# PREPARATION OF CROP WEATHER CALENDAR OF SOYBEAN CROP UNDER PARBHANI LOCATION

BY

**MISAL VAISHALI SUNIL**

**(B. Sc Agri.)**

## DISSERATION

***Submitted to the***

***Vasantrao Naik Marathwada Krishi Vidyapeeth Parbhani in Partial Fulfilment of the requirement for the award of the degree of***

## MASTER OF SCIENCE

**(Agriculture)**

**IN**

## AGRICULTURAL METEOROLOGY

**DEPARTMENT OF AGRICULTURAL METEOROLOGY,**
**VASANTRAO NAIK MARATHWADA KRISHI VIDYAPEETH,**
**PARBHANI- 431 402 (Maharashtra) INDIA**

**2019**

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**2019**

# CANDIDATE'S DECLARATION

I, hereby declare that this dissertation

or part thereof, has not been

previously submitted by

me for a degree of

any University.

Place : PARBHANI
Date : / /2019

**( Misal Vaishali Sunil )**

**Reg. No. 2017A/23M**

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# CERTIFICATE-I

This is to certify that **Miss. Misal Vaishali Sunil** has satisfactorily prosecuted course and research for a period of not less than four semesters and that the dissertation entitled, **"PREPARATION OF CROP WEATHER CALENDAR OF SOYBEAN CROP UNDER PARBHANI LOCATION"** submitted by her is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination.

I also certify that the dissertation or part thereof has not been previously submitted by her for a degree of any university.

Place: Parbhani
Date: / /2019

**(Prof. A M. Khobragade)**
Research Guide
and
Chairman Advisory Committee

# CERTIFICATE-II

This is to certify that the dissertation entitled **"PREPARATION OF CROP WEATHER CALENDAR OF SOYBEAN CROP UNDER PARBHANI LOCATION"** submitted by **Miss. MISAL VAISHALI SUNIL** to the Vasantrao Naik Marathwada Agricultural University, Parbhani in partial fulfillment of the requirement for the degree of **MASTER OF SCIENCE (Agriculture)** in the subject of **AGRICULTURAL METEOROLOGY** has been approved by the student's advisory committee after oral examination in collaboration with the external examiner.

**(                              )**
**External examiner**

**(Prof. A. M. Khobragade)**
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**Members of Advisory Committee**

**(Dr. K. K. Dakhore)**

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# ACKNOWLEDGEMENT

"My humble and whole hearted prostration to the World Supremo prinkling for his unprecedented favor upon me.

Achievement is of no mean, without the sense of gratefulness and the recognition of this is the beginning of wisdom.

I feel a great pleasure in getting this privilege to express first and foremost, my profound deep sense of gratitude towards my research guide **Prof. A. M. Khobragade**, Dept. of Agricultural Meteorology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, for suggesting need based research project. His inspiring guidance, limitless support and constant encouragement has undoubtedly helped me to excel in all endeavors. Without him, this dissertation would not have been completed.

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*Place : Parbhani* *(Misal Vaishali Sunil)*
*Date : / /2019* *Reg. No. 2017A/23M*

# CONTENTS

# LIST OF TABLE

# LIST OF FIGURE

# THESIS ABSTRACT

**THESIS ABSTRACT**

| | | |
|---|---|---|
| a) Title of the Thesis | : | **"Preparation of crop weather calendar of Soybean crop under Parbhani Location."** |
| b) Name of student | : | Miss. MISAL VAISHALI SUNIL |
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# ABSTRACT

**"PREPARATION OF CROP WERATHER CALENDAR OF SOYBEAN CROP UNDER PARBHANI LOCATION."**

**BY**

**Miss. MISAL VAISHALI SUNIL**

**DEPARTMENT OF AGRICULTURAL METEOROLOGY,**

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| **Research Guide** | **:** | **Prof. A. M. Khobragade** |
| **Department** | **:** | **Agricultural Meteorology** |


An investigation was carried out during 2018-2019 at Department of Agricultural Meteorology, College of Agriculture, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani, as "Preparation of crop weather calendar of soybean crop under Parbhani Location" with an objective to study the preparation of crop weather calendar of soybean crop under Parbhani Location, to study the phenological stages of soybean crop for crop weather calendar and to prepare the crop – weather – pest calendar for soybean crop using pest data.

In study of climatic condition during 1988-2017 (30 years data) showed variability in climatic condition at Parbhani location of Marathwada region. Temperature variability at Parbhani location results into change in the yield of soybean crop in Marathwada region. The range of highest mean maximum temperature and lowest minimum temperature recorded 33.7$^0$C and 24.3$^0$C while highest and lowest mean rainfall was recorded i.e. 785 mm since 1988-2017.

During the phenological observations, the crop weather calendar of soybean crop was found highest number of days for emergence to seedling stage (21-29 days). The lowest number of days taken for sowing to emergence (4-6 days).

However, climatic normals of rainfall highest recorded in $30^{th}$ MW (216.3mm). The mean highest Tmax ($38^0$C) and Tmin ($24^0$C) recorded in $23^{rd}$ MW. Maximum RH-I and RH-II recorded in $37^{th}$MW and $28^{th}$MW (86%) and (78%) respectively. Minimum RH-I (71%) and RH-II (34%) recorded in $23^{rd}$ MW.

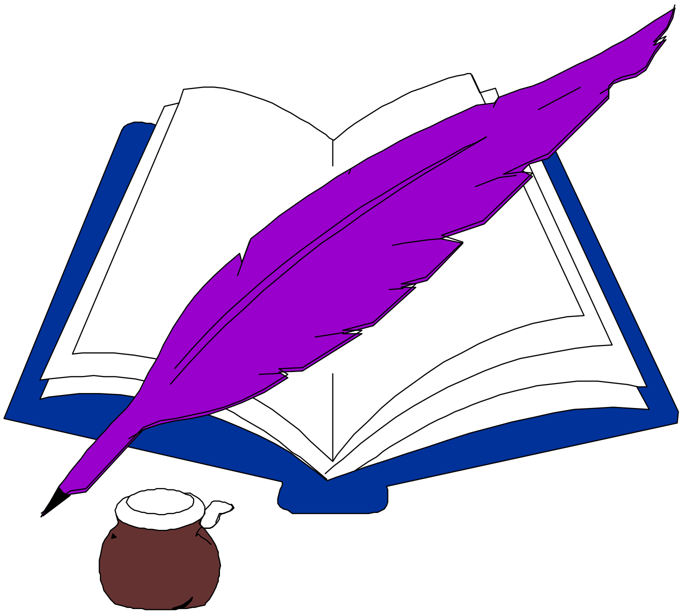
In Agrometeorological indices, the recorded highest GDD, HTU and PTU for soybean crop was 2332.2 $^0$C days, 14231.3$^0$C days hour and 24234.6$^0$C days hour in the year 2017 with meteorological week 23 MW-43MW respectively. The sowing dates D1 (27MW) accumulated maximum heat units .

Mean while the population dynamics studies indicated that, population of *Spodoptera litura* was more i.e. 9.5 larvae/mrl during 2006 as compared to remaining years. The population of girdle beetle was maximum found i.e. 36.9% infected plants during 2015 and population of green semilooper is maximum found i.e. 10.4 larvae/mrl during the year 2010 and also the population of Leaf miner was maximum recorded i.e. 6.32 larvae/mrl during the year 2008.

In case of phenological observations, the more days recorded in emergence to seedling stage (i.e. 21-29 days) and highest mean maximum and minimum temperature (i.e. 30.7$^0$C-35.5$^0$C and 22.5$^0$C-24$^0$C) in pod formation to grain formation and seedling to branching.

| ABBREVIATIONS | |
|---|---|
| % | Per cent |
| / | Per |
| @ | At the rate of |
| $^{0}C$ | Degree Celcius |
| ∑ | Summation |
| BSS | Bright Sunshine Hours |
| Cm | Centimeter |
| *et al.* | et alia (and others) |
| Fig. | Figure |
| ha. | Hectare |
| hrs. | Hours |
| i.e. | That is |
| *viz.* | Namely |
| *etc.* | Et cetera (and so on) |
| Kg | Kilogram |
| km/hr | Kilometer per hour |
| MW | Meteorological Week |
| Max | Maximum |
| Min | Minimum |
| Mm | Millimeter |
| Mrl | Meter row length |
| No. | Number |
| RH-I | Morning Relative Humidity |
| RH-II | Afternoon Relative Humidity |
| WV | Wind velocity |
| GDD | Growing degree days |
| HTU | Helio-thermal units |
| PTU | Photo-thermal units |
| Hrs/day | Hours per day |
| $T_{mean}$ | Temperature mean |
| ET | Evapotranspiration |

# Chapter-I



# INTRODUCTION

**CHAPTER-I**

# INTRODUCTION

Soybean (*Glycine max (L.) Merrill*) is a leguminous crop and belongs to family leguminosae. Soybean is also known as ‘wonder crop’ and ‘gold of century’ due to easy cultivation, high cost benefit ratio and low nitrogen requirement. Soybean is a native of Asia and the first known records, however, indicate that soybean emerged as a domesticated crop around the eleventh century BC in China. Soybean was introduced in India in 1970-80. It is an important pulse crop rich in food value. It is a cheapest, richest and easiest source of best quality protein and fat. Soybean was considered as pulse crop but due to high oil content and greater response to applied nitrogen, now it is placed in oil category. Soybean, being leguminous crop, improves soil fertility by fixing atmospheric nitrogen (AICRP on Agrometeorology, Parbhani Centre).

Soybean can be grown in regions with seasonal rainfall of 550-750 mm. Its water requirement is 450-750 mm/season. For germination, 50 per cent moisture is required. Its water use efficiency for harvested yield is 0.4 to 0.7 kg/m$^3$. Moisture stress during pod filling, pod development affects yield simultaneously, about 20 to 50 per cent. In general the crop is sensitive to frost. Floral induction is greatly inhibited at 10$^0$C and moisture stress during pod filling reduces the yield and hot dry air also reduces yield.

India rank fifth in area and production of soybean in the world after USA, Brazil, China and Argentina. According to SOPA’s assessment, the area under Soybean cultivation is 109.7 lakh hectares in the country. The production of soybean during 2017 is 91.45 lakh tones with productivity of 1045 kg ha$^{-1}$. The area under Soybean in Maharashtra is 35.80 lakh hectares. The production is estimated to be 39.45 lakh tones with an average productivity of 1102 kg ha$^{-1}$. While in Marathwada region area under soybean cultivation is 15.94 lakh hectares with production of 12.87 lakh tones and productivity of 1010 kg ha$^{-1}$.

The pictorial representation of detailed information for a crop w.r.t. sowing period and duration of important phenological stages in their life cycle, the most favourable climatic requirement for different stages of the crop and the actual and normal weather for that station/location is called the "Crop Weather Calendar" (Kaur *et al.*2013).

Agriculture is one of the most important sectors for India. Proper planning for this sector requires relevant and reliable information in timely manner. Information on crop, its stages and the week by week weather during the crop season is essential for proper management of agriculture. Thus, farm operations planned in conjunction with weather information are very likely to curtail the costs of inputs and various field operations. Crop weather calendar is a comprehensive guide for farmers. It is a tool that provides information on average weather of every week, planting, sowing and harvesting periods of locally adapted crops in a specific agro-ecological zone. Further, stage-wise pest disease infestation information can also be added. It also provides information on the sowing rates of seed and planting material and the main agricultural practices. This tool supports farmers and agriculture extentionists in taking appropriate decisions on crops and their sowing period, respecting the agro-ecological dimension. It also provides a solid base for emergency/ contingency planning of the rehabilitation of farming systems after disasters. The concept of using crop-weather calendar is not new. For instance, FAO calendars provide information on the crop sowing and harvesting dates, seed rate, operation timings of mechanical equipment in the period etc. Also, the University of Kentucky prepared production calendars for soybean and maize crops. This calendar describes the month wise weather and operations to be taken up during the period (CRIDA 2015).

Weather condition requirement is different from crop to crop. However, general climatic condition for soybean is as under.

Germination is most critical stage in soybean it requires 8.0-10.0$^0$C temperature for germination. Excessive cold, moisture or prolonged drought causes injury and therefore the most optimum temperature for its growth is 24.0-30.0$^0$C while the range is 18.0-30.0$^0$C. The minimum temperature for most growth and development is about 10.0$^0$C. Soybean is a warm season (tropical) crop but its cultivation now extends to subtropics and temperate climates. The major commercial production is between 25$^0$ and 45$^0$ N latitude at altitudes of less than 1000 m. It can be grown up to 2000 m. The general climatic requirements are approximately those of maize and the greatest development.

For most soybean varieties temperature between 26.5 to 30 $^0$C appears to be optimal. Soil temperature of 15.5 $^0$C or above favours rapid germination and vigorous seedling growth. The minimum temperature for effective growth is about 10$^0$C. Soybean is a basically a short day plant but response to day length varies with variety and temperature and developed varieties are adapted only to rather narrow latitude difference. Day length influences the rate of development of crop. In short day types, increased day length may result in the delay of flowering and taller plants with more nodes. Short day hasten flowering, particularly for late maturing varieties. The critical photoperiod for bud initiation is around 14 hrs. Subsequent photoperiods influence blossoming. At 16 to 18 hrs, soybean flowers do not open but maximum floral blossoming occurs at 10-13 hrs photoperiod. Night temperatures also influence floral initiation.

Soybean is often cultivated during *kharif* as rainfed crop and post rainy season (*rabi*) on stored moisture. However, supplemental irrigation to overcome long dry periods is generally practiced. It can come up well in areas with rainfall varying from 600 to 1000 mm. Distribution of rainfall during the crop growing season is more important than the total amount.

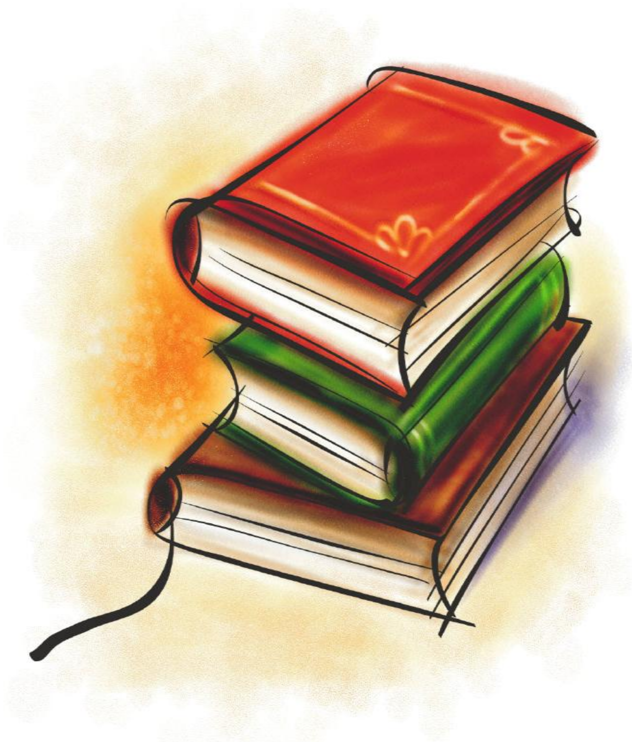
Soybean can be grown on a wide range of well drained soils but thrives best on clay looms. Optimum pH for soybean production is in the range of 6 to 6.5. Soybean is rated as moderately salt tolerant crop and reported salinity threshold is about 5 dS $m^{-1.}$ Shallow water tables, particularly during the early growth period can adversely affect the yield. The crop is sensitive to water logging, especially during early stages (AICRP on Agrometeorology, Parbhani Centre).

Incidence of soybean pests (girdle beetle, semilooper, leaf miner and *Spodoptera litura*) was studied in relation to weather parameters. Correlations between girdle beetle population and weather parameters showed significant negative association of girdle beetle with rainfall, maximum temperature and humidity (RH-I and RH-II). Similarly for leaf miner minimum temperature showed significant positive association whereas humidity (RH-II) was negatively correlated. In contrast *spodoptera litura* population showed significant negative association with minimum temperature and significant positive association with humidity (RH-II) (AICRP on Agrometeorology, Parbhani Centre). The defoliators like *Thysanoplusia orichalcea* (Fab) damages the crop from August to September during *kharif* and March to May during *rabi* season. The infestation can result into 30 per cent undeveloped pods and about 50 per cent yield loss. In case of heavy attack, the caterpillars are also found to feed on flowers and pods. Girdle beetle is more common in Madhya Pradesh, Rajasthan and West Bengal. Its first occurrence was seen in Madhya Pradesh. It has become more and more devastating insect through years. In recent years infestation observed is 60 to 80 per cent in soybean. Pod borer incidence was maximum in the month of July sown crop. The per cent incidence of stem fly was low on soybean sown in second week of June where as it was high with girdle beetle. In soybean population built up of various pests has been found to be influenced by different parameters of climate. The insect being the member of biotic community interacts with other nonliving (abiotic) components of the environment. The outcome of these interactions is population dynamics, the positive and negative growth of the population. Hence, the life system and abundance of insect can be understood by study of interaction between biotic abiotic factors. By considering above points, we are going to undertake an experiment at Marathwada Krishi Vidhyapeeth, Parbhani, entitled "Preparation of Crop weather calendar of Soybean crop under Parbhani Location." with following objectives.

**OBJECTIVES :-**

1. To study the preparation of crop weather calendar of Soybean crop under Parbhani Location.
2. To study the phenological stages of Soybean crop for crop weather calendar.
3. To prepare the crop-weather-pest calendar for Soybean crop using pest data.

# Chapter-II



# REVIEW OF LITERATURE

**CHAPTER- II**

# REVIEW OF LITERATURE

The review of literature is one of the most important aspects of any investigation. It helps the researcher to get acquainted with the subject matter under study and further channelized efforts in a desirable direction. It forms the basis for interpretation of findings and provides necessary guidelines and motivates the researcher during the course of study. A brief review of relevant and recent research work on "**PREPARATION OF CROP WEATHER CALENDAR OF SOYBEAN CROP UNDER PARBHANI LOCATION**" has been done and presented in this chapter. The universal acceptance of Statistics as an essential tool for all types of analysis for all areas of research has made to study the different statistical techniques used in data analysis. Selecting the suitable statistical procedures for given experiment must be based on expertise in statistics and in subject matter of research /experiment. Some of the important review of past research works in the field has been compiled to enable better understanding of the research in various regions, method of analysis on the research subject.

The literature pertaining to different aspects of the present study has been reviewed under the following headings:

**1. To study the preparation of crop weather calendar of Soybean crop under Parbhani Location**

Sacks *et al.* (2010) assembled a data set of global crop planting and harvesting dates for 19 major crops, explore spatial relationships between planting date and climate for two of them, and compare our analysis with a review of the literature on factors that drive decisions on planting dates.

Thuzar M *et al.* (2010) observed that environmental condition prior to the shift to reproductive development usually affect by influencing photosynthesis per unit of leaf are , a strong positive correlation between canopy photosynthesis per unit of ground area, and ignition of number exists for most crop. for many crop where they are now grown an increase of just a few ˚c significantly reduce yield.

Kaur *et al.* (2013) defined the pictorial representation of detailed information for a crop w.r.t. sowing period and duration of important phenological stages in their life cycle, the most favourable climatic requirement for different stages of the crop and the actual and normal weather for that station/location is called the "Crop Weather Calendar".

Patel and Jayesh H. (2014) defined Agricultural intensification is terms as cropping intensity, which is the numbers of crops (single, double and triple) per year in a unit crop land area. Information about crop calendar (i.e. number of crops in a parcel of land and their planting and harvesting dates and date of peak vegetative stage) is essential for proper management of agriculture.

Khobragade (2015) Prepared crop weather calendar of Cotton in Parbhani district located in Marathwada region of Maharashtra and comes under hot moist semi-arid ESR with shallow and medium loamy clayey black soils. AWHC is medium to high and LGP ranges from 120-150 days.

Rao *et al.* (2015) prepared district Level Crop Weather Calendars of Major Crops in India. Agriculture is one of the most important sectors for India. Proper planning for this sector requires relevant and reliable information in timely manner. Information on crop, its stages and the week by week weather during the crop season is essential for proper management of agriculture.

Khobragade *et al.* (2016) studied Agro Advisory Bulletin (AAB) helpful to farmers for adoption of those practices which are reduces losses in farming created by weather adversities, climate change, losses by rainfall, cropping pattern etc.

Chavan *et al*. (2017) entitled the performance of soybean (*Glycine max)*varieties under varied weather condition was designed and conducted at College of Agriculture, VNMKV, Parbhani during *kharif* season of 2016. In investigation the biometric observations *viz.* plant height, numbers of branches plant-1, number of pods plant-1 were significantly highest in $27^{th}$ MW as compare to other dates of sowing. The soybean variety MAUS-158 was highly productiveas compare to other varieties V2(MAUS-71),V3(MAUS -81) and V4(JS-335). The correlation study was carried out between weather variables prevailed during P1 to P10 growth stages of different cultivars under different sowing dates. Rainfall, Tmin, RH I, RH II and Wind velocity were positively correlated at P2, P3, P4, P6, P8, P9 and P10 stages of soybean crop and BSS and Evaporation was negatively correlated at all growth stages except P5 and P7 of V1(MAUS-158),V2(MAUS-71),V3(MAUS-81)andV4(JS-335)cultivars of soybean crop.

Jha *et al.* (2018) guided to prepare Crop Weather Calendar : A guide to the Farming Community. The Crop Weather Calendar is mainly divided into three sections, viz. crop husbandry (sowing to harvest), climate requirements (rainfall, rainy days etc.) and weather warnings.

**2. To study the phenological stages of Soybean crop for crop weather calendar**

J. Chapman (1986) reported that the photo thermal unit gave measure of the interactive effect of photoperiod and temperature on the length of the pre-flower phase. Highly significant correlation between days to flower and photothermal unit were found.

Sionit *et al.* (1986) reported that plant height and number of branches increased slightly with $CO_2$ enrichment and more significantly with increasing temperature. Root to shoot ratio remained unchanged at different $CO_2$ concentration but decreased as temperature increased. Leaf weight ratio and specific leaf weight decreased with increased as temperature. Low temperature reduced dry weight of all plant part.

Lal *et al* (1999) observed that the water stress condition during flowering and pod growth stage of the crop due to pronounced negative cumulative rainfall anomaly in 1979 (rainfall was less than normal by 45%) combined with significantly higher heat unit anomalies considerably slowed down the potential reproductive growth leading to poor biomass production and low yield in the year 1979.

