AGROMETEOROLOGY OF SOYBEAN CROP IN MARATHWADA REGION OF MAHARASHTRA STATE OF INDIA

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MESSAGE

Agrometeorological analysis for different crop / cropping systems is gaining importance in view of the variable climate and occurrence of repeated extreme weather events during the past two decades. Notwithstanding the release of new varieties and improved production technologies, the production levels of *kharif* food crops in Maharashtra that reached up to nine million tonnes has been declining in the past decade. This paradox can be ascribed both to farmers' preference to high value crops resulting in reduction in area under food crops and the impact of frequent adverse weather events. Understanding the role of weather on growth and yield of soybean is important to ensure stable production despite due to climate variability and change. Soybean is an important oil seed crops occupying nearly 15.00 lakh ha. area in Marathwada.

The Technical Bulletin "Agrometeorology of soybean crop in Marathwada region of Maharashtra state of India" brought out by AICRP on Agrometeorology, Parbhani is an important contribution in this context. Even though this publication is not fully comprehensive, the ideas put forth will help in further research programmes to deal with fluctuations in weather and climate. Untimely and adverse weather conditions have taken their toll on the crop in recent years and identification of suitable management practices for such events is essential for taking appropriate ameliorative measures. Another aspect which needs to be looked into is weather based crop insurance. Scientists have to look into various aspects of Agrometeorology to develop multiple methods and tools including a decision support system that would boost farmers' sustainability against the fluctuating weather.

I am sure this publication will serve as a reference guide to different Agrometeorologists, Agronomist, extension personnel and industry and all other Stakeholders. I congratulate the authors for their efforts in bringing out this document.

B. Venkateswarlu
(B. Venkateswarlu)

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AGROMETEOROLOGY OF SOYBEAN CROP IN MARATHWADA REGION OF MAHARASHTRA STATE OF INDIA

1. Introduction

Origin and history:

Soybean (Glycine max (L.) Merrill) is a leguminous crop and belongs to family leguminosae. 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 and easiest source of best quality protein and fat. Soybean was considered as pulse crop but due to high oil seed content and greater response to applied nitrogen, now it is placed in oil crops category.

Adaptation and geographical distribution :

Soybean withstands short period of drought after the plants are well established. Combination of high temperature and low precipitation is unfavourable to soybean. Soybean is sensitive to over-irrigation. Soybean is a short-day plant and is sensitive to photoperiods. It grows on nearly all types of soils. But the most productive soil is fertile loam. Soybean grows well in those soils are too acidic for many other crops.

In India during 2014, area sown under soybean was 108.83 lakh ha with production of 104.37 lakh metric tones and productivity of 959 kg /ha. In Maharashtra area under soybean cultivation was 38.008 lakh ha with production of 30.721 lakh metric tones and productivity of 808 kg/ha. (www.sopa.org/crop.po.doc). In Marathwada region area sown under soybean was 15.10 lakh ha with production of 12.67 lakh metric tones and productivity of 864 kg ha^{-1}. (Anonymous 2014).

Climatic and soil requirements:

Climate :

Soybean is a warm season (tropical) crop but its cultivation now extends to subtropics and temperate climates. The major commercial production is between 25° and 45°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.

Soybean grows well in warm and moist climate. For most soybean varieties temperature between 26.5 to 30 °C appears to be optimal .Soil temperature of 15.5 °C or above favours rapid germination and vigorous seedling growth. The minimum temperature for effective growth is about 10 °C. (Annon., 2007). Soybean is basically a short day plant but response to day length varies with variety and temperature and developed verities 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 days 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 soil 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.

Soil :

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.

Importance of Soybean :

Soybean being legume crop fix atmospheric nitrogen into the soil. It is also referred as green manure crop that sheds about 32 to 35 q/ha of crop residue at the time of harvesting, which not only enriches the soil fertility but also maintain the soil physical condition.

Soybean is a miracle bean. It is having high quantities of protein and fats. Due to its higher protein content, it is known as poor man's meat. It occupies third rank among the nine oil seed crops in India, after Groundnut, Rapeseed and Mustard (Rai et al 2016). Soybean is very useful in preparation of bread, biscuit, cakes, soups and many dishes. Soybean is useful for manufacturing of vanaspati, ghee and several other industrial products.

Nutritional point of view, soybean contains 40-42% protein, 20-22% oil and 20-30 % carbohydrates (Netam et al 2013). It is also rich in soluble phosphate and sulphate, apart from potassium and vitamin E, soybean protein is rich in amino acid like leucine, methionine, threonine that are required by human body. Soybean also contains superior quality oils (high linolic acid) which can be processed to yield high value industrial products like lecithins, paints etc. Besides, these, it has good amount of iron, vitamin B-complex and isoflavones such as daidzein, genesteine of glycine. The presence of calcium and iron makes it highly suitable for women who suffer from osteoporosis and anemia. The isoflavones of soybean have been found to possess health benefits, as they exhibited properties like cancer preventing, combating menopausal problem and helping to recover from diabetes.

Agrometeorological constraints :

Dry spell during the growing season adversely affects the crop. It is observed that maximum reduction in yield due to moisture stress occurs during the last week of pod development and filling stage. Further, water stress at the end of bean filling stage or at beginning of flowering has only small effects on soybean yield but stress during flowering and pod development appears to be responsible for flower and pod abortion. Stress during seed filling reduces seed size.

2. Agro-climatic characteristics of the growing region

Maharashtra falls in the 9th zone known as the Western Plateau and hills region.The state has been divided into 9 agro-climatic (NARP) zones. The Central Maharasthra Plateau Zone/ Assured rainfall zone also known as Marathwada region is one of the 9 agroclimatic Zones of the state.

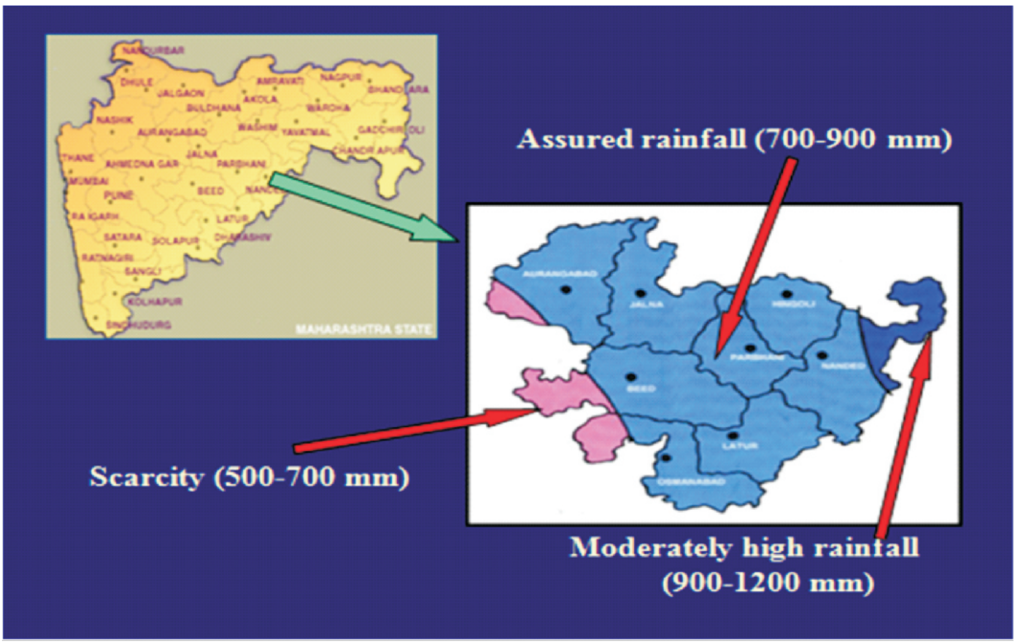

Fig. 1.1 Regions having different climate

Marathwada region of Maharashtra state comprises of eight districts, geographically lies between $17^{0}35'$ to $20^{0}40'$ N latitude and $74^{0}40'$ to $78^{0}16'$ E longitude. The altitude ranges between 300 m to 900 m above mean sea level. The total geographical area of the region is 64.5 lakh ha with 57.0 lakh ha suitable for agriculture. Out of total cultivable area 52 per cent soils are medium deep, 28 per cent are shallow and 20 per cent are deep black soils. The soils of Marathwada are low in available nitrogen; low to medium in available phosphorus however, available potash is in abundance (Maniyar et al., 2007).

