All India Coordinated Research Project on Agrometeorology

Annual Report 2020-21

ICAR-Central Research Institute for Dryland Agriculture

Santoshnagar, Hyderabad-500 059

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वी. के. सिंह
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Director

Foreword

Despite tremendous technological development brought out by the Indian Council of Agricultural Research to enhance the food grain production of the country, the weather aberrations are still threatening the food security of the country. Our country experiences extreme weather events *viz.,* drought, flood, heat & cold waves, hailstorms, cyclones etc. every year and bringing heavy losses to agriculture and allied sector. Due to the occurrence of multiple hazards during the cropping period, most of the farmers are being exposed to more risks than before, which can be attributed to variable climate, environmental degradation and urbanization.

Under these circumstances, the All India Coordinated Research Project on Agrometeorology (AICRPAM) plays a pivotal role in developing short-term and long-term measures to enhance the livelihood of the farming community of our country. The 25 cooperating centres of the AICRPAM spread across different agro-climatic zones of the country. These centres are carrying out research under five different and relevant themes to identify the suitable crop growing environment for various crops, quantifying the impact of weather and climate variability and change on different crops in the current and future scenario. AICRPAM is also making efforts to improve the quality of agromet advisory services for the benefit of the farming community.

The Coordinating Unit of AICRPAM has made an effort to develop a frost prediction model for minimising crop loss due to frost damage and also determined the district-wise agroclimatic onset date of the crop growing season using 40 different threshold combinations. The efforts of the cooperating centres of the AICRPAM in pursuing the assigned research programs are commendable.

The Annual Progress Report of 2020-21 includes the salient research results of the experiments conducted during *Kharif* 2020 and *Rabi* 2020-21 at 25 centres of AICRPAM. I take this opportunity to congratulate Dr. Santanu Kumar Bal, Project Coordinator (I/c), the team of coordinating unit and also the staff of all 25 coordinating centres for their efforts in the compilation of this excellent report. I hope that the information presented in this report will be useful for researchers, students engaged in this field and policymakers to implement the plan to manage/reduce the negative impact of abnormal weather conditions.

V. K. SINGH
Director
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Acknowledgement

I express my sincere thanks to Indian Council of Agricultural Research for its continuous and generous support during the year 2020-21. The motivation and direction received from Hon'ble Secretary, DARE & Director General, Dr. Trilochan Mohapatra and Deputy Director General (NRM), Dr. S.K. Chaudhari is gratefully acknowledged. The continuous patronage and guidance being extended by Dr. S. Bhaskar, Assistant Director General (AAF&CC) to the project is highly obliged. The help and encouragement received from Dr. G. Ravindra Chary, Dr. M. Maheswari and Dr. M. Osman, Acting Directors and Dr. V.K. Singh, Director, ICAR-CRIDA for the effective functioning of the project is acknowledged.

The sincere efforts of the Agrometeorologists and other staff of all 25 Cooperating centres are highly acknowledged for carrying out the research experiments as per the technical program and bringing out useful results that made it possible to complete a comprehensive report.

Help rendered by Dr. A.V.M. Subba Rao, Shri. N. Manikandan and Dr. M.A. Sarath Chandran for the compilation of this report are greatly acknowledged. My appreciation and thanks to Mr. A. Mallesh Yadav for extending support. I also thank Dr. V.M. Sandeep, Dr. V.P. Pramod, Dr. Deepti Verma, Mr. Sravan Kumar, Mr. Chandrakant, Ms. Manisha and Mrs. Vijayalakshmi for their contribution to this report.

Santanu Kumar Bal
Project Coordinator (Ag. Met.)

CONTENTS

1. Introduction

The All India Coordinated Research Project on Agrometeorology (AICRPAM) was initiated by ICAR in May 1983 with the establishment of Coordinating Unit at the Central Research Institute for Dryland Agriculture, Hyderabad and 12 Cooperating Centres at various State Agricultural Universities. After a detailed review and evaluation on the progress made by the project and realizing the importance of agrometeorological research support for enhancing food production, ICAR had extended the Cooperating Centres to the remaining 13 Agricultural Universities of the country w.e.f. April 1995. The 25 Cooperating Centres of the AICRPAM network are: Akola, Anantapuramu, Anand, Bengaluru, Bhubaneswar, Chatha, Dapoli, Faizabad, Hisar, Jabalpur, Jorhat, Kanpur, Kovilpatti, Ludhiana, Mohanpur, Palampur, Parbhani, Raipur, Ranchi, Ranichauri, Samastipur, Solapur, Thrissur, Udaipur and Vijayapura (Fig.1.1). The Quinquennial Review Team has reviewed the research progress of the project in 1992, 1998-99, 2006, 2011 and 2017. In the last QRT Report performance of the AICRPAM was adjudged as "Very Good".

1.1. Objectives

- To study the agricultural climate in relation to crop planning and assessment of crop production potentials in different agroclimatic regions
- To establish crop-weather relationships for all the major rainfed and irrigated crops in different agroclimatic regions
- To evaluate different techniques of modification of crop micro-climate for improving the water use efficiency and productivity of the crops
- To study the influence of weather on the incidence and spread of pests and diseases of field crops

1.2. Technical Program for 2018-21

The Technical Program for the years 2018-21 for different centres of the project and a common core program decided for all the centres with emphasis on location-specific research needs is given below.

1) Agroclimatic Characterization (All centres)

- Development of database (Block/Tehsil/Mandal level) on climate and crops (district level)

Agroclimatic Analysis

- Rainfall probability analysis
- Dry and wet spells
- Characterization of onset of crop season for crop planning
- Meteorological and agricultural drought analysis
- Length of growing season and its variability
- Preparation of crop-weather calendars
- Consolidation of agroclimatic analysis in the form of Agroclimatic Atlases and other Technical Reports
- Preparation of crop-wise manuals for weather-based decisions in crop management
- Documentation of extreme weather events and their impacts on agriculture

2) Crop Weather Relationships

- Development of weather-based crop yield prediction models
- Pooled analysis of multi-location crop weather data under AICRPAM
- Estimation of heat unit requirement of crops
- Effect of crop growing environments on yield and yield attributing parameters
- Estimation of Heat Use Efficiency (HUE), Consumptive Use of Moisture (CUM), Moisture Use Efficiency (MUE) and Radiation Use Efficiency (RUE) for various crops
- Interaction effect of the growing environment with crops/varieties

3) Crop Growth Modeling

- Calibration and validation of crop simulation models with newer genotypes
- Evaluation of genetic coefficients
- Exploring management options for better resource/ environmental management

4) Weather Effects on Pests and Diseases

The technical program as finalized in the workshop for above themes is given in Table 1.1.

5) Agromet Advisory Services (AAS) (All Centres)

- Weekly monitoring of crops and weather situations and its updation on the crop weather outlook website
- Development of crop contingency plans for the aberrant weather situations
- Monitoring of daily rainfall situation and extreme weather events, their impacts on agriculture on near real-time basis
- Value-addition to agromet information and preparation & dissemination of agromet advisories
- Economic impact assessment of agromet advisories

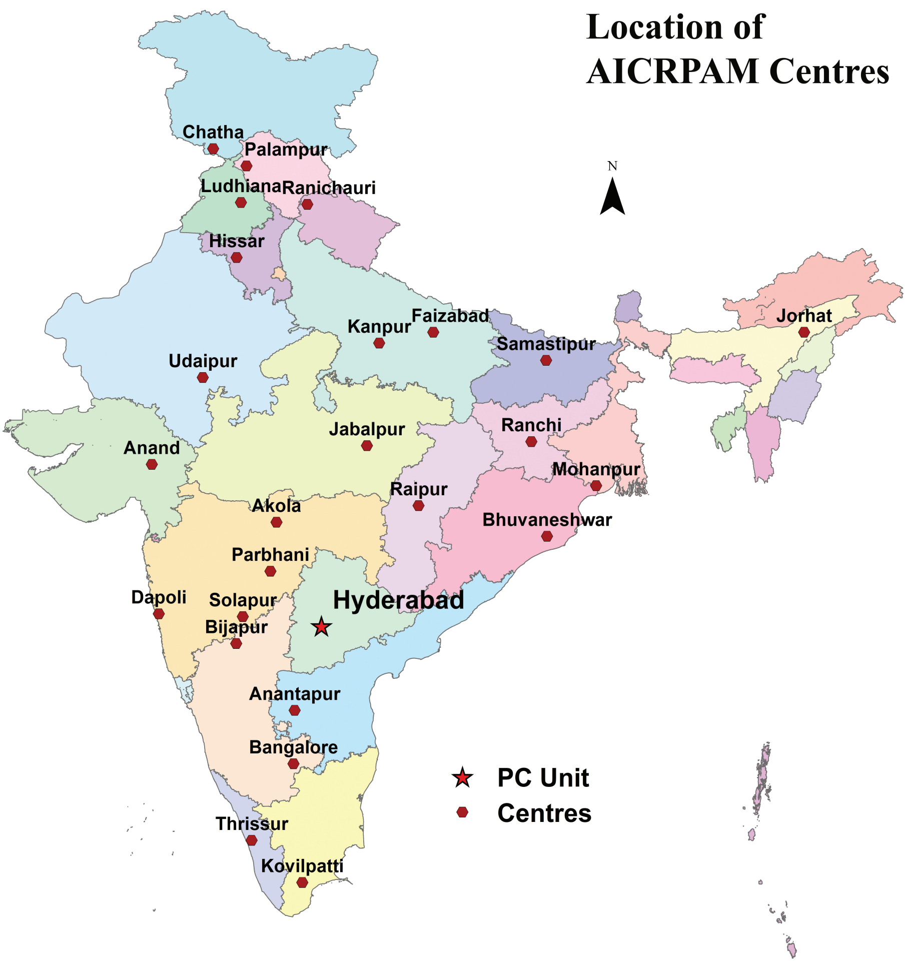


Fig.1.1: Location map of 25 Cooperating centers and Project Coordinating Unit of AICRPAM

Table 1.1: Zone-wise technical program of AICRPAM centers for three different themes during 2018-21

S. No.	Zones	Centre	Crop Weather Relationship Studies		Crop Growth Modeling	Weather Effects on Pests & Diseases
			Kharif Varieties	*Rabi* Varieties		
1	Arid and Semi Arid: Black soil	Akola	**Soybean:** JS 335, JS 9305, TAMS 9821	**Chickpea:** Vijay, JAKI 9218, Akash	Soybean	**Soybean:** Spodoptera / Semilooper
		Parbhani	**Soybean:** JS-335, MAUS- 158, MAUS-71	Fallow	Cotton	**Cotton:** Mealy bug, Sucking pest
		Solapur	**Pearl millet:** Dhanshakti, ICTP-8203, Mahyco hybrid **Sunflower:** MSFH-17, Bhanu, Phule Bhaskar	**Sorghum:** M-35-1, Phule Yeshoda, Phule Revati **Chickpea:** Vijay, Digvijay, Virat		**Sunflower:** Thrips, Bud necrosis
					Sorghum	
		Kovilpatti	Fallow	**Maize:** S-6850, NK-6240, RMH-3033 COH-(M) 6 **Sorghum:** CSV-20, K-8, K-12	Maize	**Maize:** Aphid, Leaf hopper **Black gram:** Powdery mildew
		Vijayapura	**Soybean:** JS-335, DSB-23-2, DSB-21	**Chickpea:** Vijay, JG-11, BG-11-05		**Grapes/Pomegranate:** Powdery mildew, Downy mildew, Anthracnose, BLB
2	Arid and Semi Arid: Red soil	Anantapur	**Pigeon pea:** PRG 176, LRG 41, LRG 52	**Chickpea:** JG 11, NBEG-47, NBEG-3	Groundnut	**Groundnut:** Leaf miner (DSS) **Pigeon pea:** Spotted Pod Borer
			Groundnut: K6, Kadri- Harithandhra, Dharani & Anantha			
		Bengaluru	**Pigeon pea:** PRG-176, TTB-7, BRG-1	**Mango:** Mallika		**Groundnut:** Leaf miner, Tikka Disease, Pod borer, Spotted pod borer **Pigeon pea:** Spotted boll worm
			Groundnut: Chintamani-2, JL-24, K-6			
3	Western Arid and Semi Arid: loamy soil	Anand	**Pearl millet:** GHB 558, GHB 744, GHB 538	**Mustard:** Bio 902, GM-3, GDM-4	Pearl millet	**Mustard:** Aphid

S. No.	Zones	Centre	Crop Weather Relationship Studies		Crop Growth Modeling	Weather Effects on Pests & Diseases
			Kharif Varieties	*Rabi* Varieties		
		Hisar	**Pearl millet:** GHB 558, HSB-67, HHB-272, **Guava:** Hisar Safeda	**Barley:** BH 393, BH 902, BH 946, BH 885 **Potato:** Kufri Surya, Kufri Bahar, Kufri Pushkar	Pearl millet	**Mustard:** Aphid **Wheat:** Yellow rust
		Udaipur	**Soybean:** JS-335, Pratap Soya, RKS-45	**Mustard:** Bio-902, Giriraj, Swarna Jyoti	Mustard	**Mustard:** Aphid
4	Sub-Humid alluvium-IGP	Faizabad	**Maize:** PMH 4, Naveen, UMC-1, Gaurav	**Mustard:** NDR-8501, NDRS-2001-1, Narendra Ageti Rai-4	Rice	**Chickpea:** Pod borer
		Kanpur	**Maize:** PMH 4, Azad Hy- brid-2, Malviya-2, DKC-7044	**Wheat:** HD-2967, HD-2733, K-307, K-9107	Rice, Wheat	**Maize:** Stem borer **Wheat:** Blight
		Ludhiana	**Maize:** PMH 4, PMH 1, PMH 2	**Wheat:** HD 2967, PBW 725, PBW 677	Wheat	**Cotton:** Sucking pests
		Samastipur	**Maize:** Bio-9637, Shaktiman-4, Shakstiman-5	*Rabi* **Maize:** Bio-9637, Shaktiman-4, Shakstiman-5	Maize	**Maize:** Stem borer
5	Central India- Sub Humid (Dry): Black and red soils	Jabalpur	**Rice:** MTU 1010, Kranti, Sahbhagi	**Chickpea:** JG-14, JG-1 & JJGH-1	Rice, Soybean	**Chickpea:** Pod borer
		Raipur	**Rice:** MTU-1010, Chhattisgarh Sugandhit Dhan, IGKV R-1	**Chickpea:** JG-14, Indira Chana-1, Vaibhav	Rice	**Rice:** Yellow Stem Borer, Leaf folder, Brown Plant Hopper **Chickpea:** Pod borer
		Ranchi	**Rice:** MTU 1010, Naveen, Sahbhagi	**Chickpea:** JG 14, Birsa Channa 3, GNG 1581	Rice	**Rice:** BLB (Bacterial Leaf Blight), Brown spot
6	East and NE- Hot Sub Hu- mid (Moist): Deep loamy to clayey alluvium	Bhubaneswar	**Rice:** Swarna, Satabdi, Bina-11	**Green gram:** Samrat, TARM- 1, PDM-54	Rice	**Rice:** Sheath Blight, Blast
		Jorhat	**Rice:** Swarna, TTB-404, Mahsuri	**Green gram:** Samrat, Pratap, SGC- 16	Rice	**Rice:** Stem borer

S. No.	Zones	Centre	Crop Weather Relationship Studies		Crop Growth Modeling	Weather Effects on Pests & Diseases
			Kharif Varieties	*Rabi* Varieties		
		Mohanpur	**Rice:** Swarna, Satabdi, Nayanmoni	**Green gram:** Samrat, Pant Moong-5, Meha (IPM-99-125)	Rice	**Rice:** Stem borer
7	Sub Himalayan- Warm Sub Humid: Deep loam forest soils	Chatha	**Rice:** Basmati- 370, Pusa- 1121, R.S. Pura local	**Wheat:** HD-2967, Raj-3077, RSP - 561 **Mustard:** ONK-1, GSL-1, DGS-1	Wheat	**Wheat:** Yellow Rust **Mustard:** Aphid
		Palampur	**Rice:** Basmati- 370, Pusa- 1121, Kasturi Basmati	**Wheat:** HD-2967, HS-490, VL-907 **Mustard:** ONK-1, GSL-1, HPN-1	Wheat	**Rice:** Blast
						Wheat: Yellow Rust
		Ranichauri	**Finger Millet:** PRM – 2, VL Mandua 149, VL Mandua 324	**Wheat:** HD 2967, VL Gehun 892, UP 2572	Wheat	**Finger millet:** Blast **Wheat:** Yellow Rust
8	Coastal (Western Ghats) – Hot humid to per humid: Laterite and coastal alluvium	Dapoli	**Rice:** Jaya, Karjat-5, Palghar-1, Swarna, Karjat-2	**Spice: Black Pepper:** Panniyur-1, Shakti, Thevam	Rice	**Rice:** Stem borer, Blue Beetle, BPH
		Thrissur	**Rice:** Jyothi, Kanchana and Jaya	**Spice: Black Pepper:** Panniyur 1 to Panniyur 8 (8 varieties)	Rice	**Rice:** Stem borer, Leaf roller Black Pepper: Pollu Beetle

2. Weather During 2020

A brief account of onset, progress and withdrawal of southwest monsoon (Jun-Sep) along with rainfall distribution details of northeast monsoon season (Oct-Dec) of 2020 for the country as a whole and annual rainfall of 25 centers of AICRPAM are presented hereunder:

Onset of southwest monsoon

The southwest monsoon set in over Kerala on 01st June 2020, coinciding with its normal date for onset and covered the entire country on 26th June 2020; 12 days before its normal date (08th July).

Rainfall distribution during monsoon season

The seasonal rainfall (Jun-Sep) over the country as a whole was 109% of its long period average (LPA), the third-highest after 112% of LPA in 1994 and 110% of LPA in 2019. The seasonal rainfall over Northwest India, East & Northeast (NE) India, Central India and South Peninsula were 86%, 107%, 115% and 129% of their respective LPA.

The seasonal rainfall received in 36 meteorological sub-divisions of the country during the southwest monsoon season along with respective LPA values and deviations from LPA (%) of 2020 are given in Table 2.1. Out of 36 meteorological subdivisions, 2 subdivisions (5% of the total area of the country) received large excess rainfall, 13 subdivisions (35% of the total area of the country) received excess rainfall, 16 subdivisions (45% of the total area of the country) received normal seasonal rainfall and 5 subdivisions (15% of the total area of the country) received deficient season rainfall during the season.

A total of 12 Low-Pressure Systems formed during the season, out of which only one had intensified into a Severe Cyclonic Storm “NISARGA” from 01st to 4th June. However, none of the other low-pressure systems intensified into Depression/ Deep Depression categories during the season.

Withdrawal of southwest monsoon

The withdrawal of monsoon commenced on 28th September from some parts of west Rajasthan and Punjab, against its normal date of 17th September, and withdrew from the entire country on 28th October.

Table 2.1: Rainfall in 36 meteorological sub-divisions during 2020 southwest monsoon season

S. No.	Region	Sub Division	Actual (mm)	Normal (mm)	Deviation (%)
1	East & Northeast India	Arunachal Pradesh	1972.0	1726.6	14
2		Assam & Meghalaya	2152.9	1773.7	21
3		Nagaland-Manipur-Mizoram-Tripura (NMMT)	975.6	1426.7	-32
4		Sub-Himalayan West Bengal & Sikkim	2691.1	1970.8	37
5		Gangetic West Bengal	1064.6	1181.5	-10
6		Jharkhand	898.3	1054.7	-15
7		Bihar	1272.5	1017.2	25
8	Northwest India	East Uttar Pradesh	782.4	839.4	-7
9		West Uttar Pradesh	455.3	721.3	-37
10		Uttarakhand	943.2	1176.9	-20
11		Haryana-Chandigarh-Delhi	379.8	444.0	-14
12		Punjab	387.5	467.3	-17
13		Himachal Pradesh	565.5	763.5	-26
14		Jammu & Kashmir	422.4	566.0	-25
15		West Rajasthan	336.2	265.3	27
16		East Rajasthan	593.7	602.9	-2
17	Central India	Odisha	1140.9	1155.3	-1
18		West Madhya Pradesh	966.0	857.7	13
19		East Madhya Pradesh	1025.1	1048.4	-2
20		Gujarat Region	1035.0	922.9	12
21		Saurashtra & Kutch	1146.2	507.2	126
22		Konkan & Goa	3658.1	2875.3	27
23		Madhya Maharashtra	969.3	751.2	29
24		Marathwada	867.2	668.8	30
25		Vidarbha	852.1	943.1	-10
26		Chhattisgarh	1234.3	1142.1	8

S. No.	Region	Sub Division	Actual (mm)	Normal (mm)	Deviation (%)
27	South Peninsula	A & N Island	1712.4	1653.8	4
28		Coastal Andhra Pradesh	725.3	586.9	24
29		Telangana	1095.8	751.9	46
30		Rayalaseema	756.1	411.6	84
31		Tamil Nadu & Puducherry	425.6	336.1	27
32		Coastal Karnataka	3681.9	3095.1	19
33		Karnataka (North Interior)	739.6	497.1	49
34		Karnataka (South Interior)	816.2	681.8	20
35		Kerala	2227.8	2049.3	9
36		Lakshadweep	1345.4	1013.1	33
East & Northeast India			1509.0	1410.3	7
Northwest India			516.5	599.5	-14
Central India			1122.4	976.5	15
South Peninsula			937.4	726.2	29
Country as a whole			**961.4**	**880.6**	9

Northeast monsoon

The northeast monsoon rains commenced on 28th October, coinciding with the withdrawal date of southwest monsoon from the entire country. The realized rainfall over the country as a whole during the season was 101% of LPA. It was 103%, 96% and 98% of its LPA during October, November and December months respectively. The seasonal rainfall was above normal over South Peninsular India and Central India (115%, 112% of LPA, respectively) and was below normal over East & Northeast India and Northwest India (85%, 61% of LPA, respectively). In terms of meteorological subdivisions (36), 2 received large excess rainfall, 9 received excess rainfall and normal rainfall each, 11 received deficient and 5 received large deficient rainfall.

Rainfall at cooperating centers

During the year 2020, eight out of 25 centers of AICRPAM, *viz.,* Anantapuramu, Bengaluru, Kanpur, Kovilpatti, Parbhani, Samastipur, Solapur and Vijayapura received excess rainfall, whereas Udaipur center received large excess rainfall (62%) and the remaining all centers (except Ranichauri) receive normal rainfall. In Ludhiana center, the annual rainfall was deficient by -17% during the year. The yearly rainfall of 25 AICRPAM centres during the year 2020 is furnished in Table 2.2.