Gadekar (2001) reported that the optimum temperature for germination of soybean is approximately 30 degree with base temperature of $10^0$c. Soybeans are sensitive to day length and flowering as well as maturity is controlled by day length, it requires at least 10h or more of daily darkness. Photoperiod also affects development. It is sensitive to frost, floral induction is greatly inhibited at $10^0$c.

Miller *et al*. (2001) reported that plant development depends upon temperature. Plants require a specific amount of heat to develop from one point in their life cycle to another. Growing degree days is a way of assigning a heat value are added together to give an estimate of the amount of seasonal growth your plants have achieved.

Haider *et al*. (2003) studied the influence of sowing dates on phenology and accumulated heat units of four cultivars of bread wheat (*Triticum aestivum* L.) at different phenological stages over two growing seasons (early and late). The late sown plants had significantly shorter phenological stages and lower growing degree day than the early.

Thomas *et al.* (2003) reported that high temperatures during productive development often negatively impact on seed composition.

Egli *et al.* (2005) reported that mean maximum temperature during seed filling (growth stage R5 to R7) ranged from 24.0 (Kentucky) to 37.6$^0$C (Tmax.) when seed lots infected with *phomopsis longicolla* (Hobbs) were removed from the analysis standard germination and accelerated-aging germination (AA) decreased as mean maximum temperature during seed filling increased but the decrease was significant (p=0.05) only for Huthcheson.

Medida *et al. (*2006) studied that in soybean different dates of sowing had an effect on phonological stages. Growing degree days consumed by the crop to reach physiological maturity was higher in first date of sown crop. Among the cultivars, heat use efficiency and radiation use efficiency were highest in PK -416 for dry matter production as well as seed yield.

Zhang L. (2006) indicated that photoperiod affected all stages of soybean growth and development and in some genotypes, this included pod set and seed filling. Longer photoperiods induced more vegetative growth and delayed the maturity process. Later plantings, after (mid June) resulted in significantly fewer flowers, pods and seeds per plant and in significantly lower yields. Due to accelerated reproductive processes under short photoperiods and high temperatures, the accumulation of dry matter slowed down or even reversed during the late reproductive stages for early maturity stains or other stains planted late.

Adriana *et al*. (2007) observed that a maximum duration of 75.7± 0.4 d was attained when the exposure to long photoperiod was maintained until maturity. From T0 T9 the duration of R3- R6 linearly increased about 1.5 d per 2 d of exposure to the extended photoperiod r2 =0.94, p <0.05). Reflecting the quantitative nature of the response of the reproductive development rate to the cumulative number of long photoperiod cycle perceived by the plant.

Setiyono *et al*. (2007) observed that the flowering duration was negatively correlated with mean temperature and minimum daylength, and significant correlation were found between maturity group and Tmax during the floral induction phase, pod and seed set duration and post flowering.

Kumar *et.al* (2008) reported that the decrease in the vegetative period due to prevailing of lower value of maximum temperature, higher relative humidity and vapour pressure which has reduced the overall covariation in development of phonological phases compared to early and late sowing.

Zhang Q.Y.*et al.* (2010) observed that yield decline associated with delayed sowing was primarily related to reduction in standard pod number, while increased fresh seed weight might compensate the yield loss at the fresh pod harvest stage (R6 stage). Seed dry matter accumulation period was extended for one or two weeks by late sowing.

Kashyapi *et al.*(2011) studied soybean is a major *kharif* season crop in parts of M.P., U.P., Gujarat, Punjab and Haryana, Maharashtra, Rajasthan, A.P. and Chattisgarh. The present work was undertaken to study the parameters controlling water requirement of the crop at various phenophases in soybean growing 8 ET stations (viz., Akola, Bangalore, Banswara, Dharwar, New Delhi, Parbhani, ICRISAT and Rahuri) in various agroclimatic zones. Eight phenophases of the crop (viz., germination, seedling, vegetative, active vegetative, flowering, pod formation, pod maturity and harvesting) were identified The computed best – fit ET curves provide ET demand of the crop at any point of the phenophases for the specific location. The rainfall during study period was mostly sufficient to meet the crop specific ET demand at various phenophases of soybean crop. Abundant soil moisture supported good vegetation cover. The mean Kc value varied widely from 0.61 to 0.98 among different stations studied, which reached their peak mostly at active vegetative to flowering stages, where the values were even more than 1 in most of those phenophases except 3 stations.

Golezani *et al.* (2012) assessed the effects of different irrigation treatments (I1, I2, I3 and I4: well-watering on the bases of 70 mm evaporation from class A pan and irrigation disruptions during flowering, during grain filling and during flowering and grain filling stages, respectively) on some physiological traits and grain yield of three soybean cultivars. Results showed that with increasing water stress, leaf temperature increased, while chlorophyll content index, quantum yield of the PSII (Fv/Fm) and grain yield decreased. Maximum leaf temperature and minimum chlorophyll content were observed under water stress. Maximum reduction in Fv/Fm and grain yield per unit area was observed when plants were subjected to water stress during flowering and grain filling stages (I4). Williams produced the highest grain yield per unit area, which related with higher leaf chlorophyll content of this cultivar.

Kingra and Kaur (2012) found that the crop sown on three dates (D1- 1$^{st}$ June, D2- 20th June and D1- 10th July) during all the years (*kharif* 2004, 2005 and 2006) to expose the crop to different weather conditions during its various phenological stages. The thermal units required to attain a particular phenological stage decreased as the sowing was delayed in both the cultivars (V1: M-522 and V2: M-548) during all the three crop seasons. The pheno-thermal index gradually decreased from emergence to maturity in all the three dates of sowing during all the years being the highest at emergence and lowest during maturity of the crop.

Pal *et al. (*2013) In this study, agro-meteorological indices have been calculated and used for prediction of plant stages and yield of wheat under different sowing environments with various phenophases for foot hills of Western Himalayas. The study revealed that the Higher PTU and HTU were accounted in case of variety PBW-343 followed by WH-542 during all the phenophases of wheat for both the years. Wheat crop sown on 20$^{th}$ November (normal) required less photo-thermal unit as well as helio-thermal unit, while, 09th January (late) sowing accounted higher values of PTU and HTU during crop growth period. Timely sown wheat crop (20th November) produced highest yield, while, with every 25 days delay in sowings reduction in yield was accounted by 13 to 26.1 percent in the year 2007-08, whereas, 14.6 to 29.3 percent in 2008-09.

Puteh *et al.* (2013) determined seed yield is vulnerable to temperature changes, especially during reproductive growth stage. At the beginning of flowering, the entire plants were covered with single and double layers plastic case to create temperature of around 30 and $35^0C$, respectively. The duration of temperature were 5 and 14 days for R1-R2 and R1-R5 growth stages, respectively. Results showed that longer exposure of plants (R1-R5 growth stages) to higher temperature had a more negative effect on seed yield components rather than shorter exposure (R1-R2 growth stages). At about $30^0C$, yield components were not significantly affected over control ($25^0C$), whereas yield components were negatively and significantly affected at $35^0C$ at the both growth stages. The differences in temperature sensitivity identified among varieties imply the possibility of selecting soybean genotypes with tolerance to elevated high temperature condition.

Patil *et al*. (2014) The field experiment was conducted at the department field to assess the crop weather relationship in different cultivars of soybean. The GDD was higher in $D_2$ (MW-28) *i.e.* $164.2^0C$ followed by $D_3$ (MW-29) than rest of the treatments, whereas the lowest GDD was recorded in $D_4$ (MW-30) *i.e.* $150.8^0C$. Mean heat load was reported same in four varieties $V_2$ (MAUS-71), $V_3$ (MAUS-81), $V_4$ (MAUS-158) and $V_6$ (JS-9305) *i.e.* $160.9^0C$, it may be due to same crop duration in above four varieties. Whereas, $V_1$ (MAUS-47) variety indicated less heat load than other variety *i.e.* $147.3^0C$ it may be due to small crop duration from emergence to maturity of such variety. Helio thermal units directly or indirectly affect the grain yield of soybean by delaying flowering and pod formation. The requirement of HTU was higher (925.0) in $D_2$ (MW-28), whereas HTU requirement was lower (825.8) in $D_1$ (MW-27) treatment. The mean helio thermal units was reported same in four varieties $V_2$ (MAUS-71), $V_3$ (MAUS-81), $V_4$ (MAUS-158) and $V_6$ (JS-9305) *i.e.* $915.0^0C$. It may be due to the same crop duration in above four varieties. Whereas, lowest helio thermal unit was recorded in $V_1$ (MAUS-47) *i.e.* $823.5^0C$.

Kaushik *et al.* (2015) The heat units like growing degree days (GDDs), photo-thermal units (PTU) and Helio-thermal unit (HTU) values decreased with the delay in sowing under all the varieties. However, higher values of radiation use efficiency and heat use efficiency were recorded with variety JS 97-52. Based on the results it was concluded that heat use efficiency of soybean cv. JS- 97 52 and JS-335 were far better to utilize heat units under all the sowing dates as compared to JS-93 05.

Khobragade *et al.* (2016) investigated correlation between weather parameters and phenological stages of soybean showed correlation with higher degree of association at vegetative stage i.e. at seedling to flowering and at reproductive stage i.e. at pod formation to pod development stage. The observation on various ancillary characters viz. Plant height, number of leaves per plant and number of pods per plant revealed that the soybean crop sown in $29^{th}$ MW recorded significantly highest plant height, number of leaves per plant and number of pods per plant and significantly more plant height, number of leaves per plant and number of pods per plant recorded in variety MAUS-158 over MAUS-71. Specially rainfall and rainy days showed positive and significant association(r=0.782** and 0.947**) respectively at sowing to emergence and at branching to flowering (r=0.936** and r=0.942**) respectively. Also, BSS showed highly significant correlation (r=0.917**) at dough stage to maturity.

Khobragade *et al*. (2016) reported that the whole life cycle of soybean crop (from sowing to physiological maturity) was divided into ten distinct phenophase on the basis of external morphological characteristics. the occurrence of different phenophases of soybean crop observed under four dates of sowing during *kharif* season 2003-2013. The overall numbers of days taken for physiological maturity was 92 to 115 when crop sown in meteorological week i.e. MW 27, MW28, MW29 and MW30 respectively. The result showed that the range during 2003 to 2013, no. days required for maturity when crop was sown under D1 (MW 27) where 93-112 days, D2 (MW 28) 92-115, D3 (MW 29) 94-112 and D4 (MW 30) 93-114 days during the crop growing season. Delay in the sowing induced the early flowering in the soybean crop, as the day length increase along which increased temperature because of the crop is determinant type with short day length and thermo sensitive plant and its response to yield varies with variety of temperature. Further, the variation in the maturity period in the all the treatment can be explained on the basis of the facts that temperature was higher in $D_3$ and $D_4$ as compare to $D_1$ and $D_2$.

Nico *et al*. (2016) reported that in soybean long days during post flowering increase seed number. This positive photoperiodic effect on seed number has been previously associated with increments in the amount of radiation accumulated during the crop cycle because long days extend the duration of the crop cycle.

Sudha and Latha (2016) to study the heat units requirement during different phenophases of soybean (*Glycine Max L.*). Three varieties of soybean

(JS335, JS 93-05and 97-52) were sown under different environment created through different sowing time (first and third week of July and first week of August) The growing degree days (GDD). Heliothemal units (HTU), photo thermal unit(PTU) and heat use efficiency (HUE) were work out for different phenophase. Analysis showed the early sown crop (first week of July) accumulated higher GDD, HTU, PTU and result in maximum HUE. Among the varieties highest value of heat units and HUE was found in cv. JS 97-52.

Chavan *et al.* (2018) The crop was sown on 27 MW took maximum calendar days, growing degree days, photo thermal unit, helio-thermal unit to attend different phonological stages till maturity which reduced significantly with subsequent delay in sowing time. The grain yield recorded in 27 MW were significantly highest to rest of sowing dates. The significant reduction in grain yield of timely sown varieties was recorded when sowing was delayed sowing dates. Among the varieties highest grain yield of 2611 kg $ha^{-1}$ was recorded in varieties MAUS-158, which was significantly superior over MAUS-71, MAUS-81 and JS-335. Among the varieties (MAUS-158) took highest calendar days growing degree days, photo thermal unit, helio-thermal unit to reach the maturity.

**3. To prepare the crop-weather-pest calendar for Soybean crop using pest data**

Harish (2008) reported that maximum larval population of *S.litura* and *T. orichalcea* (7.80, 12.00, 12.80, 6.50, 6.20, 8.60 larvae/mrl.) were noticed on the crop sown on 08-06-06, 27-06-06 and 08-06-06 dates. Humidity 68.00% .the larval population has positive correlation with minimum temp, maxmimum temp, and relative humidity in village of Siddauna.

Joshi and patel (2010) reported that *Aproaerema modicella* deventer incidence initiated in soybean from 3rd week after sowing and reached to peak level during 10th week after sowing.

Kaushik *et al.* (2011). reported that the population then sudsumed at first slowly then abruptly. Grossly abiotic condition such as maximum temperature, minimum temperature, gradient, average temperature, maximum relative humidity and sunshine hours had significant negative influence on L.trifolii population.

Choudhary *et al*. (2012) reported that Soybean crop is infested by 273 species of insects. Out of them 20 insect pests have been observed on soybean crop in that area. Among them Green semilooper in defoliators and girdle beetle, in borers are predominant and of economic significance which can cause severe damage and consequent reduction in yield. The girdle beetle infests the plants both in early and late phase.

Kulkarni (2012) studied correlation and regression with different weather parameters i.e. maximum temperature, minimum temperature, wind speed resulted decrease in *S. litura* population significantly in Nanded district Where as rainfall, minimum temperature, relative humidity I and II were non significant.

Biswas (2013) studied that cutworm, *Spodoptera litura* , *helicoverpa armigera*, stemfly, girdle beetle were considered as the major pests of soybean. Most of the major and minor pests appeared in the crop during vegetative and flowering stages (30-50 days after sowing) and the maximum insect pests population and their infestation occurred during flowering and pod formation stage of the crop.

Gadad *et al*. (2013) conducted survey during kharif / summer 2011-12, to study the seasonal incidence of *Spodoptera litura* and leaf miner. *Spodoptera* incidence started from 6$^{th}$ meteorological week and reached its peak during 11$^{th}$ SMW with 19.50 % leaf damage and declined thereafter the incidence of leafminer was observed during 5$^{th}$ to 12 th SMW with peak incidence between 8$^{th}$ and 9$^{th}$ SMW.

Netam *et al.* (2013) recorded he observations on sucking pests, insect population will be recorded from randomly selected twenty plants on which five leaves taken three from upper and two from bottom in each at ten days interval. During the course of study, five insects species, viz., Girdle beetle, *Obereopsis brevis*, tobacco caterpillar, *Spodoptera litura*, green semilooper, *Chryrodecxis acuta*, Jassids, *Empoasca kerri* and white flies, *Bemisia tabaci* were recorded as the major pests on soybean, variety JS 93-05 causing damage at various stages of the crop. All these insects made their first appearance on the crop to a greater or lesser extent in the last week of July. The activity of girdle beetle increased gradually with peak density of the cerambycid in the last week of August recording 3.2 damaged plants per meter row with seasonal mean of 1.73 damaged plants. The density of lepidopterous caterpillars increased gradually with peak population of 5.0 larvae per meter row during the last week of August and seasonal mean of 3.22 larvae per meter row among the sucking pests, whitefly was observed in higher numbers than jassids. The peak density of sucking pests was observed during third week of September with 4.4 sucking pests/plant and seasonal mean of 3.62 white flies and jassids per plant. Preying upon the sucking Insects, were two species of lady bird beetle, *Coccinella septumpunctata* and *Menochilus sexmaculata* and two species of spiders, lynx spider and an unidentified golden preying spider. The latter was also a recorded preying on lepidopterous larvae. A predatory pentatomid bug, *Eocanthecona furcellata* was observed sucking the body sap of lepidopterous larvae, there existed a positive but non significant correlation between lepidopterous larvae and predators and between sucking pests and predatory fauna with 'r' values 0.545 and 0.798, respectively.

Shali *et al*. (2013) reported that the population of green semilooper appeared between 50 to 55 days after germination in 2011 and 2012. The population ranged from 9.11 to 13.88 larvae/ mrl during 2011 and 2.33 to 3.00 larvae / meter row length in 2012.

Singh *et al.(*2013) reported that during *kharif* season of 2007, 12 insect species, while during 2008 and 2009 . 13 insect pests and one mite observed on soybean. These pests identified were walker, *Spodoptera litura, Helicoverpa armigera*, Gryllussp, *Melangromyza sojae* and sap feeders.

Kaur *et al.* (2014) conducted by collecting and analyzing meteorological, crop and pest data for the period of 1999-2009 to formulate the crop-weather-pest calendars for rice for seven locations in different agroclimatic zones of Punjab. The weekly and monthly normals of different meteorological parameters were computed from daily weather data for all the locations. These climatic normals were used for comparing actual data to study the effect of different meteorological parameters on yield of rice crop. The phenological calendars for the crop were computed using the crop data generated during the field experiments conducted at Ludhiana. Crop-weather-calendars have been formulated for rice by combining the weekly climatic normals and phonological calendar for the crop along with optimum climatic normals needed for different phenological stages of the crop. The optimum climatic normals were worked out from actual meteorological data of high yield crop years over the past 11 years. In addition to the above information, the crop-weather-pest calendars contain the climatic normals favourable for occurrence of particular pest at particular phenological stage. The crop-weather-pest calendars developed for rice crop for different growth stages can be used for prediction of crop yields. These calendars act as a guiding tool while issuing agro-advisory for the farmers of the region and can be used to advise them for need-based spraying of the pesticides for managing insect pests in rice crop.

Patil and Phad (2014) studied that in India, 20 insect pest species have been recorded infesting soybean crop. In Maharashtra , particularly in Marathwada 19 species have been identified infesting soybean crop. Among them Girdle beetle, stem fly, are two most important pests of soybean.

Raghuvanshi *et al*. (2014) studied that succession and incidence of insect pests of soybean in gird region and reported that five insect pests namely white fly, green semilooper, tobacco caterpillar, and girdle beetle were found infesting soybean crop. Infestation of green semilooper were started from third week of July. Infestation of girdle beetle was started from second week of August and continued till harvest.

Shali Raju *et al*. (2014) observed that the appearance of green semilooper was first observed during last week of July , 2012 recording 1 to 2 larvae / mrl with an average of 0.9 larvae /mrl. The larval and pupal period lasted for 15-21 and 7-10 days, respectively . The total life cycle period varied from 24-34 days.

Ahirwar *et al.*(2015) observed the major insect-pests attacking on soybean variety JS 335 were girdle beetle, *Obereopsis brevis*; tobacco caterpillar, *Spodoptera litura*; green semilooper, *Chrysodeixis acuta*; whitefly, *Bemisia tabaci* and jassids, *Empoasca kerri*. The peak activity of girdle beetle (1.0 damaged plant per meter row) was observed during first week of October. Whereas the peak activity of caterpillar pests that is, *S. litura* (2.5 larvae per meter row) and *C. acuta* (0.7 larvae per meter row) was recorded during second fortnight of August and that of sucking pests that is, *B. tabaci* (3.2 whiteflies per plant) and *E. kerri* (3.4 jassids per plant) was recorded during last week of August and Second week of August, respectively. The biocontrol agent's three species of lady bird beetle, Menochilus sexmaculata, Coccinella septumpunctata and Coccinella transversalis and orb weaver spider, Neoscona sp. were found predating mainly upon whiteflies and jassids. Whereas, lynx spider, Oxyopes sp. and a predatory pentatomid bug, Eocanthecona furcellata was noticed sucking the body sap of lepidopterous larvae. The peak activity of lady bird beetle in second week of August and September with 0.4 grub and adult per plant, whereas the predatory pentatomid bug and spider is both last week of August with 1.1 and 1.2 bugs and spider per plant respectively.

Dhurgude *et al.* (2015) reported that triazophos 40 ec and dimethoate 30 ec recorded lowest larval population after first spraying. Same in second spraying. However next superior treatment was thiamethoxam 70 ws followed by phorate 10 g( before sowing) and phorate 10 g ( 30-35 DAS).

Ghadage *et al*. (2015) studies on population dynamics of leaf miner. Aproaerema modicella on soybean variety Gujarat soybean-1 indicated that the incidence of leaf miner commenced from 3$^{rd}$ week a sowing with 1.30 larvae/plant, remained active throughout the crop season and peaked with 8.56 larvae/plant during 8$^{th}$ week after sowing.

Sunanda *et al.* ( 2015) reported that leaf miner incidence mostly associated with minimum temperature, evaporation and wind velocity weather parameters not variety of soybean.

Yadav *et al.* (2015) recorded some major, minor insects, natural enemies and one entomopathogenic fungus on soybean at Tikamgarh (M.P.). Among these insects, population of blue beetle increased with the increase in minimum temperature, RH and rainfall. But population of semilooper, tobacco caterpillar, jassid decreased with increase in rainfall and RH. Similarly the population of white fly, stem fly and girdle beetle also decreased with the increase in rainfall. Population of some natural enemies i.e. coccinelids, predatory bug and *Beauveria bassiana* decreases with the increase in maximum temperature but population of predatory bug increases with increase in minimum temperature and RH. High RH and low temperature favours the incidence of *Beauveria bassiana*. Population of coccinelids and spiders increased with increase in rainfall.

Bhate *et al.* (2017) studied the population dynamics of major pests of soybean revealed the incidence of girdle beetle*, O. brevis*, and Green semilooper, *G. gema* was high whereas moderate incidence of *S.litura* and leaf minor observed the incidence of *H. armigera* and *B. tabaci* was very low/ negligible. The incidence of girdle beetle studied in 31$^{st}$ MW(1.19%) and riched to peak in 40$^{th}$ MW (54.22%). The incidence green semilooper, *G.gema* was observed throughout the crop season with peak of 25.33 larve/mrl during 34$^{th}$ MW. The incidence of *Spodoptera litura* was recorded highest population of 1.30 larve/mrl during 38$^{th}$ MW.

Birajdar *et al.* (2017) studied seasonal incidence of of *Aproaerema modicella* on soybean, groundnut and bawachi as influenced by weather parameters, which showed their peak activity during 39$^{th}$ MW and 42$^{nd}$ MW, respectively. Simple correlation between leaf miner and weather parameters *viz.* maximum temperature and evaporation was positively significant, in soybean, groundnut and bawachi. Where as with minimum temperature and wind velocity negatively significant in soybean and groundnut.