The climate of Marathwada experiences wide inter district and intra district variability. About 80 per cent of annual rainfall is concentrated between the months of June to September. Aurangabad and Jalna experiences moist climate during rainy season, cold and dry during winter season, while Beed district experiences humid climate during rainy season, hot and dry conditions during rest of the part of the year. Nanded, Osmanabad, Latur, Parbhani and recently established Hingoli district are climatically very hot summer and cool winter.

Trends in production and productivity of Soybean crop in Marathwada region

The district wise production and productivity of soybean in Marathwada region are depicted in Fig. 1.2. The data are presented as the mean for the period pertaining to 1994 to 2013. Latur district recorded highest production of 1619.00 (00mt) and highest productivity in Parbhani district of 1251.00 (kg ha^{-1})

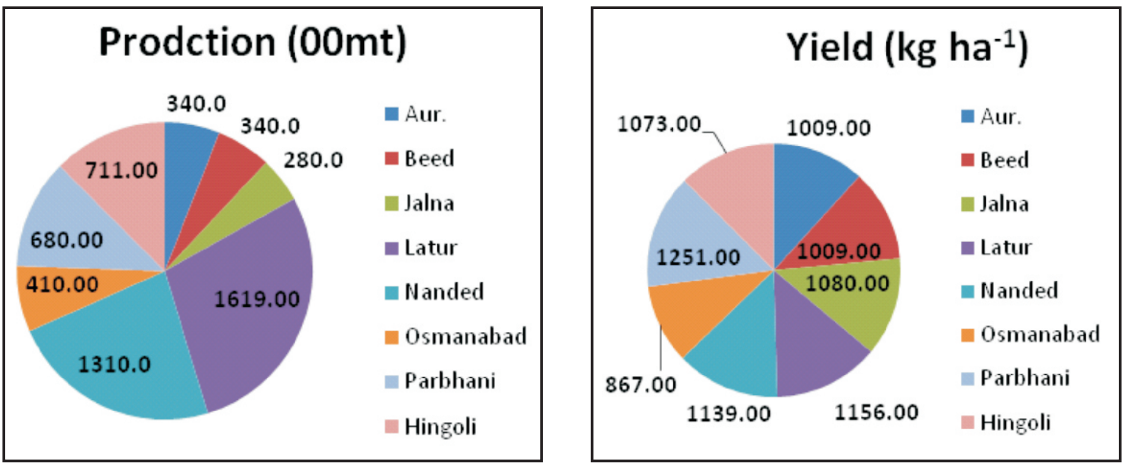

Fig. 1.2 Trends in production & Productivity of Soybean in Marathwada region (1994-2013)

Spatial weather variability of growing region :

Weather is a critical factor influencing the production of crops in any region. It is viewed by agronomists and meteorologists as a dominant climatic element influencing yield and acreage behaviour of crops while agricultural economists look at the levels of technology and other measurable inputs. The weather, like other inputs such as land, labour, high-yielding variety (HYV) seeds, fertilizers, pesticides, etc. is also a direct input to agriculture. While both sets of factors are crucial, measurable inputs are controllable, weather is not. More specifically, in a state of backward agriculture where the technology adoption and diffusion are very slow or nearly nil, the weather factors count more than others because of their direct and indirect effects on crops.

The functional relationship between weather and yield is as much complicated as the term ‘weather’ itself. In a broad definition of the term, many factors can be included in ‘weather’. However, the complexity of the term ‘weather’ gets resolved as only precipitation and temperature are mostly considered in many studies as the important factors out of many others like wet days, humidity, sunshine, wind velocity, storm, snowfall, etc. due to lack of data availability on all those factors. The functional relationship between weather factors (like rainfall and temperature) and the crop yield remains the most elusive and mysterious till today and a matter of intense debate, though research in this area dates back to 1900s. In spite of the daunting efforts being made by the research community to study the nature of relations existing between these two sets of variables, the problem continues to remain unresolved. The point that gives more impetus to initiate fresh research is that understanding of the precise linkage between weather and crop yield could provide potential implications of the effects of climate change on food security and consequently, it can facilitate some kind of institutions for securing crops from the vagaries of weather. In India, research in the area of crop-weather relations has been relatively very little.

Weather indices can be fixed on the basis of weather parameters required for particular crop according to growth stages for their optimal growth. The components of weather indices include measurable weather variable such as temperature or rainfall, a specified duration, and specified weather station. Once the weather data has been obtained, indices can be derived by how the weather variables have impacted crop yields over time. In addition, weather indices will account for the impact of weather factors on crops during different stages of development.

In methodology it is consisted that the collection of historological weather and crop data of each district of the Marathwada region. The data has collected from the different agromet observatories present at different centers which comes under V.N.M.K.V, Parbhani, So data of weather parameters collected from 23 MW to 6 MW.

Weather Data collected during 1994-2013 (23 MW to 6 MW) from state department of agriculture, statistical department, District collectorate office, Agricultural related websites, Department of Agricultural Meteorology, V.N.M.K.V.,Parbhani, India Meteorological Department, Pune. Etc

The collected data (meteorological) of each district were summed up on the basis of crop season of soybean production and yield of Marathwada region (Maharashtra).

The data was converted in to the average growing period of crop i.e. seasonally (23MW to 43MW), (23 MW to 5 MW), (24 MW to 40 MW) and (45 MW to 6 MW) for Kharif and rabi crop basis.

Standard dates of sowing (i.e 15^{th} June to end of July) recommended for soybean crop by Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

District wise Maximum temperature and minimum temperature (°C) and rainfall between 1994-2013 in Marathwada region

The data presented in Table 1.1 and Fig.1.3 to 1.9 showed that highest average maximum temperature recorded in Nanded and Beed (31.5 °C), followed by Latur (31.1 °C), Parbhani (30.7 °C), Aurangabad (30.5 °C), Jalna (30.4 °C) and Osmanabad (30.2 °C) districts respectively. During crop growing environment maximum temperature fluctuate district wise.

Name of District / Weather parameter	Auran gabad	Beed	Jalna	Latur	Nanded	Osman abad	Parbhani	Hingoli
Maximum Temperature (°C)	30.5	31.5	30.4	31.1	31.5	30.2	30.7	—
Minimum Temperature (°C)	21.5	19.1	21.4	21.2	22.5	19.2	21.3	—
Rainfall (mm)	644.6	717.5	692.5	780.0	722.9	553.8	705.7	907.3

Lowest mean minimum temperature was recorded in Beed (19.1 °C) followed by Osmanabad (19.2 °C), Latur (21.2 °C), Parbhani (21.3 °C), Jalna (21.4 °C), Aurangabad (21.5 °C) and Nanded (22.5 °C) district respectively. During crop growing environment minimum temperature fluctuate districtwise.

The highest mean precipitation received at Hingoli station (i.e. 907.3 mm) followed by Beed (i.e. 717.5 mm), Parbhani (i.e.705.7 mm), while lowest precipitation recorded at Osmanabad station (i.e. 553.8 mm) and Aurangabad (i.e. 644.6 mm) respectively.

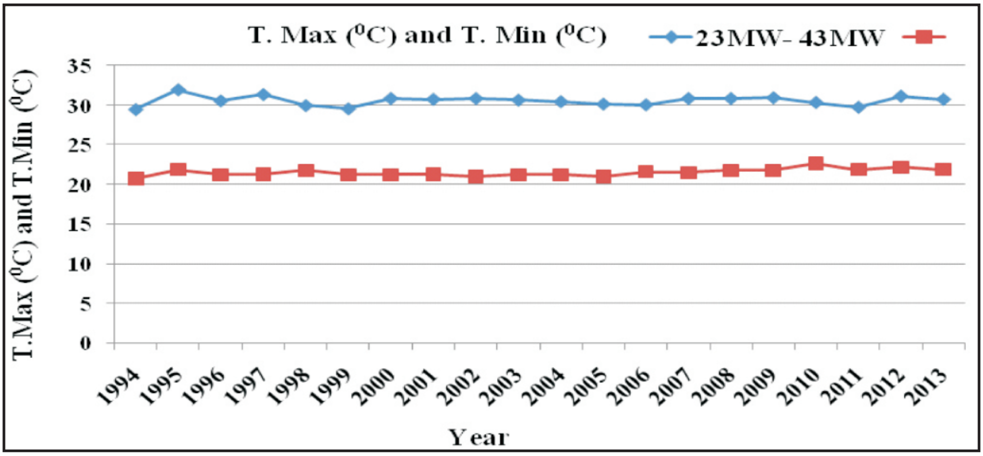

Fig.1.3 Yearly average maximum temperature and minimum temperature recorded in different meteorological week at Aurangabad