Table 2.2: Annual rainfall received at AICRPAM centers during 2020

S. No.	AICRPAM Centre	Actual (mm)	Normal (mm)	Departure (%)
1	Akola	799.1	799.0	0
2	Anand	989.4	853.0	16
3	Anantapuramu	742.8	590.0	26
4	Bengaluru	1180.0	916.0	29
5	Bhubaneswar	1732.9	1502.0	15
6	Chatha	1198.2	1124.0	7
7	Dapoli	4145.4	3529.0	17
8	Faizabad	1083.2	1002.0	8
9	Hisar	501.1	474.0	6
10	Jabalpur	1307.5	1253.0	4
11	Jorhat	1911.2	1924.0	-1
12	Kanpur	1228.7	869.0	41
13	Kovilpatti	905.5	714.0	27
14	Ludhiana	609.0	733.0	-17
15	Mohanpur	1737.3	1539.0	13
16	Palampur	2238.6	2332.0	-4
17	Parbhani	1098.7	881.0	25
18	Raipur	1305.1	1145.0	14
19	Ranchi	1496.4	1398.0	7
20	Ranichauri	1165.0	1270.0	-8
21	Samastipur	1633.2	1235.0	32
22	Solapur	886.2	721.0	23
23	Thrissur	2766.6	2757.0	0
24	Udaipur	972.6	601.0	62
25	Vijayapura	862.2	594.0	45

3. Agroclimatic Characterization

Agroclimatic information is necessary for enhancing crop productivity through better agricultural planning including land use planning, water resources availability, crop suitability, pests and disease management and also in weather-based agro-advisories. It is used to study climatic characteristics and crop performance of a particular region and also to know the climatic variability/climate change and its impact on agriculture. In order to achieve maximum and sustainable crop production from available farm resources, it is essential to have proper knowledge of the agroclimatic resources of the location/region. Therefore, a thorough understanding of the climatic conditions would help in determining the suitable agricultural management practices for taking advantage of the favourable weather conditions and avoiding or minimizing risks due to adverse weather conditions. Thus, historic data on climatic variables have to be analyzed using appropriate statistical tools enabling the development of location specific technologies/ adaptive strategies. The analysis carried out by different centers on the agroclimatic characterization is reported hereunder:

Akola

Trend analysis of extreme rainfall events in Vidarbha region, Maharashtra

Trend analysis of extreme rainfall events on annual basis as well as during southwest monsoon was carried out using tehsil level data (118 tehsils) during 1971-2020 for the Vidarbha region, Maharashtra. Trends in one-day extreme rainfall events of 75-100 mm and greater than 100 mm was carried out. Mann-Kendall test was performed using trend software and the results are presented in the form of GIS maps.

On annual basis, two tehsils (Mangrupir in Washim and Koparna Gadchiroli district) showed significant positive trend and 12 tehsils showed significant negative trend in one-day rainfall event of 75-100 mm (Fig. 3.1a). The result was same during southwest monsoon (Fig. 3.1b). In the case of one-day rainfall events >100 mm on annual basis, two tehsils showed significant positive trend and two tehsils showed significant negative trend (Fig. 3.1c). During southwest monsoon, same result was observed (Fig. 3.1d).

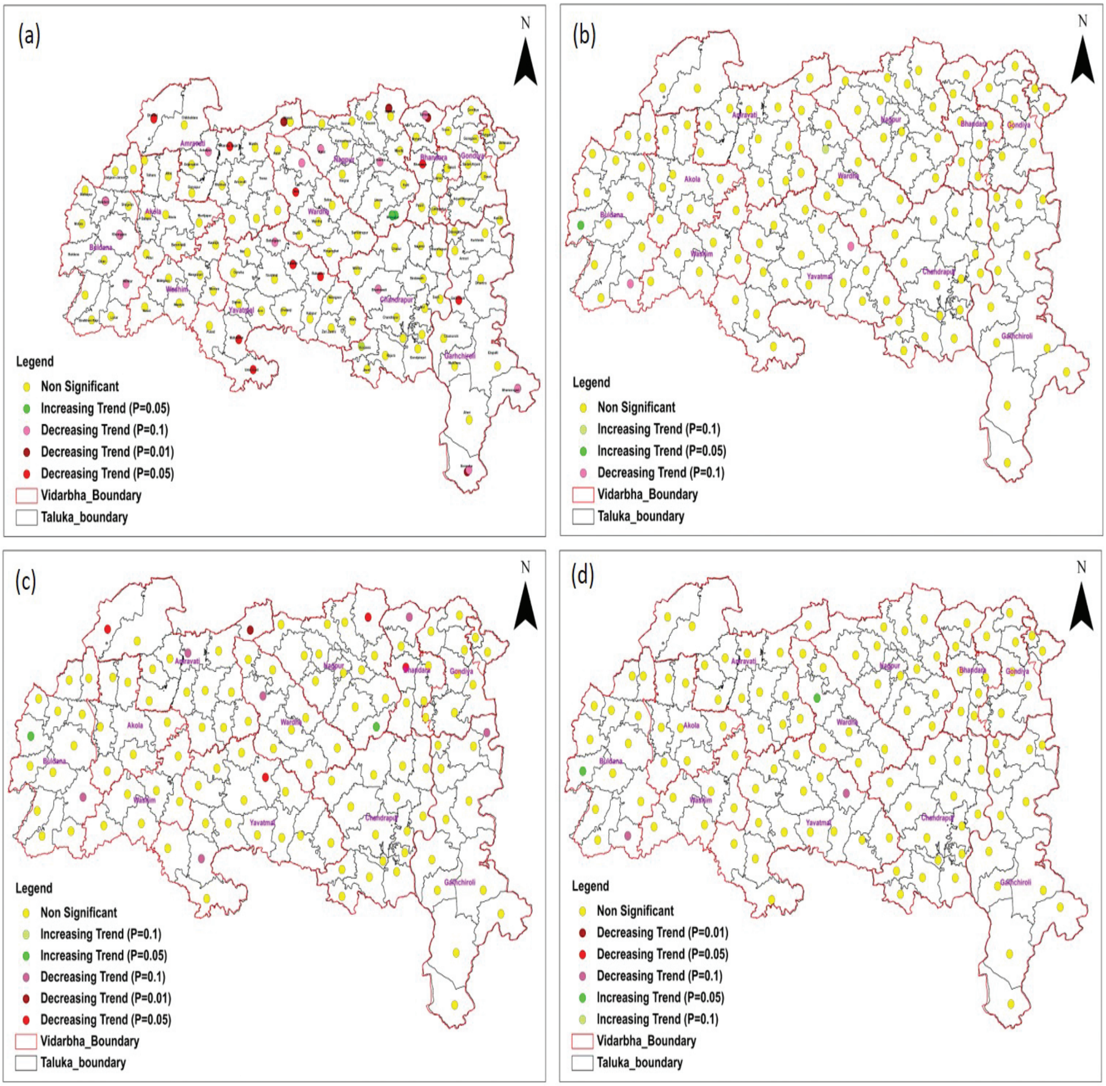


Fig.3.1: Trend in extreme rainfall events (a) one-day 75-100 mm rainfall on annual basis (b) > 100 mm on annual basis (c) 75-100 mm during southwest monsoon (d) > 100 mm during southwest monsoon season in 118 tehsils of Vidarbha region, Maharashtra during 1971-2020.

Anand

Drought characterization in Gujarat using SPI and SPEI

Two indices namely SPI and SPEI were analyzed by following standard procedure on seasonal scale of monsoon (June-September) for Anand, Bhuj, Junagadh, Navsari and SK Nagar. The details of the study locations are presented in Table 3.1.

Table 3.1 Selected meteorological stations in Gujarat state for drought characterization

Station	Latitude (°N)	Longitude (°E)	Elevation AMSL (m)	Climate	Weather data
Anand	22.58	72.92	45	Semi-arid	1958-2007
Bhuj	23.25	69.66	82	Arid	1969-2014
Junagadh	21.52	70.46	61	Semi-arid	1987-2019
Navsari	20.95	72.92	10	Sub-humid	1980-2019
SK Nagar	24.32	72.32	154	Arid	1982-2019

Stations were chosen considering the representation of different climatic condition of Gujarat state and availability of long and continuous timeseries weather data. Daily temperatures (maximum and minimum) and rainfall data for these stations were taken, and from which monthly data series are calculated. Monthly PET was computed using Thornthwaite method. SPEI was calculated following the method described in Vicente-Serrano *et al.* (2010).

Timeseries of SPI and SPEI with difference between them are depicted in Figure 3.2. In general, magnitudes and variations of SPI and SPEI were consistent for all the stations, except in few instances in the timeseries. Bhuj station representing arid region of the state showed relatively more difference (RMSE = 0.28) between the indices in most instances. The residual plot clearly depicts that Anand and Bhuj stations had more instances with slight differences. Correlation coefficients between the indices for different stations were ranged from 0.96 to 0.99. SPI and SPEI values for Navsari station had negligible difference. This might be because of station having humid environment which reduce the rate of evapotranspiration during monsoon. Drought severity reflected by the SPEI is considered more realistic than SPI. But, in the case of the stations representing different climatic conditions, the indices were similar in magnitude. So, use of SPEI or SPI does not have marked different in quantification of the severity of the drought at most part of the state. In Gujarat state, SPI should be preferred as it requires only rainfall data, and the state has more rain gauge stations than surface observatories.

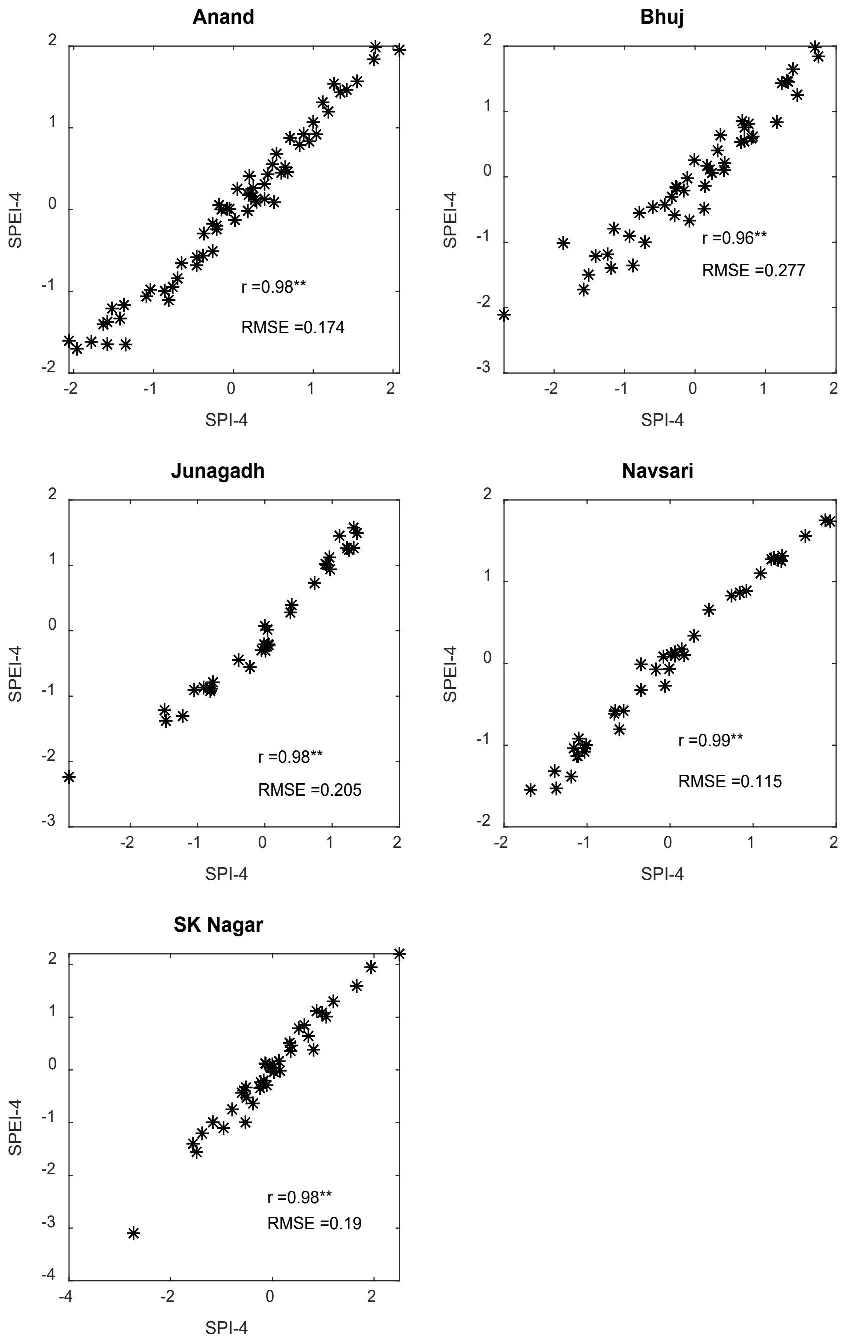


Fig.3.2: Relationship between SPI and SPEI at different stations of Gujarat

Bengaluru

Shift in seasonal rainfall distribution pattern in South Interior Karnataka

To understand the shifting patterns (shifting point) in month-wise, seasonal and annual rainfall data of South Interior Karnataka (SIK), the Likelihood-Ratio was computed by using '*changepoint*' package of R software at 5 per cent level of significance. Before applying Likelihood-Ratio test, normality of all data sets were examined using Shapiro-Wilk test, and it was observed that majority of data sets were following normal distribution. Therefore, Normal distribution was considered while applying Likelihood-Ratio test.

For each seasonal rainfall data for the period of 60 years during 1960-2019 of SIK sub-division, shifting point (year), average seasonal rainfall (mm) before and after shifting point (year) were computed are presented in Table 3.2 along with nature of shifting and normal rainfall (mm) of each season. The line graph of seasonal rainfall distribution along with rainfall shifting year, and average seasonal rainfall before and after shifting year is shown in Fig.3.3.

Table 3.2: Shifting pattern of seasonal rainfall (mm) data of SIK sub-division

Period	Shifting year	Average rainfall (mm)		Change in rainfall (mm)	Nature of shifting	Normal rainfall (mm)
		Before	After			
Winter	1993	3.45	7.14	3.69	Increasing	5.00
Pre-monsoon	2003	136.51	182.22	45.71	Increasing	145.00
Monsoon	1970	322.72	387.85	65.13	Increasing	359.00
Post-monsoon	1990	197.99	222.89	24.90	Increasing	210.00

Shifting point (year) in seasonal rainfall was found in the all seasons *viz.* winter (1993), pre-monsoon (2003), monsoon (1970) and post-monsoon (1990). Results in Table 3.2 revealed that the average rainfall was increased for winter (3.69), pre-monsoon (45.71), monsoon (65.13) and post-monsoon (24.90) seasons as compared with before and after shifting point in rainfall. Further, it can also observed from the Table 3.2, the average seasonal rainfall in winter, pre-monsoon, monsoon and post-monsoon was below normal rainfall before shifting year, but it was increased after shifting year, which was above the normal rainfall.

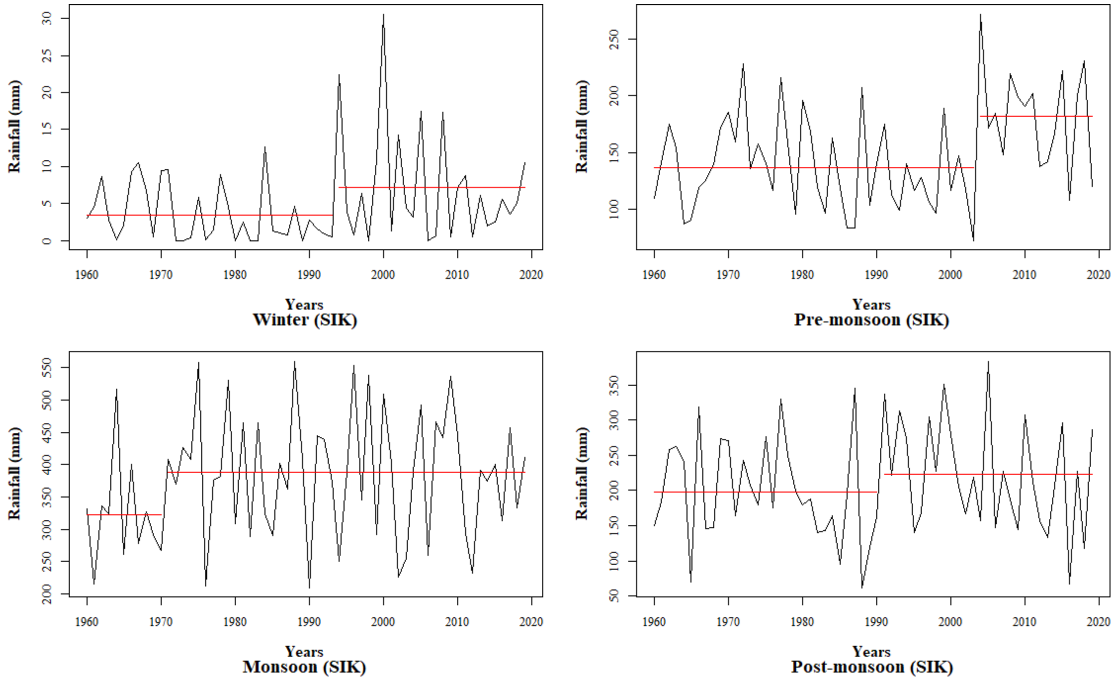


Fig. 3.3: Line graphs showing rainfall distribution along with shifting pattern for all four seasons for south interior Karnataka

Chatha

Impact of El Niño on southwest monsoon and maize production

In accordance with NOAA standard for identifying El Niño events, a total of ten El Niño events were recorded over the period from 1972 to 2020, of which five were weak (1976, 1977, 2004, 2006 and 2014), moderate (1986, 1991, 1994, 2002 and 2009) and six were strong (1972, 1982, 1987, 1997, 2015 and 2018) events. The per cent change in seasonal rainfall during El Nino years from normal were computed for different locations in Jammu province and the results are presented in Table 3.3. During south west monsoon season, the average rainfall recorded was below normal in most locations of Jammu Province under the influence of El Niño episodes except Batote, Banihal and Rajouri districts, which showed the slightly increase in rainfall. The decrease in rainfall was highest (25.1%) in Kathua district.

Udhampur, Doda and Rajouri are the major maize growing districts in Jammu province. The district-wise area, production and productivity of maize and the percent change from normal years during El Niño years are presented in Table 3.4. Among major maize growing districts, Doda recorded the highest reduction in productivity (19.4%), followed by Ramban (15.8%). All the districts, except Poonch recorded a reduction in maize productivity.

Table 3.3: Percent change in average seasonal rainfall (mm) during El Niño years compared to normal rainfall (mm) in Jammu Province

Districts	Winter (Jan.-Feb.)			Summer (March-May)			SW monsoon (June-Sept.)			Post Monsoon (Oct.-Dec.)		
	El Niño	Normal	% change	El Niño	Normal	% change	El Niño	Normal	% change	El Niño	Normal	% change
Jammu (1982-2020)	121.2	104.4	23.4	183.0	130.2	40.6	853.0	870.4	-2.0	69.4	64.3	7.9
Katra (1980-2020)	257.1	222.4	15.6	356.0	263.6	35.1	1403.0	1488.7	-5.8	136.8	103.0	32.8
Bhaderwah (1978-2020)	336.2	303.4	10.8	440.8	403.9	9.1	428.3	431.2	-0.7	188.5	154.1	22.3
Batote (1977-2020)	426.7	386.9	10.3	583.0	523.0	11.5	545.6	510.3	6.9	239.0	189.7	26
Banihal (1972-2020)	415.2	370.1	12.2	521.9	441.0	18.3	384.6	342.1	12.4	245.0	191.3	28.1
Kathua (1987-2020)	114.1	115.8	-1.5	122.2	113.0	8.1	646.5	863.1	-25.1	72.7	64.9	12.0
Rajouri (1993-2020)	199.7	160.5	24.4	214.4	165.7	29.4	590.4	578.5	2.1	94.7	77.2	22.7

Table 3.4: Percent change in average area sown, production and productivity of maize during El Niño years compared to normal rainfall (mm) in Jammu Province

Districts	Area ('000 ha)			Production ('000 MT)			Productivity (kg ha^{-1})		
	El Niño	Normal	% change	El Niño	Normal	% change	El Niño	Normal	% change
Jammu	18.23	17.57	3.8	32.14	29.83	2.31	1676	1721	-2.6
Udhampur	48.36	47.09	2.7	83.93	92.42	-8.5	1768	1972	-10.3
Doda	42.02	41.31	1.7	56.40	55.83	0.57	1355	1681	-19.4
Ramban	16.54	16.58	-0.2	19.98	24.0	-16.8	1221	1450	-15.8
Poonch	23.71	23.58	0.6	53.15	52.07	2.1	2255	2199	2.5
Kathua	18.47	18.64	-0.17	36.01	40.38	-4.37	1995	2174	-8.2
Rajouri	45.18	44.25	2.1	95.60	105.81	-10.21	2112	2396	-11.9

Solapur

Spatial variation in length of growing period in Western Maharashtra

Climatic water balance was calculated for ten locations in Western Maharashtra using daily weather data for the period 1961-2015. The estimated start, end and length of the growing season is presented in Fig.3.4.

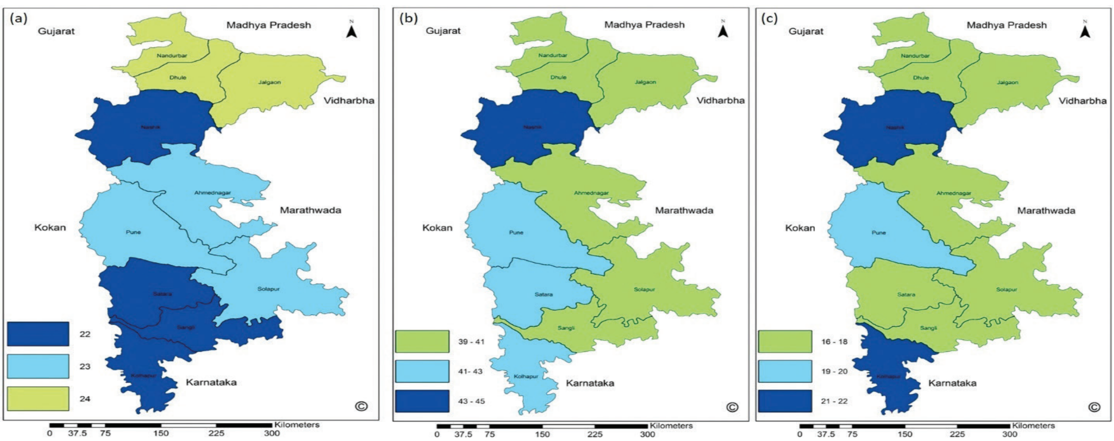


Fig.3.4: The spatial variation in (a) start (b) end and the (c) length of growing season over Western Maharashtra

The results indicate that the growing season starts early in southern part of Western Maharashtra (around 22nd standard meteorological week) and covers northern parts by 24 SMS. Similarly, the growing season ends during 39-41 SMW in north-eastern parts and 41-43 SMW in south-western parts. The length of the growing season is highest in Kolhapur and Nashik (22 weeks) and lowest in Jalgon and Nandurbar (16 weeks). This information will be useful in selection of crops in the Western Maharashtra.

Thrissur

Initial and conditional rainfall probabilities at Thrissur

The initial and conditional probability were worked out for Vellanikkara, Thrissur by using the weekly rainfall data for the last 38 years (1983-2020) by using Weathercock software. The average annual rainfall at Vellanikkara is 2782 mm. The maximum rainfall is occurring during 21-35 standard meteorological weeks. The probability analysis of the wet spell and dry spell is shown in the Figures 3.5 and 3.6. During 20 SMW to 45 SMW, the probability of getting a weekly rainfall of 25 mm is more than 50%. During this period, land preparation/sowing/ transplanting and initial development of rice cultivation is possible without any irrigation.