More and Mehtre (2017) studied the impact of abiotic weather factors on pest incidence of soybean variety MAUS-2 (Pooja). Girdle beetle, stem fly and semiloopers were the major pests at Parbhani location. During *Kharif* 2015, the girdle beetle incidence started from first week of August by recording 3.33% infested plants, gradually increased and reached to a peak of 53.93% at harvest. More increase in girdle beetle infested plants was observed from mid August to first week of September with a highest of 12.01% infestation increase in 33$^{rd}$ SMW (13 to 19 August). During *kharif* 2016 also, the girdle beetle incidence started at near to about same period i.e. second week of August but increased very slowly and reached to a peak of 15.71%, just above the economic threshold level of 15%. A maximum 6.91% increase in infested plants was observed during 35$^{th}$ SMW (27 August-2 September). Girdle beetle prefers intermittent rains and dry spells, but the continuous and heavy rains received during August and September 2016 might have arrested its infestation increase. During *kharif* 2015, semilooper incidence started in first week of August by recording 0.66 larvae / mrl increased gradually and reached to a peak of 3.66 larvae / mrl during 35$^{th}$ SMW (27 August- 2 September). While during *Kharif* 2016 the semilooper incidence started in 32$^{nd}$ SMW (6-12 August) by recording 0.33 larvae / mrl increased comparatively fast and reached to a peak of 9.00 larvae / mrl in 36$^{th}$ SMW (3-9 September) there after it decreased naturally.

Motaphale *et al.* (2017) found Insect damages the soybean crop right from germination to till harvesting stage. Stem fly *Melanagromyza sojae* (Zehntner) cause 30 to 50 per cent reduction in grain yield. Number of infested plants due to *M. sojae* was recorded on soybean between 27$^{th}$ to 38$^{th}$ MW (12.70 to 27.2 per cent) and 30$^{th}$ to 40$^{th}$ MW from (10.90 to 25.70 per cent) during 2010-2011 and 2011-2012, respectively. Simple correlation and regression studies revealed that there was significant effect of different weather parameters on incidence of stem fly of soybean.

Sable *et al.* (2017) observed during the season of *kharif* 2015, girdle beetle and stem fly as major pests. Incidence of defoliators *viz., H.armigera, S. litura* and semiloopers was found to be moderate to low while low to high incidence of jassids and white fly was observed. Population of gray weevil, *Myllocerus sp.* was also observed. Girdle beetle infestation on the crop sown on 15$^{th}$ and 30$^{th}$ June showed positive significant correlation with rainfall and morning with relative humidity whereas, it showed significant negative correlation with minimum temperature, bright sunshine hours and wind velocity while the crop sown on 15$^{th}$ July, 30$^{th}$ July and 15$^{th}$ August showed significant positive correlation with maximum temperature while minimum temperature has negative significant correlation. Semiloopers showed negative significant correlation with evaporation when the crop was sown on 15$^{th}$ June. It also showed positive correlation with minimum temperature when the crop was sown on 15$^{th}$ July and 15$^{th}$ August.

# Chapter-III

# MATERIALS AND METHODS

CHAPTER-III

# MATERIALS AND METHODS

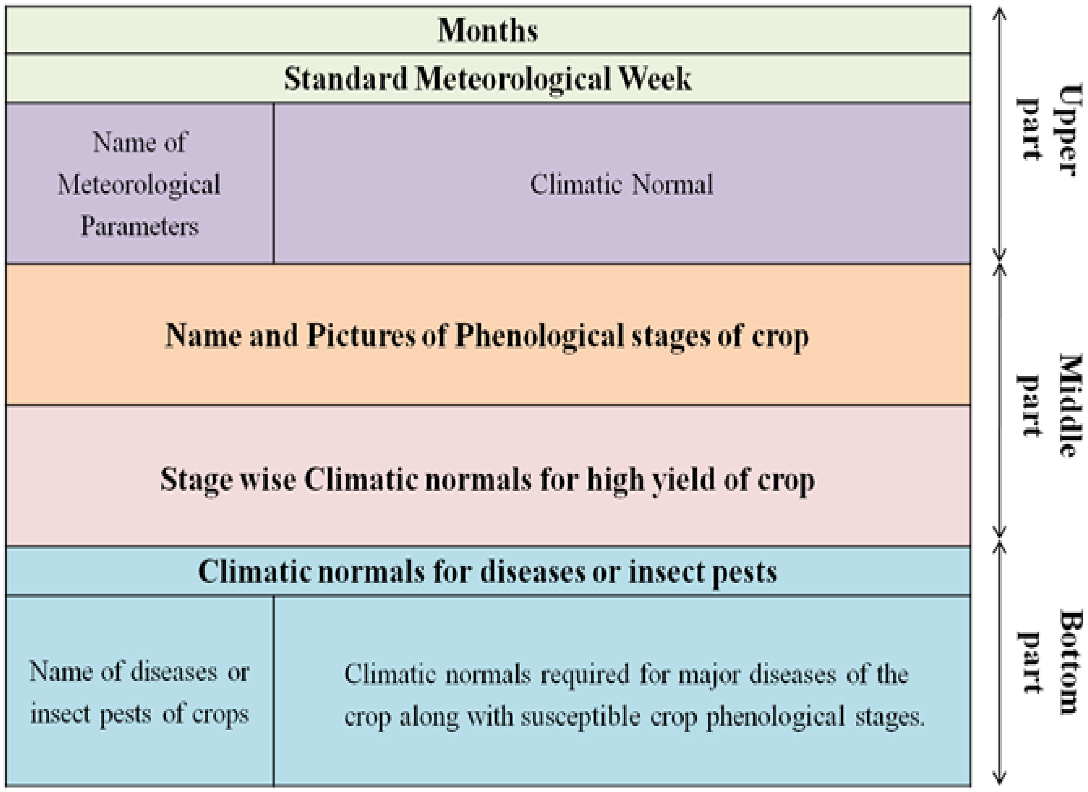
The present research work on "**PREPARATION OF CROP WEATHER CALENDAR OF SOYBEAN CROP UNDER PARBHANI LOCATION**" was conducted in the Department of Agricultural Meteorology, VNMKV, Parbhani.

The climatic conditions are the indispensible topic in rainfed as well as irrigated farming system; the agricultural researches are planned according to the expected change in weather condition regionally. Without understanding the characterization and behavior of the changing weather parameters in coming days, how we will plan the research work and prepare crop weather calendar of soybean crop. Several studies on effect of increased temperature levels and incidence of pests on crop production endorse that there would be drastic reductions in crop yields. In agricultural production weather parameters play an important role. Soil and climate are two important resources which help in crop planning. For this purpose, the study of characteristics of temperature, rainfall, relative humidity, bright sunshine hours, wind speed and evaporation and its impact on crop phenology and incidence of pests is very important.

The methodologies and data that were used are described in this chapter under appropriate heads.

## 3.1 Structure of crop weather calendar :

Structure of crop weather calendar designed by AICRPAM consist of three part in the main body as depicted in figure climatic normals for location specific crop growing season is presented in the upper portion phenological event of the crop are represented in a weekly time frame. In the middle portion together with favorable climatic parameter to realize potential or optimum yield. On the lower parts of the calendar the favorable weather conditions for development of pest are reported. The components of each part of the calendar are discussed here under.




Structure of Crop Weather Calendar

### 3.2 Crop Weather Calendars :

Weather is one of the most important factors affecting the agricultural production. The increase in climatic variability and associated extreme weather episodes such as erratic rainfall distribution, abrupt change in day and night temperatures during crop season and sudden outbreaks in pest disease population, especially in developing countries are throwing challenges to sustaining production levels of different crops. One strategy that farmers can adopt to sustain or increase crop yields in the face of a highly variable climate is to manipulate the crop environment through improved management strategies for adaptation.

Agriculture is one of the most important sectors for India. Proper planning for this sector requires relevant and reliable information in timely manner. Information on crop, its stages and the week by week weather during the crop season is essential for proper management of agriculture. Thus, farm operations planned in conjunction with weather information are very likely to curtail the costs of inputs and various field operations.

The concept of using crop-weather calendar is not new. For instance, FAO calendars provide information on the crop sowing and harvesting dates, seed rate, operation timings of mechanical equipment in the period etc. Also, the University of Kentucky prepared production calendars for soybean and maize 78 crops. This calendar describes the month wise weather and operations to be taken up during the period.

### 3.3.1 Geographical Location of study area


Parbhani district is situated in the Godawari drainage basin in the central part of the India. The area is lying on the central part of Marathwada region in Maharashtra. Climatologically it comes under semi-arid, sub-tropical region and agro climatologically is identified as plain zone of Maharashtra. The geographic location of the site (Parbhani) is 19$^o$ 16', latitude; 76$^o$ 47' E, Longitude 409 meters above mean sea level (MSL) in Marathwada division of Maharashtra state. It has an average rainfall of 963 mm, which is concentrated mostly during months from June to September i.e. from south-west monsoon. The remaining rainfall received during post monsoon period during October to December (North-East monsoon). The western part of Parbhani district surrounded by Beed and Jalana district are present to the north side Buldhana, Washim and some part of Jalana and Hingoli district. At the east side Hingoli district as well as east-south side Nanded district and to the southern side

Latur and some part of Beed district is present.

### 3.3.2 Soil Characteristics

The topography of the Parbhani district is uniform, leveled and with uniform in depth up to 60 cm. The soil comes under order vertisol clay in texture medium to deep black (Inceptisol-75% / Vertisol-25%). The soils are dominant in montmorillonite followed by moderate amount of kaolinite and traces of illite.

The soil of parbhani district is clay loam in texture, normal in reaction (pH 7.7) with low available nitrogen (173.67 kg $ha^{-1}$), medium available phosphorus (29.56 kg $ha^{-1}$) and high available potassium (467.00 kg $ha^{-1}$).

## 3.4. Climatic Data requirements

Weather Data for 1988-2017 i.e. 30 years collected from Department of Agricultural Meteorology, V.N.M.K.V. Parbhani etc. Weekly climatic normal for standard meteorological weeks for this location were computed. These normal meteorological data sets were arranged in a weekly format for cropping season from the month of sowing till the harvest of the crop.

Following climatic parameter data collected for study

| Sr. No | Climatic parameters | Unit |
|---|---|---|
| 1 | Maximum temperature. | $^0$C |
| 2 | Minimum temperature. | $^0$C |
| 3 | Relative humidity – I | % |
| 4 | Relative humidity – II | % |
| 5 | Rainfall. | mm |
| 6 | Bright sunshine hours | hrs |
| 7 | Wind speed | $Kmph^{-1}$ |
| 8 | Evaporation | mm/day |

## 3.5 Phenological data (As per available)

The study of the time pattern associated with the development of the different phenophases in the plant as affected by the plant environment is called phenology. The development of phenophases are the most essential component of soybean crop, which can be used to specify the most appropriate rate and time of the specific developmental phases for the maximization of crop yield during the crop life cycle of soybean in the field condition.

The phenological observations, i.e. no. of days required for different phenological stages, viz.

P1 : Sowing to emergence

P2 : Emergence to seedling

P3 : Seedling to branching

P4 : Branching to flowering

P5 : Flowering to pod formation

P6 : Pod formation to grain formatiom

P7 : Grain formation to pod development

P8 : Pod development to pod containing full size grain

P9 : Pod containing full size grain to dough stage

P10 : Dough stage to maturity

### 3.6 Processing of data

Processing of data was work out here on the basis of standard date of sowing recommended for given crop by VNMKV Parbhani and the standard average duration of crop for Parbhani .

#### 3.6.1 Weather data

The collected weather data of Parbhani district were arranged and calculated to find out average, summation, maximum and minimum value which was used for further analysis.

#### 3.6.2 Crop phenological data

The collected soybean crop phenological data were arranged and evaluated according to its phenological stages and different dates of sowing $D_1$ (27MW), $D_2$ (28MW), $D_3$ (29MW), and $D_4$ (30MW) dates.

#### 3.6.3 Computation of Agrometeorological indices

##### 3.6.3.1 Growing degree days (GDD)

Temperature is a major environmental factor that determines the rate of plant development. The temperature requirement and range of optimum temperature varied with species and genotype. The thermal response of genotype can be quantified by using the heat unit or thermal time concept. There is high probability of successfully predicting the development of linseed by heat unit. Growing degree days defined as the total amount of heat required between the lower and upper threshold level, for an organism from one point to another in its life cycle.

The growing degree days were worked out here on the basis of standard date of sowing recommended for given crop by VNMKV Parbhani and the standard average duration of crop for Parbhani district and base temperature of soybean is taken as 10 $^0$C (WAMIS – WMO)

In the conducted experiment GDD were calculated by computing each days GDD from the standard date of sowing to average duration of crop, GDD was calculated for each year taken. And it was done with the help of following equation given by Cross and Zuber (1972).

$$GDD = [ \sum (T_{max} + T_{min})/2 - T_{base}]$$

Where,

GDD = Growing degree days

$T_{max}$ = Maximum temperature

$T_{min}$ = Minimum temperature

$T_{base}$ = Base temperature

### 3.6.3.2 Helio -thermal units (HTU)

The Helio-thermal unit may be defined as the accumulated product of GDD and bright sunshine hours between the developmental thresholds for each day.

The HTU is the product of GDD and the mean daily hours of bright sunshine. The units of HTU for each days is calculated by following equation given by Rajput (1980).

$$HTU = GDD \times BSS$$

Where,

HTU = Helio-thermal unit

GDD = Growing degree day

BSH = Bright sunshine hours.

Bright sunshine hours was taken from actual bright sunshine hours data collected from station.

#### 3.6.3.3 Photo-thermal unit (PTU)

The Photo-thermal unit is the product of GDD and the mean maximum possible sunshine hours of that day. The units of PTU for each day is calculated by following equation given Major *et al*. (1975).

PTU = GDD × maximum possible sunshine hours

Where,

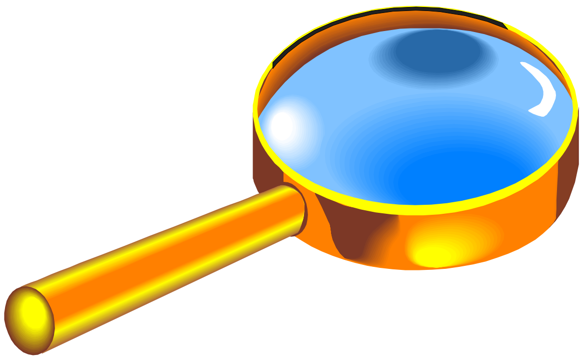
PTU = Photo-thermal unit

GDD = Growing degree days.

### 3.7 Pest data requirement (As per available)

The data on weather condition favorable for incidence of pest and the nature of the weather warnings were collected. The present investigation was undertaken to study on crop weather pest interaction in soybean for various pests like green semilooper and leaf miner, girdle beetle, *Spodoptera litura*,. The investigation is based on the data collection of pests incidence on soybean crop and weather data during *kharif* 2002-2017.

# Chapter-IV



# RESULTS AND DISCUSSION

**CHAPTER-IV**

# RESULTS AND DISCUSSION

In this section as per the objectives the results and discussion of the preparation of crop weather calendar soybean crop are discussed.

## 4.1 To study the preparation of crop weather calendar of soybean crop under Parbhani Location

Weather data was grouped under different years of soybean crop, so as to know the crop behavior to weather during different years of crop in Parbhani location weather data prevailed during 1988-2017 (23MW to 43 MW) and soybean crop data. The relevant data were presented in table and graphical form.

### 4.1.1 Crop Weather Calendar of Soybean crop:

Weather is one of the most important factors affecting the agricultural production. The increase in climatic variability and associated extreme weather episodes such as erratic rainfall distribution, abrupt change in day and night temperatures during crop season and sudden outbreaks in pest disease population, especially in developing countries, are throwing challenges to sustaining production levels of different crops. One strategy that farmers can adopt to sustain or increase crop yields in the face of a highly variable climate is to manipulate the crop environment through improved management strategies for adaptation.

Agriculture is one of the most important sectors for India. Proper planning for this sector requires relevant and reliable information in timely manner. Information on crop, its stages and the week by week weather during the crop season is essential for proper management of agriculture. Thus, farm operations planned in conjunction with weather information are very likely to curtail the costs of inputs and various field operations. Crop weather calendar is a comprehensive guide for farmers. It is a tool that provides information on average weather of every week, planting, sowing and harvesting periods of locally adapted crops in a specific agro-ecological zone. Further, stage-wise pest disease infestation information can also be added.

It also provides information on the sowing rates of seed and planting material and the main agricultural practices. This tool supports farmers and

# CROP WEATHER CALENDAR

**CROP NAME : SOYBEAN** | **DURATION: SHORT(95-120 days)** | **STATE : MAHARASHTRA** | **DISTRICT : PARBHANI**

**Climatic Normals**

| MONTH | JUNE | | | | JULY | | | | AUG | | | | | SEPT | | | | OCT | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MW / Parameter | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 |
| Rain (mm) | 58.5 | 71.2 | 59.9 | 109.6 | 101 | 126.4 | 97.9 | 216.3 | 106.8 | 80.2 | 56 | 133.9 | 100.7 | 98.5 | 88 | 121.3 | 37 | 58.7 | 47.7 | 25.4 | 2.8 |
| Tmax($^0$C) | 38 | 36.2 | 34.9 | 33.6 | 33.3 | 32.4 | 31.9 | 30.5 | 30.6 | 30.3 | 31.1 | 30.7 | 30.8 | 30.9 | 31.4 | 31.3 | 32.4 | 32.7 | 33.2 | 33.2 | 32.5 |
| Tmin ($^0$C) | 24 | 24 | 23.6 | 23.1 | 22.9 | 23.5 | 22.9 | 22.3 | 22 | 21.9 | 21.9 | 21.6 | 23.6 | 21.7 | 21.7 | 21.4 | 21 | 20.5 | 19.6 | 17.9 | 15.7 |
| RH-I (%) | 71 | 74 | 76 | 80 | 81 | 82 | 82 | 81 | 83 | 84 | 83 | 84 | 83 | 83 | 86 | 85 | 80 | 79 | 79 | 74 | 72 |
| RH-II (%) | 34 | 45 | 49 | 54 | 55 | 78 | 62 | 64 | 67 | 65 | 62 | 65 | 65 | 65 | 64 | 65 | 55 | 50 | 47 | 40 | 38 |

| Phenophases | Emergence | Seedling | Branching | Flowering | Pod formation | Grain formation | Pod development | Pod containing full size grain | Dough stage | Maturity |
|---|---|---|---|---|---|---|---|---|---|---|
| **Duration (Days)** | **4-6** | **21-29** | **4-9** | **4-6** | **4-9** | **4-9** | **4-10** | **8-10** | **10-15** | **8-14** |
| **Phenophase wise weather for better yield** | | | | | | | | | | |
| Tmax($^0$C) | 28.1-34.7 | 28.1-32.4 | **28-31.7** | 27.5-33.3 | 30-31.7 | **30.7-35.5** | 29.5-34.6 | 28-32.5 | 33.7-34 | 32.5-33 |
| Tmin ($^0$C) | 19.5-23.6 | 18.7-24 | **22.5-24** | 20-22.5 | 19-23.5 | 20.5-23 | 19.5-22.5 | 17-22 | 18.5-22.5 | **16-20.5** |
| RHm (%) | 80-87 | 81-88 | 79-88 | 85-89 | 86-88 | **89-92** | 84-88 | 75-84 | 76-82 | **75-80** |
| RHe (%) | 56-70 | 54-65 | 66-65 | 54-60 | 62-66 | **65-70** | 62-68 | 47-62 | 45-60 | **32-45** |
| BSS (hrs) | 4.2-4.6 | **3.4-4.5** | 4-5 | 4.5-6 | 3.5-4.8 | 4.5-5 | 4.2-4.6 | 5-8.5 | **4.5-9** | **5-10** |
| Rain(mm) | 40-90 | **115-290** | 45-90 | 50-115 | 115-260 | 55-60 | 75-130 | 40-100 | 35-55 | **20-30** |

**Favourable Weather Forpest incidence**

| Pest | Favourable weather |
|---|---|
| **Girdle beetle** | **Tmax:29.4-33.4$^0$C,Tmin 19.7-25.7$^0$C,RH-I 79-90%,RH-II49-70%** |
| **Semilooper** | **Tmax:29.4-33.2$^0$C,Tmin 19.6-27.8$^0$C,RH-I 69-97%, RH-II 48-70%** |
| **Leaf miner** | **Tmax:29-33.2$^0$C,Tmin 19.6-25.5$^0$C,RH-I 69-90%,RH-II48-70%** |
| **Spodoptera litura** | **Tmax:29.5-33.2$^0$C,Tmin19.3-26.8$^0$C,RH-I 80-89%,RH-II56-70%** |

**Fig 4.1: Crop Weather Calendar of Soybean crop under Parbhani Location during 2002-2017**

agriculture extentionic workers in taking appropriate decisions on crops and their sowing period, respecting the agro- ecological dimension. It also provides a solid base for emergency/ contingency planning of the rehabilitation of farming systems after disasters.

The concept of using crop-weather calendar is not new. For instance, FAO calendars provide information on the crop sowing and harvesting dates, seed rate, operation timings of mechanical equipment in the period etc. Also, the University of Kentucky prepared production calendars for soybean and maize crops. This calendar describes the month wise weather and operations to be taken up during the period.

Crop weather calendar divided in three part, Upper part, Middle part and Bottom part are pictorial represented in fig. 4.1

### 4.1.2 Upper part (Climatic normals)

These climatic normals of this centre were computed for total weekly rainfall (mm), weekly maximum temperature ($^0$C), minimum temperature ($^0$C), maximum relative humidity (%), minimum relative humidity (%), arranged in standard meteorological week wise in the upper portion of crop weather calendar. An arrange climatic normal for soybean crop at Parbhani centre are depicted in fig. 4.1. The highest total rainfall recorded in 30$^{th}$ MW (216.3mm) whereas, the mean highest Tmax (38$^0$C) and Tmin (24$^0$C) recorded in 23$^{rd}$ MW. Maximum RH-I and RH-II recorded in 37$^{th}$MW and 28$^{th}$MW (86%) and (78%) respectively and minimum RH-I (71%) and RH-II (34%) recorded in 23$^{rd}$ MW.