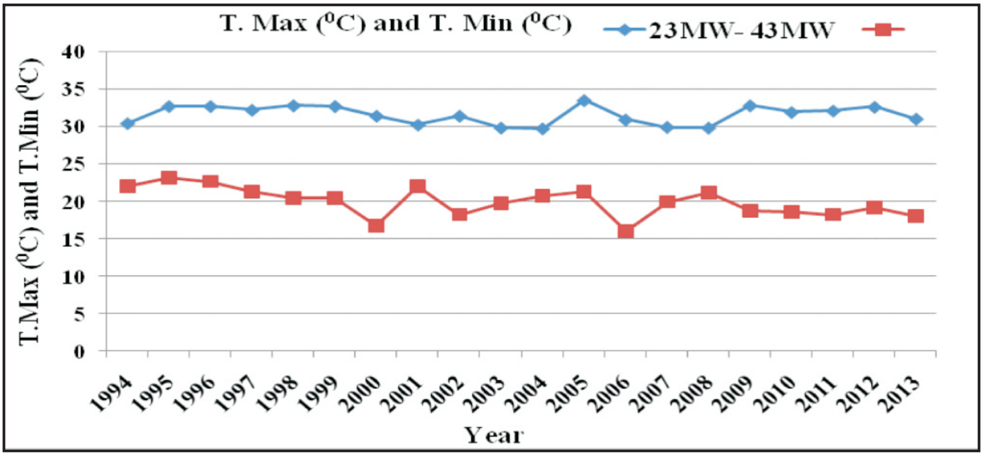

Fig.1.4 Yearly average maximum temperature and minimum temperature recorded in different meteorological week at Beed

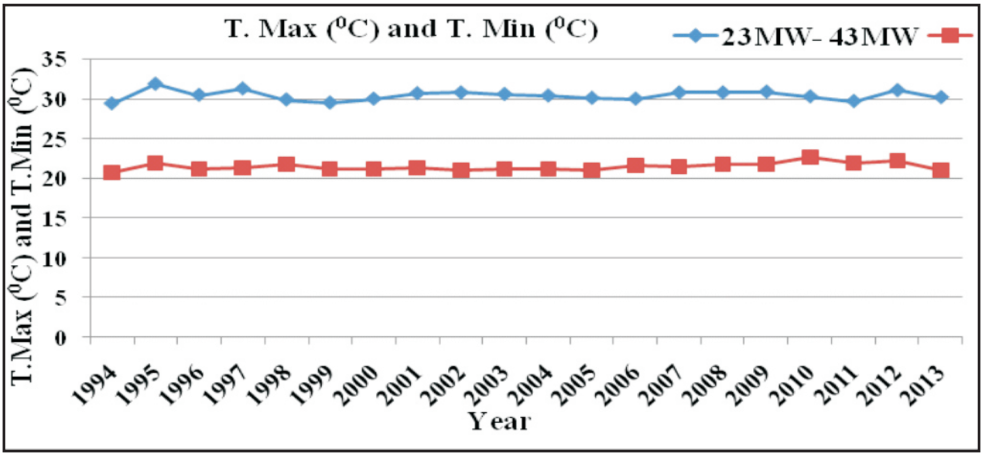

Fig.1.5 Yearly average maximum temperature and minimum temperature recorded in different meteorological week at Jalna

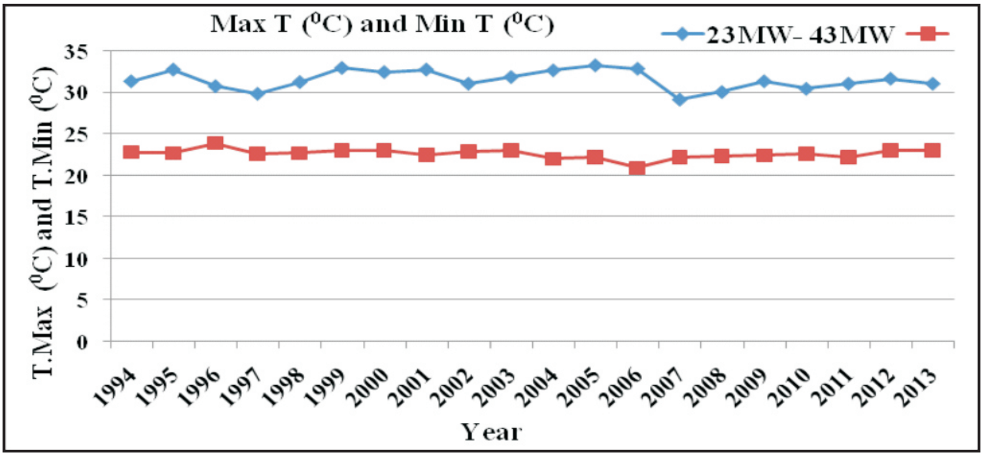

Fig.1.6 Yearly average maximum temperature and minimum temperature recorded in different meteorological week at Nanded

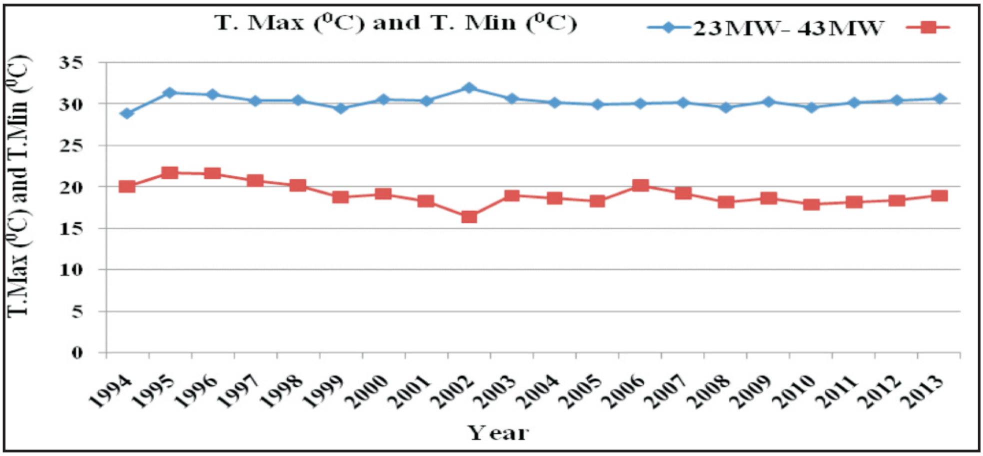

Fig.1.7 Yearly average maximum temperature and minimum temperature recorded in different meteorological week at Osmanabad

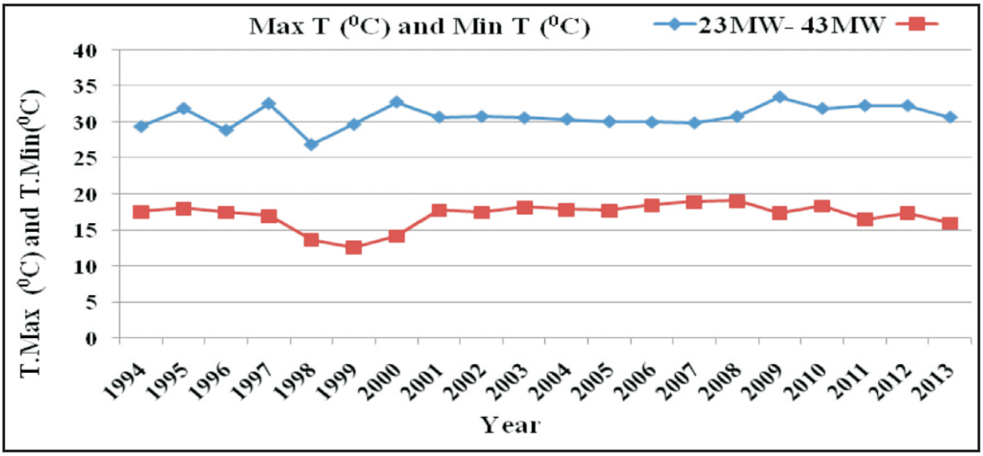

Fig.1.8 Yearly average maximum temperature and minimum temperature recorded in different meteorological week at Parbhani