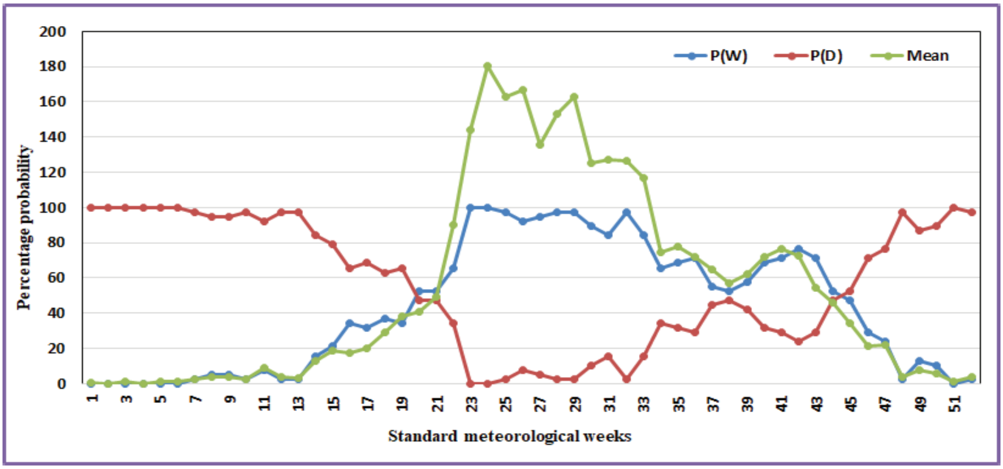


Fig.3.5: Initial probabilities of wet week and dry week in Vellanikkara, Thrissur

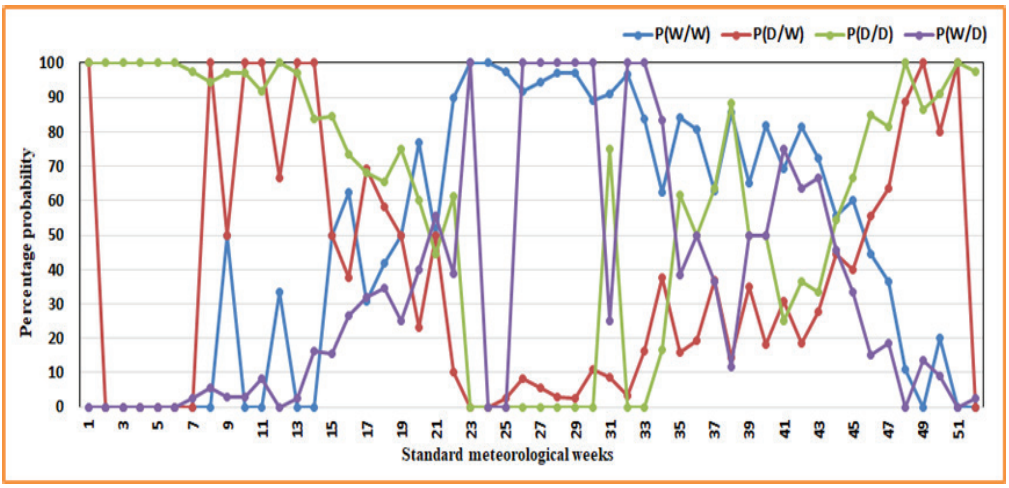


Fig.3.6: Conditional probabilities of rainfall at Vellanikkara, Thrissur

Udaipur

Rainfall probability analysis

Incomplete Gamma Distribution of Rainfall at Udaipur (1970-2020) was worked out by using "weathercock" software. The results show that at 90, 75 and 50% probability level the chances of getting annual rainfall is 421.6 mm, 514.0 and 631.7 mm, respectively as against the normal rainfall of 649.1 mm (Fig.3.7a). Chances of getting assured (at 75% probability) weekly rainfall of 10 mm to 15 mm is in the SMW 30-34 (23 July to 26 August). However, at 50% probability the chances of getting 33.5 mm to 36.2 mm rainfall in the SMW 30-32 at Udaipur (Fig.3.7b).

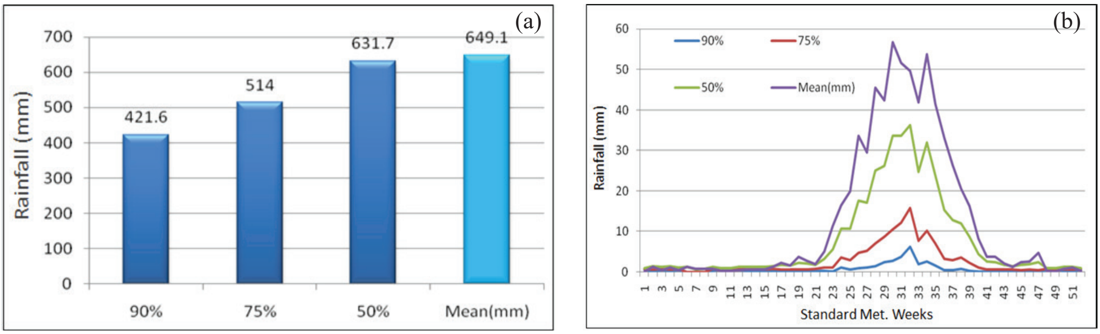


Fig.3.7: Probability of receiving various amounts of (a) annual rainfall (b) weekly rainfall at Udaipur, Rajasthan

Jorhat

Rainfall probability analysis

The initial and conditional probabilities of getting dry or wet weeks was done following Markov Chain procedure. The limit for determining dry and wet weeks for Morigaon and Nagaon districts of Central Brahmaputra Valley Zone (CBVZ) of Assam was considered as 10 mm, 20 mm and 30 mm rainfall in a week. The duration of the analysis was 30 years (1988 - 2018) for Nagaon and 21 years (1989 - 2010) for Morigaon district of CBVZ of Assam. The initial probability of getting wet week in Morigaon is more than 50% from 13 - 41 SMW, 16 - 40 SMW and 20 - 39 SMW respectively for 10 mm, 20 mm and 30 mm rainfall (Fig.3.8a). Similarly, the initial probability of getting wet week in Nagaon district is also more or less same as the Morigaon district; where probability was more than 50% from 17 - 38 SMW for at least 30 mm rainfall (Fig.3.8b). Hence the possibility of getting mid-season drought is less for Sali rice crop.

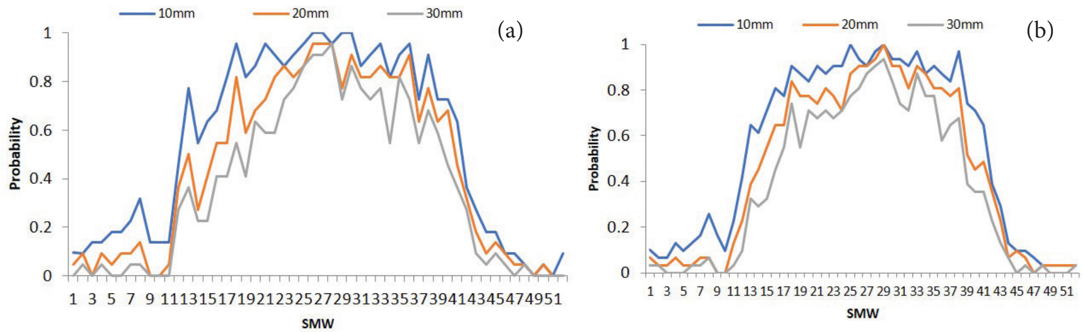


Fig.3.8: Probability of getting wet week with 10, 20 and 30 mm of weekly rainfall in (a) Morigaon and (b) Nagaon district of Central Brahmaputra Valley Zone of Assam

Incomplete Gamma distribution for different levels of probabilities in Morigaon and Nagaon districts of CBVZ of Assam revealed that rainfall received at 50% probability level is close to the mean weekly rainfall. However, for crop planning purpose, the rainfall amounts at 75% level of probability may be considered as safest (Fig.3.9a and b). The chance of receiving a rainfall amount of 10 mm is very less during post-monsoon and winter season (from 44 - 07 SMW) in both the districts. Similarly, the chance of receiving weekly rainfall amount of 25 mm is higher at 75% probability during 24 - 36 SMW in Morigaon and 25 - 35 SMW in Nagaon district of CBVZ, Assam. The probability of receiving weekly rainfall amount of 50 mm is higher (75% probability) during 26 - 28 SMW in Morigaon, whereas in Nagaon, it is only during 29 SMW.

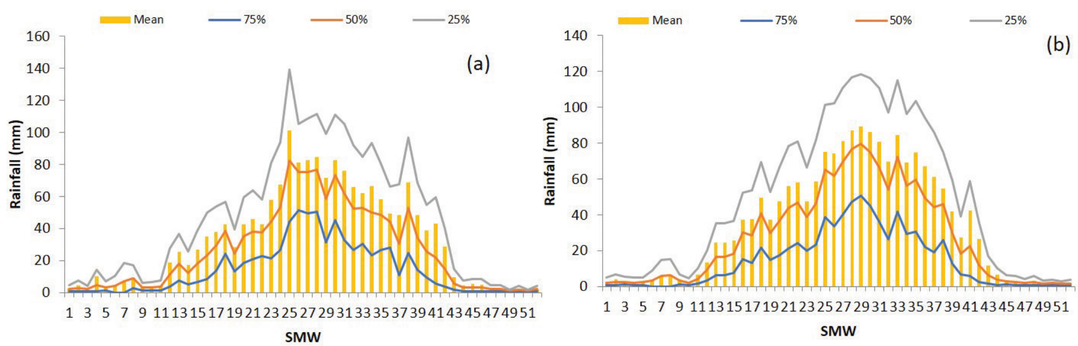


Fig.3.9: Incomplete Gamma probability of receiving weekly normal rainfall at 25, 50 and 75 per cent in (a) Morigaon and (b) Nagaon district of CBVZ of Assam

Ludhiana

Variability in monsoon rainfall over past 120 years at Ludhiana

Analysis of monsoon rainfall data for the past 120 years (1901-2020) at Ludhiana showed seasonality with a slight increasing trend of 1.3 mm/year (Fig. 3.10). There was below normal monsoon rainfall during 64 years with prominent extended deficit rainfall years (>2 years) of 1902-08, 1911-13, 1920-22, 1927-29, 1934-39, 1943-44, 1948-49, 1960-61, 1968-69, 1972-74, 1979-81, 1986-87, 1991-92, 1999-2000, 2004-07, 2014-2017, 2019-20. During such deficit rainfall years, the production of crops either gets adversely affected, or if the irrigation is applied the ground water resources get depleted. On the other hand, excessive monsoon rainfall during years, are not properly utilized by agricultural crops. But the cyclicity in monsoon rainfall is one of the major abiotic components which is responsible in determining the water resources and crop productivity.

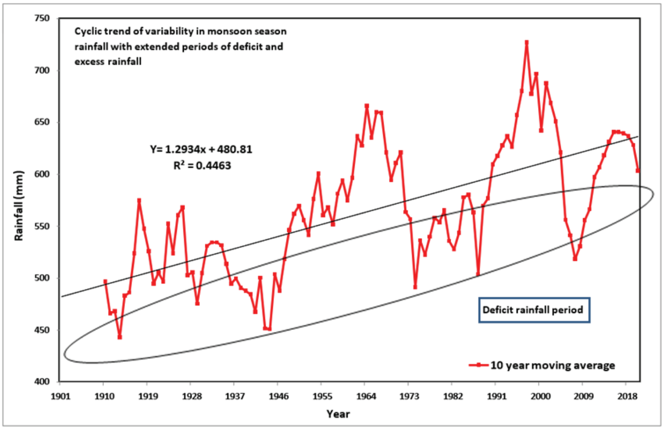


Fig.3.10: Variability in monsoon rainfall over past 120 years (1901-2020) at Ludhiana

Samastipur

Probability of continuous dry spell in Bihar

Probabilities of having dry spell of successive two weeks during *kharif* season in different districts of Bihar have been worked out and presented in Fig.3.11. The rainfall amount of 20 mm per week was found to provide enough moisture for sowing of uplands crops and hence 20 mm rainfall per week in the beginning of the season was considered as sowing rain. This weekly rainfall amount of 20 mm in the beginning of crop growing season is regarded as sowing rain. Once sowing is done, weekly rainfall ≥10 mm is sufficient to sustain the rainfed crops. The results revealed that the probability of having dry spell (threshold weekly rainfall <5 mm) of consecutive two weeks remains very low (<10 percent) during major part of *kharif* crop growing season. The results also indicated that the probability for two consecutive weeks of dry spells are less during July and August (1-6%) and higher during June (1-30%) and September (0-19%). Compared to the western districts, the probability for dry spells are higher in eastern districts of Bihar.

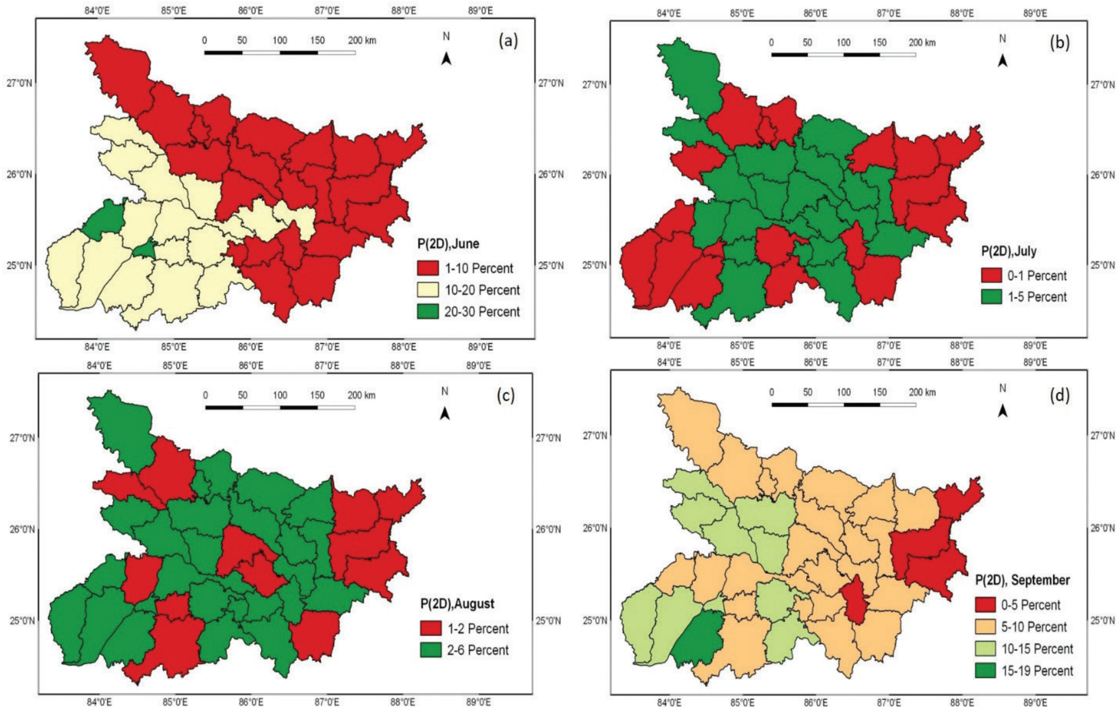


Fig.3.11: Probability of dry spell for two continuous weeks during (a) June (b) July (c) August and (d) September in Bihar

4. Crop Weather Relationship Studies

Kharif 2020

Rice

Bhubaneswar

Growth and yield of six rice cultivars *viz.,* Mandakini, Bina-11, Manaswini, Prativa, Gobinda and OR-25-12-05 was evaluated with a field experiment undertaken with RBD design. The crop was sown on 25 July 2021 and transplanted on 14 August 2021. The accumulated growing degree days (AGDD) requirement for attaining different growth stages was estimated and is presented in Table 4.1.

Table 4.1: Variation in accumulated growing degree days (AGDD) for attaining different growth stages in rice at Bhubaneswar during *kharif* 2020

Varieties	Tillering	PI	Heading	Flowering	Physiological maturity	Grain yield (kg ha^{-1})
Mandakini	635	1194	1534	1611	1864	2837
Bina-11	651	1234	1629	1848	2095	3410
Manaswini	666	1255	1441	1514	2003	3231
Prativa	635	1194	1477	1574	1931	3547
Gobinda	685	1311	1611	1723	2050	4057
OR-25-12-05	666	1213	1594	1685	1950	2836

The cultivars differed in the AGDD during all the phenological stages. Rice cultivar Bina-11 recorded the highest AGDD (2095 degree days) to attain physiological maturity, followed by cv Gobinda (2050 degree days) and cv Mandakini recorded the lowest AGDD (1864 degree days). However, the highest yield was recorded by Gobinda (4057 kg ha^{-1}) and the lowest by Mandakini (2837 kg ha^{-1}).

Chatha

Crop weather relationship studies in Basmati rice was conducted by undertaking a field experiment with three dates of sowing (10 June, 25 June and 10 July 2020) and three basmati cultivars (Pusa-1121, SJR-129, Basmati 370). The effect of dates of sowing and cultivars on radiation use efficiency was estimated and the results are presented in Table 4.2.

Table 4.2: Radiation use efficiency (g MJ^{-1}) at fortnight interval from 30 days after sowing of Basmati rice varieties sown under different swing environments during *kharif* 2020 at Chatha

Sowing Environments	Days after sowing						
	30	45	60	75	90	105	120
10st June 2020	0.30	0.50	0.56	0.63	0.67	0.71	0.73
25th June 2020	0.32	0.42	0.47	0.55	0.56	0.60	0.66
10st July 2020	0.28	0.39	0.41	0.44	0.50	0.54	0.57
Varieties							
Pusa 1121	0.31	0.44	0.45	0.54	0.62	0.64	0.65
SJR-129	0.29	0.40	0.41	0.47	0.50	0.52	0.57
Basmati 370	0.30	0.48	0.56	0.61	0.66	0.70	0.73

The RUE is an important quantifier of crop production in relation to photosynthesis, as it combines both the amount of solar radiation captured by the crop and the efficiency of the crop to produce dry matter assuming other factors are not limiting. Radiation Use Efficiency (RUE) of the direct-sown crop under three different environments showed an increase in RUE and found a maximum at 120 DAS of the crop and thereafter decreased till the harvesting of crop under all the sowing environments (Table 4.2). The maximum RUE (0.73 g MJ^{-1}) was found in crop sown on 10 June showed followed by 25th June (0.66 g MJ^{-1}) and minimum in crop sown on 10 July (0.57 g MJ^{-1}). Among different varieties, the RUE of variety Basmati 370 was recorded highest (0.73 g MJ^{-1}) followed by variety Pusa 1121 (0.65 g MJ^{-1}) and SRJ 129 (0.57 g MJ^{-1}) at 120 days after sowing of the crop. Further, pooling the field experiment data of 2017-2020, a correlation study between stage-wise mean weather elements and grain yield was undertaken and the results are presented in Table 4.3.

Table 4.3: Correlation coefficients between seed yield and meteorological parameters at different phenophases under direct seed sowing of basmati crop during *kharif* 2017-2020

Weather variables / Stages	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)	EPO (mm)	Sunshine (hrs)	Morning relative humidity (%)	Evening relative humidity (%)
P_1	0.111	-0.038	0.058	-0.027	-0.143	-0.226	-0.257
P_2	-0.028	-0.082	-0.067	0.388*	-0.205	-0.073	-0.186
P_3	-0.191	-0.139	0.047	0.144	-0.246	-0.308	-0.341

Weather variables / Stages	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)	EPO (mm)	Sunshine (hrs)	Morning relative humidity (%)	Evening relative humidity (%)
P_4	-0.309	0.059	0.287	-0.244	-0.073	-0.079	0.354*
P_5	-0.099	0.337*	0.300	0.330	-0.004	0.255	0.404*
P_6	0.039	0.149	0.580**	0.224	-0.067	-0.029	0.468**
P_7	0.460**	0.175	0.408*	0.338	0.100	-0.420*	0.370*
P_8	0.818**	0.179	0.130	0.474**	0.543**	-0.049	0.305

*Significant at 0.05, **Significant at 0.01, P_1- Germination; P_2-Tillering; P_3-Jointing; P_4-Panicle Emergence; P_5-Flowering; P_6 - Milking; P_7 - Hard dough; P_8 - Physiological Maturity.

Rainfall had significantly positive effect at the milking and hard dough stages. The evaporation and sunshine hours had significant positive impact at physiological maturity stage and only the evaporation had significant positive impact on tillering stage. The morning relative humidity has significant negative impact at hard dough, while evening relative humidity had positive effect at panicle emergence, flowering and hard dough stage and highly significant positive effect on milking stage.

Dapoli

Correlation between meteorological elements during crop growth stages and grain yield of rice under different sowing dates were carried out using the pooled field experimental data of 2013-20 and the results are presented in Table 4.4.

When rice was sown on 23 SMW, mean minimum temperature (Tmin) during panicle initiation showed significant positive correlation ($p<0.05$) with rice yield. Mean relative humidity during seedling, tillering, panicle initiation, panicle development and flowering stages showed significant negative correlation ($p<0.05$) with rice yield. While mean wind speed during germination stage exhibited significant negative correlation, that of tillering, grain filling and maturity stages showed significant positive correlation with rice yield. Mean seasonal rainfall during panicle initiation exhibited significant negative correlation with rice yield.

Table 4.4: Correlation coefficient between meteorological variables during crop growth stages and grain yield when crop sown on 23rd SMW during 2013-20 at Dapoli

Parameters	Physiological stages of Rice					
	Germination	Seedling	Tillering	Panicle Initiation	Panicle Development and Flowering	Grain Filling and Maturity Stage
T_{max}	-0.1	0.1	0.2	0.2	0.3	0.1
	31.4	29.6	28.2	28.6	29.4	31.3
	28.5-35.5	27.8-31.0	26.7-29.3	27.2-29.9	27.5-33.1	28.7-34.0
T_{min}	0.1	0.2	-0.1	0.37*	-0.1	-0.1
	24.4	24.0	23.6	23.4	23.0	22.5
	22.5-26.2	22.9-24.7	22.9-24.2	22.7-24.2	21.8-23.8	20.9-23.3
RH-I	0.0	-0.447*	-0.461*	-0.2	-0.1	0.2
	92	93	95	94	94	93
	84-99	89-97	93-97	92-96	90-98	90-96
RH-II	-0.2	-0.3	-0.409*	-0.324*	-0.393*	0.0
	79	86	89	86	83	76
	50-97	76-95	80-93	79-92	70-93	60-87
Wind speed	-0.43*	0.1	0.32*	0.2	0.0	0.42*
	7.9	7.4	7.7	5.1	3.8	2.6
	3.5-11.3	4.9-10.2	4.7-10.2	2.4-11.2	2.0-6.1	0.8-5.0
Rainfall	0.0	-0.3	-0.3	-0.37*	-0.2	0.3
	197	854	1507	379	454	253
	1.2	277.4	446.0	100.3	27.2	1.8
BSS	-0.1	0.2	0.2	-0.2	0.1	-0.2
	3.6	3.1	1.9	2.8	3.9	5.2
	0.7	1.2	0.3	0.3	1.4	2.8
Epan	0.2	0.1	-0.1	0.0	0.0	-0.2
	3.8	3.4	2.8	3.1	3.3	3.7
	1.4	2.4	1.4	1.2	2.4	2.4

*Significant at 5% level

Value below the correlation indicate mean and range of weather parameters

Jorhat

Crop weather relationship studies in *sali* rice was conducted with three rice cultivars (Mahsuri, Swarna sub-1 and TTB-404) and three transplanting dates (26 June, 11 July and 27 July). Correlation study between grain yield and phenophase-wise mean meteorological elements was conducted and the results are presented in Table 4.5.

