)	No. of Rainy days	Bright sunshine hours	Wind speed km/hr.	Evaporation (mm)
			Max	Min	Mor	Eve					
01-07	Jan.11	1	26.3	8.1	44	26	0.0	0.0	0.0	3.6	1.9
08-14		2	27.7	7.7	48	27	0.0	0.0	0.0	2.0	2.9
15-21		3	29.5	10.1	54	32	0.0	0.0	0.0	2.4	2.7
22-28		4	30.7	12.5	66	27	0.0	0.0	0.0	2.0	2.9
29-04	Feb.11	5	31.1	14.8	59	30	0.0	0.0	0.0	3.1	3.5
05-11		6	32.3	13.5	56	25	0.0	0.0	0.0	2.2	3.9
12-18		7	33.2	16.3	56	26	0.0	0.0	0.0	2.9	4.5
19-25		8	28.6	15.4	63	44	18.4	2.0	0.0	4.5	3.5
26-04	Mar.11	9	32.6	17.4	57	30	0.0	0.0	0.0	3.4	4.8
05-11		10	37.1	20.0	47	21	0.0	0.0	0.0	3.5	5.5
11-18		11	36.1	16.5	33	14	0.0	0.0	0.0	3.4	5.3
19-25		12	39.0	19.6	39	17	4.2	1.0	0.0	3.4	6.8
26-01	April 11	13	37.4	20.5	28	12	0.0	0.0	0.0	5.0	9.2
02-08		14	38.0	21.2	40	25	9.8	1.0	0.0	4.7	7.4
09-15		15	38.3	22.2	53	26	9.7	1.0	0.0	4.0	6.0
16-22		16	38.5	24.3	56	29	6.6	2.0	0.0	5.5	7.0
23-29		17	38.6	22.8	51	24	0.0	0.0	0.0	4.1	7.6
30-06	May 11	18	41.4	26.4	39	19	0.0	0.0	0.0	6.9	9.4
07-11		19	42.9	27.5	27	15	0.0	0.0	0.0	6.5	12.3
14-20		20	44.2	28.3	33	15	0.0	0.0	0.0	4.7	9.9
21-27		21	42.6	29.6	39	20	1.4	1.0	0.0	6.8	11.1
28-03	Jun 11	22	42.9	29.4	34	23	0.0	0.0	0.0	6.4	10.6
04-10		23	38.5	26.4	69	43	12.0	2.0	0.0	5.9	8.1
11-17		24	38.0	26.1	67	44	50.4	3.0	0.0	7.4	8.0
18-24		25	35.3	26.1	72	55	9.4	3.0	0.0	8.0	8.2
25-01	July11	26	30.3	24.3	82	66	33.4	5.0	0.0	5.8	4.0
02-08		27	37.4	25.3	75	44	24.9	4.0	0.0	5.2	4.6
09-15		28	34.0	25.1	82	66	74.7	5.0	0.0	6.2	4.5
16-22		29	30.0	24.4	95	82	139.8	7.0	0.0	4.5	2.8
23-29		30	29.8	24.2	85	74	42.3	5.0	3.0	3.3	2.9
30-05	Aug 11	31	31.8	25.2	88	73	86.8	5.0	4.2	4.1	3.7
06-12		32	29.9	24.2	87	74	106.7	6.0	1.1	4.5	2.4
13-19		33	30.2	24.1	90	72	75.8	5.0	1.9	3.7	2.9
20-26		34	31.9	24.4	90	72	45.4	3.0	2.8	2.6	2.8
27-02	Sept 11	35	28.5	24.1	92	89	102.4	6.0	1.5	3.0	2.6
03-09		36	30.3	23.9	92	72	119.2	7.0	1.7	3.6	2.9
10-16		37	31.7	24.3	84	67	27.2	4.0	3.9	3.2	2.8
17-23		38	32.4	24.3	80	59	11.0	4.0	5.1	5.8	3.9
24-30		39	33.6	23.1	77	46	0.0	0.0	8.2	6.3	5.2
01-07	Oct 11	40	34.0	21.6	66	48	5.0	1.0	8.3	2.6	4.4
08-14		41	33.5	22.6	68	46	0.0	0.0	7.5	3.4	3.9
15-21		42	34.1	20.8	65	31	0.0	0.0	8.6	2.4	4.1
22-28		43	33.3	18.2	62	29	0.0	0.0	9.6	2.5	3.9
29-04	Nov 11	44	31.2	14.7	64	25	0.0	0.0	9.2	2.4	3.9
05-11		45	33.1	15.4	58	27	0.0	0.0	8.8	1.9	4.0
12-18		46	32.3	15.5	57	29	0.0	0.0	8.3	2.0	3.7
19-25		47	30.9	14.2	60	31	0.0	0.0	8.0	2.3	3.4
26-02	Dec 11	48	30.3	14.3	60	34	0.0	0.0	6.7	2.1	3.0
03-09		49	30.5	13.7	67	35	0.0	0.0	7.1	1.5	2.9
10-16		50	29.5	11.2	58	28	0.0	0.0	7.6	1.9	2.9
17-23		51	28.9	09.8	50	25	0.0	0.0	8.3	1.7	2.7
24-31		52	28.9	11.7	53	34	0.0	0.0	7.7	2.5	3.2

(i) June 2011 to Dec-2011 Total Rainfall - 966.4mm, Number of rainy days -- 75
(ii) Jan 2011 to Dec-2011 Total Rainfall - 1016.5mm, Number of rainy days – 83



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