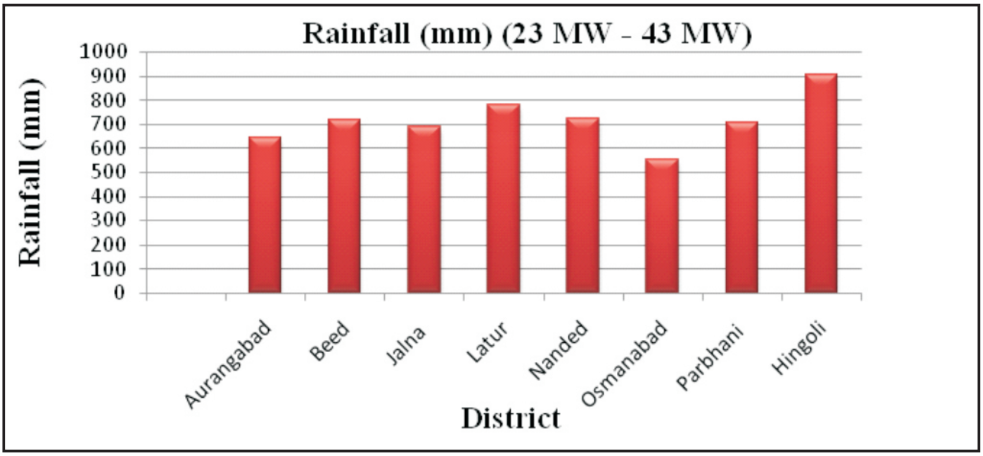

Fig. 1.9 Yearly average Rainfall recorded in different meteorological week in Parbhani during 1994-2013

Computation of Agrometeorological indices for Marathwada region Average cumulative GDD, HTU and PTU of Soybean crop in Marathwada region (1994-2013)

The graph presented in Fig. 1.10 revealed that highest requirement of growing degree days (^{0}C day) were recorded in Nanded district (1643^{0}C day) and lowest in Osmanabad (1505 ^{0}C day) while in case of Helio thermal unit highest HTU were recorded in Aurangabad (8930^{0}C day) and lowest HTU were observed in Osmanabad district (8128 ^{0}C day). Therefore maximum requirement of photo thermal unit was observed in Nanded district (18550 ^{0}C day) and minimum requirement of PTU was observed in Osmanabad district (17011 ^{0}C day) in soybean crop.

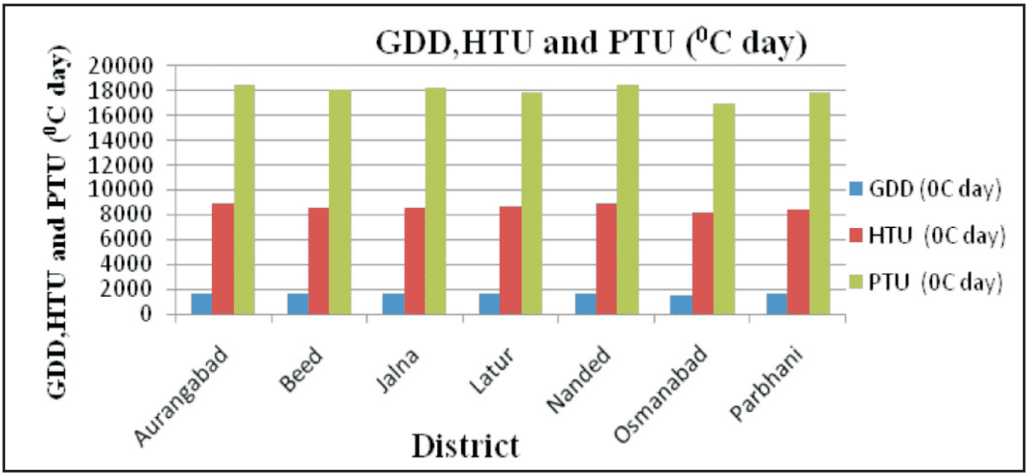

Fig. 1.9 Average cumulative GDD, HTU, and PTU Soybean crop of different district of Marathwada region (1994-2013)

3. Crop weather relation studies:

The weather conditions prevailed during the crop growing season i.e. Kharif 2003-2013 are presented graphically by plotting different meteorological elements average over standard meteorological weeks. The weather elements discussed viz. rainfall, air temperature, relative humidity, evaporation, bright sun shine hours and wind velocity. Weather conditions prevailed at Parbhani during the crop growing season and its impact on growth, development and yield of soybean crop.

Field experiments conducted at Experimental Farm, Department of Agricultural Meteorology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani under AICRP on Agrometeorology on soybean crop during kharif 2003-2013 to assess the impact of agro ecological environment on growth and yield of soybean and to identify suitable genotypes for varied weather conditions with four dates of sowing in different meteorological week i.e. 27 MW, 28 MW, 29 MW and and 30 MW with six cultivars i.e. MAU-2 (V1), MAUS-32 (V2), MAUS-47(V3), MAUS-71(V4), MAUS-81(V5) and JS-335 (V6) using layout of split plot design.

The above mentioned the Fig.1.11 the highest seed yield was observed in dates of sowing and varietal performance i.e. D3 V4 (1873.9 kg ha^{-1}) and lowest in D4 V3 (i.e. 1101.1 kg ha^{-1}) and it was recorded during 2003-2013. The seed yield and weather variables demonstrated that the high maximum temperatures prevailed at pod formation to grain formation and consistently low minimum temperatures throughout entire growing season caused reduction in seed yield.

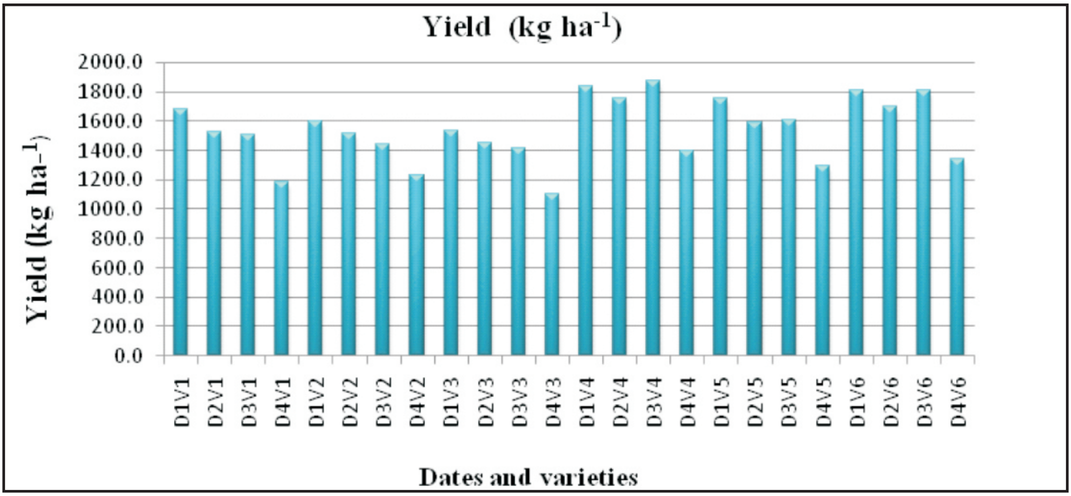

Fig. 1.11 Comparative Yield of soybean recorded during different sowing dates & varieties in different growing environment (27MW-43MW) of Soybean crop during 2003-2013 at Parbhani district

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 of the specific developmental phases for the maximization of crop yield during the crop life cycle of soybean in the field condition.

Table 1.2 : Mean number of days required to complete different phonophases of soybean (phenophases) during the life cycle of soybean crop during 2003-2013 at Parbhani district

Sr. No.	Phenological stage of soybean	Number of days required different phenophases	Duration of Crop for different sowing dates
1	Sowing to emergence	4-6	D1-MW27 (93-112 days) D2-MW28 (92-115 days) D3-MW29 (94-112 days) D4-MW30 (93-114 days)
2	Emergence to seedling	21-29	
3	Seedling to branching	4-8	
4	Branching to flowering	3-6	
5	Flowering to pod formation	4-8	
6	Pod formation to grain formation	4-8	
7	Grain formation to pod development	4-10	
8	Pod development to pod containing full size grain	8-10	
9	Pod containing full size grain to dough stage	10-15	
10	Dough stage to maturity	8-15	

In the present investigation, the whole life cycle of soybean crop (from sowing to physiological maturity) was divided into 10 distinct phenophases which was shown in the Table 1.2 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 2003-2013. The overall number of days taken for physiological maturity was 92 to 115 which was shown in the Table 1.2. When crop sown in meteorological week i.e. MW 27, MW 28, MW 29 and MW 30 respectively.

The result showed that the range during 2003 to 2013, number of days required for maturity when crop was sown under D_1 (MW 27) were 93-112 days, D_2 (MW 28) 92-115, D_3 (MW 29) 94-112 and D_4 (MW 30) 93-114 during the crop growing season. Delay in the sowing induced the early flowering in the soybean crop, as the day length increases 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 of temperature.

Further, the variation in the maturity period in all the treatments 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.