Table 4.5: Correlation between grain yield and phasic mean meteorological parameters in *kharif* rice 2020

Weather parameters	Phenological stages	Grain yield (kg ha^{-1})	Max LAI	Effective tillers/m^2
Tmax (mean)	Transplanting to PI	0.05	0.01	0.62
	PI to 50% Flowering	0.05	-0.23	0.14
	50% flowering to PM	-0.59	-0.19	-0.36
Tmin (mean)	Transplanting to PI	-0.21	0.18	0.72*
	PI to 50% Flowering	-0.25	0.09	-0.08
	50% flowering to PM	-0.55	-0.14	-0.27
BSSH (mean)	Transplanting to PI	0.05	-0.07	0.64
	PI to 50% Flowering	0.54	0.04	0.13
	50% flowering to PM	0.48	0.24	0.01
RF (Total)	Transplanting to PI	0.25	0.12	-0.72*
	PI to 50% Flowering	-0.67*	-0.40	-0.45
	50% flowering to PM	-0.45	-0.22	-0.36
RH (mean)	Transplanting to PI	-0.03	0.03	-0.63
	PI to 50% Flowering	-0.71*	-0.17	0.21
	50% flowering to PM	-0.43	-0.08	-0.25
Evaporation (Cumulative)	Transplanting to PI	0.21	-0.12	-0.86**
	PI to 50% Flowering	-0.21	-0.52	-0.62
	50% flowering to PM	-0.58	0.11	0.38

** and **significant at 5 and 1 percent levels, respectively*

The results indicated that maximum temperature, minimum temperature, bright sunshine hours, rainfall, mean relative humidity and pan evaporation has multiple effects on the growth and development of rice crop. During vegetative (transplanting to panicle initiation) and maturity stages (50% flowering to physiological maturity); no significant association was observed among different weather parameters and grain yield. However, rainfall and mean RH during the reproductive stage showed a significant negative association with grain yield with correlation coefficient -0.67* and -0.71*, respectively. Similarly, the number of effective tillers per square meter showed a significant association with minimum temperature, rainfall and evaporation. During the vegetative stage (transplanting to PI) of the crop, minimum temperature showed significant positive association (0.72*) with numbers of effective tillers per square meter; whereas the negative association was observed with rainfall (-0.72*) and evaporation (-0.86*). Thus, an increase in minimum temperature was found favorable for an increase in the numbers of effective tillers per square meter in rice.

Jabalpur

Crop-weather relationship studies in rice during *kharif* 2020 was conducted at Jabalpur with three dates of sowing (6 July, 22 July and 10 August) and five cultivars (Kranti, Sahbhagi, IR-36, MTU 10-10 and JR-81.

The correlation studies between grain yield and weather parameters among different phenological stages were presented in the Table 4.6. The results indicated that both maximum and minimum temperatures during vegetative, milking, and dough to physiological maturity stages showed a positive relationship with grain yield of the crop. However, it exhibited a negative relationship from tillering to panicle initiation for maximum temperature whereas positive association with minimum temperature. The bright sunshine hours observed a significant negative relationship during vegetative and flowering stage, and again positive during milk and dough stages of the crop. Both rainfall and rainy days exhibited a positive relationship with grain yield among all the growth stages of the crop, except flowering stage.

Table 4.6: Correlation between weather parameters and grain yield among different phenological stages in direct-seeded rice in Jabalpur during *kharif* 2020

Phenological stage		Max T	Min T	Mean T	Sunshine	GDD	HTU	PTU	RH mor	RH eve	Winds peed	Evapo ration	Rainfall	Rainy days
Sowing to Emergence	Correlation	.730**	.703**	.784**	0.508	-.802**	0.493	-.795**	-.808**	-.680**	-0.163	.681**	-.603*	-.745**
	Sig. (P<0.05)	0.002	0.003	0.001	0.053	0	0.062	0	0	0.005	0.562	0.005	0.017	0.001
Emergence to Tillering	Correlation	.655**	.796**	.713**	0.317	.783**	.561*	.792**	-0.173	-0.17	-.780**	-.603*	-0.458	0.08
	Sig.	0.008	0	0.003	0.249	0.001	0.03	0	0.537	0.545	0.001	0.017	0.086	0.776
Tillring to Panicle Ini.	Correlation	-.813**	.798**	-.628*	-.820**	-.514*	-.818**	-0.382	.805**	.838**	.843**	.731**	.777**	.737**
	Sig.	0	0	0.012	0	0.05	0	0.16	0	0	0	0.002	0.001	0.002
Panicle Ini. to Hading	Correlation	0.125	.761**	.652**	-0.42	-0.428	-.517*	-0.401	0.135	.637*	-.744**	-0.431	0.141	0.326
	Sig.	0.657	0.001	0.008	0.119	0.112	0.048	0.139	0.63	0.011	0.001	0.108	0.616	0.236
Heding to Flower Ini.	Correlation	0.446	.825**	.898**	-0.407	0.065	-0.362	0.347	-0.003	.645**	-.660**	-0.34	-0.141	0.111
	Sig.	0.096	0	0	0.132	0.819	0.184	0.205	0.993	0.009	0.007	0.215	0.617	0.694
Flower Ini. to Milking	Correlation	.724**	.840**	.852**	-.847**	-0.219	-.703**	0.021	.655**	.864**	-.808**	.516*	.708**	.657**
	Sig.	0.002	0	0	0	0.433	0.003	0.941	0.008	0	0	0.049	0.003	0.008
Milking to Dough	Correlation	0.154	.796**	.724**	-.829**	0.304	-.744**	0.41	.869**	.820**	-0.394	0.5	.612*	0.472
	Sig.	0.584	0	0.002	0	0.271	0.001	0.129	0	0	0.146	0.058	0.015	0.076
Dough to Physiological maturity	Correlation	.793**	.774**	.801**	0.18	.883**	.836**	.891**	.624*	0.498	-.761**	.790**	-0.345	-0.152
	Sig.	0	0.001	0	0.521	0	0	0	0.013	0.059	0.001	0	0.208	0.588
Physiological maturity to harvest maturity	Correlation	.828**	.860**	.867**	-0.345	.588*	0.501	.614*	.619*	.514*	.569*	.796**	0.208	0.184
	Sig.	0	0	0	0.208	0.021	0.057	0.015	0.014	0.05	0.027	0	0.458	0.51

* Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed).

Mohanpur

Crop weather relationship studies in *kharif* rice was studied using four sowing dates (19 June, 3 July, 17 July and 31 July 2020) and three cultivars (Nayanmani, Satabdi and Swarna). Effect of dates of sowing and cultivars on absorbed PAR and radiation use efficiency was studied. It was observed that the absorption percentage of PAR increased (25%) from tillering to panicle initiation stage for all the dates of transplanting, except 19 June (Fig.4.1). For 19 June transplanted crop, the rate of change of absorption percentage of PAR was very low up to flowering stage and it increased (7%) from flowering to milking stage. At the harvesting stage, maximum and minimum APAR was observed on 19 June and 31 July transplanted crops, respectively.

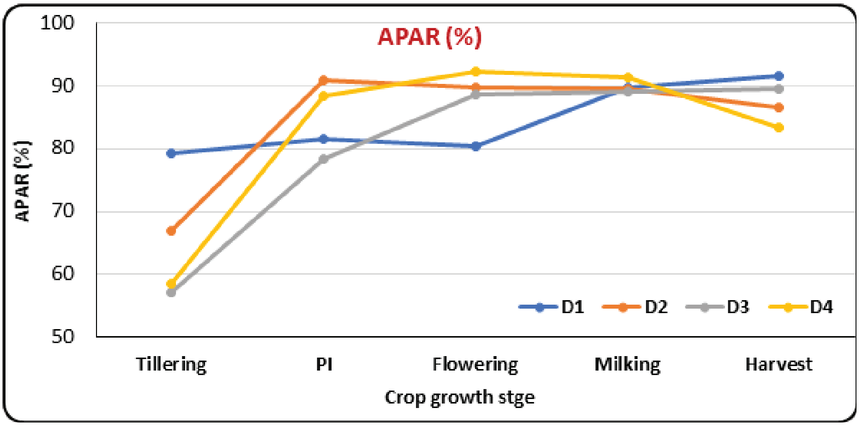


Fig.4.1: Variation in absorbed PAR in rice due to date of transplantation [19 June (D1), 3 July (D2), 17 July (D3) and 31 July (D4)] at Mohanpur during *kharif* 2020.

Much variation in APAR was not observed among the varieties. For Satabdi, APAR was lower in tillering and PI stages (Fig.4.2). From flowering to harvesting, APAR of Nayamani was the lowest. APAR for Satabdi and Swarna was almost similar.

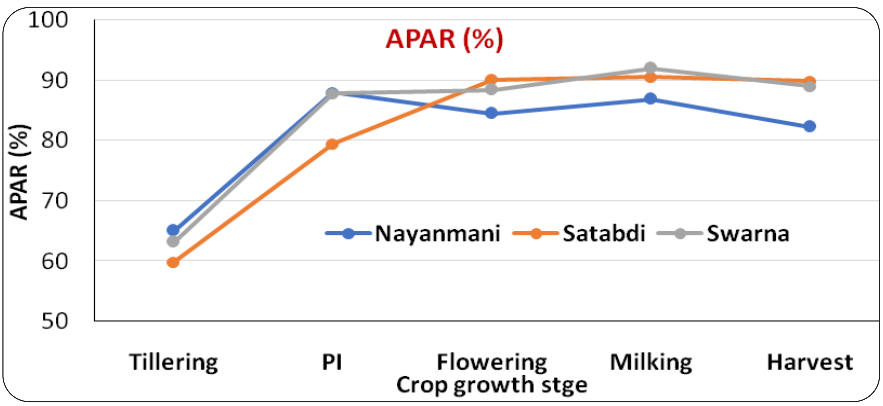


Fig.4.2: Variation in absorbed PAR in rice cultivars Nayanmani, Satabdi and Swarna at Mohanpur during *kharif* 2020.

Table 4.7: Variation in total absorbed PAR, grain yield and radiation use efficiency in rice at Mohanpur during *kharif* 2020

Treatments	Total APAR (MJ)	Grain yield (kg ha^{-1})	RUE (g MJ^{-1})
Date of transplanting			
19 June	1350	5422	0.45
3 July	1490	4692	0.35
17 July	1240	3848	0.32
31 July	1382	3581	0.27
Cultivar			
Nayanmani	1054	4920	0.47
Satabdi	1293	4984	0.38
Swarna	1750	3253	0.19

The influence of dates of transplanting and cultivars on total APAR, grain yield and radiation use efficiency of rice are presented in Table 4.7. Crop transplanted on 19 June recorded highest grain yield (5422 kg ha^{-1}) and RUE (0.45 g MJ^{-1}). The lowest yield and RUE were recorded by crop transplanted on 31 July. Among the cultivars, Nayanmani recorded highest RUE (0.47 g MJ^{-1}), followed by Shatabdi (0.38 g MJ^{-1}).

Raipur

Correlation between phenophase-wise mean weather parameters and grain yield of rice cultivars MTU-1010, Rajeshwari and CG Sugandhit Bhog was undertaken with field experiment data of *kharif* 2017, 2018 and 2019. Mean weather data of five growth stages *viz.,* sowing-tillering (P-I), tillering-panicle initiation (P-II), panicle initiation-flowering (P-III), flowering-milking (P-IV) and milking-maturity (P-V) were used for the study. The result obtained for cultivar MTU-1010 is presented in Table 4.8.

Table 4.8: Correlation coefficients between weather parameters during different growth stages and rice yield (MTU-1010)

Stage	Tmax	Tmin	BSS	RF	RH-I	RH-II
P-I	-0.845**	-.865**	-0.762*	0.688*	0.912**	0.850**
P-II	-0.067	-0.463	-0.100	0.214	0.707*	0.110
P-III	-0.245	-0.510	0.138	-0.175	-0.021	-0.168
P-IV	0.241	-0.360	0.449	0.165	0.018	-0.603
P-V	0.417	-0.576	0.429	-0.896*	0.070	-0.664*

*** Significant at 95%, * Significant at 90%*

It was found that maximum temperature has significant effect only during P-I stage and is negatively correlated with grain yield. Hence, higher Tmax values above threshold level during P-I stage will have negative effect on grain yield. Tmin and bright sunshine hours also showed similar result. Rainfall during P-I had significant positive correlation while that of P-V stage had significant negative correlation with grain yield. RH-1 during P-I and P-II had significant positive correlation with grain yield. While RH-2 during P-I had significant positive correlation, that of P-V had significant negative correlation with grain yield.

Results of correlation study between grain yield of cultivar CG Sugandhit Bhog and weather parameters are presented in Table 4.9. Mean Tmax and BSS during P-V showed significant positive correlation with grain yield. At the same time, total rainfall and RH-2 during P-V had significant negative correlation. All other parameters during each stage had non-significant positive/negative correlation with grain yield.

Table 4.9: Correlation of mean weather parameters during different growth stages with yield of rice cv. CG Sugandhit Bhog at Raipur

Stage	Tmax	Tmin	BSS	RF	RH-I	RH-II
P-I	-0.31	-0.44	-0.38	0.34	0.40	0.16
P-II	-0.00	-0.43	-0.19	0.04	0.31	0.04
P-III	0.23	-0.33	0.07	-0.56	-0.01	-0.49
P-IV	0.26	-0.24	0.29	-0.35	-0.13	-0.29
P-V	0.85**	-0.23	0.88**	-0.75*	-0.62	-0.77*

*** Significant at 95%, * Significant at 90%*

Ranchi

Study on effect of various growing environments and cultivars on heat and radiation use efficiencies in rice were undertaken at Ranchi. The experiment consisted of three dates of sowing *viz.,* 5th June (early sowing), 15th June (Normal sowing) and 25th June (Late sowing) and three cultivars *viz.,* Sahbhagi, Naveen and MTU 1010. Five years experimental data was pooled to undertake the analysis and the results are presented in Table 4.10.

Table 4.10: Heat Use Efficiency and Radiation Use Efficiency of rice varieties under different sowing dates

Treatments	HUE (kg ha^{-1} degree day^{-1})	RUE (g MJ^{-1})
Date of sowing		
Early	2.22	2.18
Normal	2.16	2.14
Late	2.23	2.22
SEm	0.07	0.06
CD at 5%	NS	NS

Treatments	HUE (kg ha^{-1} degree day^{-1})	RUE (g MJ^{-1})
Variety		
Sahbhagidhan	2.02	2.07
Naveen	2.39	2.34
MTU1010	2.19	2.12
SEm	0.07	0.06
CD at 5%	0.21*	0.18*
Interaction		
SEm	0.12	0.11
CD at 5%	NS	NS

Among the dates of sowing, late sown crop recorded highest HUE and RUE, followed by early sown crop. However, the differences among dates of sowing was not significant. Among the cultivars, Naveen recorded the highest HUE and RUE, followed by MTU 1010. The difference in HUE and RUE among the three cultivars were significant at $p<0.05$. However, the interaction effect between dates of sowing and cultivars was not significant.

Maize

Faizabad

Impact of growing environment and cultivars on yield and heat use efficiency in maize was studied during *kharif* 2020. Three crop growing environments (5 July, 15 July and 25 July) and three maize cultivars (Kanchan, Azad hybrid-1 and Azad hybrid-2) were used in the field experiment. Yield and HUE of maize as affected by growing environments and cultivars are presented in Table 4.11.

Table 4.11: Effect of crop growing environment on yield and HUE of *kharif* maize varieties

Treatments	Yield (kg ha^{-1})	HUE (kg ha^{-1} ^{o}C day^{-1})
Crop growing environments		
05 July	3360	1.78
15 July	2820	1.74
25 July	1940	1.32
Cultivars		
Kanchan	3120	1.87
Azad hybrid-1	2620	1.62
Azad hybrid-2	2440	1.46

The results indicated that the crop sown on 05 July recorded highest yield (3360 kg ha^{-1}) and HUE (1.78 kg ha^{-1} °C day^{-1}), followed by that of 15 July. A reason for higher yield and HUE of 05 July sown crop may be that among the crop growing environments, 05 July sown crop had longest duration and hence, accumulated highest growing degree days. Among the cultivars, Kanchan recorded highest yield and HUE, followed by Azad hybrid-1.

Pearl millet

Anand

Relation between phase-wise mean weather parameters and pearl millet yield was studied during *kharif* season of 2017-2020 with three dates of sowing (sowing with the onset of monsoon rainfall, 10 days after the onset and 20 days after the onset) and three cultivars (GHB-538, GHB-558 and GHB-744). The correlation analysis revealed that the crop's production performance was negatively associated with rainfall and minimum temperature during the emergence to booting phase (Table 4.12).

Table 4.12: Phase-wise correlation coefficient between weather parameters and pearl millet grain yield (2017-2020) (n=36)

Phase	BSS (h)	Rain (mm)	Tmax (°C)	Tmin (°C)	RH-I (%)	RH-II (%)
Emergence- Booting	-0.26	-0.73**	-0.21	-0.43**	0.55**	0.32
Booting -50% Flowering	-0.03	-0.21	-0.04	-0.35*	-0.06	-0.12
50% Flowering - 100% flowering	0.05	-0.23	0.00	-0.41*	-0.02	-0.11
100% flowering - Grain filling	-0.13	-0.12	-0.19	-0.27	0.26	0.26
Grain filling – Physiological maturity	0.24	0.26	0.26	-0.08	0.09	0.01

The production was positively associated with morning relative humidity prevailed during some growth phases. Strong negative association (r = -0.73**) with rainfall receipt during emergence to booting might might be due to high rainfall events which might have affected germination and initial growth of the crop. Minimum temperature till 100% flowering phase, correlated negatively. It indicates that low night temperature lowers the production performance of pearl millet. In general, pearl millet crop is more sensitive to the weather experienced by crop during emergence to booting phase and night temperature affects the crop up to 100% flowering. Out of 30 independent parameters (phases × weather parameters), stepwise regression retained rainfall, maximum temperature and relative humidity during emergence to booting phase, sunshine hours during 50 - 100% flowering and rainfall during 100% flowering to grain filling. Resulted regression model has adjusted coefficient of determination 0.88 and RMSE 331 kg ha^{-1}.

$Y\ (kg\ ha^{-1}) = -78.8 \times BSS_{p3} - 4.5 \times RF_{p1} - 2 \times RF_{p4} + 1587 \times Tmax_{p1} + 299.4 \times RH\text{-}I_{p1} + 317 \times RH\text{-}II_{p1} - 96918.5$ (AdjR^2=0.88; RMSE 331 kg ha^{-1})

p1 = emergence to booting phase

p3 = 50% to 100% flowering

p4 = 100% flowering to grain filling

It was also found that the crop sown during the onset of monsoon had the highest yield, which reduced as the sowing got delayed (Fig.4.3).

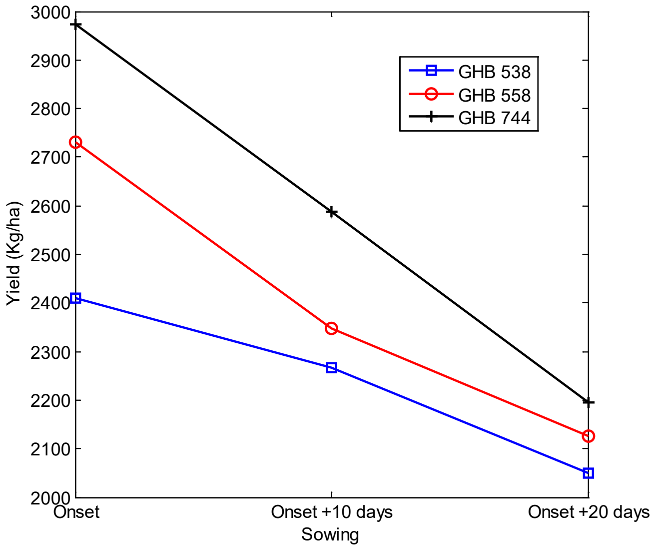


Fig.4.3: Productivity of pearl millet cultivars during different rainfed growing environments (2017-2020) at Anand

Hisar

Crop weather relationship study in pearl millet was undertaken using three dates of sowing (28 June, 9 July and 25 July 2020) and three cultivars (GHB-558, HHB-67 and HHB-272) during *kharif* 2020. Effect of dates of sowing and cultivars on chlorophyll concentration index (CCI). A portable, non-destructive, and lightweight instrument (CCM-200; Opti-Sciences Inc., Hudson, NH, USA) was used to estimate CCI in pearl millet, which provided instantaneous, *in situ* information.

CCI values were estimated from the bottom, middle and top of fully expanded functional leaf on each selected plant. Total of three plants were measured in each plot, and three CCI readings per leaf, including one reading around the midpoint of leaf blade and two readings three cm apart from midpoint. These values were averaged for the mean CCI reading of each leaf. Leaf

CCI values at the different growing stages were sensitive to relative chlorophyll content, which increased and then decreased with advancement of crop which is evident from the Table 4.13. The CCI of pearl millet increased gradually up to 49 DAS and then decreased till PM. The growing environment did not significantly influence the CCI at all growth stages except at 35 and 49 DAS. At maximum leaf area stage (49 DAS), highest CCI was recorded under 28th June sown crop (70.9) followed by 25th July (63) and 9th June (59.8). The CCI also did not differ significantly among the varieties at all growth stages except at 21 and 28 DAS (Table 4.13). HHB 67 improved recorded maximum values of chlorophyll content index followed by GHB 558 and HHB 272 throughout the crop growth.

Table 4.13: Effect of sowing dates on chlorophyll concentration index (CCI) of bajra varieties during 2020

Treatment	Chlorophyll Concentration Index (CCI)						
	21 DAS	28 DAS	35 DAS	42 DAS	49 DAS	56 DAS	PM
Sowing dates							
D_1 (28th June)	16.77	28.01	32.77	61.43	70.95	50.74	39.58
D_2 (9th July)	17.21	28.73	43.05	56.40	59.86	46.51	41.53
D_3 (25th July)	15.59	26.03	35.03	64.33	63.04	53.58	38.41
SE(m)	2.03	3.38	2.39	4.33	3.34	3.80	2.99
CD @ 5%	NS	NS	7.02	NS	9.81	NS	NS
Varieties							
GHB-558	13.70	22.87	37.91	60.01	58.58	48.10	39.28
HHB-67 (improved)	23.48	39.21	39.22	62.92	68.06	52.11	41.94
HHB-272	12.39	20.69	33.73	59.23	67.21	50.62	38.30
SE(m)	2.03	3.38	2.39	4.33	3.34	3.80	2.99
CD @ 5%	5.95	9.93	NS	NS	NS	NS	NS

Solapur

Effect of crop growing environments and cultivars on consumptive use of moisture (CUM) and moisture use efficiency (MUE) in pearl millet was studied during *kharif* 2016-2020 using three dates of sowing (2nd fortnight of June, 2nd fortnight of July and 2nd fortnight of August) and three varieties (ICTP-8203, Mahyco hybrid and Dhanshakti). The crop sown in second fortnight of July recorded higher CUM (383.7 mm) and mean MUE (3.95 Kg ha^{-1} mm) compared to other two growing environments. Dhanshakti recorded highest mean value of CUM (356.2 mm) and MUE (3.82 Kg ha^{-1} mm) which indicated that Dhanshakti variety utilized the moisture most efficiently for productions of grains. The relationship between grain yield with CUM and MUE is presented in Figures 4.4 and 4.5, respectively.