### 4.1.3 Middle part (Phenological observation)

Phenological stages of soybean crop arranged in such way that sowing to at harvesting stage of soybean crop are depicted in fig. 4.1. The more days required for emergence to seedling stage of soybean crop i.e. (21-29 days). The highest range of mean T max and T min found 30.7 $^0$C - 35.5$^0$C and 22.5 $^0$C – 24.0$^0$C pod formation to grain formation stage and seedling to branching respectively. Mean maximum RH-I and RH-II observed in pod formation to grain formation stage. BSS maximum record at dough stage to maturity. The maximum rainfall record in seedling to branching stage of soybean crop is depicated as fig. 4.1.

### 4.1.4 Bottom part

The part of the crop weather calendar which contain the climatic normals required for major pest and disease of soybean crop as well as susceptible crop phenological stages of soybean crop. The more major pest i.e. green semilooper, leaf miner, *spodoptera litura* and girdle beetle were observed during branching to flowering, flowering to pod formation and pod formation to grain formation due to insufficient rainfall and aberrant weather condition.

### 4.1.5 Recorded Parbhani location weather data during 1988-2017 of soybean crop

The weather data in the Parbhani has been classified into different years of the widely grown soybean crops during 1988-2017 (23 MW to 43 MW) using 30 years data. This yearly data can help in planning the expansion of thrust crops implementing projects to expand areas under the crops currently grown or to introduce new crops or their cultivars into the new area in the suitable farming situations of Parbhani.

The relevant weather parameters data presented in table 4.1 and graphically depicted in fig. 4.1.1 to fig. 4.1.6 shows that weather parameters during 1988-2017 (23MW- 43MW) at Parbhani location are briefly discussed.

**Temperature ($^0$C)**

The maximum and minimum temperature is a basic and indispensable weather factor for crop production. Its quality largely determine the variety and magnitude of agriculture production. The mean maximum and minimum temperature corresponding yearly were presented in table 4.1 and graphically depicted in fig. 4.1.1 showed at Parbhani location weather data during 1988-2017 (23MW-43MW) since last 30 years.

The data revealed that the maximum temperature was less to normal during pre-monsoon season and fluctuated monsoon season at Parbhani location. During *kharif* season, maximum and minimum temperature was below the normal. During *rabi* season, maximum temperature was normal however these more fluctuation in minimum temperature at Parbhani location.

**Table 4.1. Yearly average weather data recorded different meteorological week during 1988-2017 (23MW-43MW) soybean crop at Parbhani location**

| | Average weather data | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Year** | **T. Max ( $^0$C)** | **T. Min ($^0$C)** | **RH-I (%)** | **RH-II (%)** | **RF (mm)** | **Bright Sunshine (hrs)** | **Evaporation (mm)** | **Wind Speed (Km hr$^{-1}$)** |
| **1988** | 33.2 | 20.5 | 68 | 52 | 1553.3 | 6.0 | 5.0 | 8.6 |
| **1989** | 32.6 | 21.1 | 62 | 42 | 1269 | 6.2 | 5.9 | **9.7** |
| **1990** | 29.2 | 19.9 | 62 | 53 | **1556.2** | 5.4 | 5.1 | 9.4 |
| **1991** | 32.5 | 18.0 | 56 | 33 | 700.7 | 6.3 | 5.7 | 8.7 |
| **1992** | 32.5 | 21.4 | 65 | 36 | 684.7 | 7.3 | 6.2 | 7.6 |
| **1993** | 31.3 | 20.2 | **18** | **11** | 713 | 6.8 | 6.0 | 7.8 |
| **1994** | 28.7 | 21.2 | 66 | 44 | 654.1 | 5.3 | 5.2 | 7.6 |
| **1995** | 31.5 | 22.3 | 65 | 47 | 621.4 | 6.9 | 6.0 | 7.0 |
| **1996** | 28.5 | 21.7 | 67 | 49 | 746.9 | 6.8 | 5.9 | 6.7 |
| **1997** | 33.0 | 21.2 | 82 | 28 | 513.4 | **7.5** | 5.4 | 6.8 |
| **1998** | **24.3** | 15.7 | 73 | 26 | 1161 | 5.8 | **4.0** | **3.7** |
| **1999** | 29.2 | 12.0 | 66 | 27 | 782 | 5.8 | 4.4 | 6.5 |
| **2000** | 32.2 | **11.7** | 58 | 41 | 657.8 | 6.7 | 4.8 | 5.6 |
| **2001** | 30.7 | 21.4 | 68 | 50 | 550.3 | 5.7 | 4.5 | 6.2 |
| **2002** | 29.8 | 21.2 | 62 | 44 | 706.1 | 6.5 | 5.4 | 6.2 |
| **2003** | 30.0 | 21.4 | 63 | 46 | 630 | 6.7 | 5.3 | 5.7 |
| **2004** | 30.3 | 21.2 | 61 | 44 | 446.2 | 6.7 | 5.7 | 6.0 |
| **2005** | 29.7 | 21.8 | 60 | 46 | 1030.5 | 6.1 | 4.8 | 5.5 |
| **2006** | 29.4 | 21.6 | 66 | 50 | 837.2 | 6.3 | 4.9 | 5.6 |
| **2007** | 28.9 | 21.9 | 69 | 45 | 700.1 | 6.9 | 4.5 | 5.1 |
| **2008** | 30.4 | 21.9 | 70 | 57 | 550.2 | 5.5 | 5.1 | 5.3 |
| **2009** | 33.3 | 21.3 | 62 | 50 | 552.5 | 6.4 | 5.7 | 5.9 |
| **2010** | 31.4 | 22.0 | 65 | **64** | 928.7 | 5.6 | 4.5 | 5.0 |
| **2011** | 31.9 | **23.6** | 85 | 55 | 624.5 | 6.1 | 5.2 | 5.5 |
| **2012** | 32.2 | 22.3 | 84 | 54 | 558.7 | 5.6 | 5.2 | 5.0 |
| **2013** | 30.5 | 22.5 | **88** | 63 | 863 | **4.4** | 4.3 | 4.8 |
| **2014** | 33.6 | 22.0 | 80 | 50 | 414.7 | 5.6 | 4.5 | 5.3 |
| **2015** | **33.7** | 22.8 | 78 | 48 | **408.1** | 6.5 | **6.8** | 5.9 |
| **2016** | 31.7 | 22.1 | 85 | 60 | 1126.7 | 5.3 | 5.1 | 5 |
| **2017** | 32.2 | 22.5 | 84 | 60 | 995.7 | 5.7 | 4.9 | 4.4 |
| **Mean** | **30.94** | **20.6** | **68** | **45** | **785** | **6.1** | **5.2** | **6.2** |

*(Source: I.M.D., NDC, Pune and Dept. of Agril. Meteorology, VNMKV, Parbhani)*

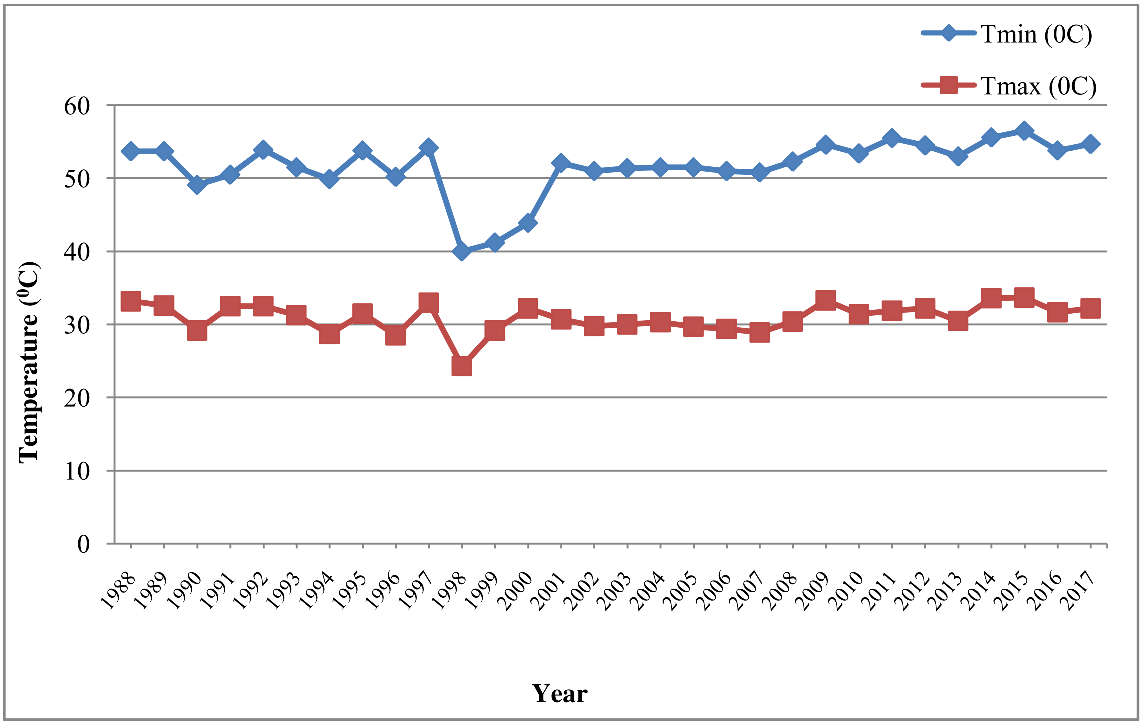



**Fig 4.1.1 Yearly average maximum and minimum temperature recorded in different meteorological week at Parbhani location during 1988-2017**

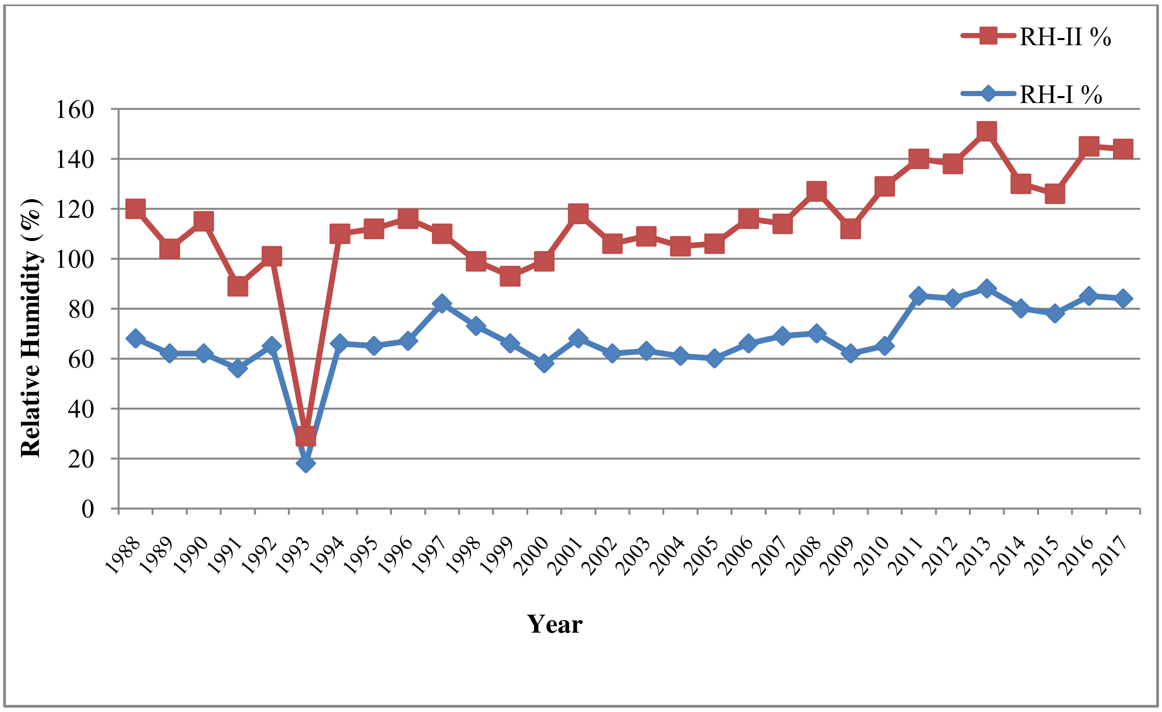



**Fig 4.1.2 Yearly average RH-I% and RH-II% recorded in different meteorological week at Parbhani location during 1988 -2017**

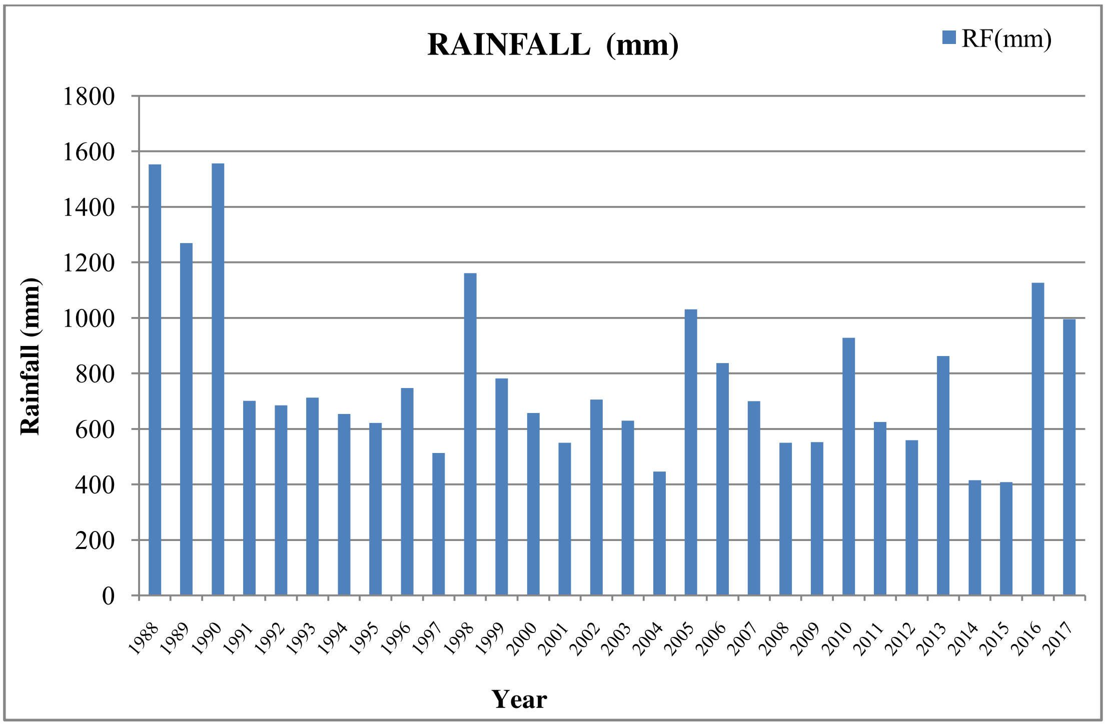



**Fig 4.1.3 Yearly average Rainfall (mm) recorded in different meteorological week at Parbhani location during 1988-2017**

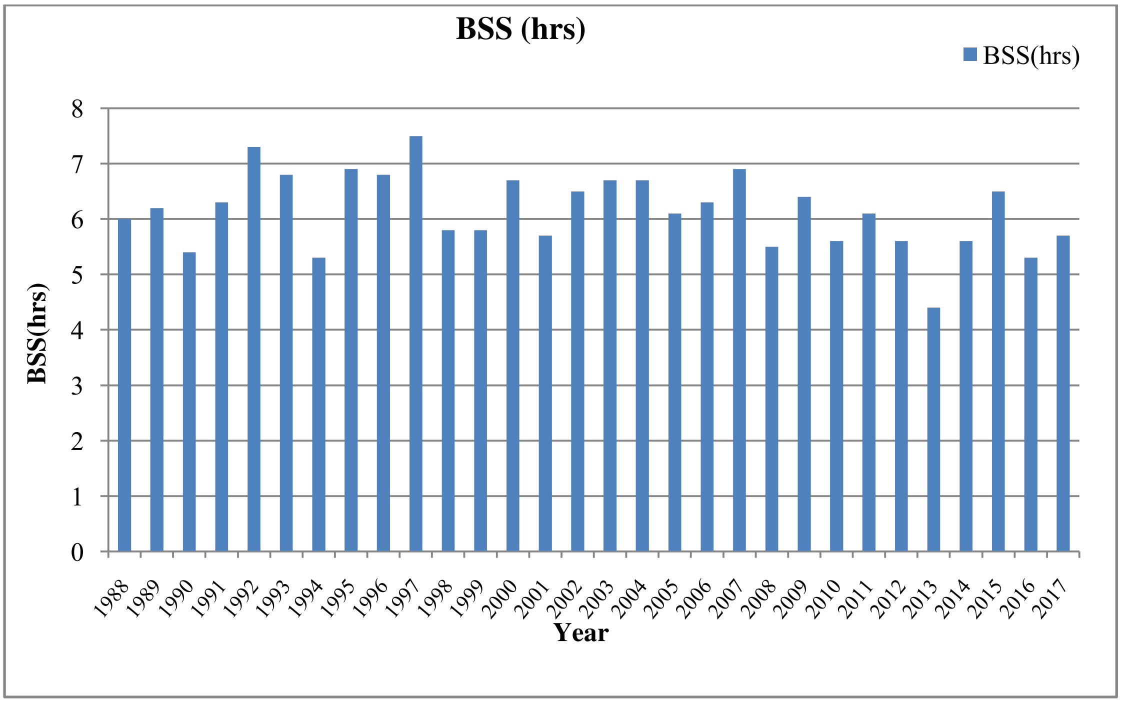



**Fig 4.1.4 Yearly average Bright Sunshine Hours (hrs.) recorded during different meteorological week at Parbhani location during 1988-2017**

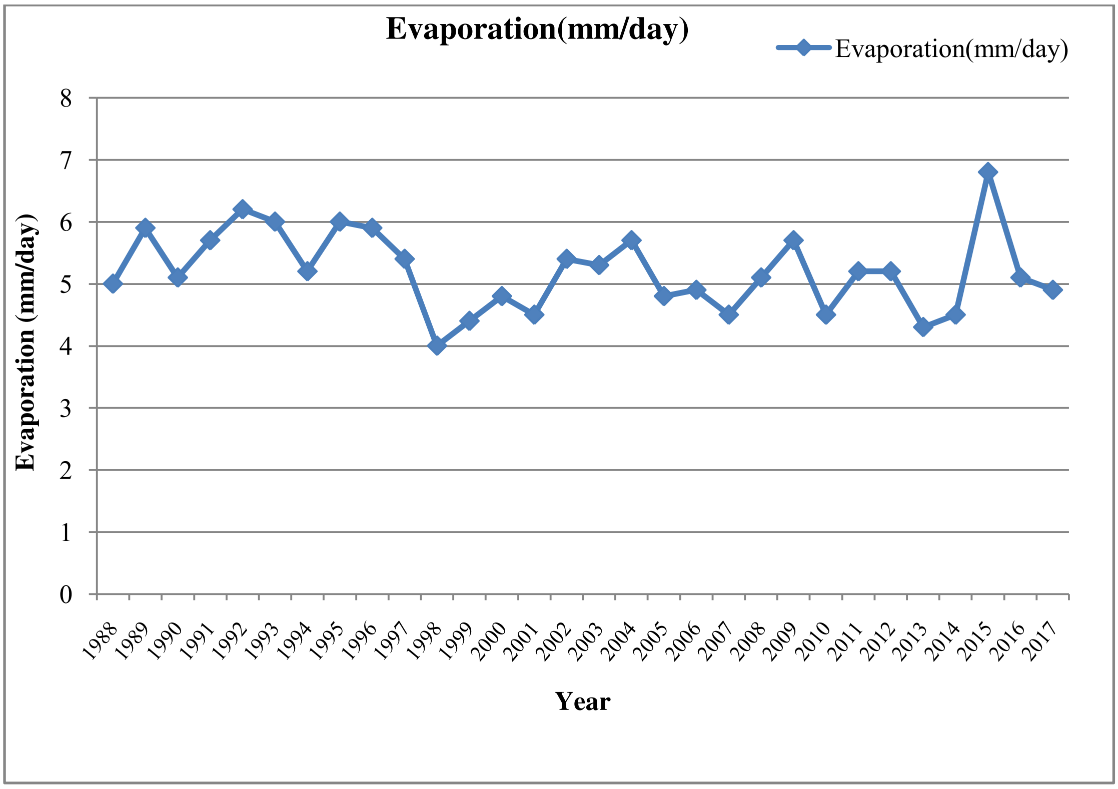



**Fig 4.1.5 Yearly average Evaporation (mm/day) recorded in different meteorological week at Parbhani location during 1988- 2017**

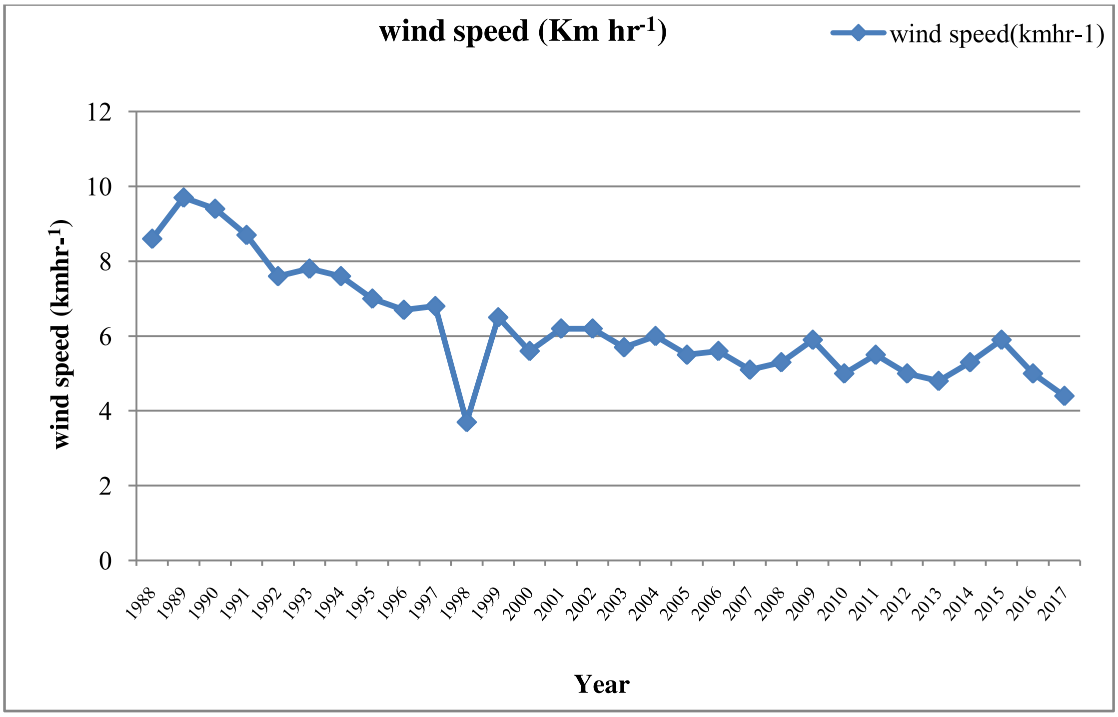



**Fig 4.1.6 Yearly average Wind Speed (kmhr$^{-1}$) recorded in different meteorological week at Parbhani location during 1988-2017**

During 1988 to 2017 data showed that the range of average highest maximum temperature (33.7$^0$C) was recorded in the year 2015 and lowest maximum temperature (24.3$^0$C) was recorded during the year 1998 respectively. Whereas, the highest minimum temperature (23.6 $^0$C) in 2011 and lowest (11.7 $^0$C) in the year 2000 respectively, during the years, in between 1988-2017 the total average mean maximum temperature recorded (30.94$^0$C) and mean minimum temperature (20.6$^0$C). These findings are in conformity of the result given by Khobragade and Karunakar (2016).