Effect of weather variables on growth and yield :

In Maharashtra, mainly the soybean is cultivated as rainfed crop. The adverse climatic conditions especially rainfall, higher humidity temperature etc. reduces the seed yield and seed quality in kharif season as crop become more prone to insect and disease incidence. This unfavourable environmental conditions not only causes the reduction in yield but also affect the germination per cent in kharif soybean production.

Correlation and regression studies

The correlation and regression studies were undertaken to assess the impact of different variables prevailed during the crop growing period for the various phenological stages. The phases considered for the study are sowing to emergence (P_1), emergence to seedling (P_2), seedling to branching (P_3), branching to flowering (P_4), flowering to pod formation (P_5), pod formation to grain formation (P_6), grain formation to pod development (P_7), pod development to pod containing full size grain (P_8), pod containing full size grain to dough stage (P_9) and dough stage to maturity (P_{10}). The correlation coefficient between seed yield and weather variables prevailed in different phenophases of soybean are presented in Table 1.3 to 1.8. and Regression models developed between yield and weather parameter during different phenological stages of six varieties and presented in table 1.9 to 1.14.

The data presented in table 1.3 to 1.8 reveled that during P_8 (pod development to pod containing full size grain) and P_9 (pod containing full size grain to dough stage) rainfall showed positive association with seed yield in all varieties. Whereas, maximum temperature showed negative association with yield during P_1 to P_7 stage. It was therefore, infered that high day time temperatures in the early phase affected seed yield by causing loss of early phenological potential for biomass accumulation. In variety V2 (MAUS-32) negative association of maximum temperature on yield observed in P_6 (-0.34*) and P_8 (-0.51**) stages while in variety V3 (MAUS-47) the negative effect was in P_3 (-0.35*), P_5 (-0.30*), P_8 (-0.33*) and P_9 (-0.35*) . However, the observed negative association maximum temperature with seed yield in varieties V4 (MAUS-71),V5 (MAUS-81) and V6 (JS-335) was observed in most of the growth stages from P_1 to P_{10}.

Table 1.3. Correlation coefficient between seed yield and weather variables prevailed during different phenophases of Soybean Variety MAUS-2 from 2003 to 2013

PARAMETER	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
RAINFALL	0.06	0.14	0.06	0.12	-0.23	0.097	0.22	0.40**	0.38*	0.23
T.MAX.	-0.02	-0.13	0.00	-0.20	-0.18	-0.22	-0.10	-0.30*	-0.32*	0.11
T.MIN.	0.21	0.47**	0.20	0.49**	0.62**	0.55**	0.52**	0.52**	0.75**	0.63**
BSS	-0.21	-0.20	-0.18	-0.32*	-0.31*	-0.47**	-0.66**	-0.78**	-0.81**	-0.66**

* = Significant at 5% level, ** = Significant at 1% level

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-seed 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 1.4. Correlation coefficient between seed yield and weather variables prevailed during different phenophases of Soybean Variety MAUS-32 from 2003 to 2013

PARAMETER	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
RAINFALL	0.15	0.06	-0.11	0.08	-0.23	-0.19	0.29	0.32*	0.44**	0.22
T.MAX.	-0.27	-0.14	-0.22	-0.17	-0.00	-0.34*	-0.27	-0.51**	-0.28	-0.07
T.MIN.	0.04	0.33*	0.10	0.34*	0.41**	0.45**	0.35*	0.36*	0.59**	0.51**
BSS	-0.29	-0.11	-0.31*	-0.20	-0.36*	-0.49**	-0.63**	-0.67**	-0.69**	-0.01

* = Significant at 5% level, ** = Significant at 1% level

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-seed 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 1.5. Correlation coefficient between seed yield and weather variables prevailed during different phenophases of Soybean Variety MAUS-47 from 2003 to 2013

PARAMETER	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
RAINFALL	0.02	0.06	0.15	0.09	-0.03	0.05	0.12	0.26	0.37*	-0.02
T.MAX.	-0.09	-0.10	-0.35*	-0.08	-0.30*	0.21	-0.27	-0.33*	-0.35*	-0.26
T.MIN.	0.02	0.20	0.02	0.30*	0.31*	0.25	0.24	0.19	0.31*	0.33*
BSS	-0.03	0.02	-0.15	-0.18	-0.25	0.00	-0.35*	-0.56**	-0.55**	0.58**

* = Significant at 5% level, ** = Significant at 1% level

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-seed 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 1.6. Correlation coefficient between seed yield and weather variables prevailed during different phenophases of Soybean Variety MAUS-71 from 2003 to 2013

PARAMETER	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
RAINFALL	0.01	0.06	-0.22	0.17	0.16	0.06	0.25	0.41**	0.17	0.04
T.MAX.	0.03	0.17	-0.07	-0.11	-0.19	0.02	-0.21	-0.17	-0.19	-0.01
T.MIN.	0.02	0.08	0.16	0.24	0.19	0.30*	0.27	-0.01	0.14	0.09
BSS	-0.12	0.00	-0.11	-0.22	-0.31*	-0.40**	-0.44**	-0.66**	-0.51**	-0.49**

* = Significant at 5% level, ** = Significant at 1% level

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-seed 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 1.7. Correlation coefficient between seed yield and weather variables prevailed during different phenophases of Soybean Variety MAUS-81 from 2003 to 2013

PARAMETER	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
RAINFALL	0.00	0.05	-0.20	0.18	0.18	0.09	0.21	0.42**	0.28	0.01
T.MAX.	0.00	0.20	0.06	-0.10	-0.15	0.02	-0.16	-0.18	-0.33*	-0.01
T.MIN.	-0.02	0.09	0.06	0.19	-0.09	0.01	0.01	0.07	0.20	0.11
BSS	-0.09	0.08	-0.05	-0.22	-0.25	-0.41**	-0.37*	-0.62**	-0.57**	-0.46**

* = Significant at 5% level, ** = Significant at 1% level

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-seed 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 1.8. Correlation coefficient between seed yield and weather variables prevailed during different phenophases of Soybean Variety JS-335 from 2003 to 2013

PARAMETER	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
RAINFALL	0.04	0.02	-0.21	0.17	0.18	0.11	0.22	0.42**	0.19	0.01
T.MAX.	0.01	0.14	-0.03	-0.16	-0.15	0.03	-0.23	-0.14	-0.26	-0.05
T.MIN.	-0.03	0.08	0.13	0.14	0.17	0.32*	0.27	0.02	0.17	0.11
BSS	-0.08	0.08	-0.10	-0.19	-0.22	-0.39**	-0.38**	-0.63**	-0.51**	-0.47**

* = Significant at 5% level, ** = Significant at 1% level

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-seed 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

Minimum temperature however, showed positive relationship at all the phonological stages in all the six cultivars. In variety V1 (MAUS-2) and V2 (MAUS-32) minimum temperature showed significantly positive association during eight out of ten phases there by indicating the influence of higher minimum temperature on seed yield in there two variety. In variety V3 (MAUS-47) observed positive relation was significant in P_4 (0.30*) to P_5 (0.31*) and P_9 (0.31*) to P_{10} (0.33*) stages only. In case of bright sun shine hours, growth stages exhibited negative association with seed yield in all the varieties, it was significant from P_7 to P_{10} growth stages of all varieties. Rainfall and bright sun shine hours played a great role, either directly or indirectly, in the expression of yield than any other source of variation in the yield of all varieties over the years 2003-2013.

Weather based yield prediction model

Weather parameters influencing the soybean growth and development were identified through correlation analysis and those weather parameters showing significant correlations in different phenological stages of the crop were used to develop yield prediction equations through stepwise regression technique. The result in equations are presented in table 1.9 to 1.14.

The regression coefficient values indicated that major weather parameter were very important as plant water requirement around growth stages of soybean crop. In case of Variety MAUS-47 the range of R^2 values is increased from P_7 (0.12), P_8 (0.32), P_9 (0.31) and P_{10} (0.34). The BSS are significant to produce the yield. Meanwhile Variety MAUS-71 the R^2 values was increased from P_5 (0.09), P_6 (0.16), P_7 (0.20) and P_8 (0.43) stage. The maximum R^2 values was observed for bright sunshine hours during P_7 to P_{10} stage was relatively stable but across sowing it ranged from 4.0 to 6.5 hrs.