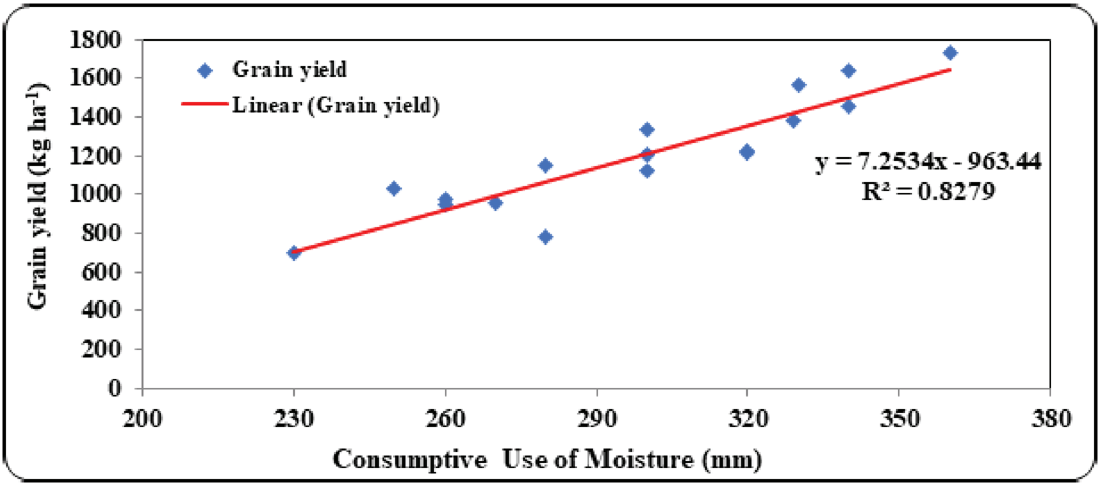


Fig.4.4: Relation between grain yield with consumptive use of moisture in pearl millet during 2016-2020 at Solapur

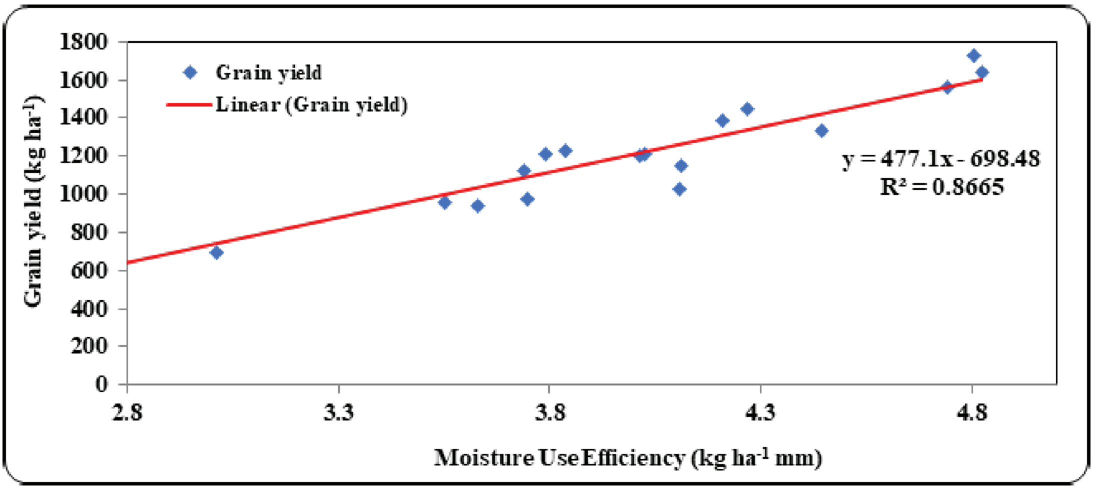


Fig.4.5: Relation between grain yield with moisture use efficiency in pearl millet during 2016-2020 at Solapur

Finger millet

Ranichauri

Field experiment was conducted during *kharif* 2020 with three dates of sowing (3, 12 and 26 June 2020) and three finger millet varieties (VLM-324, PRM-2, VLM-347) to study the crop weather relationship. Accumulated growing degree days (AGDD) was estimated for different growth stages of the crop (Table 4.14).

Table 4.14: Cumulative Growing Degree Days during different phenological phases of finger millet

S. No.	Parameters	Cumulative GDD		
		D1	D2	D3
1	Emergence	117.9	224.9	172.9
2	Tillering stage	230.6	360.1	294.9
3	Terminal spikelet (Jointing)	455.2	577.9	413.9
4	50% flowering	720.5	798.6	735.2
5	Beginning of grain filling	901.2	972.12	907.9
6	Physiological maturity	1081.4	1091.4	993.4

Among the dates of sowing, crop sown on 12 June recorded highest AGDD, followed by that of 3 June. The data pertaining to Plant height, dry matter accumulation, 1000- seed weight and grain yield of finger millet is presented in Table 4.15.

Table 4.15: Plant height, dry matter accumulation (DMA), 1000 seed weight and grain yield of finger millet as influenced by sowing dates and varieties

Treatments	Plant height (cm) at maturity	DMA/m^2 at maturity	1000-seed wt (g)	Grain yield (kg ha^{-1})
Sowing Dates				
02.06.2020	79.4	274	2.94	1663
12.06.2020	70.1	233	2.81	1206
22.06.2020	68.2	198	2.70	1445
SEm±	2.3	17	0.01	153
CD (P=0.05)	8.5	52	**NS**	**NS**
Varieties				
VLM-324	70	241	2.91	1325
PRM-2	72	217	2.82	1735
VLM-347	76	247	2.73	1255
SEm±	2.3	17	0.01	153
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**

Sowing dates as well as varieties did not differ significantly for all these parameters, except for plant height and dry matter accumulation where sowing dates differed significantly for these two parameters. Maximum plant height was observed for the crop sown on 02 Jun and it remained significantly superior over other two sowing dates. Similarly, maximum dry matter accumulation was observed in crop sown on first date and it remained significantly superior over third sowing date. No significant difference was observed between first and second sowing date for dry matter accumulation. Higher weight of thousand seeds and also grain yield was recorded with first sowing date, however the difference was non-significant. The interaction between sowing date and varieties were also found to be non-significant for all these parameters.

Soybean

Akola

Correlation between mean weather elements during growth stages and seed yield of soybean was studied using four dates of sowing (26 June, 7 July, 12 July and 21 July 2020) and three varieties (JS-335, JS-9305 and AMS-1001) during *kharif* 2020. The Pearson's correlation coefficient between seed yield and weather variables is presented in Table 4.16.

Table 4.16: Pearson's correlation coefficient between seed yield and weather variables prevailed in different phenophases of soybean- 2020-21

Parameters	VG	FL	PF-SF	Total growing period
Tmax	0.74**	-0.74**	0.04*	-0.40*
Tmin	0.83**	-0.42*	0.43*	0.63**
RH-I	-0.55**	0.38*	0.66**	-0.67**
RH-II	-0.71**	0.64**	0.59**	0.27*
Rainfall	0.16*	0.52**	0.82**	0.84**
Rainy days	0.75**	0.33*	0.59**	0.66**
BSS	0.57**	-0.65**	0.28*	-0.52*
EVP	0.84**	-0.79**	0.28*	0.45**

**Significant at 0.05 level **Significant at 0.01 level*

During the vegetative stage (VG) the weather variables like temperature (maximum and minimum), bright sunshine hours, evaporation, GDD and PTU showed significant positive and both the relative humidity in negative association with seed yield. During the flowering (FL) stage, both the temperatures, bright sunshine hours and evaporation showed significant negative association. Pod formation to seed formation all weather parameters showed positive association with seed yield. Maximum temperature indicated positive linear trend during vegetative phase and negative linear trend during reproductive phase (Fig.4.6). The optimum value of maximum temperature was 31.0 °C during vegetative phase and 31.5 °C for reproductive phase. Minimum temperature exhibited positive linear trend during both vegetative and reproductive phase and optimum value was 23.2 °C and 21.5 °C for vegetative and reproductive phases, respectively.

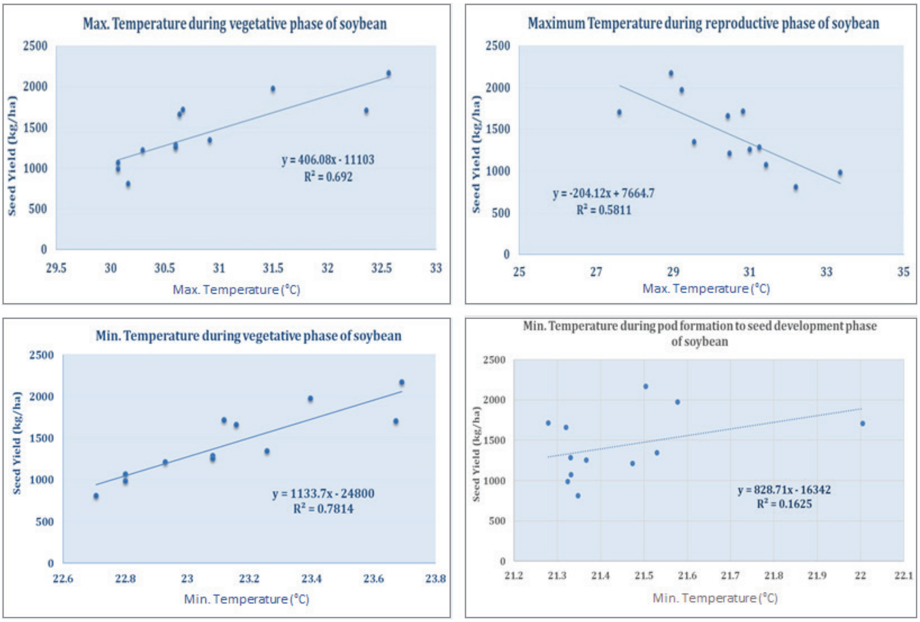


Fig.4.6: Impact of Tmax and Tmin during vegetative and reproductive phases of soybean at Akola during *kharif* 2020

Further, effect of dates of sowing and varieties on water productivity of soybean was studied and the results are presented in Table 4.17. Water productivity (WP), as a ratio of yield to actual crop water use, was maximum under 26 MW sowing (D_1) and decreased with later sowings. Among the varieties, JS-9305 showed higher Et_a followed by JS-335and AMS-1001. WP was higher with JS 335 followed by AMS-1001 and JS-9305.

Table 4.17: Water productivity in soybean as influenced by dates of sowing and varieties in Akola during *kharif* 2020

Treatment	Seed yield (kg ha^{-1})	Eta (mm)	WP (kg ha-mm^{-1})
Sowing dates			
D_1- 26 SMW (26 June)	1950	393	4.96
D_2- 27 SMW (07 July)	1575	369	4.27
D_3- 28 SMW (12 July)	1252	339	3.70
D_4- 29 SMW (21 July)	956	362	2.64
Varieties			
V_1- JS-335	1560	366	4.26
V_2- JS-9305	1270	375	3.39
V_3- AMS-1001	1470	356	4.13

Jabalpur

Correlation of weather parameters with seed yield at different phenological stages in soybean was studied using field experiment conducted during *kharif* 2020 with three dates of sowing (14 June, 29 June and 14 July 2020) and three varieties (JS-20-98, JS-20-34 and JS-20-69). The result suggested that GDD and HTU exhibited a significant relation with positive association between GDD and HTU with seed yield during vegetative stage in soybean (Table 4.18). Similarly, a negative association observed between GDD and PTU with seed yield during flower to pod formation stages. The minimum temperature observed a negative correlation with seed yield at maturity stage whereas bright sunshine hours and evaporation exhibited a positive correlation with seed yield at similar stage.

Parbhani

Correlation studies between weather parameters and seed yield of soybean was conducted using the field experiment conducted during *kharif* 2020 with four dates of sowing (18 June – 25 SMW, 25 June – 26 SMW, 2 July – 27 SMW and 9 July – 28 SMW) and three cultivars (MAUS-158, MAUS-71 and JS-335). The correlation studies between seed yield and weather parameters prevailed during crop growing season are presented in Table 4.19.

The rainfall has been significantly positively correlated with seed yield at P2, P3, P6, P9 and P10 stages and negative correlated of P1 and P7 stages of MAUS-158, MAUS-71 and JS-335 varieties. The maximum temperature has significantly positively correlated with seed yield at all stages of all varieties except P6 and P7 stage of MAUS-158 & MAUS-71 and P6 and P10 stage of JS-335 variety has been negatively correlated. The minimum temperature has significantly positively correlated with seed yield at all stages of MAUS-158, MAUS-71 and JS-335 varieties except P7 stage. The RH-I and RH-II has significantly negative correlated with seed yield of all stages of MAUS-158, MAUS-71 and JS-335 varieties however RH-I and RH-II has positively correlated of P6 and P9 of MAUS-158 and MAUS-71 and P6, P8 and P10 of JS-335. The Bright sunshine hours has significantly positively correlated with seed yield at P2, P3 and P4 stages of MAUS-158, MAUS-71 and JS-335 and negative correlated at P2, P3, P7 and P10 stages of MAUS-158 and JS-335 varieties however bright sunshine hours has positive correlated at all stages except P2, P3, P7 and P10 stage has negative correlation of MAUS-71.

Table 4.18: Correlation of weather parameters with seed yield at different phenological stages in soybean

		T max	Tmin	Mean	SSH	GDD	HTU	PTU	RHe	RH m	WS	Evap	Rain	Rainydays
Sowing to Emergence	Pearson Correlation	-0.554	0.539	-0.290	-0.255	0.185	-0.084	0.184	0.159	0.429	-0.072	0.058	0.178	0.306
	Sig. (2-tailed)	0.122	0.135	0.449	0.508	0.634	0.830	0.635	0.682	0.250	0.854	0.882	0.647	0.424
Emergence to Branching	Pearson Correlation	-0.554	0.539	-0.290	-0.255	0.185	-0.084	0.184	0.159	0.429	-0.072	0.058	0.178	0.306
	Sig. (2-tailed)	0.122	0.135	0.449	0.508	0.634	0.830	0.635	0.682	0.250	0.854	0.882	0.647	0.424
Branching to Flowering	Pearson Correlation	0.063	-0.141	0.014	0.220	0.927**	0.545	.931**	0.147	0.018	-0.436	-0.202	0.309	0.333
	Sig. (2-tailed)	0.872	0.718	0.971	0.570	0.000	0.129	0.000	0.706	0.964	0.241	0.603	0.418	0.381
Flowering to Pod Development	Pearson Correlation	-0.510	-0.024	-0.453	-0.473	-0.640	-0.489	-0.642	0.410	0.400	0.251	-0.307	-0.073	0.147
	Sig. (2-tailed)	0.161	0.952	0.221	0.198	0.063	0.182	0.062	0.273	0.286	0.515	0.422	0.851	0.706
Pod Development to Physiological Maturity	Pearson Correlation	0.074	-0.058	0.000	0.120	-0.089	0.234	-0.100	-0.125	-0.096	-0.096	0.425	-0.088	-0.162
	Sig. (2-tailed)	0.851	0.882	1.000	0.758	0.820	0.545	0.798	0.749	0.805	0.805	0.254	0.822	0.678
Physiological Maturity to Harvest Maturity	Pearson Correlation	0.317	-0.657	-0.565	.689*	-0.345	0.497	-0.405	-0.299	-0.547	-0.330	.705*	-0.373	-0.373
	Sig. (2-tailed)	0.406	0.055	0.113	0.040	0.363	0.174	0.279	0.434	0.128	0.386	0.034	0.323	0.323

Table 4.19: Correlation coefficient between seed yield and weather variables prevailed in different phenophases of Soybean during *kharif* 2020 at Parbhani

Parameters	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}
V1 (MAUS 158)										
Rainfall	-0.970**	0.919**	0.329	-0.094	-0.196	0.712**	-0.867**	0.121	0.469*	0.377
Tmax	0.732**	0.971**	0.847**	0.830**	0.255	-0.677**	-0.676**	0.273	-0.414	-0.232
Tmin	0.843**	0.953**	0.945**	0.756**	0.940**	0.940**	-0.871**	0.659**	0.117	0.920**
RH-I	-0.244	-0.738**	-0.911**	-0.706**	-0.627**	0.219	0.324	-0.230	0.495*	-0.858**
RH-II	-0.520*	-0.999**	-0.678**	-0.816**	-0.129	0.699**	0.432	0.229	0.531*	0.366
BSS hrs/day	-0.110	0.983**	0.657**	0.856**	0.237	-0.684**	-0.362	0.289	-0.657**	-0.329
V2 (MAUS 71)										
Rainfall	-0.983**	0.972**	0.434	-0.298	-0.044	0.744**	-0.952**	0.322	0.287	0.557*
Tmax	0.757**	0.968**	0.936**	0.926**	0.118	-0.804**	-0.532*	0.109	-0.387	-0.425
Tmin	0.750**	0.956**	0.992**	0.860**	0.912**	0.870**	-0.953**	0.768**	-0.054	0.975**
RH-I	-0.096	-0.862**	-0.971**	-0.838**	-0.504*	0.418	0.133	-0.031	0.359	-0.874**
RH-II	-0.475*	-0.974**	-0.785**	-0.918**	-0.013	0.817**	0.258	0.414	0.356	0.546*
BSS hrs/day	0.046	0.993**	0.784**	0.935**	0.096	-0.822**	-0.180	0.105	-0.490*	-0.516*
V3 (JS-335)										
Rainfall	-0.960**	0.990**	0.558*	-0.481*	0.075	0.776**	-0.994**	0.498*	0.111	0.700**
Tmax	0.781**	0.933**	0.974**	0.985**	0.012	-0.908**	-0.384	-0.028	-0.297	-0.609**
Tmin	0.645**	0.931**	0.993**	0.940**	0.860**	0.773**	-0.986**	0.818**	-0.192	0.993**
RH-I	0.089	-0.950**	-0.979**	-0.934**	-0.388	0.597**	-0.045	0.152	0.238	-0.876**
RH-II	-0.450	-0.905**	-0.878**	-0.981**	0.062	0.914**	0.096	0.563*	0.150	0.712**
BSS hrs/day	0.233	0.963**	0.858**	0.983**	-0.013	-0.923**	-0.012	-0.061	-0.292	-0.687**

* = Significant at 5% ; ** = Significant at 1% ; 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

Vijayapura

Results of the field experiments conducted during *kharif* 2016-2020 were pooled and statistically analyzed for establishing relationships between stage wise meteorological variables and soybean yield through correlation procedure, and the results are presented in Table 4.20.

Table 4.20: Correlation co-efficient between seed yield of soybean (all 3 varieties) and stage-wise agrometeorological variables

Parameter	Germination	Seedling	Vegetative	Flowering	Pod Development	Maturity
Tmax	0.52	0.10	0.28	0.03	-0.28	-0.50
Tmax	0.60	0.17	0.48	0.51	0.61	0.61
VP1	0.58	0.27	0.42	0.41	0.65	0.66
VP2	0.09	-0.47	0.14	0.34	0.75	0.74
RH-1	-0.15	-0.10	-0.06	0.25	0.63	0.68
RH-II	-0.43	-0.11	-0.10	0.09	0.73	0.76
TR	0.41	0.07	0.16	-0.16	-0.48	-0.62
RHR	0.45	0.06	0.07	0.02	-0.54	-0.42
CC-I	-0.28	0.30	0.46	0.70	0.72	0.60
CC-II	-0.23	0.37	0.29	0.10	0.53	0.70
EVAP	0.37	0.12	-0.01	-0.22	-0.32	-0.63
RF	-0.23	0.26	-0.11	0.14	0.06	0.15
GDD	0.60	0.12	0.38	0.24	0.08	0.01
Level of Significance				5%		1%

Minimum temperature and morning vapor pressure in all stages other than seedling stage, showed highly significant positive correlation with yield. Maximum temperature, temperature range and afternoon humidity during germination stage, temperature range and relative humidity range in germination stage showed positive association whereas afternoon relative humidity in gemination stage showed negative association with soybean yield. Afternoon vapour pressure during seedling stage showed negative significant correlation, while morning cloud cover in flowering stage showed significant positive correlation with yield. Morning and afternoon vapour pressure, morning and afternoon relative humidity and morning and afternoon cloud cover during pod development and maturity stages showed highly significant positive correlation, whereas temperature range and relative humidity range in these stages showed negative correlation with soybean yield.

Cotton

Akola

Field experiment was taken up with two dates of sowing (normal and late), two planting density (60 x 10 cm, 75 x 10 cm) and three genotypes [AKH-081, AKA-7 and Balwan (NCS 8899 BG-II (Bt Cotton))]. Canopy temperature (CT) and canopy temperature depression (CTD) have been recognized as indicators of overall plant water status and used in such practical applications as evaluation of plant response to environmental stress, irrigation scheduling, cultivar comparison for water use and tolerance to heat and drought. Cooler CT is favorable for higher yield and this association is stronger and more consistent under heat/moisture stress. Cooler canopy temperature especially at reproductive phase could improve development of yield attributes and consequently higher yield. CT measurements were made by infrared thermometer which was focused on 10:1 m and at clear weather period (13:00 to 14:00 h). The data for each plot were the mean of three readings, taken from the same side of each plot at an angle of approximately 45° to the horizontal in a range of directions such that they covered different regions of the plot and integrated many leaves. The result is presented in Table 4.21.

Table 4.21: Canopy temperature (°C) and canopy temperature depression in cotton

Treatment	60 DAE			90 DAE			120 DAE		
	CT	CTD	S.Ed	CT	CTD	S.Ed	CT	CTD	S.Ed
Weather variability									
Normal sowing	28.2	4.5	±0.862	27.8	0.8	±0.431	31.2	1.7	±0.975
Late sowing	29.4	1.4	±0.784	30.1	1.2	±1.304	33.7	-0.5	±1.240
Population density									
60 x 10 cm	28.7	3.0	±0.933	28.6	1.2	±0.551	32.2	0.8	±1.452
75 x 10 cm	28.9	2.9	±1.025	29.2	0.8	±1.053	32.7	0.4	±1.348
Genotype									
AKH 081	29.2	2.6	±0.589	29.5	0.4	±0.566	33.2	-0.2	±1.131
AKA 7	28.2	3.5	±0.352	28.8	1.2	±0.933	31.7	1.5	±1.194
Balwan	29.0	2.8	±0.684	28.6	1.3	±0.856	32.5	0.5	±0.629

Canopy temperature at 60 days after emergency (DAE) and 90 DAE was lower in monsoon sowing with higher canopy temperature depression indicating lower degree of field-scale plant water stress in normal sown crop. Higher plant density 60 x 10 cm indicated comparatively low canopy temperature and more canopy temperature depression. After cessation of monsoon season at 120 DAE, canopy temperature was lowest in AKA-7 with high canopy temperature depression indicating lower degree of field-scale plant water stress, closely followed by Balwan and AKH-081. Further, influence of the treatments on seed cotton yield, stalk yield, biological yield, harvest index and thermal use efficiency was studied and the results are presented in Table 4.22.

Table 4.22: Seed cotton yield, cotton stalk yield, biological yield and harvest index as influenced by different treatments in Akola during *kharif* 2020

Treatment	Seed cotton yield (kg ha^{-1})	Cotton stalk yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Thermal use efficiency kg ha^{-1} (^{O}Cday)$^{-1}$
Weather variability					
D_1-Monsoon sowing	1530	2374	3904	35.6	2343.3
D_2- Late sowing	1224	1928	3152	34.4	2121.6
SE(m)+	5.5	14.7	19.3	--	--
CD (P=0.05)	19.2	50.9	66.8	--	--
CV%	7.2	12.3	9.8	--	--
Population density					
P_1- 60 x 10 cm (1,66,666 pl/ha)	1419	2293	3712	34.0	2206.9
P_2- 75 x 10 cm (1,33,333 pl/ha)	1336	2009	3345	36.0	2258.1
SE(m)+,	5.5	14.7	19.3	--	--
CD (P=0.05)	19.2	50.9	66.8	--	--
CV%	7.2	12.3	9.8	--	--
Genotype					
V_1-AKH 081	1315	2087	3402	34.4	2163.3
V_2-AKA 7	1262	1941	3203	35.0	2222.3
V_3-Balwan	1554	2425	3980	35.6	2311.8
SE(m)+	13.0	19.7	28.7	--	--
CD (P=0.05)	39.2	59.4	86.4	--	--
CV%	11.3	11.0	9.7	--	--
Interaction					
DxP	NS	NS	NS		--
DxV	NS	NS	NS		--
PxV	NS	NS	NS		--
D x P x V	NS	NS	NS		--

Figures in parentheses indicate thermal use efficiency in terms of biomass

Significantly highest seed yield (1530 kg ha^{-1}) was obtained when crop was sown on 28 June (Monsoon sowing) and significant decrease in seed cotton yield (1224 kg ha^{-1}) was recorded with late sowing (D2 - 12 July). This was due to reduced soil moisture regime and less favourable weather variables encountered across late sown crop. Cotton stalk yield, biological yield and harvest index followed similar trend as that of seed cotton yield. Higher harvest index in monsoon sowing shows better translocation efficiency in timely sown cotton crop. Aspacingof 60 x 10 cm produced marginally higher seed cotton yield (1490 kg ha^{-1}) than population density of 75 x 10 cm, which yielded 1336 kg ha^{-1}and the differences were statistically significant. With regard to stalk yield and biological yield, aspacingof 60 x 10 cm produced significantly higher stalk yield and total biomass than that of 75 x 10 cm spacing. Harvest index also followed similar trend.