**Relative humidity (%)**

The relative humidity was most important weather parameter of crop production. The mean yearly morning and afternoon relative humidity recorded were presented in table 4.1 and graphically depicted in fig. no. 4.1.2 indicated that both the morning and afternoon relative humidity showed continuous fluctuation during 1988 to 2017. During 2011 to 2017 mean morning and afternoon relative humidity increasing trend to above normal and rest of period it was less than normal in Parbhani location. The afternoon relative humidity during 1988 to 1993 continuously decreases and after 2007 increase at Parbhani.

The highest morning relative humidity (88 %) was recorded in 2013 and lowest morning relative humidity (18 %) in 1993 respectively. Whereas, the highest afternoon relative humidity (64 %) was recorded in 2010 and lowest afternoon relative humidity (11 %) in 1993 respectively. And total mean morning relative humidity recorded (68 %) and mean afternoon relative humidity (45%) at Parbhani. The similar work obtained by Khobragade and Karunakar (2016).

**Rainfall (mm)**

Rainfall weather factor was most important for crop growth, development and production. Information on the yearly total rainfall for a location is helpful for crop planning, cultivar selection, run off estimation, determining crop water needs and for designing watersheds and ultimately irrigation system. The rainfall distribution on yearly basis with the association variability for the Parbhani location during 1988 to 2017 (23MW-43MW) since last 30 years data presented in table 4.1 and graphically depicted in fig. 4.1.3 The normal rainfall of Parbhani location is 963 mm. Total rainfall was most variable of year to year at Parbhani location since 30 years. Out of the total year selected for the study, others below the normal.

The highest and lowest total rainfall recorded in 1990 i.e. (1556.2 mm) and during 2015 (408.1 mm) respectively while mean rainfall was recorded (785) mm at Parbhani. Similar study also concluded by Khobragade *et al.* (2016)

Gadekar (2001) reported that soybean can be grown in region with rainfall of 550 to 750 mm because the water requirement of soybean is 450 to 750 mm per season. For germination, 50% moisture is required. Moisture stress during pod filling pod development affects yield significant, about 20 to 50 % dry air in atmosphere also reduces yield.

**Bright sunshine hours (hrs)**

The Bright sunshine hours is a basic and indispensable weather factor for crop production. Its quality largely determine the variety and magnitude of agriculture production. The mean BSS corresponding yearly were presented in table 4.1 and graphically depicted in fig. 4.1.4 showed in Parbhani location weather data during 1988-2017 (23MW-43MW) since last 30 years. The data revealed that the bright sunshine hours were normal during pre-monsoon season and fluctuation trend observed during 1988 to 2017 since last 30 years.

During 1988 to 2017 (23MW-43MW) the highest bright sunshine hour (7.5 hrs) was recorded in 1997 and the lowest bright sunshine hour (4.4hrs) was recorded in 2013 respectively. Against the average bright sunshine hours of 6.1hrs at Parbhani location.

**Evaporation (mm/day)**

The evaporation is a most affected weather factor for crop production. The mean evaporation of corresponding year were presented in table 4.1 and graphically depicted in fig. 4.1.5 showed at Parbhani location weather data during 1988-2017 (23MW-43MW) since last 30 years .The data revealed that the evaporation was above normal during pre-monsoon season and fluctuated monsoon season at Parbhani location. During *Kharif* season, evaporation was above the normal. The evaporation showed decreasing trend of during 1988 to 2017 since last 30 years.

During 1988 to 2017, highest evaporation (6.8 mm) was recorded in 2015 and lowest evaporation (4.0 mm) was recorded in 1998 respectively. The average evaporation recorded (5.2 mm) at Parbhani location.

**Wind speed (km hr$^{-1}$)**

The mean wind speed of corresponding year were presented in table 4.1 and graphically depicted in fig. no. 4.1.6 showed at Parbhani location weather data during 1988-2017 (23MW-43MW) since last 30 years .The data revealed that the wind speed was normal during pre-monsoon season and fluctuated monsoon season at Parbhani. The wind speed showed continuous decreasing trend of during 1988 to 2017 since last 30 years.

Highest and lowest wind speed recorded in 1989 i.e. (9.7kmhr$^{-1}$) and recorded in 1998 i.e. (3.7kmhr$^{-1}$) at Parbhani location respectively. During crop growing environment weather parameter was fluctuate year wise. The total average wind speed recorded during 1988-2017 (23MW-43MW) is (6.2 kmhr-$^{1}$) at Parbhani location.

## 4.2 To assess the phenological stages in relation to weather parameter of soybean

### 4.2.1 Agro meteorological indices

Soybean crop in Marathwada region is mainly cultivated as a rainfed crop and grown during *kharif* season. However, cultivation of irrigated soybean was also recorded. The climatic requirement of soybean varies in different phenological stages.

The average temperature requirement of soybean ranges between 26.5 $^{0}$C to 30.0 $^{0}$C. Any fluctuation in this range may result in stunted growth of crop finally lead to the reduction in yield.

Soybean is the short day plant grown in subtropical and temperate regions in which weather play major role in crop production. Among the climatic factors, temperature plays a key role in determining the sowing time and consequently the duration of different phenophases, which affect the crop productivity. Hence, knowledge of the exact duration of all the developmental phases and their association with yield determinants is essential for achieving high yield. Growing degree days

(GDD), Helio-thermal units (HTU) and Photo-thermal units (PTU) are estimators of soybean growth stages.

Agrometeorological indices like Growing degree days (GDD), Helio-thermal units (HTU) and Photo-thermal units (PTU) show the temperature impact on the growth of crop.

**Average cumulative GDD, HTU and PTU of Soybean crops during 23MW – 43 MW at Parbhani location (2003-2017)**

The Agrometeorological indices data presented in table 4.2 and graphically depicted in fig. 4.2.1 to fig. 4.2.4 showed Parbhani location 2003-2017. In Parbhani location Soybean mostly grow under rainfed condition during 23 MW – 43 MW.

**Growing degree days (GDD)**

Growing degree days plays a key role in determining the consequently the duration of different years , which affect the crop productivity.The result observed that Growing degree days shows continuously variability trend during 2003 to 2017 in Parbhani.

The growing degree days for *kharif* soybean were calculated by using daily maximum, minimum and base temperature of soybean. The data given in the table 4.2 and graphically depicted in fig. 4.2.2.1 shows that the number of growing degree days was accumulated during the each year at the base temperature of 10 $^0$C (45 $^0$F) and it was obtained 1864.0$^0$days as general mean. The results showed that the growing degree days was significantly affected by different phenophase of soybean crop during 2003 to 2017 and the highest number of growing degree days recorded in 2017 (2332.2 $^0$C days). Whereas, the lowest number of GDD was accumulated in 2016 (1749.5$^0$C days).

It means that the daily mean temperature is more, the number of GDD required less and it may be due to this 2017 required more GDD and least required at 2016 in Parbhani.

**Table 4.2. Average cumulative GDD HTU and PTU of Soybean crop during 2003-2017 (23MW-43MW) of Parbhani location**

| Year | GDD ( $^0$C Days) | HTU ( $^0$C Days hour) | PTU ( $^0$C Days hour) |
|---|---|---|---|
| 2003 | 1829.86 | 10429.8 | 20128.4 |
| 2004 | 1844.05 | 11801.9 | 20284.5 |
| 2005 | 1852.5 | 10188.7 | 20377.5 |
| 2006 | 1800.95 | 9545.0 | 19810.4 |
| 2007 | 1880.6 | 11471.6 | 20686.6 |
| 2008 | 1877.96 | 8826.4 | 20657.5 |
| 2009 | 2002.5 | 10813.5 | 22027.5 |
| 2010 | 1936.4 | 9488.3 | 21300.4 |
| 2011 | 2130 | 11289 | 23430 |
| 2012 | 1994 | 9172.4 | 21934 |
| 2013 | 1891.1 | 7564.4 | 20802.1 |
| 2014 | 2024.5 | 9920.0 | 22269.5 |
| 2015 | 2236.2 | 13718 | 23698.2 |
| 2016 | 1749.5 | 9110.5 | 21134.7 |
| 2017 | **2332.2** | **14231.3** | **24234.6** |
| **Mean** | **1958.82** | **10504.72** | **22518.39** |

**Helio-thermal unit (HTU)**

The data on helio-thermal degree day hrs unit are presented in table 4.2 and graphically depicted in fig. 4.2.2.2. The helio-thermal unit for different years was calculated by using GDD multiply by mean BSS.

The results showed that the helio-thermal unit was significantly affected by different phenophases of soybean crop during 2003 to 2017 and HTU requirement for soybean crop changes with yearly such as maximum HTU requirement was recorded in 2017 (14231$^0$C day hour). Whereas, the lowest number of HTU was accumulated in 2016 (9110.5$^0$C day hour) in Parbhani

**Photo thermal unit (PTU)**

The data on photo thermal unit (degree day hrs) are presented in table 4.2 and graphically depicted in fig. 4.2.2.3. The photo thermal unit during 2003 to 2017 was calculated by using GDD multiply by day length.

The results showed that the photo thermal unit was significantly affected by different phenophases of soybean crop during 2003 to 2015 and photo thermal unit requirement for soybean crop was changes with requirement for the

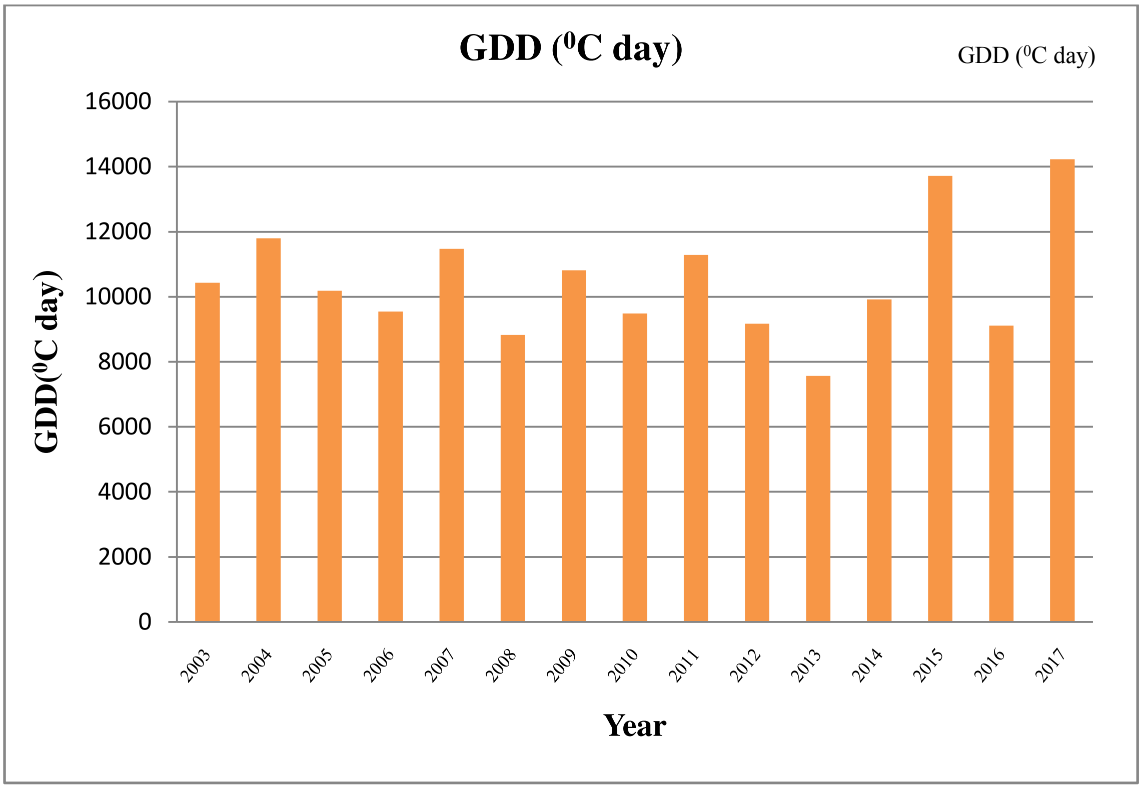



**Fig 4.2.2.1 Average cumulative GDD of Soybean crop of Parbhani location during 2003-2017**

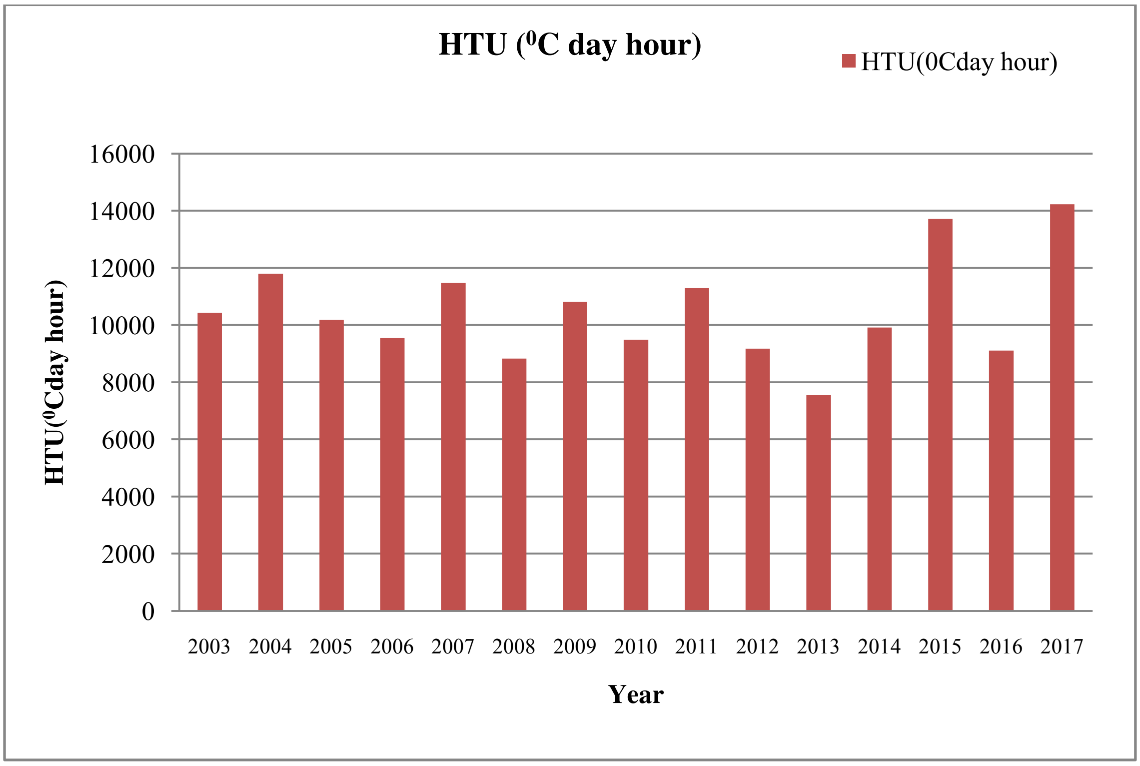



**Fig 4.2.2.2 Average cumulative HTU of Soybean crop of Parbhani location during 2003-2017**

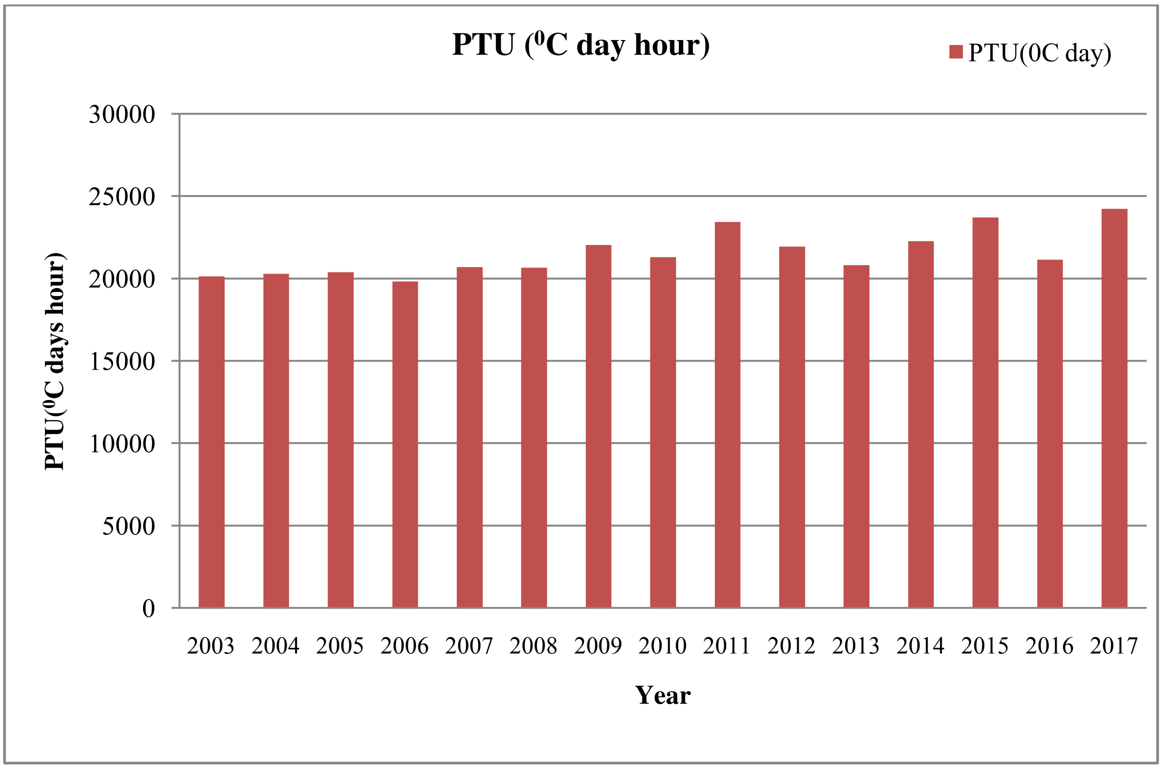



**Fig 4.2.2.3 Average cumulative PTU of Soybean crop of Parbhani location during 2003-2017**

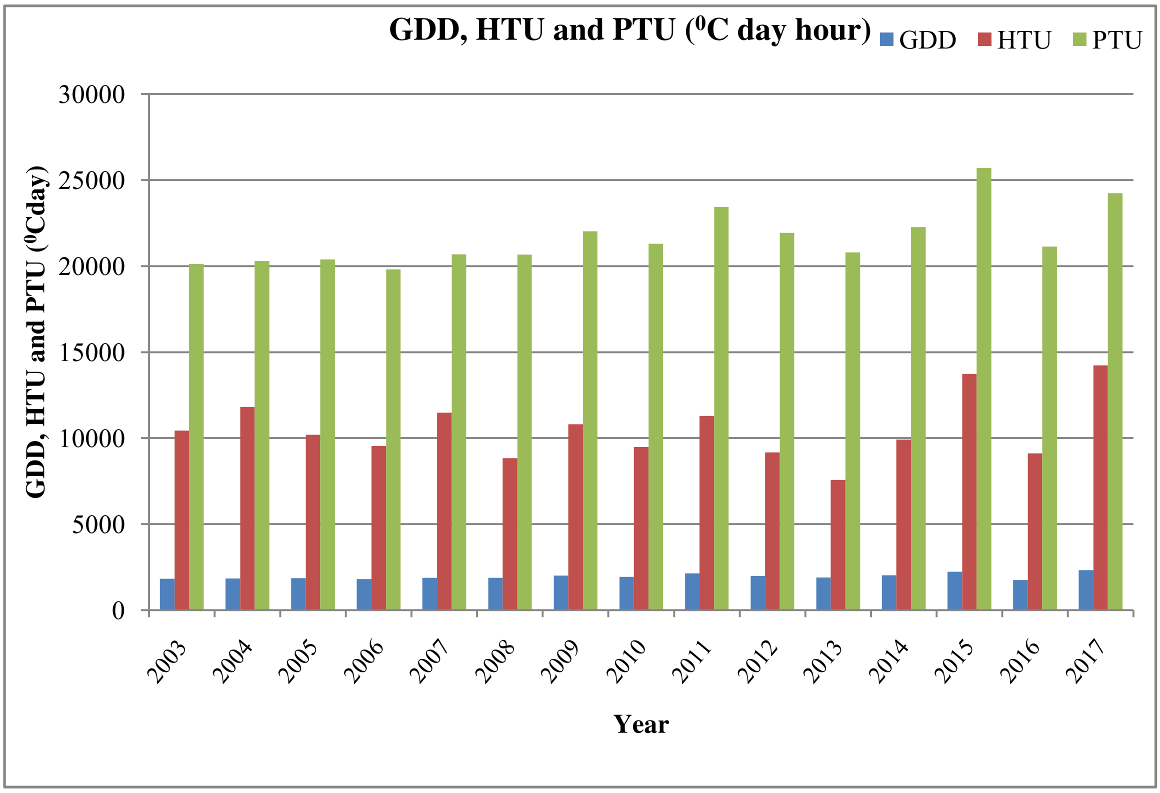



**Fig 4.2.2.4 Average cumulative GDD HTU and PTU of soybean crop of Parbhani location during 2003-2017**

soybean crop variation observed year by year due to difference in temperature such as maximum photo thermal unit requirement in 2017 (i.e. $24234.6^0$C day hour) . Whereas, the lowest number of photo thermal unit was accumulated in 2006 (i.e. $19810.6^0$C day hour) in Parbhani. The similar results were given by Khobragade and Karunakar (2016).