Table 1.9 Regression equation for seed yield and weather variables prevailed in different phenophases of Soybean Variety MAUS-2) from 2003 to 2013

STAGE	REGRESSION EQUATION (YIELD vs MAUS-2)	R^2
P1	————-	
P2	Y= - 7256.045 + 400.694 TMIN	0.22
P3	————-	
P4	Y= - 5474.65 + 344.757 TMIN - 96.263 BBS	0.24
P5	Y= - 11661.771 + 607.891 TMIN	0.38
P6	Y= - 8261.772 + 486.009 TMIN - 142.935 BSS	0.30
P7	Y= - 1624 - 127-232.192 BSS + 208.305 TMIN	0.44
P8	Y= 3385.418 - 280.530 BSS	0.60
P9	Y= 3435.231- 258.201 BSS	0.66
P10	Y= 3057.734 -199.237 BSS	0.43

(Where, Y = Dependant variable, T.Min. = Minimum temperature, BSS = bright sun shine hours)

Table 1.10 Regression equation for seed yield and weather variables prevailed in different phenophases of Soybean Variety MAUS-32 from 2003 to 2013

STAGE	REGRESSION EQUATION (YIELD vs MAUS-2)	R^2
P1	———-	
P2	Y= - 2999.374 + 202.866 TMIN	0.11
P3	Y= 1856.942 - 89.586 BSS	0.10
P4	Y= - 2410.458 + 178.503 TMIN	0.12
P5	Y= - 3111.244 + 230.137 TMIN - 80.584 BSS	0.17
P6	Y= - 3780.025 - 121.073 BSS + 269.803 TMIN	0.24
P7	Y= 2640.118 - 211.044 BSS	0.40
P8	Y= 2593.091 - 169.814 BSS	0.45
P9	Y= 2651.372 - 162.170 BSS	0.47
P10	Y=132.018 + 74.639 TMIN	0.26

(Where, Y = Dependant variable, T.Min. = Minimum temperature, BSS = bright sun shine hours)

Table 1.11 Regression equation for seed yield and weather variables prevailed in different phenophases of soybean Variety MAUS-47 from 2003 to 2013

STAGE	REGRESSION EQUATION (YIELD vs MAUS-2)	R^2
P1	———-	——-
P2	—————	——
P3	Y= 5242.996 - 126.965 TMAX	0.12
P4	Y= - 642.404 + 93.598TMIN	0.09
P5	Y=1464.547 + 135.622 TMIN - 97.833 TMAX	0.09
P6	———	——
P7	Y= 1906.244 - 99.640 BSS	0.12
P8	Y= 2244.789 - 161.231 BSS	0.32
P9	Y= 2191.563 -126.302 BSS	0.31
P10	Y=2210.961 - 116.582 BSS	0.34

(Where, Y = Dependant variable, T.Min. = Minimum temperature, BSS = bright sun shine hours)

Table 1.12 Regression equation for seed yield and weather variables prevailed in different phenophases of Soybean Variety MAUS-71) from 2003 to 2013

STAGE	REGRESSION EQUATION (YIELD vs MAUS-2)	R^2
P5	Y= 2208.693 - 103.430 BSS	0.09
P6	Y= 2444.017 - 136.645 BSS	0.16
P7	Y= 2718.693 - 189.236 BSS	0.20
P8	Y= 3110.390 - 229.387 BSS	0.43
P9	Y= 2811.094 - 158.615 BSS	0.26
P10	Y= 2713.549 - 133.668 BSS	0.24

(Where, Y = Dependant variable, BSS = bright sun shine hours)

Table 1.13 Regression equation for seed yield and weather variables prevailed in different phenophases of Soybean Variety MAUS-81 from 2003 to 2013

STAGE	REGRESSION EQUATION (YIELD vs MAUS-2)	R^2
P6	Y= 2239.401 - 126.961 BSS	0.16
P7	Y= 2320.851 - 143.291 BSS	0.13
P8	Y= 2744.839-195.257 BSS	0.39
P9	Y=2678.827 - 161.518 BSS	0.33
P10	Y= 2430.976 - 116.371 BSS	0.22

(Where, Y = Dependant variable, BSS = bright sun shine hours)

Table 1.14 Regression equation for seed yield and weather variables prevailed in different phenophases of Soybean Variety JS-335 from 2003 to 2013

STAGE	REGRESSION EQUATION (YIELD vs MAUS-2)	R^2
P6	Y= 2353.100 - 129.158 BSS	0.15
P7	Y= 2488.406 - 155.591 BSS	0.15
P8	Y= 2933.017 - 208.650 BSS	0.40
P9	Y= 2708.872 - 151.191 BSS	0.26
P10	Y= 2590.815 - 124.078 BSS	0.22

(Where, Y = Dependant variable, BSS = bright sun shine hours)

4. Weather effect on pest relationship:

Collection of data

Parbhani district is selected from marathwada region. The long term soybean pest data was collected from All India Co-ordinated Research Project on Soybean V.N.M.K.V. Parbhani. The data of pest incidence during 2002 to 2013 years for four major pests of Soybean viz. *Spodoptera litura,* Girdle beetle, Green Semi looper, and Leaf miner were collected.

Weekly meteorological data for the Parbhani district during the same years was collected from Department of Agricultural Meteorology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

Correlation between weather parameters and major pests of Soybean

Incidence of soybean pests (girdle beetle, semilooper,leaf miner and spodoptera litura) was studied in relation to weather paramentrs. Pest population dynamics were analyzed using correlation based on the dataset of 2002-2013 presented in Table 1.15.

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). Minimum temperature and BSS showed significant positive association in the buildup of girdle beetle population. 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). Correlation coefficient values were relatively on the higher side for girdle beetle.

Table No. 1.15 Correlation coefficients between weather parameters and Soybean pest during 2002- 2013 (Pooled data)

Parameter / Pest	Rainfall (mm)	Tmax. (^{0}C)	Tmin. (^{0}C)	RH-I (%)	RH-II (%)	BSS (Hrs)
Girdle beetle	-0.19*	-0.55**	0.70**	-0.60**	-0.70**	0.26**
Semilooper	0.02	0.12	0.03	0.07	0.05	-0.09
Leaf miner	0.02	-0.04	0.30**	-0.05	-0.22**	-0.22
Spodoptera litura	-0.04	0.03	-0.17*	0.19*	-0.09	-0.17

*significant at 5%   ** significant at 1%

Regression equation for Soybean pest and weather parameters (2003-2013 pooled data)

Weather parameters influencing the soybean growth and development were identified through correlation analysis and those weather parameters showing significant correlations in different pest of the crop were used to develop yield prediction equations through statistical method. The resultant relations are presented in Table 1.16.

Table . 1.16. Weather based yield prediction models for soybean crop

PEST	REGRESSION EQUATION	R^2
Girdle beetle	Y= -21.027+ 0.08010 RF + 1.020 Tmax + 0.2744 Tmin + 0.3014 RH I - 0.644 RH II – 0.0742 BSS	0.51
Leaf miner	Y= - 4.4274+0.0445 RF + 1.2060 Tmax + 0.751 Tmin + 0.0484 RH I - 0.198RH II + 0.0289 BSS	0.11
Green Semilooper	Y= - 0.1534 + 0.0048 RF + 0.4321 Tmax + 0.1150 Tmin + 0.02022 RH I + 0.02076 RH II – 0.1247 BSS	0.05
Spodoptera litura	Y= 0.2662 – 0.00048 RF – 0.02550 Tmax – 0.0969 Tmin + 0.02689 RH I – 0.00729 RH II + 0.0235 BSS	0.05

(Where, Y = Dependant variable, Tmax.= Minimum temperature, Tmax.= Maximum temperature, RH I = morning relative humidity, RH II = Afternoon relative humidity and BSS = bright sun shine hours)

5. Crop contingency of Marathwada region:

As desired by the Parliamentary Consultative Committee the district-level contingency plans are to be prepared for all the major weather related aberrations including extreme events viz., droughts, floods, heat wave, cold wave, untimely and high intensity rainfall, frost, hailstorm, pest and disease outbreaks. These plans need to integrate information for agriculture and allied sectors.

In this regard there was a need to develop a standard template to ensure a uniform format for providing contingency strategies across the country. The challenge is to bring uniformity in format so that it can be computerized in future with options to retrieve information for any district and at the same time accommodate the regional varieties in climate and cropping patterns. Detailed strategies for weather related contingencies in the case of crops/cropping systems starting with delay in onset of monsoon and mid season breaks resulting in drought both in rainfed and irrigated situations and strategies for untimely rains, floods, extreme events.

In rainfed districts, drought is frequent. Floods are common in river basin/catchment/canal command areas when heavy rains occur. Cyclones are devastating in nature in coastal areas. Hailstorms are basically physiographic, weather and season related. Heat wave, cold wave, frost are localized temperature extreme events for short periods causing extensive crop damage. Certain pests and diseases are triggered by weather events and result in outbreaks causing severe losses to both crops and animals. It is pertinent to identify the proneness of the district to one or more major weather related aberrations (regular or sporadic) so as to focus in developing appropriate contingency strategies.