All the cotton genotypes differed from each other for seed cotton yield ha^{-1}. Genotype B*t* cotton Balwan recorded significantly higher seed cotton yield (1554 kg ha^{-1}) than *hirsutum* cotton AKH 081 (1315 kg ha^{-1}) and *arboreum* cotton AKA 7 (1262 kg ha^{-1}) Stalk yield and biological yield were significantly higher with Balwan followed by AKH 081 and AKA 7. Harvest index was significantly higher under Balwan (35.6%) followed by AKA 7 (35.0%) and least under AKH 081 (34.4%).

Thermal use efficiency was found to be higher for normal sown crop (D_1) with respect to both seed cotton and biomass production and it decreased in subsequent late sowing (D_2). As of the different population densities, thermal use efficiency in terms of seed cotton yield and biomass production was higher with the spacing of 60 x 10 cm followed by 75 x 10 cm. Thermal use efficiency was found to be higher in genotype Balwan (V_3) and AKA 7 (V_2) with respect to seed cotton and biomass production. It was followed by genotypes and AKH 081(V_1).

Sunflower

Solapur

Field experiments were conducted during *kharif* seasons of 2015-2020 using three dates of sowing (2nd fortnight of June, 2nd fortnight of July and 2nd fortnight of August) and three varieties (Bhanu, MSFH-17 and Phule Bhaskar). During vegetative stages, crop sown on 2nd fortnight of June had higher RUE, followed by crop sown on 2nd fortnight of July. However, the reverse was true during reproductive stages. Among the cultivars, Phule Bhaskar recorded higher RUE under all the three dates of sowing, followed by MSFH-17. RUE has a linear relationship with grain yield as indicated by Fig.4.7.

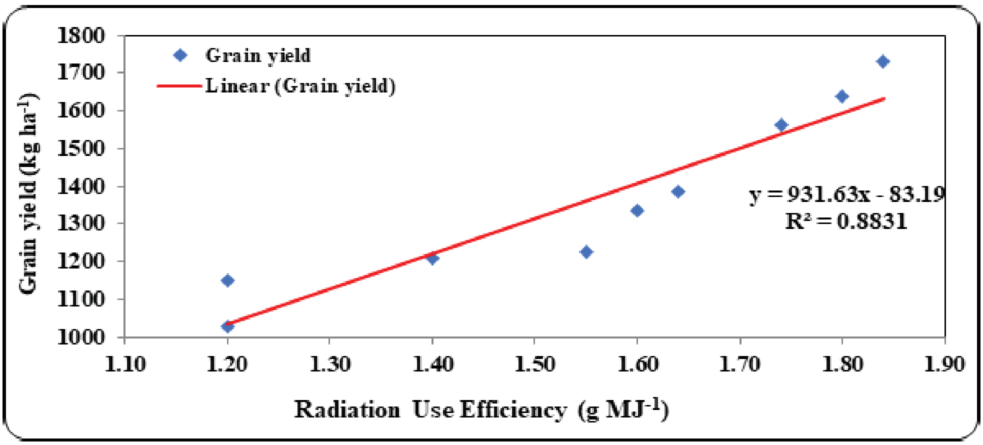


Fig.4.7: The relationship of RUE with grain yield in sunflower at Solapur (2015-2020)

Parbhani

Correlation study between stage-wise mean weather parameters and seed cotton yield was undertaken with a field experiment conducted with four dates of sowing (25, 26, 7 and 28 SMW), three hybrids (Ajit-155, Ankur, Mallika) and two plant protection measures (control and recommended plant protection measures).

Table 4.23: Correlation co-efficient exhibited by weather parameters prevailed in different phenophases with seed cotton yield (2020-21)

(Ajit 155)							
Parameters	P_1	P_2	P_3	P_4	P_5	P_6	P_7
Rainfall	-0.653**	0.859**	-0.459*	-0.357	0.725**	-0.703**	0.703**
Tmax	0.813**	0.828**	0.261	0.539*	-0.518*	-0.545*	-0.805**
Tmin	0.976**	0.975**	0.388	0.835**	0.708**	-0.534*	0.691**
RH-I	-0.094	0.675**	-0.002	-0.685**	-0.419	0.580**	0.752**
RH-II	-0.861**	-0.916**	-0.372	-0.196	0.717**	0.441	0.704**
BSS hrs/day	0.608**	-0.448*	0.226	0.655**	-0.364	-0.284	-0.688**
Ankur							
Parameters	P_1	P_2	P_3	P_4	P_5	P_6	P_7
Rainfall	-0.355	-0.105	0.274	0.351	-0.170	0.330	-0.338
Tmax	0.036	0.615**	-0.368	-0.147	0.435	0.341	-0.302
Tmin	0.358	0.562**	-0.328	-0.129	-0.483*	-0.027	-0.241
RH-I	-0.911**	-0.196	0.402	0.278	0.436	-0.823**	-0.232
RH-II	-0.476*	0.219	0.181	0.252	-0.623**	-0.318	-0.206
BSS hrs/day	-0.289	0.675**	-0.515*	-0.004	0.592**	-0.036	0.224
Mallika							
Parameters	P_1	P_2	P_3	P_4	P_5	P_6	P_7
Rainfall	-0.423	0.920**	-0.632**	-0.425	-0.069	-0.781**	0.813**
Tmax	0.939**	0.912**	0.626**	0.352	-0.608**	-0.533*	-0.993**
Tmin	0.995**	0.723**	0.690**	0.893**	0.816**	0.025	0.850**
RH-I	0.078	0.884**	-0.401	-0.711**	-0.972**	0.240	0.874**
RH-II	-0.937**	-0.447*	-0.626**	0.019	0.616**	0.623**	0.873**
BSS hrs/day	0.988**	-0.159	0.582**	0.532*	0.076	-0.575**	-0.878**

*Significant at 5% level; **Significant at 1% level; P_1 = Sowing to emergence; P_2 = Emergence to seedling; P_3 = Seedling to square formation; P_4 = Square formation to flowering; P_5 = Flowering to boll setting; P_6 = Boll setting to boll bursting, P_7 = Boll bursting to 1st picking

The rainfall had significant positive correlation with seed cotton yield during P_2, P_5 & P_7 stages of Ajit-1555 and P_2 & P_7 stages of Mallika (Table 4.23). However, it was non-significant during all stages for Ankur. The maximum temperature had significant positive correlation with seed cotton yield during all stages of Ajit-155 and Mallika, P_2 stage of Ankur. However, it had significant negative correlation during P_6 stage of Ajit-155 and P_5 stage of Ankur variety. The minimum temperature was positively correlated with seed cotton of all stages, except P_9 stage of Ajeet-155, Mallika and Ankur. The RH-I and RH-II had significant positive correlation with seed cotton at P_2, P_5, P_6 and P_7 stage of Ajit-155 and Mallika and negative correlation of P_1, $P_{2,}$ P_4 stage of Ajit-155$_,$ P_1, $P_{5,}$ P_6 stage of Ankur variety and P_1, $P_{2,}$ P_3 P_4 and $P_{5,}$ stage of Mallika variety. The Bright sunshine hours had significant positive correlation with seed cotton yield at P_4 stage of Ajit-155; P_2, P_5 stages of Ankur and P_1, P_3 and P_4 stages of Mallika and negative correlation with P_2, P_7 stage of Ajit-155, P_3 stage of Ankur and P_6 stage of Mallika.

Horticultural and Plantation Crops

Turmeric

Thrissur

A field experiment was conducted with four different dates of plantings (1 May, 15 May, 1 June and 15 June) and four different mulching conditions (white polythene mulch (M_1), black polythene mulch (M_2), Paddy straw (M_3) and Green leaves (M_4)). Turmeric variety Kanti was used in the experiment. The total life cycle of crop was divided into 3 phenophases (P1- duration to 50% of germination, P2- time taken for 50% of active tillering, P3- time taken for 50% drying of leaves). The crop was harvested 8 months after its dates of planting and the yield was recorded. The comparison of date of plantings showed that the two early plantings are on par in terms of yield, but the late plantings showed significant decrease in yield with the early planted ones (Fig.4.8a). Influence of mulch on yield showed that paddy straw mulch was having higher yield and green leaves was on par with straw mulch (Fig.4.8b). The least yield was recorded in black polythene mulch.

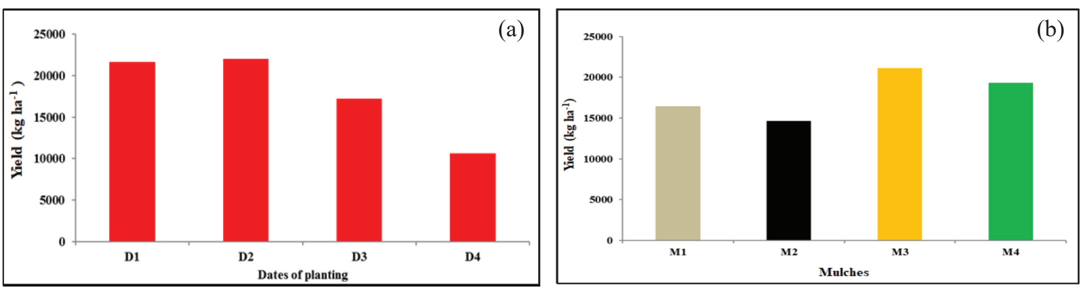


Fig.4.8: Effect of (a) dates of planting and (b) different mulches on turmeric (cv Kanti) yield at Thrissur during 2020

Turmeric took more days for germination from sowing to 50 per cent germination in first date of planting. Central zone of Kerala, during first date of planting weather condition was hot and dry with high soil temperature and low rainfall, which might have prevented the rhizome to initiate sprouting when compared to late plantings (Fig.4.9 a, b).

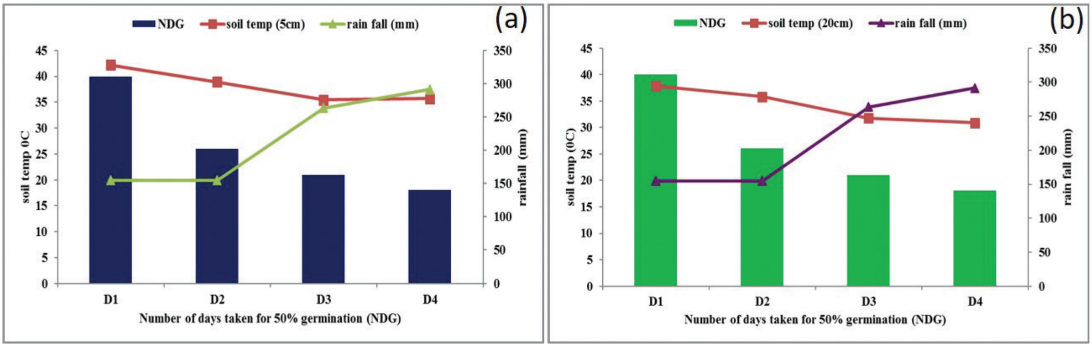


Fig.4.9: Effect of (a) soil temperature at 15 cm and rainfall and (b) soil temperature at 15 cm on number of days taken for 50% germination in turmeric at Thrissur during 2020

Black pepper

Thrissur

Crop weather relationship studies in pepper variety Panniyur-1 for the year 2018 and 2019 showed in the Table 4.24. Yield showed a negative relation with maximum temperature, minimum temperature, afternoon relative humidity, wind speed, bright sunshine hours and evaporation and a positive correlation with forenoon relative humidity.

Table 4.24: Correlation between pepper yield and weather variables during the year 2018 and 2019 at Thrissur

Varieties	Tmax (˚C)	Tmin (°C)	RH I (%)	RH II (%)	WS (kmph)	BSS (hrs)	Ep (mm)
Panniyur-1	-0.10	-0.07	0.01	-0.04	-0.07	-0.08	-0.10

Table 4.25 represents correlation between pepper yield and micrometeorological parameters during the year 2018 and 2019. Yield showed a positive correlation with all the micrometeorological parameters.

Table 4.25: Correlation between pepper yield and micrometeorological parameters during the year 2018 and 2019 at Thrissur

Variety	Lux	Incoming / Initial PAR	Transmitted PAR	Reflected from Soil& Canopy	Reflected PAR from Soil	Intercepted PAR	Reflected PAR	Absorbed PAR
Panniyur-1	0.37	0.47	0.31	0.46	0.42	0.52	0.48	0.53

Guava

Hisar

Hisar-Safeda, the popular existing guava variety in university orchard was studied in relation to prevalent weather parameters using appropriate correlation techniques. The plant age was 11 years and the planting density was 275 plants ha^{-1}. The average fruit weight (g/fruit) was significantly and positively correlated with RHm (r=0.79) and water use efficiency (r=0.71), whereas Tmax (-0.65), Tmin (-0.47) and wind speed (-0.60) showed negative correlation. The fruit yield per plant found non-significant positive correlation with the weather parameter. Atmospheric humidity has its effect on fruit quality during the respective stages. RH_m has significant positive correction with TSS, whereas, the acidity has significant and negative correlation with RH_m and RH_e. The water use efficiency (kg ha^{-1} mm^{-1}) was significant positive correlation with yield per plant kg ha^{-1}) and TSS (%) but acidity (%) of guava fruit non-significant negative correlation (Table 4.26). The in winter followed by spring season guava plants faced the grass minimum temperature varies -0.3 to 13.5 °C (49th to 12th SMWs), in the current year 2020-21 the minimum temperature was higher -0.4 to 1.4 °C, over the minimum temperature over 2019-20.

Table 4.26: Correlation of guava quality with weather parameter under Hisar condition (pooled data analysis, 2013-14 to 2020-21)

Weather parameters	Yield & quality parameters			
	Average fruit weight (g fruit^{-1})	Yield (kg ha^{-1})	TSS (%)	Acidity (%)
T_{max} (°C)	-0.65*	0.15	-0.10	0.27
T_{min} (°C)	-0.47*	0.27	0.06	0.11
SVPm (mm of Hg)	-0.38	0.34	0.14	0.06
SVPe (mm of Hg)	-0.54	0.34	0.15	0.01
RH_m (%)	0.79*	0.08	0.50*	-0.48*
RH_e (%)	0.44*	0.36	0.46*	-0.52*
WS (km/hr)	-0.60*	0.18	-0.18	0.32
BSS (hr)	-0.54*	0.02	-0.15	0.4
Ep (mm/day)	-0.61*	0.22	-0.11	0.39
RF (mm/day)	-0.16	0.19	0.12	-0.07
RD (day)	-0.22	0.34	0.19	0.03
RF (mm/season)	0.06	-0.46*	-0.23	-0.46*
PAR (MJm^{-2} day^{-1})	-0.03	0.08	0.12	0.31
Rnet (MJm^{-2} day^{-1})	-0.08	0.09	0.05	0.35
Max. possible sunshine hours (hr)	-0.76*	0.05	-0.26	0.40
Et (mm)	-0.50*	0.09	-0.14	0.37
WUE (kg ha^{-1} mm^{-1})	0.71*	0.53*	0.47*	-0.14

*Values are significant at 0.05 probability level (N=24)

The guava yield prediction model based on weather parameters was developed using seven years (21 seasons) pooled data analysis (2013-14 to 2019-20). The multiple regression models were developed for rainy, winter and spring seasons. The models developed are presented in Table 4.27.

Table 4.27: Yield prediction equations for guava developed based on weather parameters by Hisar centre

Multiple regression equation	R^2	Adj. R^2
Guava yield model for rainy season		
Yield (kg ha^{-1}) = 24825.66-17.52*Accu.RF-203.3*Tmin+227.1*SVPm-847.17*Ep-136.3*SVPe-141.2*WUE	0.93	0.54
Guava yield model for winter season		
Yield (kg ha^{-1}) = 17287.1-268.5*Et-3526.2*3990.5*SVPm-21.74*Accu.RF-174.94*WUE	0.97	0.92
Guava yield model for spring season		
Yield (kg ha^{-1}) =270301-10312.4Tmax-1404.5*RHm+6395.6*BSS-1589*Rf+9740.14*SVPm	0.87	0.55

T_{max}= Av. Maximum temperature (°C) during season, T_{min}= Av. Minimum temperature (°C); RH_m= Av. morning relative humidity (%), WUE= Av. Water use efficiency (kg ha^{-1} mm^{-1}); RF= Total rainfall during season (mm), Accu. RF=Seasonal accumulated rainfall (mm), Et=Crop reference evapotranspiration (mm), BSS=Bright sunshine hours (hr) SVPm&SVPe=Saturated vapour pressure morning & evening (mm of Hg)

The guava yield was predicted using above models for different seasons of 2020-21 and model prediction was validated with observed yield of 2020-21 (not included in model development) and are presented in Table 4.28. The model for rainy season underestimated (-13.1%) the guava yield, whereas, for winter and spring season model overestimated the yield with 8.8 and 15.5% deviation from the observed.

Table 4.28: Validation of season-wise guava yield prediction during 2020-21 at Hisar

Season	Observed	Prediction	Deviation (%)
Rainy	13750	11949.1	-13.1
Winter	11550	12562.8	8.8
Spring	3300	3811.8	15.5

Mango

Dapoli

Based on BBCH (Biologische Bundesanstalt, Bundessortenamt and Chemische Industrie) scale, phenology of various vegetative and reproductive growth phases of Alphonso mango was studied at Palghar, Dapoli, Rameshwar, Mulde and Phondaghat (June 2019 to May 2020) and their association with prevailing climatic factors at respective center was worked out and recorded for further study of annual trend of phenology and presented in Table 4.29. There was no any significant correlated weather parameter in case of dormant bud stage. The weather parameters Tmax, BSS and Epan exhibited significant negative correlation and RH-I, RH-II and rainfall showed significant positive correlation at 1 per cent significance level during vegetative phage. Tmin exhibited significant positive correlation at 5 per cent significance level during vegetative phage. Weather parameters Tmin, RH-I and RH-II showed significant negative correlation at 1 per cent significance level, while BSS exhibited significant positive correlation at 5 per cent of significance level during flower bud opening.

Table 4.29: Weather parameter at different phenological stages and correlation between weather parameter and different phenological stages of mango cv. Alphonso of Konkan region. (June 2019 – May 2020)

Stage	MW	Tmax	Tmin	RH-I	RH-II	WS	Rainfall	BSS	Epan
Dormant bud	MW 23-52 (2019) to MW 1 & 14-17 (2020)	0.042 (26.5 - 35.3)	0.059 (16.6 - 26.1)	0.055 (80.0 - 99.1)	-0.046 (40.0 - 96.0)	-0.092 (1.0 - 10.7)	-0.008 (0.0 - 771.6)	-0.034 (0.0 - 8.9)	-0.080 (2.0 - 4.4)
Vegetative stage	MW 23 (2019) to MW 22 (2020)	-0.620 (**) (26.5 - 38.3)	0.294 (*) (12.7 - 29.2)	0.457 (**) (61.0 - 99.1)	0.562 (**) (31.0 - 96.0)	0.071 (0.4 - 11.1)	0.358 (**) (0.0 - 771.6)	-0.527 (**) (0.0 - 11.4)	-0.489 (**) (1.1 - 6.8)
Flower bud Opening	MW 44-52 (2019) to MW 1-14 (2020)	0.153 (28.26 - 38.30)	-0.580 (**) (12.71- 25.11)	-0.436 (**) (61.00 - 94.57)	-0.361 (**) (31.00 - 85.00)	-0.069 (1.30 - 4.70)	-0.217 (0.00 - 0.00)	0.330 (*) (7.10 - 10.49)	0.269 (3.10 - 6.31)
Flowering	MW 1 (2020) to MW 18 (2020)	0.315 (*) (28.26 - 38.30)	-0.267 (12.71 - 25.93)	-0.144 (61.00 - 94.57)	-0.359 (**) (31.00 - 85.00)	-0.012 (1.30 - 5.44)	-0.154 (0.00 - 1.20)	0.273 (*) (7.20 - 10.97)	0.399 (**) (3.30 - 6.39)
Flower drop	MW 11 (2020) to MW 22 (2020))	0.424 (**) (30.8 - 38.3)	0.046 (17.3 - 29.2)	-0.172 (61.0 - 94.6)	-0.143 (33.0 - 81.3)	0.042 (1.8 - 11.1)	-0.109 (0.0 - 110.4)	0.341 (*) (6.4- 11.4)	0.530 (**) (2.8 - 6.8)
Fruiting	MW 23-27 (2019) to MW 4-22 (2020)	0.338 (*) (28.5 - 38.3)	0.261 (15.2 - 29.2)	-0.093 (61.0 - 94.6)	-0.128 (33.0 - 85.7)	0.001 (0.4 - 6.9)	-0.159 (0.0 - 616.8)	0.262 (1.1 - 11.4)	-0.054 (1.9 - 6.8)
Fruit drop	MW 23-26 (2019) to MW 5-22 (2020)	0.352 (*) (29.1 - 38.3)	0.293 (*) (15.2 - 29.2)	-0.144 (61.0 - 94.6)	-0.193 (33.0 - 84.0)	0.050 (0.4 - 11.1)	-0.150 (0.0 - 162.3)	0.218 (2.8 - 11.4)	-0.104 (2.4 - 6.8)

(Value in the parenthesis indicates range of weather parameter).

Weather parameter RH-II showed significant negative correlation and Epan showed significant positive correlation at 1 per cent significance level, while Tmax and BSS exhibited significant positive correlation at 5 per cent of significance level during stages of flowering. Tmax and Epan exhibited significant positive correlation at 1 per cent while, BSS exhibited significant positive correlation at 5 per cent of significance level for flower drop. This indicated that variation in Tmax and Epan may be more responsible for flower drop.

Cashew

Dapoli

Correlation between phenology of cashew and mean weather parameters was studied in Vengurla-4 variety. During vegetative and bud opening stages, Tmin, RH-I, RH-II and rainfall showed significant positive correlation (Table 4.30). This indicate that variation in temperature and relative humidity may be responsible for enhancing vegetative and bud opening stage. Weather parameter Tmin, RH-II, WS and RF showed significantly positive correlation with flower and fruit drop (100), out of this Tmin, RH-II and RF showed significance at 1 per cent of level. This indicates that the variation in temperature, relative humidity, and rainfall may be responsible weather parameters for flower or fruit drop. BSS showed significant positive correlation with flowering stages at 5 per cent level of significance. Tmax, BSS and Epan showed significant positive correlation at 1 per cent level of significance during fruiting.