### 4.2.2. Effect of dates of sowing on accumulated thermal indices at different phenophases during 2003-2017

The data recorded on these aspects were not subjected to 'F' test of variances and results are interpreted on the basis of values.

**Effect of Growing Degree Days (GDD)**

Growing degree days (GDD) for soybean crop under different sowing dates from sowing to maturity are presented in table 4.2.1 during 2003-2017 .The data presented in table 4.2.1 revealed that the highest mean heat load was reported during $D_1$ (MW-27) 178.8 $^0$C days and lowest $D_4$ (MW-28) 158.7 $^0$C days and $D_2$ (MW-28) and to $D_3$ (MW-29) i.e. 166.4 $^0$C days and 162.6 $^0$C days respectively. It may be due to dry spell occurred during crop life cycle. Whereas, D1 (MW-27) treatment indicated more heat load than other treatment of date of sowing i.e. 178.8 $^0$C days. It may be due to maximum air temperature observed at the time of sowing (MW-27). It is cleared that when the temperature of air was maximum then it will definitely affect GDD of soybean crop.

**Table 4.2.1 Growing Degree Day (GDD) at different phenological stages of soybean crop under Parbhani Location during 2003-2017**

| Treatments | Phenological stages of soybean | | | | | | | | | | Total | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ | $P_9$ | $P_{10}$ | | |
| **Date of sowing** | | | | | | | | | | | | |
| **$D_1$(27MW)** | 90.5 | 425.3 | 80.5 | 92.5 | 102.7 | 195.3 | 215.5 | 178.7 | 175.5 | 231.5 | 1788 | **178.8** |
| **$D_2$(28MW)** | 95.5 | 378.5 | 71.5 | 92.8 | 98.7 | 105.5 | 198.5 | 212.5 | 175.5 | 234.5 | 1663.5 | 166.4 |
| **$D_3$(29MW)** | 88.9 | 385.5 | 70.8 | 93.6 | 90.5 | 103.5 | 180.7 | 215.5 | 175.5 | 221.5 | 1626 | 162.6 |
| **$D_4$(30MW)** | 89.6 | 355.6 | 67.9 | 95.6 | 81.9 | 117.6 | 180.5 | 205.6 | 196.7 | 195.5 | 1586.5 | 158.7 |
| **Variety** | | | | | | | | | | | | |
| **MAUS-71** | 89.5 | 380.8 | 67.2 | 85 | 89.4 | 99 | 187.8 | 218.9 | 188.8 | 232.8 | 1639.2 | **163.9** |
| **MAUS-81** | 88.9 | 375.5 | 70.8 | 93.6 | 90.5 | 98 | 180.7 | 215.5 | 175.5 | 221.5 | 1610.5 | 161.05 |
| **JS-335** | 82.2 | 365.2 | 66.5 | 79.5 | 85.4 | 92.2 | 185.2 | 215.7 | 188.2 | 221.2 | 1581.3 | 158.13 |
| **MEAN** | 86.9 | 373.8 | 68.2 | 86 | 88.4 | 96.4 | 184.6 | 216.7 | 184.2 | 225.2 | 1610.3 | 161 |

$P_1$- sowing to emergence
$P_2$-emergence to seedling
$P_3$- seedling to branching
$P_4$- branching to flowering
$P_5$-flowering to pod formation
$P_6$- pod formation to grain formation
$P_7$- grain formation to pod development
$P_8$ -pod development to pod containing full grain size
$P_9$- pod containing full grain size to dough stage
$P_{10}$- dough stage to maturity

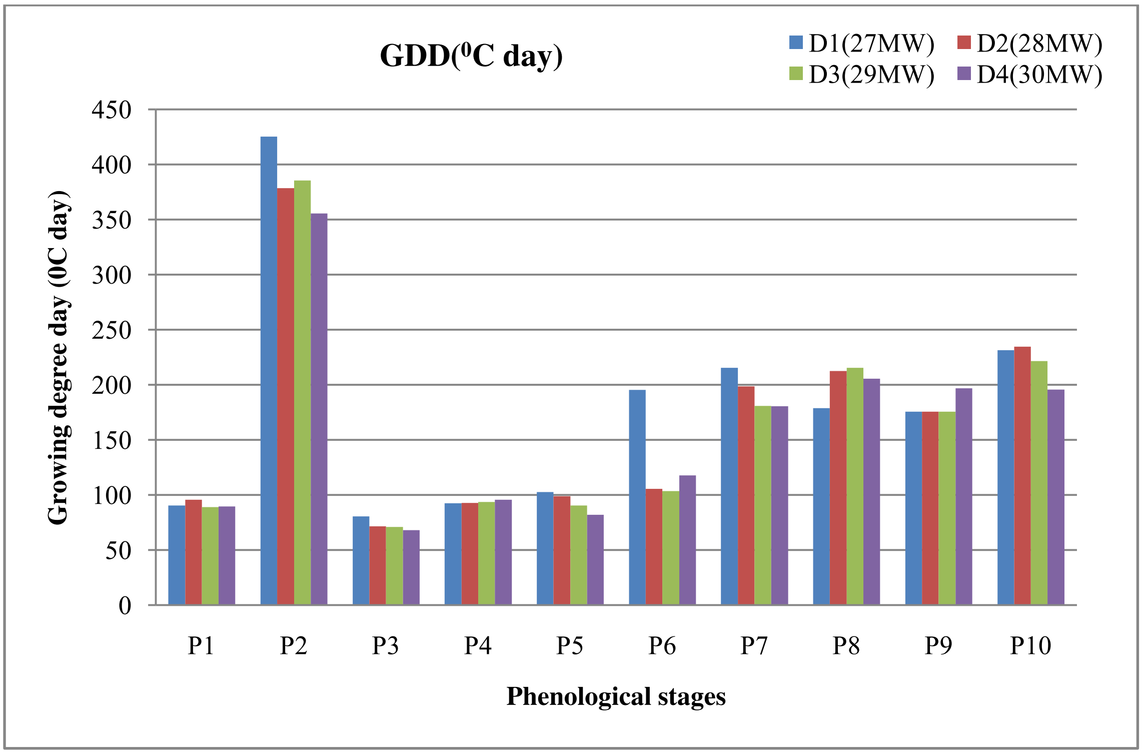



**Fig 4.2.1 Growing Degree Day (GDD) at different phenophases of soybean crop under Parbhani location during 2003-2017.**

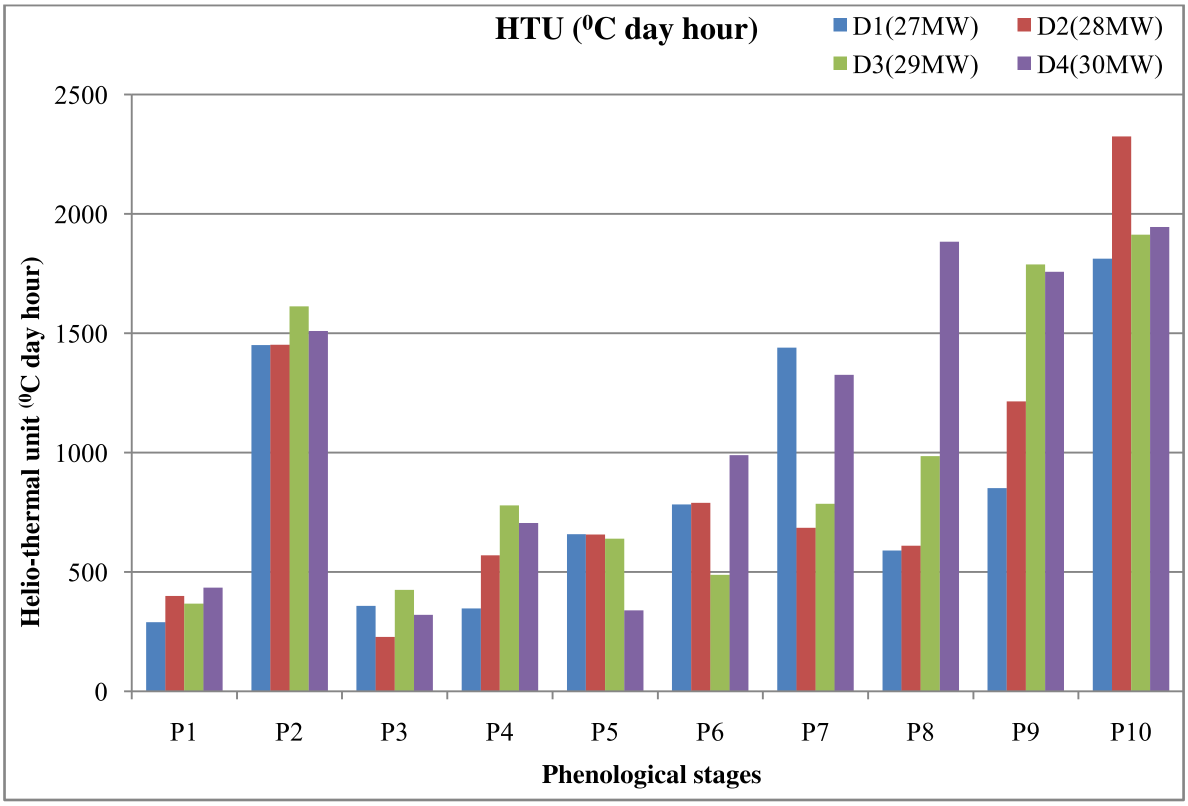



**Fig 4.2.2 Helio-Thermal Units (HTU) at different phenophases of soybean crop under Parbhani location during 2003-2017**

The data presented in table 4.2.1. and fig.no.4.2.1. revealed that the mean heat requirement variety during crop life cycle ranged from 163.9 $^0$C day to 158.1 $^0$C day. The mean heat load reported was 3 varieties $V_1$ (MAUS-71), $V_2$ (MAUS-81) and $V_3$ (JS-335) i.e. 163.9 $^0$C day, 161.05 $^0$C day, and 158.13 $^0$C day respectively. It may be occurs due to small crop duration, from emergence to maturity of such varieties.

**Effect of Helio-Thermal Unit (HTU)**

The data presented in table 4.2.2. and fig. no. 4.2.2. Helio-thermal units for each phenophase were different required by different dates of sowing during 2003-2017. The mean helio-thermal units were observed, in date of sowing ($D_1$ to $D_4$) ranged from 858.8 to 1121.05$^0$C days hours. The HTU were higher in fourth date of sowing i.e. 1121.05$^0$C days hours and lowest HTU were in $D_1$ (MW-27) i.e. 858$^0$C days hours than rest of the treatments due to variation of temperature, bright sunshine and dry spell occurred during the crop growing season. The helio-thermal units directly or indirectly affect the grain yield of soybean by delaying flowering, pod formation. Higher HTU are not conducive for better yield of soybean.

The requirement of mean helio-thermal units of different variety during crop life cycle was ranged from 946.2 $^0$C days hours to 966.5 $^0$C days hours. It may be due to same crop duration in above three varieties. Whereas, the HTU were lowest in $V_1$ (MAUS-71) i.e. 946.2 $^0$C days hours than rest of the treatments due to variation of temperature, growing period, bright sunshine and dry spell occurred during the crop growing season Chavan *et al*. (2018).

**Effect on photo-thermal unit (PTU)**

The variation in PTU in different treatments at emerging and maturity has been presented in table 4.2.3 and fig no.4.2.3. The varieties sown on 27 MW required maximum PTU (1964.9 $^0$C days hour) till maturity which was superior over 28 MW, 29 MW and 30 MW sown crop at all stages. MAUS-71 requires maximum PTU (1958.7 $^0$Cdays hour) at all stage which was significantly superior over rest of varieties. The higher PTU value in early sown crop may be due to fact that crop took longer duration to reach Phenological stage. The similar results were also indicating by the finding of Chavan *et al*. (2018)

According to Chavan *et al*. (2018) the crop was sown on 27$^{th}$ MW took maximum calendar days, growing degree days, photo thermal unit and helio-thermal unit to attain different phenological stages till maturity and reduced significantly with subsequent delay in sowing time. The grain yield recorded in 27$^{th}$MW were significantly highest to rest of sowing dates. The significant reduction in grain yield of timely sown varieties was recorded when sowing was delayed from normal sowing dates.

### 4.2.3 Phenophases of soybean in relation to weather parameters at Parbhani Location during (2003-2017)

The weather conditions prevailed during the crop growing season during 2003 to 2017 are presented in table 4.2.4 for different meteorological elements viz. rainfall, air temperature, relative humidity, evaporation and bright sunshine hours, at Parbhani, during the crop growing season and its impact on growth, development and yield of soybean crop.

The Phenophase wise range of weather data given in Table 4.2.4 revealed that the average weather condition observed at different phenophases of soybean crop grown at Parbhani during 2003-2017.

Crop phenology which refers to the development differentiation and initiation of organs according to particular phenophases was influenced by varying weather parameters.

The decrease in the vegetative period due to prevailing of lower value of maximum temperature, higher relative humidity and vapour pressure which has reduced the overall covariation in development of phenological phases compared to early and late sowing. This resembles to finding of Kumar *et al*. (2008) and Singh *et al.* (1974).

**Phenological stages of soybean crop**

The study of the time pattern associated with the development of the different phenophases in the plant as affected by the plant environment is called phenology. The development of phenophases are the most essential component of soybean crop, which can be used to specify the most appropriate rate and time specific developmental phases for maximization of crop yield during the crop life cycle of soybean in the field condition.

**Table 4.2.2 Helio -Thermal Unit (HTU) at different phenological stages of soybean crop under Parbhani Location during 2003-2017**

| Treatment | Phenological stages of soybean | | | | | | | | | | Total | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ | $P_9$ | $P_{10}$ | | |
| **Date of sowing** | | | | | | | | | | | | |
| **$D_1$(27MW)** | 289.6 | 1450.7 | 358.2 | 347.2 | 658.7 | 782.4 | 1439.9 | 590 | 850.9 | 1812.5 | 8588.83 | 858.83 |
| **$D_2$(28MW)** | 399.5 | 1451.5 | 227.3 | 570.3 | 656.9 | 789.8 | 685.5 | 609.4 | 1215.1 | 2324.1 | 8929.4 | 892.94 |
| **$D_3$(29MW)** | 366.8 | 1612.7 | 425.6 | 778.3 | 638.8 | 488.3 | 785 | 985.4 | 1788 | 1912.8 | 9781.7 | 978.17 |
| **$D_4$(30MW)** | 434.6 | 1510 | 320.5 | 705.3 | 338.5 | 988.8 | 1326.4 | 1883.2 | 1757.5 | 1945.7 | 11210.5 | **1121.05** |
| **Variety** | | | | | | | | | | | | |
| **MAUS-71** | 220.8 | 1250.7 | 315.6 | 304 | 610.2 | 794.5 | 1127 | 1750 | 1399 | 1690.2 | 9462 | 946.2 |
| **MAUS-81** | 218.5 | 1456 | 285.6 | 332.2 | 670.2 | 795 | 1280 | 1754 | 1572 | 1857.5 | 10221 | 1022.1 |
| **JS-335** | 215.5 | 1326 | 329 | 345 | 703.6 | 774 | 1257 | 1753 | 1705 | 1257.6 | 9665.7 | 966.5 |
| **MEAN** | 218.26 | 1344.2 | 310 | 327 | 661.3 | 787.8 | 1221.3 | 1752.3 | 1558.6 | 1601.76 | 9782.9 | 978.26 |

$P_1$- sowing to emergence
$P_2$-emergence to seedling
$P_3$- seedling to branching
$P_4$- branching to flowering
$P_5$-flowering to pod formation
$P_6$- pod formation to grain formation
$P_7$- grain formation to pod development
$P_8$ -pod development to pod containing full grain size
$P_9$- pod containing full grain size to dough stage
$P_{10}$- dough stage to maturity

**Table 4.2.3 Photo-Thermal Unit (PTU) at different phenological stages of soybean crop under Parbhani Location during 2003-2017**

| Treatment | Phenological stages of soybean | | | | | | | | | | Total | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $P_1$ | $P_2$ | $P_3$ | $P_4$ | $P_5$ | $P_6$ | $P_7$ | $P_8$ | $P_9$ | $P_{10}$ | | |
| **Date of sowing** | | | | | | | | | | | | |
| **$D_1$(27MW)** | 1150.5 | 4896 | 959.1 | 1201.3 | 1203.3 | 1178.7 | 2116.7 | 2419.2 | 2001.2 | 2523.3 | 19649.3 | **1964.9** |
| **$D_2$(28MW)** | 1130.4 | 4202.9 | 802.5 | 1104.4 | 1450.3 | 1181 | 2105.8 | 2367.3 | 1939.6 | 2420.8 | 18705 | 1870.5 |
| **$D_3$(29MW)** | 1052.5 | 4510.5 | 886.8 | 1083.9 | 1003.1 | 1144.6 | 2015.4 | 2470.9 | 1998 | 2266.1 | 18431.8 | 1843.1 |
| **$D_4$(30MW)** | 1038.4 | 4304.1 | 789.4 | 1099.5 | 986.49 | 1256.2 | 1980.5 | 2196.7 | 2031.4 | 2050.2 | 17732.8 | 1773.2 |
| **Variety** | | | | | | | | | | | | |
| **MAUS-71** | 1451.3 | 4510.7 | 798.2 | 998.4 | 1035.7 | 1317.2 | 2401 | 2404.1 | 2016.6 | 2654.2 | 19587.4 | **1958.7** |
| **MAUS-81** | 989.6 | 4536.8 | 785.8 | 1001.2 | 999.4 | 1167.4 | 2407.5 | 2234.1 | 2502.5 | 2098.5 | 18722.8 | 1872.2 |
| **JS-335** | 999.8 | 4483.5 | 781.9 | 999.3 | 987.8 | 1426.3 | 1879.4 | 2304.1 | 2004.7 | 2530.2 | 18397 | 1839.7 |
| **MEAN** | 1146.9 | 4510.3 | 788.6 | 999.6 | 1007.6 | 1303.6 | 2229.3 | 2314.1 | 2174.6 | 2427.6 | 18902.4 | 1890.2 |

$P_1$- sowing to emergence
$P_2$-emergence to seedling
$P_3$- seedling to branching
$P_4$- branching to flowering
$P_5$-flowering to pod formation
$P_6$- pod formation to grain formation
$P_7$- grain formation to pod development
$P_8$ -pod development to pod containing full grain size
$P_9$- pod containing full grain size to dough stage
$P_{10}$- dough stage to maturity

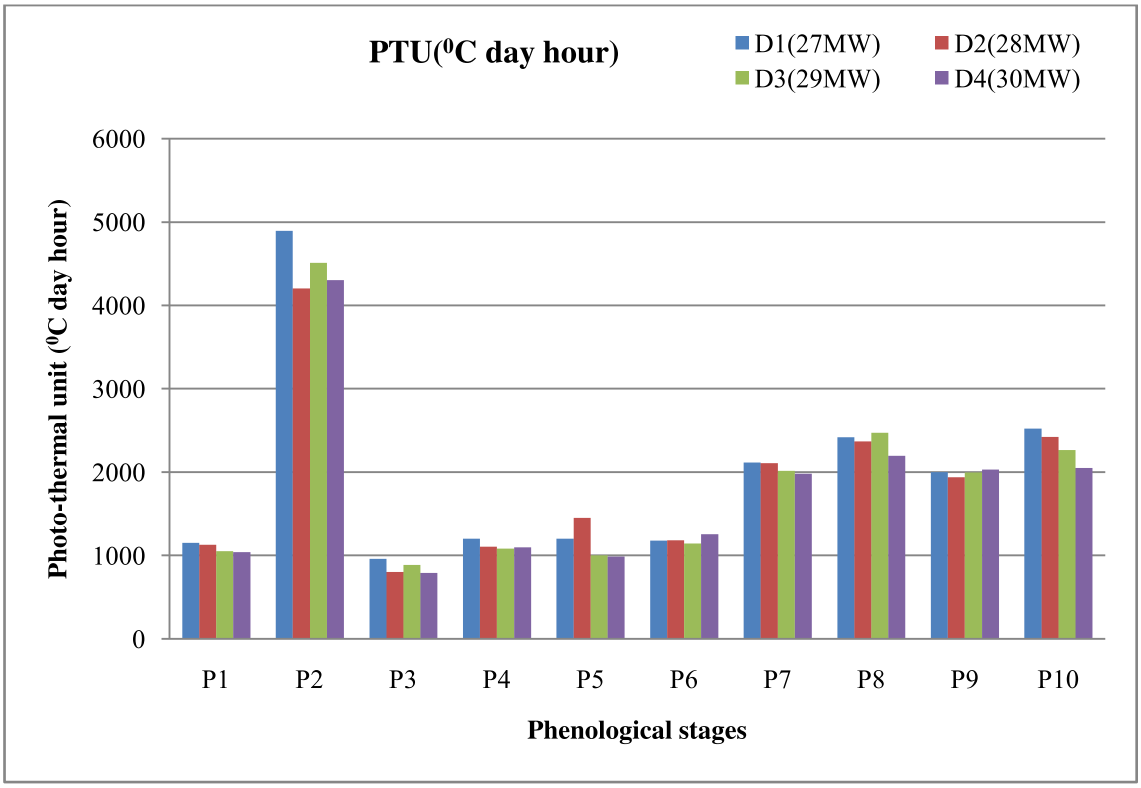



**Fig 4.2.3. Photo-Thermal Units (PTU) at different phenophases of soybean crop at Parbhani location during 2003-2017**

In the present investigation, the whole life cycle of soybean crop (from sowing to physiological maturity) was divided in to ten distinct phenophases which was shown in the table 4.2.4 on the basis of external morphological characteristics. The occurrence of different phenophases of soybean crop observed in the present study under the four dates of sowing during *kharif* season during 2003-2017. The overall number of days taken for physiological maturity was 92 to 117 which was shown in the table 4.2.3 When crop sown in meteorological week i.e. 27MW, 28MW, 29MWand 30 MW respectively.