Strategies for weather related contingencies

Drought :

Drought is a recurrent phenomenon resulting from deficit in soil moisture and or water both in rainfed and irrigated areas. The effect is pronounced due to delays in onset of monsoon, prolonged breaks in monsoon and deficit rainfall, inflows into water bodies or poor recharge leading to reduction in cropped area, cropping intensity, dip in crop and livestock productivity and sometimes total crop failures adversely impacting rural livelihoods and economy.

Rainfed situation :

Contingent planning for rainfed crops is important when the onset of monsoon is delayed. Generally the south west monsoon covers the whole of the country in 8 weeks time starting first of June. Historical monsoon behaviour indicates the delays by 2 to 6 weeks across the country and in exceptional cases by 8 weeks. The contingency measures suggested against the normal crop / cropping systems are in the form of alternate choice of crop / cropping systems, appropriate cultivars, and changes in agronomic measures.

A. Early season drought (delay in onset of monsoon by 2, 4, 6 and 8 weeks)

a. **Major farming situation:** Provides information on growing environment (rainfall and soil information - color, depth & texture) such as low rainfall shallow red sandy loam soils, high rainfall deep black soils, uplands, medium lands, eroded hill slopes etc.

b. **Normal crop or cropping system**: The normal crops / cropping systems adopted in a given farming situation.

c. **Change in crop / cropping system including variety:** Based on the extent of delay in monsoon and the sowing window for the major crops for a given farming situation, changes in crop / cropping systems are suggested. These suggestions are based on research conducted by the local agricultural research stations.

d. **Agronomic measures:** Again based on the extent of delay in monsoon and major farming situation, appropriate agronomic measures are suggested for alternate crops / cropping systems. These measures are mostly related to sowing operations such as increase in seed rate, changes in spacing, intercropping in case of sole crops and inter terrace land management practices like ridges and furrows, dust mulching, broad bed furrow method of planting etc.

B. Normal onset on monsoon followed by early, mid-season and terminal drought

The crop is sown under normal onset of monsoon. However, dry spells occur at various stages during the cropping season resulting in early, mid-season and terminal droughts adversely impacting performance of standing crops.

i) Early season drought due to 15-20 days dry spell after sowing

In case of normal onset followed by early season dry spell immediately after sowing leading to poor germination and poor crop establishment, re-sowing, gap filling, thinning may be necessary depending upon the crop and soil type. In addition, moisture conservation measures, nutrient management and life saving irrigation wherever possible are suggested.

ii) Mid-season drought at vegetative and reproductive stages of crop

In case of mid season drought, crop, soil nutrient management and moisture conservation measures are suggested. These include intercultivation for weed management, mulching and other in situ moisture conservation measures, protective irrigation, split or postponement of fertilizer application, foliar sprays of nutrients or anti-transpirants etc.

iii) Terminal drought

In case of terminal drought due to dry spells or early withdrawal of the south west monsoon, crop management measures such as life saving irrigation are suggested as in the case of mid season drought wherever feasible. In case of impending crop failure, harvesting at physiological maturity or early harvest of grain crops and use as fodder for livestock are suggested. In case of total crop failure, early *rabi* crop planning with suitable crops/varieties is suggested

Drought in irrigated situation

Contingent planning for irrigated crops is also important under conditions such i) delayed release of water due to low rainfall ii) limited release of water in canals due to low rainfall iii) non-release of water in canals under delayed onset on monsoon in catchment area iv) lack of inflows into tanks due to insufficient / delayed onset of monsoon and v) insufficient groundwater recharge due to low rainfall. The contingency measures suggested against the normal crop / cropping systems are in the form of alternate choice of crop / cropping systems, appropriate cultivars, and changes in agronomic measures along with suggested linkages with ongoing governmental schemes / programmes in the district.

a. Major Farming Situation: Provides information on farming situations describing physiography, soils and source of irrigation such as tank fed medium or deep black/loamy/red soils, tube well irrigated red soils, canal irrigated red soils, well irrigated black soils etc. This is important as with in a district there are distinct soil-climatic regions which require different strategies.
b. Normal crop or cropping systems grown in a given irrigated situation
c. Change in the crop, variety or cropping system is indicated in view of delay in release of irrigation water, less water availability etc.
d. Agronomic measures like improved methods of irrigation (skip row etc.), micro irrigation (drip/sprinkler/sub-surface), deficit irrigation, limited area irrigation, mulching etc, that improve water use efficiency and make best use of limited water including methods of ground water recharge and sharing are indicated.

Unusual rains (untimely, unseasonal) both in rainfed and irrigated situations

In the recent past, continuous high rainfall in a short span leading to water logging and heavy rainfall coupled with high speed winds in a short span are being experienced at various growth stages of annual and perennial crops leading to serious crop losses, outbreak of pests and diseases and sometimes total crop failure. These events at post-harvest stages lead to huge economic losses due to low prices and marketing failures of poor quality or damaged produce. The livestock and poultry sector suffer due to short supply of quality feed and fodder.

Suggested contingency measures include re-sowing, providing surface drainage, application of li hormones/nutrient sprays to prevent flower drop or promote quick flowering/fruiting and plant protection measures against pest/disease outbreaks with need based prophylactic / curative interventions. At crop maturity stage suggested measures include prevention of seed germination and harvesting of produce. Post harvest measures include shifting of produce to safer place for drying and maintaining the quality of grain/fodder and protection against pest/disease damage in storage etc.

Crop contingency of Marathwada region:

Contingency crop planning of Marathwada region are presented in tabular form.

Strategies for weather related contingencies

Drought

Rainfed situation

Condition			Suggested Contingency Measures	
Early season drought (delayed onset)	**Major Farming situation**	**Normal Crop / Cropping system**	**Change in crop / cropping system including variety**	**Agronomic Measures**
Delay by 2 weeks 4th week of June	Medium deep to deep black soils with assured rainfall	Soybean	No change Use MAUS 71, MAUS 81, MAUS158, MAUS 162	Sowing on Ridges and furrow or by BBF planter
	Shallow black soils with assured rainfall	Soybean/Soybean+ PP (4:2)	No change Use MAUS 71, MAUS 81, MAUS158, MAUS 162	Sowing on Ridges and furrow or by BBF planter
Delay by 4 weeks 2nd week of July	Medium deep to deep black soils with assured rainfall	Soybean	No change or intercropping with pigeonpea in 4:2 or 2:1 row proportion or cotton + soybean (1:1 or 2:1) Use MAUS 71, MAUS 81, MAUS 158, MAUS 162 and for pigeonpea BSMR 736, 853 BDN 708, 711 for intercropping	Normal package of practices recommended by VNMKV, Parbhani or adopt 10% more seed rate than recommended. Follow *in situ* soil moisture conservation measures Sowing on Ridges and furrow or by BBF planter

Condition			Suggested Contingency Measures	
Early season drought (delayed onset)	**Major Farming situation**	**Normal Crop / Cropping system**	**Change in crop / cropping system including variety**	**Agronomic Measures**
		Soybean	No change or intercropping with pigeonpea in 4:2 or 2:1 row proportion or cotton + soybean (1:1 or 2:1) Use MAUS 71, MAUS 81, MAUS 158, MAUS 162 and for pigeonpea BSMR 736, 853 BDN 708, 711 for intercropping	Normal package of practices recommended by VNMKV, Parbhani or adopt 10% more seed rate than recommended. Follow *in situ* soil moisture conservation measures Sowing on Ridges and furrow or by BBF planter
	Medium deep to deep black soils with low rainfall (Vaijapur and Gangapur tehsils)	Soybean	Soybean (JS-335, MAUS-71)+ Pigeon pea (BSMR 736, BSMR 853, BDN 708, BDN- 711) in 4 : 2 row proportion	Normal package of practices recommended by VNMKV, Parbhani or adopt 10% more seed rate than recommended. Follow *in situ* soil moisture conservation measures Sowing on Ridges and furrow or by BBF planter
	Shallow black soils with assured rainfall (Vaijapur and Gangapur tehsils)	Soybean	Pearl Millet+ Pigonpea, Prefer varieties like ICTP-8203, GHB- 558, AIMP-92901 Shardha, Saburi + Pigeon pea (BSMR 736, BSMR 853, BDN 708, BDN- 711) 2:1, 3:3	Normal package of practices recommended by VNMKV, Parbhani