Table 4.30: Weather parameter at different phenological stages and Correlation between weather parameter and different phenological stages of cashewnut cv. Vengurla-4 at Dapoli center

Stage	Year	Period	Tmax	Tmin	RH-I	RH-II	WS	Rainfall	BSS	Epan
Vegetative and bud opening stage (101-109)	Oct 2018-May 2019	MW 41 (2018) to MW 22 (2019)	0.366 (**) (26.60-34.86)	0.381 (**) (10.14-23.87)	-0.415 (80.57-91.00)	0.151 (51.86-72.570	-0.063 (0.10-6.94)	-0.175 (0.00-8.80)	0.241 (5.84-9.33)	0.062 (3.77-7.19)
	Jun 2019-May 2020	MW 23 (2019) to MW 47 (2020)	-0.363 (26.46-34.51)	0.406 (**) (19.11-25.86)	0.422 (**) (86.43-99.14)	0.514 (**) (54.57-96.00)	-0.023 (0.49-11.11)	0.318 (*) (0.00-771.60)	-0.489 (0.00-8.94)	-0.529 (1.11-6.83)
Flower or fruit drop (100)	Oct 2018-May 2019	MW 40-47 (2018) & MW 22 (2019)	-0.301 (33.17-34.59)	-0.225 (15.23-23.87)	0.277 (*) (81.14-90.86)	0.419 (**) (56.86-72.57)	-0.575 (0.46-6.20)	0.318 (*) (0.00-28.20)	-0.546 (5.14-8.90)	-0.698 (4.20-7.19)
	Jun 2019-May 2020	MW 23-43 (2019) & MW 16-22 (2020)	-0.298 (26.46-34.61)	0.574 (**) (19.76-25.86)	0.219 (84.29-99.14)	0.582 (**) (49.14-96.00)	0.315 (*) (0.49-11.11)	0.366 (**) (0.00-771.60)	-0.444 (0.00-11.43)	-0.084 (1.11-6.83-)

Stage	Year	Period	Tmax	Tmin	RH-I	RH-II	WS	Rainfall	BSS	Epan
Flowering (200-207)	Oct 2018-May 2019	MW 43 (2018) to MW 16 (2019)	-0.619 (26.60-34.63)	-0.887 (10.14-21.71)	0.272 (83.57-91.00)	0.024 (51.86-67.86)	-0.334 (0.10-5.69)	-0.234 (0.00-0.00)	0.184 (6.07-9.10)	-0.557 (3.77-6.89)
	Jun 2019-May 2020	MW 46 (2019) to MW 10 (2020)	0.027 (28.26-34.93)	-0.690 (12.71-20.06)	0.078 (88.86-93.71)	-0.461 (44.71-60.25)	-0.331 (2.09-4.07)	-0.295 (0.00-0.00)	0.289 (*) (6.10-10.29)	-0.181 (3.17-5.20)
Fruiting (300-307)	Oct 2018-May 2019	MW 49 (2018) to MW 22 (2019)	0.165 (26.60-34.86)	0.306 (*) (10.14-23.87)	-0.080 (80.57-91.00)	-0.573 (51.86-66.13)	0.771 (**) (0.10-6.94)	-0.181 (0.00-0.00)	0.064 (6.07-9.33)	0.847 (**) (3.77-7.19)
	Jun 2019-May 2020	MW 08 (2020) to MW 22 (2020)	0.592 (**) (29.86-34.93)	-0.183 (14.29-24.49)	-0.684 (81.14-90.86)	-0.534 (44.71-76.86)	0.122 (2.96-6.10)	-0.308 (0.00-27.00)	0.546 (**) (7.24-11.43)	0.780 (**) (4.60-6.73)

(Value in the parenthesis indicates range of weather parameter). Tmax: Maximum Temperature; Tmin: Minimum Temperature; RH-I: Morning Relative humidity; RH-II: Evening Relative humidity; WS: Wind Speed; BSS: Bright sun shine; Epan: Evaporation

Rabi 2020-21

Chickpea

Akola

An experiment was conducted to understand the influence of different sowing environments on chickpea phenology, heat use efficiency and yield. Chickpea varieties JAKI-9218, Akash-97 and Vijay were sown on three different dates *viz.,* Nov 3 (44 SMW), Nov 9 (45 SMW) and Nov 17 (46 SMW). The accumulated heat units (GDD) to reach various growth stages varied among the sowing dates and GDD requirement declined when date of sowing was delayed. Among the sowing dates, highest (1735 ^{0}C-day) and lowest (1608 ^{0}C-day) heat units required to physiological maturity was availed by the crop sown crop on November 9 (45 MW) and November 17 (46 MW), respectively. In the case of cultivars, the highest heat units were accumulated by JAKI-9218 (1747 ^{0}C-day) followed by AKASH (1676 ^{0}C-day) and VIJAY (1645 ^{0}C-day). Data regarding number of days taken to achieve different phenophases indicated that crop sown during 44 SMW, 45 SMW and 46 SMW took 97, 95 and 92 days, respectively for reaching maturity. The maturity period for the cultivars was 97, 95 and 91 days for JAKI-9218, AKASH-797, and VIJAY, respectively.

The seed and biomass yield of chickpea under different growing environments revealed that the sowing environment had significant effect. Significantly higher seed (1680 kg ha^{-1}) and biomass (4043 kg ha^{-1}) yields were obtained for the crop sown on November 03 (44 MW) followed by November 09 (45 MW) sown crop (Table 4.31). Crop sown on November 17 (46nd MW) yielded the lowest seed (1471 kg ha^{-1}) and biomass (3424 kg ha^{-1}). Among the varieties, JAKI-9218 recorded significantly higher seed over Vijay, followed by Akash-797. Interaction effect of date of sowing and varieties in respect seed yield was also found to be non-significant.

Table 4.31: Effect of treatments on seed and biomass yield of chickpea

Treatment	Seed yield (kg ha^{-1})	Biomass yield (kg ha^{-1})
Dates of sowing		
D_1-44 MW (03.11.20)	1680	4043
D_2-45 MW (09.11.20)	1532	3590
D_3-46 MW (17.11.20)	1471	3424
SE m +	41	87
CD (P=0.05)	124	262
Varieties		
V_1 - JAKI-9218	1702	3939
V_2 – Akash-797	1544	3701
V_3 - Vijay	1437	3418
SE m +	41	87
CD (P=0.05)	124	262
Interaction		
SE m +	71	151
CD (P=0.05)	NS	NS
CV (%)	8	7

Heat use efficiency (kg ha^{-1} °C day^{-1}) with respect to seed yield and biomass production (Table 4.32) under different dates of sowing showed that first sowing on November 3 recorded higher heat use efficiency with respect to both seed and biomass production. Sowing on 09 November (D_2) and 13 November (D_3) recorded almost more or less similar heat use efficiency. Amongst the varieties, heat use efficiency with respect to grain yield and biomass production is higher in V_3 (JAKI-9218). Vijay (V_3) recorded the minimum heat use efficiency.

Table 4.32: Heat use efficiency of chickpea varieties in terms of seed and biomass production (kg ha^{-1} °C day^{-1}) under different dates of sowing

Varieties	Sowing date			
	D_1-44 MW (03.11.20)	D_2-45 MW (09.11.20)	D_3-46 MW (17.11.20)	Mean
V_1 - JAKI-9218	1.06 (2.46)	0.93 (2.14)	0.93 (2.16)	0.97 (2.25)
V_2 - Akash	0.99 (2.38)	0.86 (2.07)	0.92 (2.17)	0.92 (2.21)
V_3 - Vijay	0.87 (2.17)	0.86 (2.00)	0.89 (2.06)	0.87 (2.08)
Mean	0.97 (2.34)	0.88 (2.07)	0.91 (2.13)	

Figures in parentheses indicate heat use efficiency in terms of biomass

Anantapuramu

Influence of weather parameters experienced during different growing environments on chickpea cultivars was studied in split plot design. Three cultivars *viz.,* JG 11, NBeG 3 and NBeG 49 were sown on three dates *viz.,* October 19, 2020, October 31, 2020 and November 11, 2020, respectively. Results indicated that prevalence of optimum maximum temperature (28-32 °C) and minimum temperature (16-19 °C) during flowering to maturity was congenial for obtaining higher chickpea yield (Table 4.33). Crop sown on Oct. 19 and Nov 11 experienced more than optimum mean minimum temperature during 50% flowering - pod initiation and pod initiation - pod development (20.0 °C) stage, respectively. At the same time, crop sown on Oct. 31, the optimum minimum temperature was within the congenial range and hence highest chickpea yield (1962 kg ha^{-1}).

Table 4.33: Days taken and maximum and minimum temperature prevailed in various crop stages of chickpea varieties under different sowing environments during *rabi* 2020-21

Crop stage	Oct 19, 2020			Oct 31, 2020			Nov 11, 2020		
	DAS	Tmax (ºC)	Tmin (ºC)	DAS	Tmax (ºC)	Tmin (ºC)	DAS	Tmax (ºC)	Tmin (ºC)
Sowing – Emergence	0-5	31.2	24.7	0-6	33.0	23.5	0-5	31.6	21.7
Emergence- 50% Flowering	6-41	32.1	22.7	7-41	31.1	21.8	6-41	30.1	20.2
50% Flowering - Pod initiation	42-53	28.5	20.6	42-52	30.3	18.9	42-52	29.4	16.5
Pod initiation - Pod development	54-62	30.1	17.9	53-60	29.7	18.5	53-60	29.3	20.4
Pod development - Maturity	63-94	29.7	18.7	61-92	30.1	18.7	61-92	31.4	18.5

It was observed that seed yield of chickpea varieties JG 11, NBeG 3 and NBeG 49 was not significantly influenced by sowing environments. The crop sown on Oct. 31 gave highest seed yield (1962 kg ha^{-1}) followed by the crop sown on Nov. 11 (1930 kg ha^{-1}) and lowest on Oct. 19 (1768 kg ha^{-1}). Among the three varieties evaluated, the mean seed yield across the sowing environment, did not vary significantly (Table 4.34). However, the seed yield for the variety JG 11 was higher (2004 kg ha^{-1}) than for the variety NBeG3 (1846 kg ha^{-1}) and NBeG49 (1809 kg ha^{-1}).

Table 4.34: Seed yield (kg ha^{-1}) of chickpea as influenced by sowing environment & varieties during *rabi* 2020-21

Sowing Environment	Seed yield (kg ha^{-1})			
	JG11	NBeG 3	NBeG 49	Mean
19.10.2020	1782	1735	1787	1768
31.10.2020	2094	1926	1865	1962
11.11.2020	2137	1877	1776	1930
Mean	2004	1846	1809	
	D	**V**	**DXV**	**VXD**
CD	NS	NS	NS	NS
SEm±	152	186	185	214

Vijayapura

Effect of weather elements during different growing environments on growth, development and yield of chickpea was studied at Vijayapura center. Five cultivars of chickpea (JG-11, BGD-111-1, JAKI-9218, BGD-103 and Vijay) were sown on four growing environments (Sept 25, Oct 06, Oct 20 and Nov 11). It was noticed that the mean yield of all varieties was highest in third growing environment (1051.6 kg ha^{-1}) followed by the second growing environment (1021.1 kg ha^{-1}). The yield of first (798.8 kg ha^{-1}) and fourth growing environments (752.2 kg ha^{-1}) were lower. In the case of cultivars, the highest yield was obtained for variety Vijay (970.6 kg ha^{-1}) and the lowest yield was for the variety JAKI-9218 (834.6 kg ha^{-1}) (Table 4.35).

Table 4.35: Yield of chickpea varieties under different growing environments

Variety	GE 1 (Sept.25)	GE 2 (Oct.06)	GE 3 (Oct.20)	GE 4 (Nov.11)	Mean
JG-11	726.8	932.2	960.4	733.2	**838.1**
BGD-111-1	778.6	1034.3	1296.1	728.7	**959.4**
Jaki-9218	641.0	981.3	1050.7	665.4	**834.6**
BGD-103	930.6	993.1	928.4	810.2	**915.6**
Vijay	916.9	1119.7	1022.5	823.2	**970.6**
Mean	798.8	1012.1	1051.6	752.1	903.7

Stage-wise weather prevailed during all growing environments and the response of different varieties were analyzed. It was noticed that there was as much as 175 mm rainfall during seedling stage and 110 mm in vegetative stage of GE1. This seems to be very high and must have hampered growth of the seedlings and grand growth, which must have reduced the yield of all varieties in GE1. On the other hand, there was very little rainfall after sowing of crop, which must have caused extended stress period and caused reduction in yield of all varieties in GE4

(Fig.4.10). However, rainfall distribution in GE2 and GE3, it was observed that in GE2, about 100 mm rainfall was received during vegetative stage of GE2 and in seedling stage of GE3, respectively. Thus, it could be inferred that rainfall of 100 mm in either seedling or vegetative stage, or total 100 mm rainfall in the two stages was sufficient for getting good yield of chickpea crop.

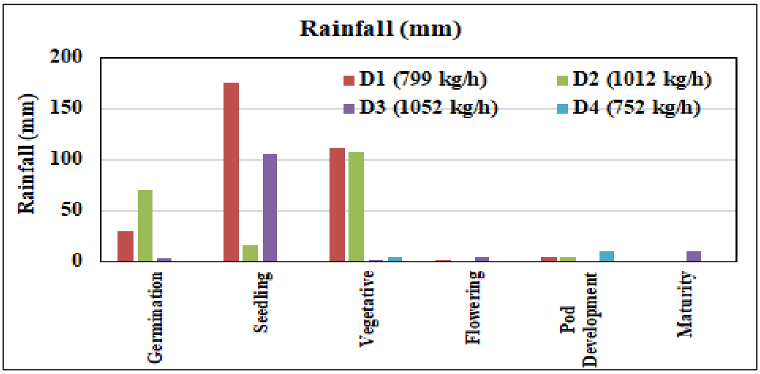


Fig.4.10: Stage wise rainfall pattern in chickpea growing environments during *rabi* 2020-21

Germination stage of GE1 crop experienced very low maximum temperature of less than 30 °C in germination to vegetative stages and in pod development stage, but it was around 30.5 °C in flowering and maturity stages. Both GE1 and GE4 experienced maximum temperature between 30 °C and 32 °C in maturity stage. There was considerable fluctuation of maximum temperature in different growing environments in various growth stages and no pattern was followed. However, the higher maximum temperature in maturity stage could have reduced the chickpea yield in GE4 (Fig.4.11).

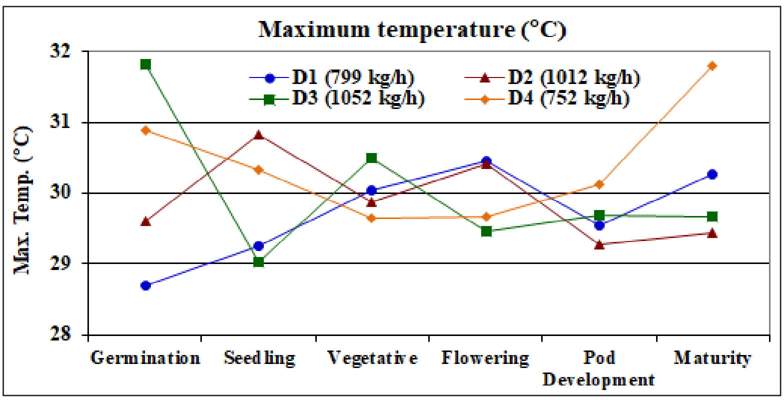


Fig.4.11: Stage wise maximum temperature pattern in chickpea growing environments (2020-21)

On the other hand, in case of minimum temperature (Fig.4.12), the values were moderate during vegetative and flowering stages for GE2 and GE3 in which yield was higher in all varieties, whereas the values were high in GE1 and very low in GE4. It was seen that low minimum temperature from germination to flowering stage for the growing environment 4, which could impact the chickpea yield when compared to other growing environments.

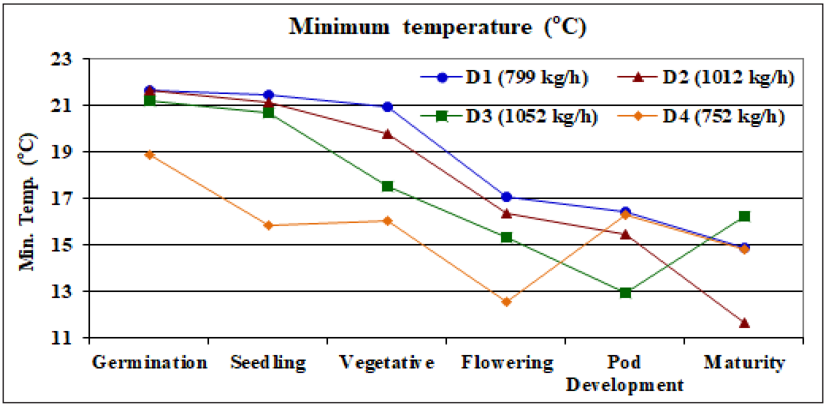


Fig.4.12: Stage wise minimum temperature pattern in chickpea growing environments (2020-21)

Raipur

At Raipur centre, response of different chickpea varieties growth, development and yield to the various growing environments was studied during *rabi* 2020-21. Three varieties *viz.,* V_1 -Vaibhav, V_2-JG 14, and V_3 –JG16 were planted on three growing environments (D_1 – 10 Nov. 2020; D_2 – 25 Nov. 2020; D_3 – 10 Dec. 2020) under RBD factorial statistical disign.

Table 4.36: Correlation between stage-wise weather parameters and chickpea yield

Varieties	weather parameter	Crop stage having significant relation with yield
Vaibhav	Tmin	P-II (-0.906**)
	BSS	P-VI (0.779*)
	RF	P-VI (-0.697*)
JG-14	Tmin	P-II (-0.767*) P-V (-0.668*)
	RF	P-VI (-0.663*)
	RH-I	P-VI (-0.740*)
	RH-II	P-IV (-0.655*) P-V (-0.768*)
JG-16	Tmin	P-II (-0.866**)
	BSS	P-VI (0.843**)
	RF	P-VI (-0.759*)
	RH-I	P-VI (-0.772*)

P-I - Emergence – Branching; P-II - Branching - flower initiation; P-III - Flower initiation - 50% flowering; P-IV - 50% flowering - 100% flowering; P-V-100% flowering - pod formation; P-VI - Pod formation – Maturity

On the basis of three years database of chickpea (2017-18, 2018-19 and 2019-20), correlation analysis was carried out to find out the weather parameters prevailed during various crop growth stages affecting the chickpea yield significantly (Table 4.36). Significant negative relation was found between minimum temperature during branching to flower initiation stage and chickpea yield in all the three cultivars. Dry weather and clear days with bright sunshine duration during pod formation to maturity stage are essential requirement to reap higher chickpea yield. This is evident that rainfall and morning relative humidity had significant negative relation with yield as well as significant positive relation between bright sunshine hour duration and chickpea yield.

Table 4.37: Yield and yield attributes of chickpea varieties as influenced by different growing environments (*Rabi* 2020-21)

Treatments	Dry matter production at maturity (g)	Total number of seeds per plant	Test Weight for 100 seeds (g)	Stover yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index (%)
Dates of sowing						
D_1 (15 Nov)	88.9	54.1	22.1	1053.6	1029.1	49.2
D_2 (30 Nov)	77.4	58.5	22.1	821.1	929.7	52.9
D_3 (15 Dec)	75.6	44.9	22.1	863.1	931.0	51.8
SEm ±	3.1	2.9	0.4	38.4	54.6	0.6
CD(p=0.05)	NS	NS	NS	NS	NS	NS
Varieties						
V1: Vaibhav	73.5	53.6	23.5	801.3	771.5	49.3
V2: JG-14	95.7	43.7	25.5	1045.6	1114.1	51.5
V3: JG-16	72.8	60.2	17.3	891.0	1004.1	53.0
SEm ±	3.1	2.9	0.4	38.4	54.6	0.6
CD (p=0.05)	9.0	8.7	1.1	115.2	163.6	1.8
Interaction (D x V)						
SEm ±	5.3	5.0	0.6	66.6	94.5	1.0
CD(p=0.05)	NS	NS	NS	NS	NS	NS

The individual and combined effect of different growing environments and varieties on chickpea dry matter production, total number of seeds per plant, test weight, stover yield, seed yield is furnished in the Table 4.37. It indicates that significant influence of sowing dates as well as interaction effect of sowing dates and varieties on these yield parameters were not observed. However, it was noticed that higher grain yield was recorded for D_1 sow crop (1029.1 kg ha^{-1}) than the D_2 and D_3 growing environments. Yield reduction in late sown crop may be attributed to thermal stress as it was evident that late sown crop matured early when compared to early sown. Therefore, in Chhattisgarh plains, every effort should be made to complete the gram sowing latest by end November for harvest more grain yield. However, different varieties influenced the grain yield significantly as the grain yield of Vaibhav variety (771 kg ha^{-1}) was lower significantly than JG-14 (771 kg ha^{-1}) and JG-16 (771 kg ha^{-1}) varieties and at the same time, grain yield of JG-14 and JG-16 varieties were statistically on par.

Ranchi

Experiment was conducted at Ranchi centre with three varieties of chickpea *viz.,* JG 14, GNG 1581 and Birsa Chana 3 which were sown on 10 Nov (Early), 25 Nov (Normal) and 10 Dec (Late) to find out the response of chickpea to varied weather conditions. The results indicated that yield and yield defining characters were not significantly influenced due to different sowing times. Grain yield of chickpea sown by 10 Nov (Early) was higher (2011 kg ha^{-1}) than the crop sown on 25 Nov (1676 kg ha^{-1}) and 10 Dec (1682 kg ha^{-1}). However, yield of GNG 1581 (2036 kg ha^{-1}) and Birsa Chana 3 (1946 kg ha^{-1}) varieties were significantly superior than JG 14 (1386 kg ha^{-1}).

Heat (HUE) and Radiation (RUE) Use Efficiency

Heat and radiation use efficiencies in terms of yield of chickpea (Table 4.38) showed early sown crop registering higher heat and radiation use efficiency compared to the late sown crop. Among the varieties, Birsa Chana 3 achieved highest heat use efficiency (1.4 kg ha^{-1} °days) as well as highest radiation (1.2 kg ha^{-1} MJ^{-1}) use efficiencies in early sown condition. The higher heat and radiation use efficiencies in case of early sowing and Birsa Chana 3 were also reflected in their highest yields.

Table 4.38: Heat (HUE) and radiation (RUE) Use Efficiency of chickpea cultivars under different thermal regimes

Sowing Date	Variety	HUE (kg ha^{-1} °days)	RUE (kg ha^{-1} MJ^{-1})	Yield (kg ha^{-1})
10 Nov	IG -14	1.0	0.8	1512
	GNG -1581	1.2	1.0	2067
	Birsa Chana 3	1.4	1.2	2455
25 Nov	IG -14	0.8	0.6	1205
	GNG -1581	1.2	0.9	1938
	Birsa Chana 3	1.2	0.9	1883
10 Dec	IG -14	1.0	0.7	1443
	GNG -1581	1.4	1.1	2103
	Birsa Chana 3	1.0	0.8	1500

Solapur

Effect of weather parameters prevailed during different crop stages on chickpea yield was studied through experiments from 2016-2020. The data recorded during these years were pooled and crop weather relationship analysis was carried out. Results indicated that there was significant effect of growing environments on chickpea yield. Among the different growing environments, the crop sown during 38 SMW (Sept 17-23) recorded significantly superior yield than the other growing environments *viz.,* 40 SMW (Oct 01-07), 42 SMW (Oct 15-21) and 44 SMW (Oct 29 - Nov 04) (Table 4.39). Likewise, chickpea cultivar Digvijay produced significantly higher yield (720 kg ha^{-1}) than the cultivar Vijay (587 kg ha^{-1}). However, no significant interaction effect of growing environment and varieties were not observed. Hence, it can be inferred that sowing chickpea Digvijay cultivar during 38 SMW would lead to higher yield at Solapur region.