The result showed that the range during 2003 to 2017 number of days required for maturity when crop was sown under $D_1$ (MW27) were 92-112 days , $D_2$(MW 28) 93-115 ,$D_3$ (MW29) 94-114 days and $D_4$(MW30) 93-112 during the crop growing season . Delay in the sowing induced the early flowering in the soybean crop, as the day length increase along with the increased temperature because of the crop is determinant type with short day length and thermo sensitive plant and its response to yield varies with variety temperature.

Further, the variation in the maturity period in all the treatment can be explained on the basis of the fact that the temperature was higher in $D_3$ and $D_4$ as compared to $D_1$ and $D_2$ The similar results were given by Khobragade *et al.* (2016).

**Rainfall (mm)**

The nature and distribution of rainfall and the time of its receipt during the crop growing period seems to be much more important than the total quantity of rainfall with reference to the performance and yield of soybean crop.

The data given in table 4.2.4. showed that the rainfall received during each phenophase and the average highest rainfall (115-290) was received at emergence to seedling stage and followed by flowering to pod formation stage (115-260 mm), sowing to emergence stage (90 mm), and lowest rainfall 20-30 mm) recorded at dough stage to maturity of soybean crop The similar results were given by Khobragade *et al.* (2016).

**4.2.4 Mean of different phenophases of soybean in relation to weather parameters at Parbhani location during 2003-2017**

| Phenophases | No. of days required to phenophases | Duration of crops at diff$^n$ sowing dates | Weather Parameter | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Tmax ($^0$C) | Tmin ($^0$C) | RH-I (%) | RH-II (%) | BSS (hrs) | Rainfall (mm) |
| **Sowing to emergence($P_1$)** | 4-6 | D$_1$- 27 MW (92-112days) D$_2$- 28 MW (93-115days) D$_3$- 29 MW (94-114 days) D$_4$- 30 MW (93-112 days) | 28.1-34.7 | 19.5-23.6 | 80-87 | 56-70 | 4.2-4.6 | 40-90 |
| **Emergence to seedling($P_2$)** | 21-29 | | 28.1-32.4 | 18.7-24 | 81-88 | 54-65 | **3.4-4.5** | **115-290** |
| **Seedling to branching($P_3$)** | 4-9 | | **28-31.7** | **22.5-24** | 79-88 | 66-65 | 4-5 | 45-90 |
| **Branching to flowering($P_4$)** | 4-6 | | 27.5-33.3 | 20-22.5 | 85-89 | 54-60 | 4.5-6 | 50-115 |
| **Flowering to pod formation($P_5$)** | 4-9 | | 30-31.7 | 19-23.5 | 86-88 | 62-66 | 3.5-4.8 | 115-260 |
| **Pod formation to grain formation($P_6$)** | 4-9 | | **30.7-35.5** | 20.5-23 | **89-92** | **65-70** | 4.5-5 | 55-60 |
| **Grain formation to pod development ($P_7$)** | 4-10 | | 29.5-34.6 | 19.5-22.5 | 84-88 | 62-68 | 4.2-4.6 | 75-130 |
| **Pod development to pod containing full size grain($P_8$)** | 8-10 | | 28-32.5 | 17-22 | 75-84 | 47-62 | 5-8.5 | 40-100 |
| **Pod containing full size grain to dough stage($P_9$)** | 10-15 | | 33.7-34 | 18.5-22.5 | 76-82 | 45-60 | **4.5-9** | 35-55 |
| **Dough stage to maturity($P_{10}$)** | 8-14 | | 32.5-33 | **16-20.5** | **75-80** | **32-45** | **5-10** | **20-30** |

**Temperature ($^0$C)**

The data given in table 4.2.4. showed that the diurnal temperature variation during 2003 to 2017 of soybean crop showed that the highest maximum temperature range (30.7-35.5$^0$C) recorded at pod formation stage and followed by pod containing full size grain to dough stage (33.7-34$^0$C), at pod development stage (28-32.5$^0$C). Mean while, lowest and highest maximum and minimum temperature range recorded at seedling to branching stage i.e. 28-31.7$^0$C and 22.5-24$^0$C and followed by (18.7-24$^0$C) emergence to seedling stage and lowest minimum temperature (16-20.5 $^0$C) recorded at dough stage to maturity of soybean crop.

Khobragade *et al*. (2016) the seed yield and weather variables demonstrated that the high maximum temperature prevailed at pod formation to grain formation and consistently low minimum temperature throughout inter growing season caused reduction in seed yield.

**Relative humidity (%)**

The data given in table 4.2.4. showed that the diurnal relative humidity variation during 2003 to 2017 of soybean crop showed that the highest morning relative humidity range (89-92 %) recorded at grain formation and followed by pod development, seedling stage (84% - 88%) , (81-88%) respectively while lowest morning relative humidity range recorded (75-80%) at dough stage to maturity of soybean crop and the highest afternoon relative humidity range (65% - 70%) recorded at grain formation stage and followed by pod formation stage and sowing to emergence stage (62–66%) and (56% - 70 %) respectively while lowest afternoon relative humidity range was recorded (32% - 45%) at maturity stage of soybean crop in Parbhani location during 2003-2017 (Khobragade *et al.* 2016)

**Bright sunshine hours (hrs)**

The data given in table 4.2.4. showed that the diurnal bright sunshine hours variation during 2003 to 2017 of soybean crop showed that the highest bright sunshine hours range (5-10hrs) recorded at maturity stage and followed by pod containing full grain size to dough stage (4.5-9hrs) respectively while lowest bright sunshine hours range recorded (3.4-4.5 hrs ) at emergence to seedling stage of soybean crop at Parbhani location. The similar results were also found by Khobragade and Karunakar (2016).

## 4.3 Pest data of soybean Girdle beetle, Green semilooper, leaf miner, and *Spodoptera litura* in relation to weather parameters at Parbhani location from 2002 - 2017 ( As per available)

Girdle beetle is one of the most serious pest of soybean. female lay eggs inside the stem up to 200 to 300 eggs. Grub is the damaging stage which is completed in 24 to 38 days. The pupal period is 8 to 10 days. It takes 45 to 55 days for whole life cycle and 1 to 2 generations per year. The incidence of girdle beetle started from $31^{st}$ MW (0.252 %) and first peak activity was observed at $34^{th}$ MW (0.419 %). When the weather conditions Tmax-27.5$^{0}$C, Tmin-15.3$^{0}$C and RH-I 91%, RH-II 76%. The similar results were given by Khobragade *et al.* (2016).

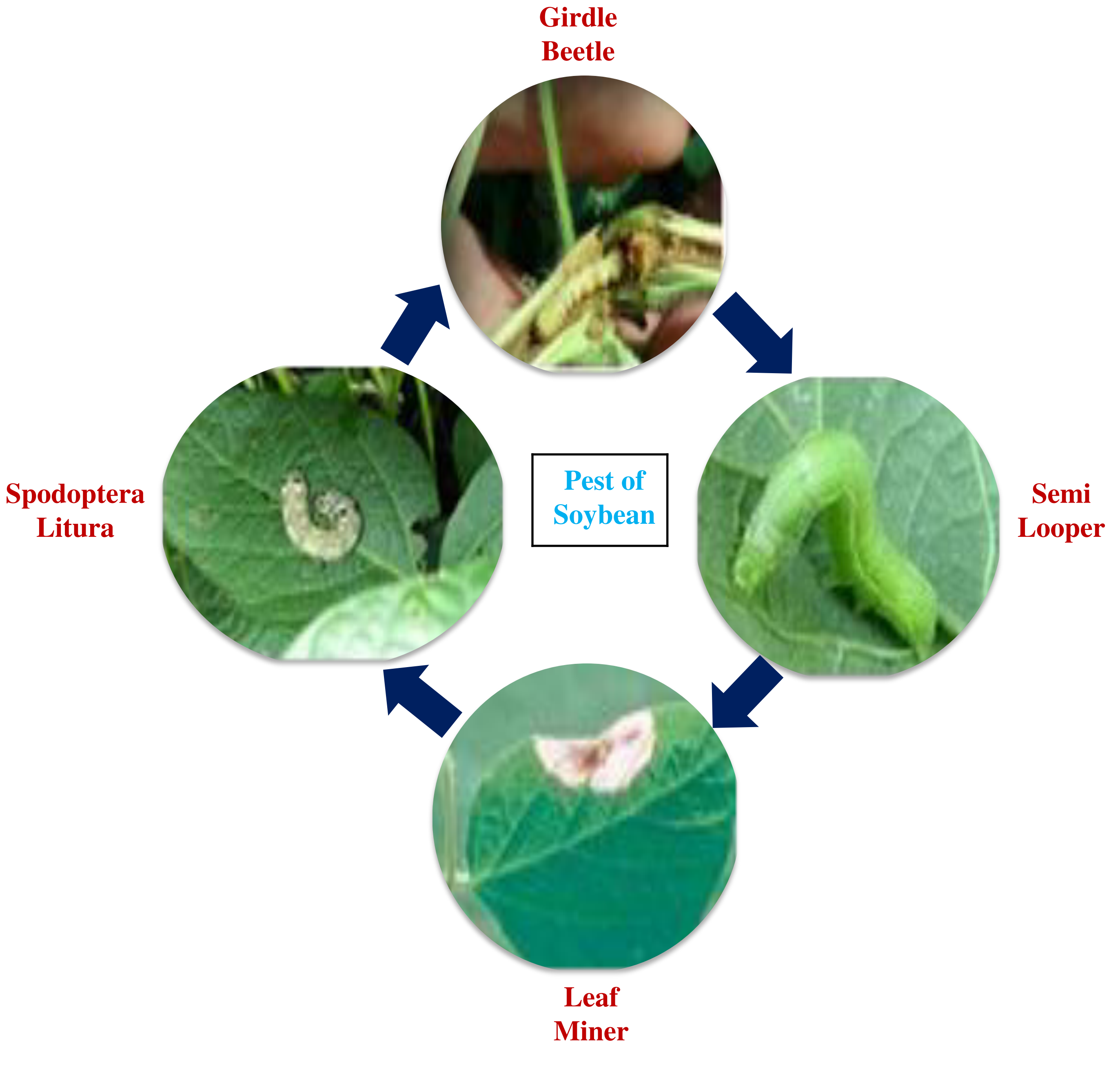
The data presented in table 4.3.1 and fig. 4.3.1 The population of girdle beetle was maximum i.e. 36.9 % during 2015. The weather parameters viz. rainfall, Tmax, Tmin, RH-I, RH-II and BSH were 65.2 mm, 33.4$^{0}$C, 21.7$^{0}$C, 79 %, 49 % and 6.7 hrs. respectively.

The population of girdle beetle, was minimum i.e. 1.25 % during 2002. The weather parameters viz. rainfall, Tmax, Tmin, RH-I, RH-II and BSH were 45.1 mm, 29.8$^{0}$C, 21.6$^{0}$C, 86%, 68% and 6.4 hrs. respectively.

Green semilooper lay 200-300 eggs on leaves. 4 to 5 larval instars are completed in 16 to 18 days. The pupal period lasts for 7 to 8 days and then adult in 6 to 8 days.

The data presented in table 4.3.2 and fig. 4.3.2. The population of green semilooper was maximum i.e. 10.4 larvae/mrl during 2010. The weather parameters viz. rainfall, Tmax, Tmin, RH-I, RH-II and BSH were 69.4 mm, 29.5$^{0}$C, 22.5$^{0}$C, 89%, 60 % and 9.29 hrs. respectively whereas, the population of green semilooper was not recorded in the year 2006.

Leaf miner moths lay single, white shiny eggs on the young foliage. A female can lay up to 473 eggs within average of 186 eggs. Five larval instars are completed in 9 to 17 days. Pupation takes place inside the mine or webbed leaves. The pupal period lasts for 3 to 7 days. The leaf miner has a restricted host range which include groundnut and soybean.




| | |
|---|---|
| **Girdle Beetle** | **Tmax :29.4-33.4⁰C, Tmin 19.7-25.7⁰C, RH-I 79-90%, RH-II 49-70%** |
| **Semilooper** | **Tmax :29.4-31.2⁰C, Tmin 18.6-27.8⁰C, RH-I 69-97%, RH-II45-70%** |
| **Leaf miner** | **Tmax :29-32.2⁰C, Tmin 19.6-25.5⁰C, RH-I-67-90%, RH-II 48-70%** |
| **Spodoptera Litura** | **Tmax :29.5-33.2⁰C, Tmin 19.3-26.8 ⁰C, RH-I-80-89, RH-II 56-70%** |

**Fig. 4.3 : Crop weather pest calendar of Soybean crop under Parbhani location**

**Table 4.3.1 Mean pest of soybean (Girdle beetle) in relation to weather parameters at Parbhani location during 2002-2017**

| Year | Weather Parameter | | | | | | Pest Incidence |
|---|---|---|---|---|---|---|---|
| | RF(mm) | Tmax($^0$c) | Tmin($^0$c) | RH I (%) | RH II (%) | BSH(Hrs) | Girdle beetle % Infestation per plants |
| 2002 | 45.1 | 29.8 | 21.6 | 86 | 68 | 6.4 | 1.25 |
| 2003 | 60.3 | 30.2 | 22.5 | 88 | **70** | 4.8 | 2.2 |
| 2004 | 25.6 | 30.8 | 21.7 | 85 | 65 | 5.4 | 4.6 |
| 2005 | 30.9 | 30.7 | 21.3 | 85 | 66 | 5.1 | 3.4 |
| 2006 | 61.7 | 30.8 | 21.9 | 82 | 64 | 4.5 | 9.33 |
| 2007 | 52.1 | 31.5 | 20.03 | 85 | 62 | 4.6 | 2.69 |
| 2008 | 17.6 | 31.8 | 21.4 | 85 | 63 | 5.5 | 10.7 |
| 2009 | 44.4 | 31.0 | 24.6 | 81 | 58 | 6.01 | 12.7 |
| 2010 | 74.7 | 29.6 | 22.3 | 89 | 68 | 4.6 | 6.3 |
| 2011 | 40.8 | 30.8 | **25.7** | 90 | 65 | 4.4 | 10 |
| 2012 | 35.8 | 30.9 | 22.3 | **90** | 64 | 5.1 | 25.5 |
| 2013 | 42.9 | 29.4 | 21.3 | 85 | 59 | 4.1 | 36.5 |
| 2014 | 61.4 | 32.3 | 20.9 | 82 | 57 | 5.4 | 22.6 |
| 2015 | 65.2 | **33.4** | 21.7 | **79** | **49** | 6.7 | 36.9 |
| 2016 | 52.3 | 30.7 | 21.8 | 88 | 66 | 5.6 | 8.7 |
| 2017 | 40.4 | **29.4** | **19.7** | 86 | 65 | 5.5 | 9.5 |

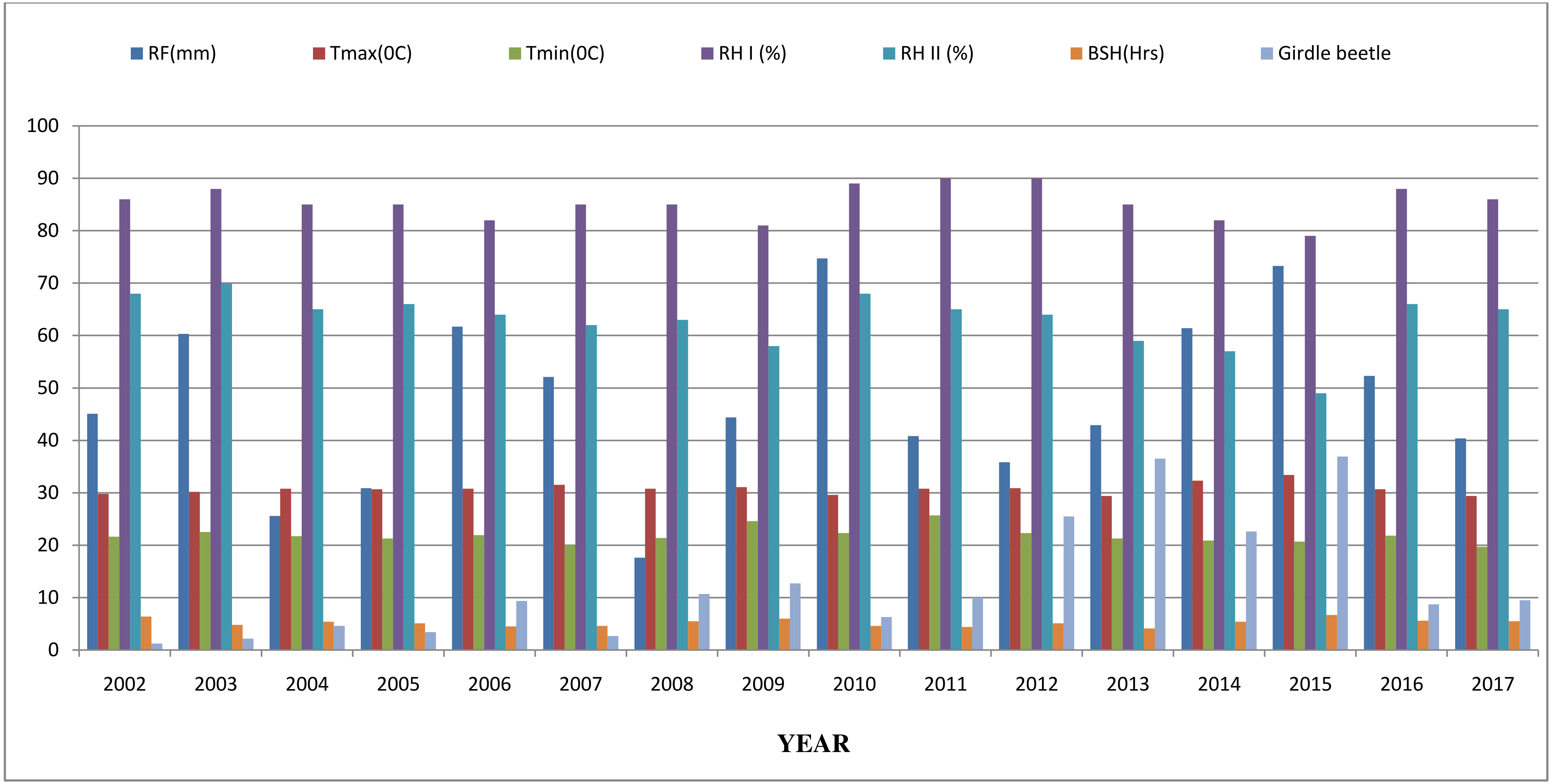



Fig. 4.3.1.Mean pest of soybean (Girdle beetle) in relation to weather parameters at Parbhani location during 2002-2017

**Table 4.3.2 Mean pest of soybean (Green semilooper ) in relation to weather parameters at Parbhani location during 2002-2017**

| Year | Weather Parameter | | | | | | Pest incidence |
|---|---|---|---|---|---|---|---|
| | RF(mm) | Tmax($^0$c) | Tmin($^0$c) | RH I (%) | RH II (%) | BSH(Hrs) | Green Semilooper larvae / mrl |
| 2002 | 39.7 | 30 | 21.4 | **97** | 66 | 4.8 | 1.58 |
| 2003 | 49.9 | 30.03 | 22.2 | 88 | **70** | 4.5 | 7.2 |
| 2004 | 21 | 31.4 | 21.6 | 85 | 64 | 5.1 | 6.3 |
| 2005 | 33.9 | 30.71 | 20.9 | 87 | 65 | 5.05 | 8.2 |
| 2006 | 61.3 | 30.72 | 21.7 | 73 | 64 | 4.9 | 0 |
| 2007 | 52.8 | 31.3 | **19.6** | 86 | 63 | 4.7 | 3.5 |
| 2008 | 34.8 | 30.8 | 21.1 | **69** | 65 | 5.1 | 7.3 |
| 2009 | 47.3 | 30.5 | 27.8 | 78 | 59 | 5.7 | 7.5 |
| 2010 | 69.4 | 29.5 | 22.5 | 89 | 60 | 4.9 | 10.4 |
| 2011 | 36.6 | 30.9 | **27.8** | 89 | 64 | 9.2 | 8.4 |
| 2012 | 41.8 | 31.1 | 22.2 | 90 | 64 | 5.2 | 9.03 |
| 2013 | 55.3 | 28.7 | 21.01 | 83 | 59 | 4 | 0.37 |
| 2014 | 61.3 | 32.2 | 20.5 | 83 | 52 | 6.2 | 2.45 |
| 2015 | 72.7 | **31.2** | 21.3 | 78 | **45** | 6.1 | 1.87 |
| 2016 | 51.5 | 30.8 | 21.8 | 87 | 66 | 6.5 | 4.45 |
| 2017 | 40.3 | **29.4** | 20.9 | 86 | 65 | 6.2 | 2.95 |