Condition			Suggested Contingency Measures	
Early season drought (delayed onset)	**Major Farming situation**	**Normal Crop / Cropping system**	**Change in crop / cropping system including variety**	**Agronomic Measures**
Delay by 6 weeks 4th week of July	Medium deep to deep black soils with assured rainfall	Soybean	Soybean (JS-335, MAUS-71)+ Pigeon pea (BSMR 736, BSMR 853, BDN 708, BDN- 711) in 4 : 2 row proportion	Normal package of practices recommended by VNMKV Parbhani
	Shallow black soils with assured rainfall	Soybean	Pearl millet (ICTP-8203, GHB- 558, AIMP-92901, Shradha, Saburi)+ Pigeon pea (BDN- 711) in 4:2 row proportion/ Soybean (JS-335, MAUS-71) + Pigeon pea (BDN-711) in 4 : 2 row proportion	Normal package of practices recommended by VNMKV, Parbhani (or) adopt 20-25% more seed rate than recommended and reduce fertilizer dose by 25 per cent.
	Medium deep to deep black soils with low rainfall (Vaijapur and Gangapur tehsils)	Soybean	Pearl millet (ICTP-8203, GHB- 558, AIMP-92901, Shradha, Saburi)+ Pigeon pea (BDN-711) in 4:2 row proportion / Soybean (JS-335, MAUS-71)+ Pigeon pea (BDN-711) in 4 : 2 row proportion	Normal package of practices recommended by VNMKV, Parbhani (or) adopt 20-25% more seed rate than recommended and reduce fertilizer dose by 25 per cent.

Condition			Suggested Contingency Measures	
Early season drought (delayed onset)	**Major Farming situation**	**Normal Crop / Cropping system**	**Change in crop / cropping system including variety**	**Agronomic Measures**
Delay by 8 weeks 2nd week of August	Medium deep to deep black soils with assured rainfall	Soybean	Pearlmillet, Sunflower	Follow *in situ* soil moisture conservation measures like alternate furrow opening with Balaram plough.
	(Gangapur tehsils)		Pearlmillet, Sunflower	Follow *in situ* soil moisture conservation measures like alternate furrow opening with Balaram plough.
Normal onset followed by 15-20 days dry spell after sowing leading to poor germination / crop stand etc.	Medium deep to deep black soils with assured rainfall	Soybean	Raise pigeonpea seedlings in polythene bags and transplant when sufficient soil moisture is available. or if the plant population is less than 50% go for re sowing of the crop	Avoid applying fertilizers till sufficient soil moisture is available Interculture with weeding or harrows or hoe Dust mulching Sowing on Ridges and furrow
	Shallow black soils with assured rainfall	Soybean	-do- or if the plant population is less than 50% go for re sowing of the crop	-- do --

Condition			Suggested Contingency Measures	
Mid season drought (long dry spell, consecutive 2 weeks rainless (>2.5 mm) period)	**Major Farming situation**	**Normal Crop / Cropping system**	**Change in crop / cropping system including variety**	**Agronomic Measures**
At vegetative stage	Medium deep to deep black soils with assured rainfall	Soybean	Interculture for weeding and to create soil mulch.	Opening of furrow after every 4 or 6 row with Balaram plough Spraying of 1% KNO3
	Shallow black soils with assured rainfall	Soybean	Gap filling within the rows with same or short duration cultivar to maintain at least 75% plant population	Opening of furrow after every 4 or 6 row with Balaram plough
	Medium deep to deep black soils with low rainfall (Vaijapur and Gangapur tehsils)	Soybean	Gap filling within the rows with same or short duration cultivar to maintain at least 75% plant population	Opening of furrow after every two row with Balaram plough Spraying of 2% urea or DAP
	Shallow black soils with low rainfall (Vaijapur and Gangapur tehsils)	Soybean	Gap filling within the rows with same or short duration cultivar to maintain at least 75% plant population	Opening of furrow after every 4 or 6 row with Balaram ploug

Condition			Suggested Contingency Measures	
Mid season drought (long dry spell)	**Major Farming situation**	**Normal Crop / Cropping system**	**Crop Management**	**Soil Nutrient & moisture conservation measures**
At flowering / fruiting	Medium deep to deep black soils with assured rainfall	Soybean	Give protective irrigation with sprinkler	• Foliar spray of 1% KNO_3 or 2 % urea or 2 % DAP.
	Shallow black soils with assured rainfall	Soybean	Give protective irrigation with sprinkler	• Foliar spray of 1% KNO_3 or 2 % urea or 2 % DAP.
	Medium deep to deep black soils with low rainfall (Vaijapur and Gangapur tehsils)	Soybean	Give protective irrigation with sprinkler	-----
	Shallow black soils with low rainfall (Vaijapur and Gangapur tehsils)	Soybean	Give protective irrigation with sprinkler	• Foliar spray of 1% KNO_3 or 2 % urea or 2 % DAP.

Condition			Suggested Contingency Measures	
	Major Farming situation	Normal Crop / Cropping system	Crop Management	Soil Nutrient & moisture conservation measures
Terminal drought (Early withdrawal of monsoon)	Medium deep to deep black soils with assured rainfall	Soybean	Life saving irrigation	Plan for *Rabi* crops chickpea / safflower
	Shallow black soils with assured rainfall	Soybean	Life saving irrigation with sprinkler	––
	Medium deep to deep black soils with low rainfall (Vaijapur and Gangapur tehsils)	Soybean	Life saving irrigation with sprinkler	––

Unseasonal rainfall and wind damage

Field Crops	Suggested Contingency Measures			
	Vegetative stage	Flowering stage	Crop maturity Stage	Post harvest
Soybean	Provide drainage to drain excess water	Provide drainage to drain excess water	Timely harvest of produce at physiological maturity stage	Timely harvest of produce at physiological maturity stage

6. Summary

The report presented the weather data and climatic variability patterns field experiment during the year 2003-2013 at AICRP on Agrometeorology centre, under Vasantrao Naik Marathwada Krishi Vidyapeeth,Parbhani.

In marathwada region showed that maximum average temperature recorded in Nanded and Beed (31.5 ^{0}C) and minimum temperature were recorded in Beed and Osmanabad (19.1^{0}C and 19.2^{0}C) respectively during crop period .

Overall Eight district of precipitation received during the crop growing season i.e. 23 MW to 43 MW during 2003-2013. The highest mean precipitation received at Hingoli district (907.3 mm) followed by Beed (717.5 mm) respectively.

The high relative humidity prevailed in pod development stage stage of crop may have resulted in good seed yield of soybean by favouring low relative humidity (dry air) is one of the major factors influencing seed yield of soybean. The highest seed yield was observed with dates of sowing and varietal performance i.e. D3 V4 (1873.9 kg ha^{-1}) and lowest with D4 V3 (i.e. 1101.1 kg ha^{-1}) and it was recorded during 2003-2013.

In case of emergence to seedling maximum temperature ranged from 30.0^{0}C to 33.3^{0}C due to which emergence in MW 29 (D_3) and MW 30 (D_4) was better than other date of sowing. It means that the duration of higher temperature was found to decrease as sowing was delayed. This maximum temperature prevailed during crop growing period have effect on seed yield of soybean and also on the duration of crop season in different date of sowing. Rainfall showed positive association with seed yield in all varieties.

Whereas, maximum temperature showed negative association with yield during P1 to P7 stage. In variety V1 (MAUS-2) and V2 (MAUS-32) minimum temperature showed significantly positive association during eight out of ten phases, there by indicating the influence of higher minimum temperature on seed yield in there two variety. In variety V3 (MAUS-47) observed positive relation was significant in P_4 (0.30*) to P_5 (0.31*) and P_9 (0.31*) to P_{10} (0.33*) stages only. Meanwhile Variety MAUS-71 the R^2 values was increased from P_5 (0.09), P_6 (0.16), P_7 (0.20) and P_8 (0.43) stage. The maximum R^2 values was observed for bright sunshine hours during P_7 to P_{10} stage was relatively stable but across sowing it ranged from 4.0 to 6.5 hrs.

In the year 2002 it showed that weather parameter RH II (r=-0.522*) was having significant negative effect on the population of *spodoptera litura,* and BSS (r=0.641**) is having significant positive effect on population of *spodptera litura* in year 2002. During

2009, Tmax (r=-0.580*) showed were significant negative influence on the population *of spodoptera litura.* And Tmin (r=0.602*) was positively.

While, 2002 the Tmax and BSH (r= 0.758** and 0.726**) respectively were positively correlated with incidance of girdle beetle. The soybean pest showed that non significant relation with weather parameters and green semilooper in 2002, 2003, 2004, 2005and 2009 respectively.

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