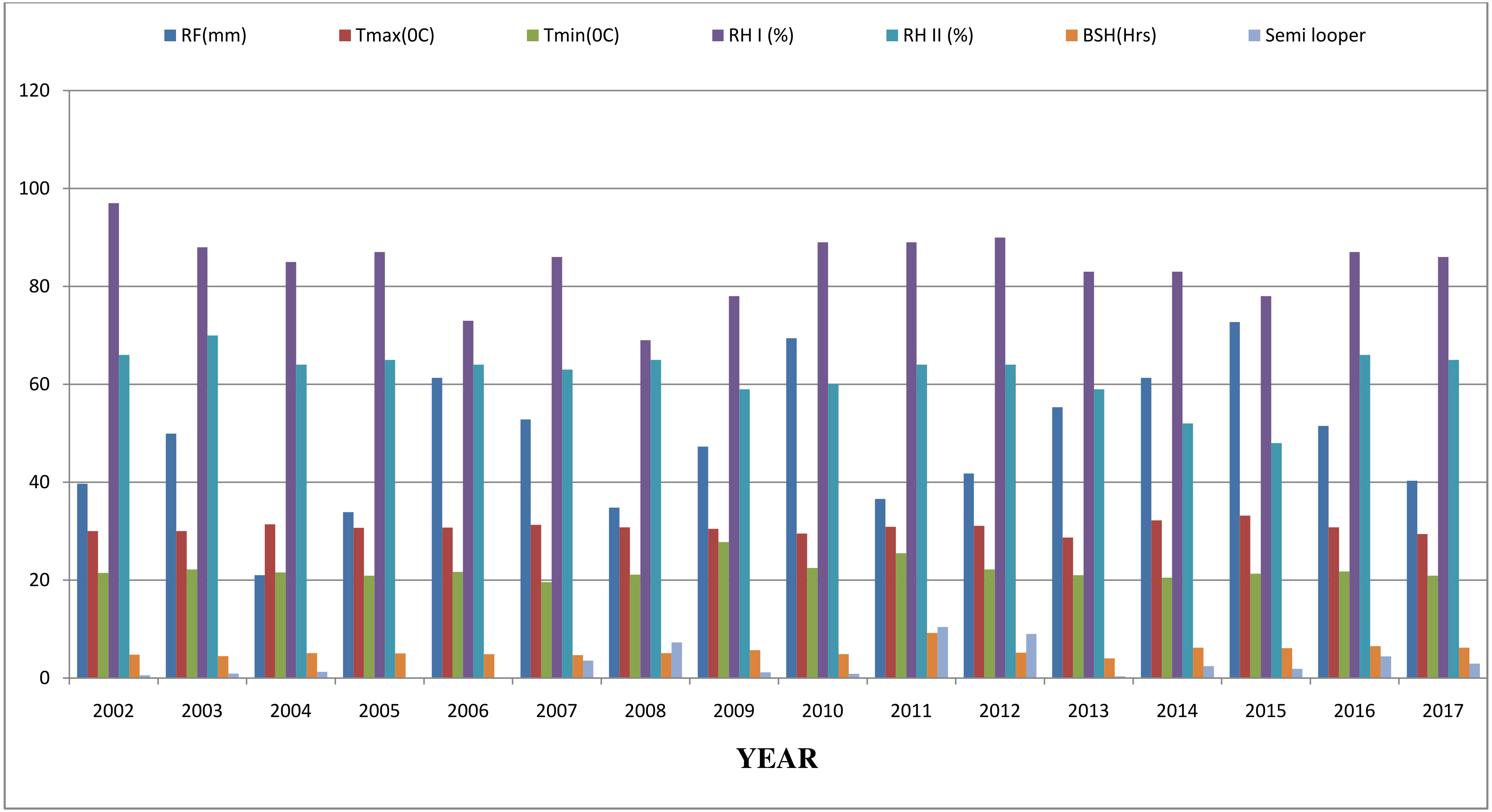



Fig. 4.3.2.Mean pest of soybean (Green semi looper ) in relation to weather parameters at Parbhani location during 2002-2017

**Table 4.3.3 Mean pest of soybean (leaf miner) in relation to weather parameters at Parbhani location during 2002-2017**

| Year | Weather Parameter | | | | | | Pest incidence |
|---|---|---|---|---|---|---|---|
| | RF(mm) | Tmax($^0$c) | Tmin($^0$c) | RH I (%) | RH II (%) | BSH(Hrs) | Leaf miner larvae / mrl |
| 2002 | 39.7 | 30 | 21.4 | **97** | 66 | 4.8 | 4.2 |
| 2003 | 49.9 | 30.03 | 22.2 | 88 | **70** | 4.5 | 0.13 |
| 2004 | 21 | 31.4 | 21.6 | 85 | 64 | 5.1 | 0.08 |
| 2005 | 33.9 | 30.71 | 20.9 | 87 | 65 | 5.05 | 0.05 |
| 2006 | 61.3 | 30.72 | 21.7 | 73 | 64 | 4.9 | 0.82 |
| 2007 | 52.8 | 31.3 | **19.6** | 86 | 63 | 4.7 | 1.98 |
| 2008 | 34.8 | 30.8 | 21.1 | 69 | 65 | 5.1 | 6.32 |
| 2009 | 47.3 | 30.5 | 27.8 | 78 | 59 | 5.7 | 0.19 |
| 2010 | 69.4 | **29.03** | 22.5 | 89 | 60 | 4.9 | 0.14 |
| 2011 | 36.6 | 30.9 | **25.5** | 89 | 64 | 9.2 | 0.56 |
| 2012 | 41.8 | 31.1 | 22.2 | 90 | 64 | 5.2 | 0 |
| 2013 | 55.3 | 28.7 | 21.01 | 83 | 59 | 4 | 0.04 |
| 2014 | 61.3 | 32.2 | 20.5 | 83 | 52 | 6.2 | 0.08 |
| 2015 | 72.7 | **33.2** | 21.3 | **67** | **48** | 6.1 | 5.36 |
| 2016 | 51.5 | 30.8 | 21.8 | 87 | 66 | 6.5 | 0.48 |
| 2017 | 40.3 | 29.4 | 20.9 | 86 | 65 | 6.2 | 2.22 |

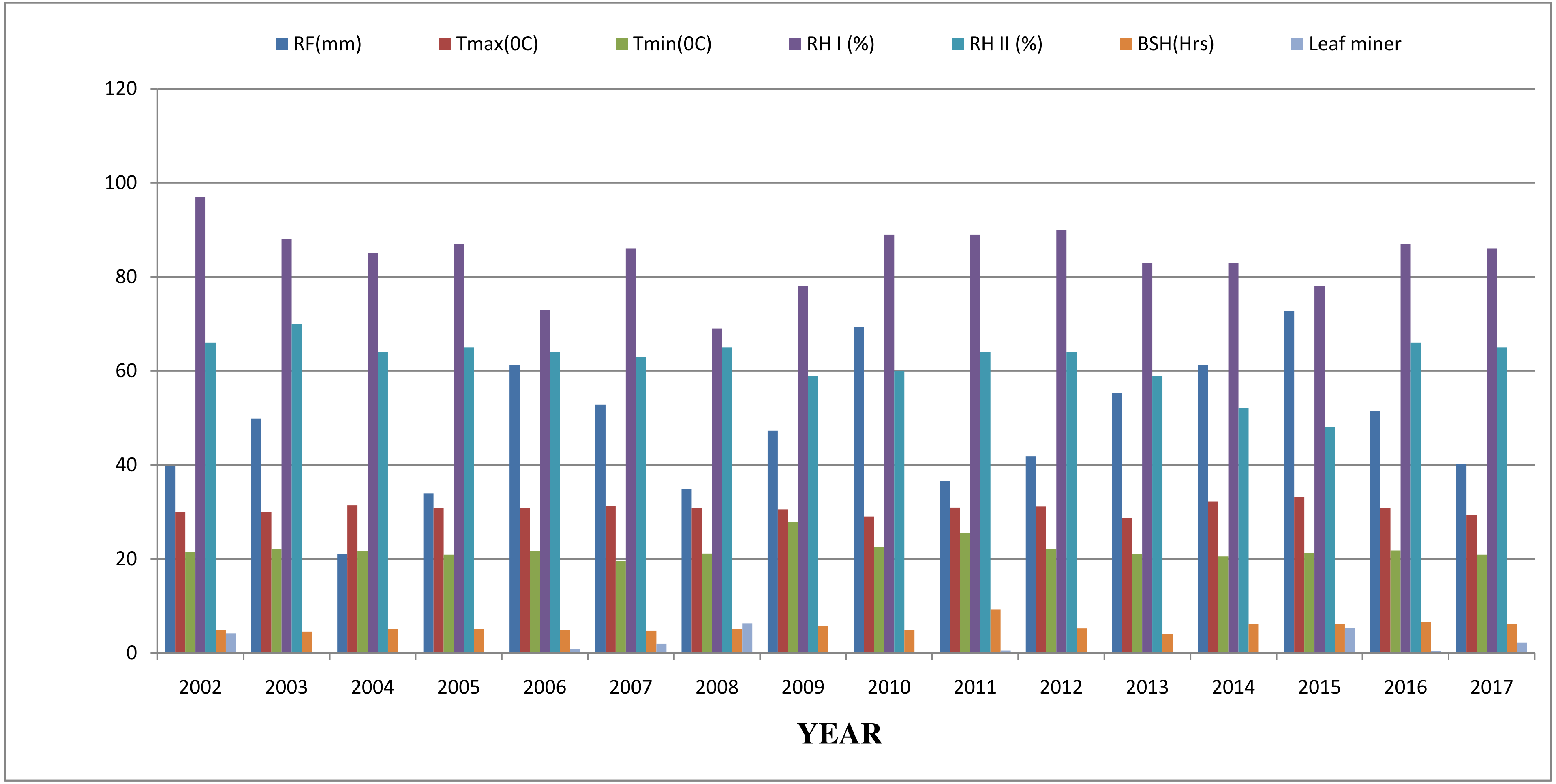



Fig. 4.3.3.Mean pest of soybean (Leaf miner) in relation to weather parameters at Parbhani location during 2002-2017

**Table 4.3.4 Mean pest of soybean (*Spodoptera litura*) in relation to weather parameters at Parbhani location during 2002-2017**

| Year | Weather Parameter | | | | | | Pest incidence |
|---|---|---|---|---|---|---|---|
| | RF(mm) | Tmax($^0$c) | Tmin($^0$c) | RH I (%) | RH II (%) | BSH(Hrs) | Spodoptera litura larvae / mrl |
| 2002 | 43.1 | 29.8 | 21.5 | 86 | 67 | 4.7 | 4.5 |
| 2003 | 55.3 | 30.1 | 22.3 | 88 | **70** | 4.6 | 1.5 |
| 2004 | 21.08 | 31.4 | 21.6 | 85 | 64 | 5.9 | 0 |
| 2005 | 61.8 | 30.7 | 21.8 | 83 | 64 | 4.6 | 0.95 |
| 2006 | 33.5 | 30.6 | 21.05 | 88 | 66 | 5.3 | 9.5 |
| 2007 | 52.5 | 31.4 | 19.7 | 86 | 63 | 4.7 | 3.22 |
| 2008 | 20.01 | 31.0 | 21.3 | 86 | 64 | 5.3 | 1.95 |
| 2009 | 45.1 | 30.9 | 25.7 | **80** | **56** | 5.8 | 2.5 |
| 2010 | 70.8 | 29.4 | 22.5 | 89 | 61 | 5.2 | 2.4 |
| 2011 | 40.2 | 30.9 | **26.8** | **89** | 65 | 4.4 | 2.41 |
| 2012 | 36.4 | 31.1 | 22.1 | 89 | 64 | 5.2 | 3.7 |
| 2013 | 45.2 | 29.0 | 21.4 | 84 | 60 | 4 | 8 |
| 2014 | 61.6 | 32.2 | 20.6 | 86 | 67 | 4.7 | 6.5 |
| 2015 | 83.6 | **33.2** | 21.5 | 88 | 70 | 5.2 | 7.9 |
| 2016 | 51.5 | 30.7 | 21.7 | 87 | 65 | 5.7 | 4.12 |
| 2017 | 42.2 | **29.5** | **19.3** | 87 | 67 | 5.6 | 5.95 |

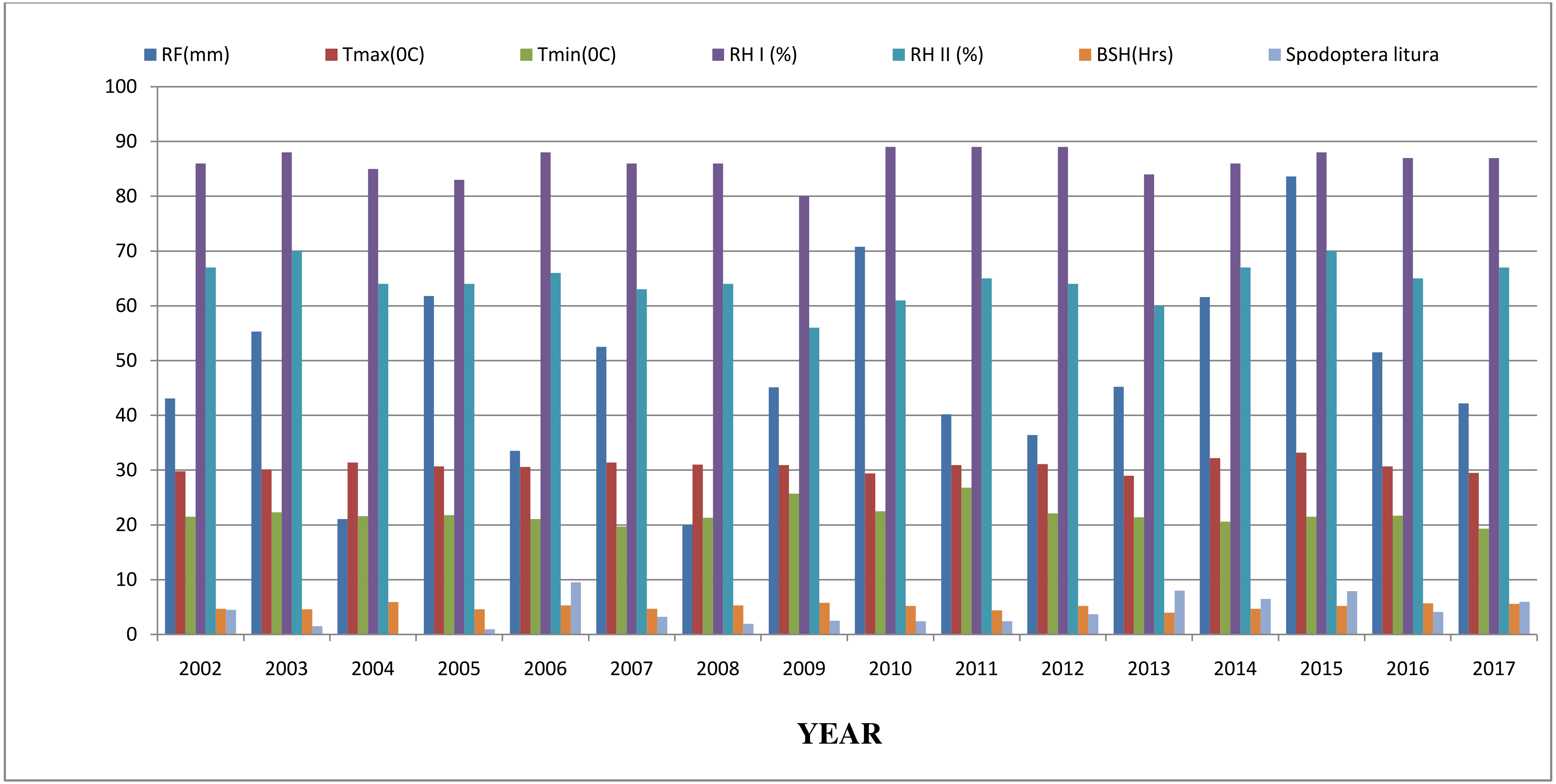


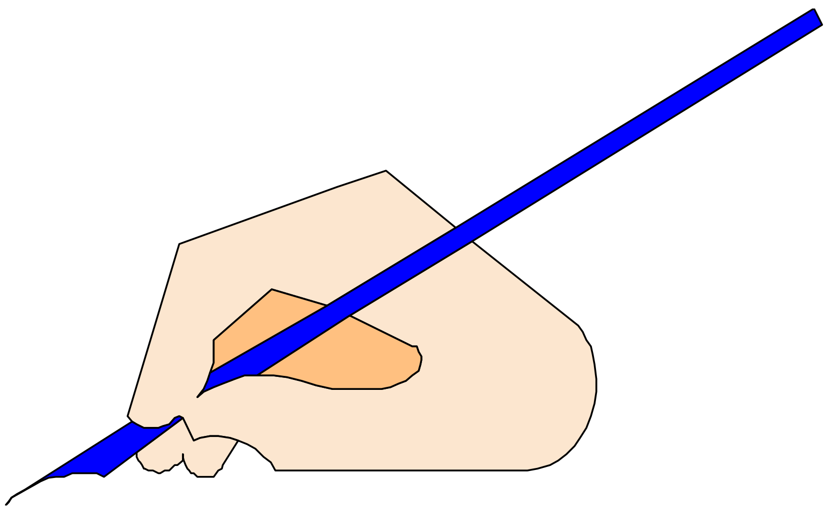

Fig. 4.3.4.Mean pest of soybean (*Spodoptera litura*) in relation to weather parameters at Parbhani location during 2002-2017

The data presented in table 4.3.3 and fig. 4.3.3 The population of leaf miner, was maximum i.e. 6.32 larvae/mrl during 2008. The weather parameters viz. rainfall, Tmax, Tmin, RH-I, RH-II, BSH were 34.83 mm, $30.8^0$C, $21.10^0$C, 69%,65%, 5.1 hrs. respectively and the population of leaf miner was not recorded in the year 2012.

The tobacco caterpillar *Spodoptera litura* has been reported to be a major pest on Soybean. Egg masses containing about 40-400 eggs are laid on leaves. They hatch in 3 to 4 days. Six larval instars are completed in 15-21 days. Adults emerge in about 10 days. The larvae are polyphagous. The incidence of *Spodoptera litura* started from $31^{st}$ MW (0.052) larvae/mrl and increased steadily with its first peak, in $36^{th}$ MW. When the weather conditions Tmax-$30.4^0$C, Tmin-$18.7^0$C, RH-I 80%, RH-II 71% (Khobragade *et al.* 2016).

The data presented in table 4.3.4 and fig. no. 4.3.4 The population of *Spodoptera litura*, was maximum i.e. 9.5 larvae/mrl during 2006. The weather parameters viz. rainfall, Tmax, Tmin, RH-I, RH-II and BSH were 33.5 mm, $30.6^0$C, $21^0$C, 88%, 66% and 5.3 hrs. respectively and he population of *Spodoptera litura* was not reported in the year 2004.

# Chapter-V



# SUMMARY AND CONCLUSIONS

**CHAPTER-V**

# SUMMARY AND CONCLUSION

The present investigation "Preparation of Crop weather calendar of Soybean crop under Parbhani Location" was carried out at Parbhani location. The temperature, humidity, Bright sunshine hours, rainfall data, evaporation and wind speed of Parbhani location were collected for the period of 1988-2017. This data was converted in to the average growing period of soybean with standard meteorological week 23MW to 43MW.

The highest and lowest mean maximum and minimum temperature recorded i.e. 30.9$^0$C and 20.6$^0$C respectively. Among the mean highest and lowest RH–I recorded 88% and 18% during the period of 1988-2017. The average of RH-I throughout the year was 68% due to aberrant weather condition. While afternoon highest and lowest RH –II was recorded 64% and 11% between the years 1988-2017 and total average of RH –II during the years were 45% due to most of the cloudy weather situation. After the most favorable factors, rainfall affected the cropping pattern during the crop growing environment. The total rainfall was recorded highest at Parbhani location (i.e. 1556 mm). The range of mean bright sunshine hours was observed at Parbhani location (i.e. 4.4 -7.5 hrs). In case of evaporation, the highest and lowest mean observed i.e. 6.8 mm in 2015 and 4.0 mm in the year 1998 throughout the year. The mean evaporation recorded 5.2 mm respectively. In respect of wind speed highest and lowest mean wind speed observed was i.e. 9.7 kmhr$^{-1}$ in the year 1989 and i.e. 3.7 kmhr$^{-1}$ during 1998.

In the case of soybean crop the maximum GDD, HTU and PTU requirement was (2332.2 $^0$C days), (14231.3$^0$C days hour) and (i.e. 24234.6$^0$C days hour) found in the year 2003-2017 respectively.

During 2003-2017 the highest GDD accumulated in $D_1$ (8 July 27MW) 178.8$^0$C days as well as highest HTU accumulated $D_4$ (29 July 30MW) i.e. 1121.05$^0$C days hour while highest PTU is accumulated $D_1$ (8 July 27MW) i.e. 1964.9$^0$C days and also maximum GDD accumulated in MAUS-71 163.9$^0$C days while HTU in MAUS-81 i.e.1022.1$^0$C days hour and PTU in MAUS-71 i.e.1958.7$^0$C days hour according to their phenophases the maximum duration of crop accumulated highest heat units.

For Soybean crop ten phenological stages were required according to phenophases. The number of days required was highest from emergence to seedling stage 21-29 days. The lowest number of days required from branching to flowering 4-6 days. The various phenological stages were in relation to weather parameter likes rainfall, temperature, relative humidity, bright sunshine hour. Due to aberrant condition of weather these parameters affected the phenophases of soybean crop.

As per available of pest data the incidence of green semilooper, was maximum i.e. 10.4 larvae/mrl during 2010. The weather parameters viz. rainfall, Tmax, Tmin, RH-I, RH-II and BSH were 69.4 mm, $29^0$C, $22.5^0$C, 89%, 60% and 9.29hrs. respectively.

The population of leaf miner, was maximum i.e. 6.32 larvae/mrl during 2008. The weather parameters viz. rainfall, Tmax, Tmin, RH-I, RH-II and BSH were 34.83 mm, $30.8^0$C, $21.10^0$C, 69%, 65% and 5.1 hrs. respectively.

The population of *Spodoptera litura*, was maximum i.e. 9.5 larvae/mrl during 2006. The weather parameters viz. rainfall, Tmax, Tmin, RH-I, RH-II and BSH were 33.5 mm, $30.6^0$C, $21^0$C, 88%, 66% and 5.3 hrs. respectively.

The population of girdle beetle, was maximum i.e. 36.9 % during 2015. The weather parameters viz. rainfall, Tmax, Tmin, RH-I, RH-II and BSH were 65.2 mm, $33.4^0$C, $21.7^0$C, 79%, 49% and 6.7 hrs. respectively.

# CONCLUSION

1. In crop growing period the highest total Rainfall was observed at Parbhani i.e. 1556.2 mm and lowest i.e.408.1 mm, highest and lowest mean T max 33.7$^0$C and 24.3$^0$C and T min recorded 23.6$^0$C and 11.7 $^0$C, highest and lowest mean RH-I 88% and 18%, highest and lowest mean RH-II 64% and 11% and mean BSS 7.5 hrs and 4.4 hrs respectively in the year 1988-2017.

2. The recorded highest GDD, HTU and PTU for soybean crop recorded 2332.2 $^0$C days, 14231$^0$C days hour and 24234.6$^0$C days hour in the year 2017 with meteorological week 23 MW-43MW respectively. Effect of dates of sowing on accumulated thermal indices at different phenophases during 2003 to 2017. The sowing dates $D_1$ (27MW) accumulated maximum heat units .The variety MAUS-71, MAUS-81, and JS-335 also accumulated heat units during their growing period.

3. The population dynamics studies indicated that, population of green semilooper was more i.e.10.4 larvae/mrl during 2010 as compared to remaining years. The population of leaf miner was more i.e. 6.32 larvae/mrl during 2008. While the population of *Spodoptera litura* was more i.e. 9.5 larvae/mrl during 2006 as compared to throughout the years and the population of girdle beetle was more i.e. 36.9 % during 2015. The micro level i.e. (field experimental level) study is required for accurate results on soybean insect pests population and effect of weather parameters on pest incidence.

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