Table 4.39: Grain yield (kg ha^{-1}) of *rabi* chickpea as influenced by various sowing dates and varieties (2016 to 2020)

Treatment	2016-17	2017-18	2018-19	2019-20	2020-21	Pooled
Main=Sowing dates						
S_1 = MW 38 (Sept 01-07) *Uttara nakshatra*	1255.8	660.0	564.5	712.5	1061.2	850.8
S_2 = MW 40 (Oct 01-07) *Hasta nakshtra*	1113.1	510.6	467.1	507.9	880.3	695.8
S_3 = MW 42 (Oct 15-21) *Chitra nakshtra*	985.6	483.2	413.3	396.5	769.0	609.5
S_4= MW 44 (Oct 29-Nov 04) *Swati nakshtra*	812.3	354.5	310.3	342.7	465.9	457.2
Mean	1041.7	502.1	438.8	489.9	794.1	653.3
S.E.+	25.2	29.1	26.7	40.4	41.4	28.6
C.D. at 5%	80.6	93.1	85.4	129.2	132.3	88.0
Sub=Varieties						
V_1 = Vijay	937.1	433.9	371.6	439.7	751.6	586.8
V_2 = Digvijay	1146.3	570.3	506.0	540.1	836.6	719.9
Mean	1041.7	502.1	438.8	489.9	794.1	653.3
S.E.+	20.1	19.2	15.7	26.7	27.5	10.4
C.D. at 5%	62.0	59.2	48.3	82.2	84.8	31.2
Interaction effect (SD X V)						
S.E.+	40.2	38.5	31.3	53.4	55.0	20.8
C.D. at 5%	NS	NS	NS	NS	NS	NS

Mustard

Anand

Experiment was conducted to study the effect of weather parameters on the yield of mustard; to explore favourable weather condition for getting higher yield; and to develop yield predictive models for mustard. It is understood that the productivity of mustard cultivars under different growing environments of *rabi* season indicated sowing at 10 October provided favourable growing environment to all the three cultivars (Bio-902, GM-3 and GDM-4) and they produced higher yield and the mustard yield declined linearly with delay in sowing (Fig.4.13). In the case of cultivars, GM-3 has distinctly higher productivity under all the growing environments. Considering yield performance of the cultivars under different growing environments, optimal weather variable ranges for different growth stages of the mustard crop were determined and furnished in Table 4.40.

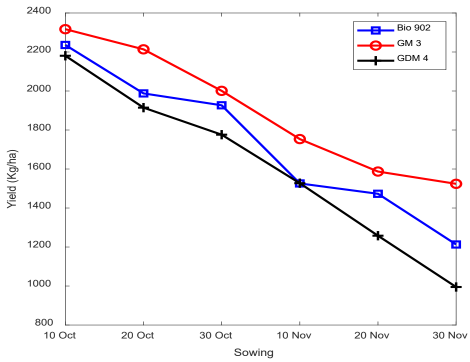


Fig.4.13: Productivity of mustard cultivars during different growing environments

Table 4.40: Optimum weather condition for different phenophases of mustard for high productivity

Phase	BSS (h)	MinT (°C)	MaxT (°C)	RHm (%)	RHe (%)
Emergence – Early vegetative	8.7-10.1	12.5-22.0	33.0-38.5	73-97	26-57
Early vegetative -Flowering initiation	1.3-10.0	11.5-19.0	29.0-37.0	75-96	18-51
Flowering initiation – Pod initiation	6.3-9.6	9.0-17.5	25.8-31.0	64-93	29-56
Pod initiation – Seed development	0.0-9.8	6.0-17.5	24.2-33.0	69-100	20-98
Seed development – Physiological Maturity	0.0-10.2	5.5-17.2	18.2-32.5	53-96	16-82

Association between mustard yield and phase wise weather parameters

The phenological stage wise average weather parameters were correlated with mustard yield using four years' *rabi* season (2017-18 to 2020-21) data. Weather parameters during early growth stages (up to flowering initiation) of mustard showed strong positive association with seed yield. Sunshine hours and afternoon relative humidity of initial growth phases were not associated to crop yield. Both maximum and minimum temperatures from emergence to pod initiation stage had significant positive association. However, weather parameters like BSS, maximum and minimum temperature during seed development to maturity showed significant negative relation with mustard yield and morning & evening relative humidity had positive relation significantly (Table 4.41). In general, mustard crop is more sensitive to the weather experienced by crop during emergence to flowering initiation and seed development to physiological maturity phases. Out of 25 independent variables (phases × weather parameters), stepwise regression retained morning relative humidity during emergence to early vegetative, maximum temperature during early vegetative to flowering initiation phase and pod initiation to seed development. The regression model developed by stepwise regression has coefficient of determination 0.74 with RMSE 200 kg ha^{-1}.

Table 4.41: Phase wise correlation coefficient between weather parameters and mustard pod yield

Phase	BSS (h)	MaxT (°C)	MinT (°C)	RHm (%)	RHe (%)
Emergence – Early vegetative (p1)	0.08	0.76**	0.49**	0.43**	0.09
Early vegetative -Flowering initiation (p2)	-0.04	0.77**	0.49**	0.35*	-0.04
Flowering initiation – Pod initiation (p3)	0.01	0.36*	0.29*	0.08	0.10
Pod initiation – Seed development (p4)	-0.15	0.17	0.20	0.04	0.15
Seed development – Physiological Maturity	-0.50**	-0.68**	-0.33*	0.31*	0.61**

Mustard Yield (kg ha^{-1}) = 154.2×MaxTp2 -63.4×MaxTp4+ 30.9×RH1p1-3820 (R^2=0.74; AdjR^2=0.72; RMSE 200 kg ha^{-1})

Faizabad

In order to evaluate the growth and yield performance of different mustard varieties (NDR-8501, Bio-902 and Varuna) under various crop growing environments (Oct 25, Nov 04 and Nov 14), experiment was conducted at Faizabad centre during *rabi* 2020-21. Results indicated that dry matter accumulation varied significantly due to growing environments at all the stages of mustard. It was observed that higher dry matter accumulation was recorded for the mustard sown on 25 Oct. which was significantly superior over other crop growing environments. Among the varieties, highest dry matter accumulation was recorded in NDR-8501 which was at par with Bio-902 while significant over Varuna at all the stages of mustard. Data also reveal that Varuna variety recorded lowest dry matter accumulation at all the growth stages of mustard.

Data pertaining to mustard seed yield showed that different crop growing environments influenced the yield significantly. Maximum yield was recorded when crop was shown on 25 Oct which was significantly superior over the crop sown on 4 Nov and 14 November. Higher yield was recorded with NDR-8501 variety which was significant over Varuna while at par with variety Bio-902 of mustard variety (Table 4.42).

Table 4.42: Yield of mustard as affected by growing environment and varieties

Treatments	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Crop growing environments				
25 Oct	1900	6440	8520	21.5
04 Nov	1820	5150	6750	21.3
14 Nov	1550	4560	5840	20.4
SEm±	332	122	152	0.42
CD at 5%	984	363	451	NS
Varieties				
NDR-8501	1860	5850	8130	22.7
Bio-902	1630	5540	7150	21.5
Varuna	1710	4550	6260	21.3
SEm±	332	122	152	0.42
CD at 5%	984	363	451	NS

Wheat

Jammu

An experiment was conducted to investigate the influence of different growing environments (Nov 05, Nov 20 and Dec 05) and cultivars (HD-2967, Raj-3077 and RSP-561) on radiation use efficiency and grain yield during *rabi* 2020-21.

Radiation use efficiency (RUE) increased gradually with advancement of the growth stages of wheat crop up to 110 days after sowing and thereafter it decreased at later growth stage under different sowing environments. The highest RUE was recorded at 110 DAS, when crop was planted on 05 November (1.59 gm MJ^{-1}) followed by 20 Nov (1.46 gm MJ^{-1}) and lowest under 05 December sown (1.20 gm MJ^{-1}) (Fig.4.14). Among the varieties, the maximum RUE was found for HD-2967 (1.55 gm MJ^{-1}), at 100 DAS followed by RSP-561 (1.42 gm MJ^{-1}) and Raj-3077 (1.30 gm MJ^{-1}) (Fig.4.15). The reason for this decline in RUE might be due to reduced interception of photosynthetically active radiation by the crop during later growth stages as the matured leaves contain decreased chlorophyll content. In addition, slower rate of increase in biomass during this period due to high temperature stress and leaf senescence.

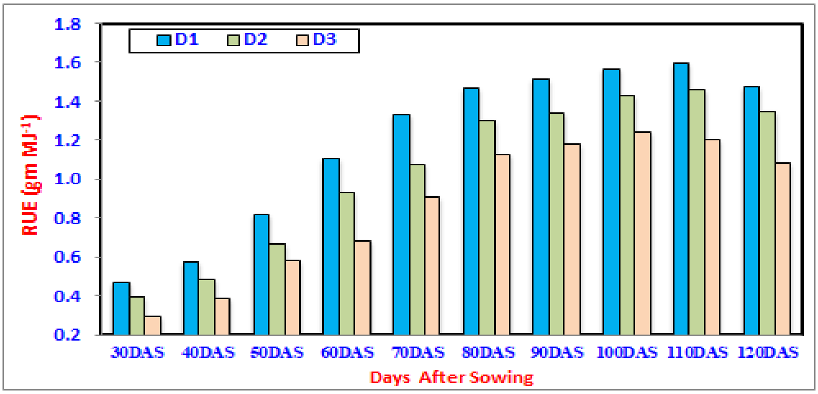


Fig.4.14: Effect of sowing environments on radiation use efficiency (gm MJ^{-1}) of wheat during *rabi* 2020-21

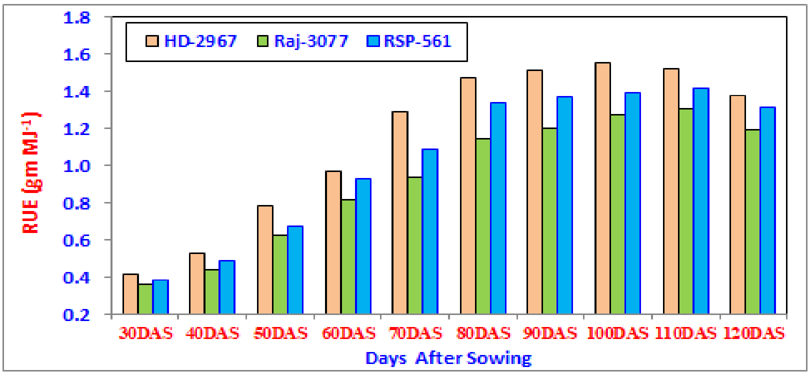


Fig.4.15: Influence of different cultivars on radiation use efficiency (gm MJ^{-1}) wheat during *rabi* 2020-21

The yield attributing parameters and grain yield were recorded at physiological maturity stage of various wheat varieties sown under different sowing environments. The grain yield of wheat crop significantly differed with sowing environments and various varieties. The wheat crop sown on 05 November (early sown) produced significantly higher grain yield (3614 kg ha^{-1}) than 05 December (late sown) sown wheat crop, but at par with 20 November (normal) sown wheat crop. The increase in the grain yield under early (05 Nov.) and normal (20 Nov.) sown wheat crop amounted to 19.23% and 12.01% as compared to late (05 Dec) sown wheat crop, respectively. Among the varieties, the grain yield of variety HD-2967 was significantly higher (3691 kg ha^{-1}) than RSP-561 (3302 kg ha^{-1}) and Raj 3077 (3041 kg ha^{-1}) (Table 4.43). Hence, it is understood that early sowing (first week of November) wheat variety HD-2967 lead to higher radiation use efficiency which in turn results higher yield than the other sowing environments and varieties.

Table 4.43: Effect of sowing environments and varieties on yield and yield attributing characters of wheat crop during *rabi* 2020-21

Treatments	No. of spikes/ plant	No. of grains/ spike	1000 seed wt	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index
D_1 (05-11-2020)	4.10	43.64	46.11	3614	9802	37
D_2 (20-11-2020)	3.91	39.18	43.23	3395	9430	36
D_3 (05-12-2020)	3.66	35.08	40.23	3031	9272	33
SE(m)	0.14	2.88	1.84	205	290	2.52
CD at 5%	NS	0.96	0.61	68	97	0.84
V_1(HD-2967)	4.15	43.30	49.00	3691	9958	37
V_2 (Raj-3077)	3.62	35.91	38.36	3041	9162	33
V_3 (RSP-561)	3.90	38.71	42.21	3302	9382	35
SE(m)	0.14	0.31	1.84	205	290	2.52
CD at 5%	NS	0.10	0.61	68	97	0.84

Kanpur

To study the effect of weather parameters on yield and yield attributing characters of wheat and also to develop the wheat yield predictive models, an experiment was conducted at Kanpur centre. Four genotypes (V_1 - HD-2733, V_2 - K-307, V_3 - K-9107 and V_4 - HD-2967) of wheat were sown in three sowing dates *viz.,* 25 Nov (D_1), 10 Dec (D_2) and 25 Dec (D_3) of *rabi* 2020-21.

From the results it is understood that wheat grain yield and yield attributing characters such as number of spikelets per ear, number of grains per ear, grains weight per ear and 1000 grain weight were greatly influenced by the different growing environments and genotypes. The number of spikelets per ear was significantly affected by different sowing dates and recorded higher number of spikelets per ear (19.3) in 25th Nov sowing followed by 10th Dec (18.8) and 25th Dec sown crop (18.1). Among the varieties, number of spikelets per ear under the variety HD-2967 was observed higher (19.3) which is significantly higher than the HD-2733 (18.9), K-9107 (18.7), and K-307 (18.0) (Table 4.44). One of the important factors responsible in determining the yield of wheat was number of grains per ear. The result indicated that number of grains was reduced with delayed sowing. The data revealed that early sown (25th Nov.) crop produced significantly higher grain per ear (40.5) when compared to late sowing of 10th Dec (37.8) and very late of 25th Dec (34.6). Among the varieties, HD-2967 produced significantly higher number of grains (38.9) followed by HD-2733 (38.1), K-307 (37.1) and then K-9107 (36.4).

Table 4.44: Influence of sowing date and varieties and its interaction on yield and yield attributing characters of wheat during 2020-21

Treat -ments	Yield (kg ha^{-1})			No. of spike-lets/ ear	No. of grains /ear	Grain wt./ ear(g)	1000 grain wt. (g)	Harvest index (%)
	Grain	Straw	Biomass					
Date of Sowing								
D_1	4560	7760	12310	19.3	40.5	37.1	2.06	35.7
D_2	3790	7640	11430	18.8	37.8	33.2	1.92	33.8
D_3	3350	6980	10340	18.1	34.6	32.5	1.72	32.1
SE +	103	52	147	0.06	0.07	0.50	0.02	0.11
CD 5%	257	128	365	0.15	0.17	1.25	0.04	0.27
Genotypes								
V_1	3990	7400	11390	18.9	38.1	34.8	1.93	34.1
V_2	3760	6790	10550	18.0	37.1	35.5	1.87	33.6
V_3	3540	8320	11860	18.7	36.4	29.7	1.80	33.0
V_4	4320	7330	11650	19.3	38.9	36.9	2.01	34.9
SE +	58	58	100	0.08	0.11	0.30	0.01	0.12
CD 5%	120	120	198	0.16	0.23	0.61	0.02	0.26
Interaction effect (Date of sowing x Genotypes)								
SE +	135	101	205	0.13	0.18	0.67	0.03	0.22
CD 5%	313	220	NS	0.28	0.39	1.54	NS	0.47

The highest significant grain yield was recorded when the crop sown on 25th November (4560 kg ha^{-1}) followed by 10th Dec (3790 kg ha^{-1}) and 25th December (3350 kg ha^{-1}) sown crop (Table 4.48). Delay in sowing time resulted in decline in wheat grain yield 16.9% and 26.5%, when crop sown on 10 and 25 December, respectively than the crop sown on 25 November. Among the varieties, HD-2967 produced higher grain yield (4320 kg ha^{-1}) followed by HD-2733 (3990 kg ha^{-1}), K-307 (3760 kg ha^{-1}) and K-9107 (3540 kg ha^{-1}). Significantly higher biomass was recorded when crop sown on 25 November (12310 kg ha^{-1}) followed by 10 Dec (11430 kg ha^{-1}) and then 25 December (10340 kg ha^{-1}) sown crop. Among the varieties, K-9107 produced significantly higher biomass yield (11860 kg ha^{-1}) followed by HD-2967 (11650 kg ha^{-1}), HD-2733 (11390 kg ha^{-1}) and K-307 (10550 kg ha^{-1}), respectively. However, no significant interaction effects between date of sowing and varieties were observed in respect to biomass yield.

Palampur

Weather variations were imposed through date of sowing to find the influence of different growing environments (Nov 5, Nov 20, Dec 5 and Dec 20) on yield of wheat varieties (HD-2967, HS-90 and VL-907) during 2017-18 to 2020-21 and data were combined for pooled analysis. Statistical analysis indicated that growing environment (5 Nov) gave highest yield (3286 $kgha^{-1}$) when compared to other three growing environments. It was also observed that no significant yield difference between the crop sown on Nov 5 and Nov 20 and also between Nov 20 and Dec 5. At the same time, late sown crop (Dec 20) gave significantly lower yield (2018 kg ha^{-1}) than other early sown crops (Fig.4.16). Among the varieties, VL-907 yielded more than other two varieties. Analysis showed that grain yield by the wheat cultivars VL-907 and HS-490 were on par and HD-2967 gave significantly lower yield than VL-907 and HS-490.

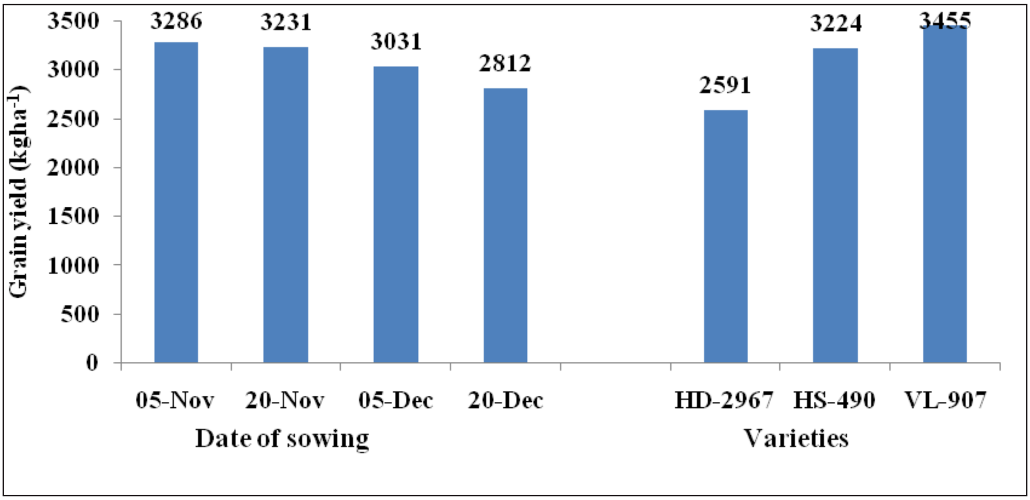


Fig.4.16: Effect of date of sowing and varieties on wheat grain yield at Palampur

Barley

Hisar

An experiment was conducted to understand the weather prevailed during different growing environments on barley phenology, yield and yield attributes. Four varieties of barley were sown in four different growing environments i.e. 30 November, 14 December, 28 December and 08 January during *rabi* 2020-21.

Results indicated that different growing environments and varieties have significant effect on phenology of barley crop. The barley crop sown in D_1 (30 Nov) took minimum days and D_4 (08 Jan) took maximum days for emergence. Maximum days to reach at physiological maturity was taken by D_1 (119 days), followed by D_2 (110 days), D_3 (103 days) and D_4 (94 days). Among barley varieties, BH 946 took significantly higher days for each phenological stage *i.e.* emergence (10 days), CRI (27 days), tillering (44 days), jointing (59 days), booting (76 days), anthesis (87 days), milking (93 days), dough (100 days) and physiological maturity (111 days), while, BH393 took lowest number of days (103 days) to attain the respective phenological stages.

Weather parameters prevailed during different sowing environments affected the yield attributes and yield of barley. Significantly higher number of effective tillers (877 m^{-2}) was recorded in D_1 as compared to subsequent sowing dates. Among varieties, BH 902 recorded significantly more effective tillers per unit area (700 m^{-2}) than BH 946 (618 m^{-2}) and BH 885 (580 m^{-2}). In the case of grains per spike, highest was found D_1 (50) when compared to subsequent sowing dates. Among the varieties, maximum grains per spike were observed in BH946 (55) followed by BH902 (53) and BH393 (44). Different dates of sowing and varieties showed significant influence on test weight (Table 4.45). Significantly higher test weight was recorded in D_1 (43.9 g) over D_4 (41.0 g). It was at par with D_2 (43.8) and D_3 (43.3 g). Among the varieties, BH885 (44.4 g) recorded significantly higher test weight (due to bold grains) than BH 946 (43.1 g), however it was at par with BH902 (44.0 g). Significantly higher grain yield was recorded in D_1 (5200 kgha^{-1}) when compared to D_3 (4380 kgha^{-1}) and D_4 (40.9 kgha^{-1}). Among the barley varieties, BH946 recorded higher grain yield (5050 kgha^{-1}) than BH 393 (4430 kgha^{-1}). Lowest grain yield was recorded in BH 885 (4370 kgha^{-1}). Harvest index showed that significantly highest harvest index was observed for D_4 (43.7%) and D_3 (42.2%) sown crop when compared to D_2 (36.1%) and D_1 (36.4%).

Table 4.45: Effect of sowing dates on yield attributes and yield of barley varieties during 2020-21

Treatment	ET	GS	SW	TW	GY	SY	HI
Sowing dates							
D_1 (30/11/2020)	877	50	3.3	43.9	5200	9050	36.4
D_2 (14/12/2020)	737	48	2.9	43.8	4910	8790	36.1
D_3 (28/12/2020)	503	44	2.1	43.3	4380	6160	42.2
D_4 (08/01/2021)	305	44	2.4	41.0	4090	5340	43.7
SEm	31.77	3.40	0.19	0.53	120	294	1.54
CD @ 5%	92.21	NS	0.55	1.55	352	852	4.47
Varieties							
BH 393	523	44	2.3	40.5	4430	6740	42.2
BH 902	700	53	3.0	44.0	4730	8010	37.7
BH 946	618	55	3.1	43.1	5050	6880	43.0
BH 885	580	34	2.2	44.4	4370	7710	36.3
SEm	31.77	3.40	0.19	0.19	120	294	1.54
CD @ 5%	92.21	9.87	0.55	0.55	352	852	4.47

ET- Effective Tiller/m^2, GS- Grains/spike (number), SW- spike weight (g), TW- test weight (g), GY- grain yield (kgha^{-1}), SY- Straw yield (kgha^{-1}), HI- harvest index (%)

Daily weather parameters *viz* maximum & minimum temperatures, wind speed and rainfall during the barley growing season starting from 30th Nov, 2020 with the sowing of first treatment (D_1) up to 15th April 2021 *i.e.* physiological maturity of the last sowing *i.e.* 8th Jan, 2021 (D_4) is shown in Fig. 4.16. It is understood that at reproductive stage of D_3 and D_4 sown crop was coincided with high terminal heat stress (due to failure of rain and rise of minimum temperature) which led forced maturity and reduced yield when compared to D_1 and D_2 sown crop.

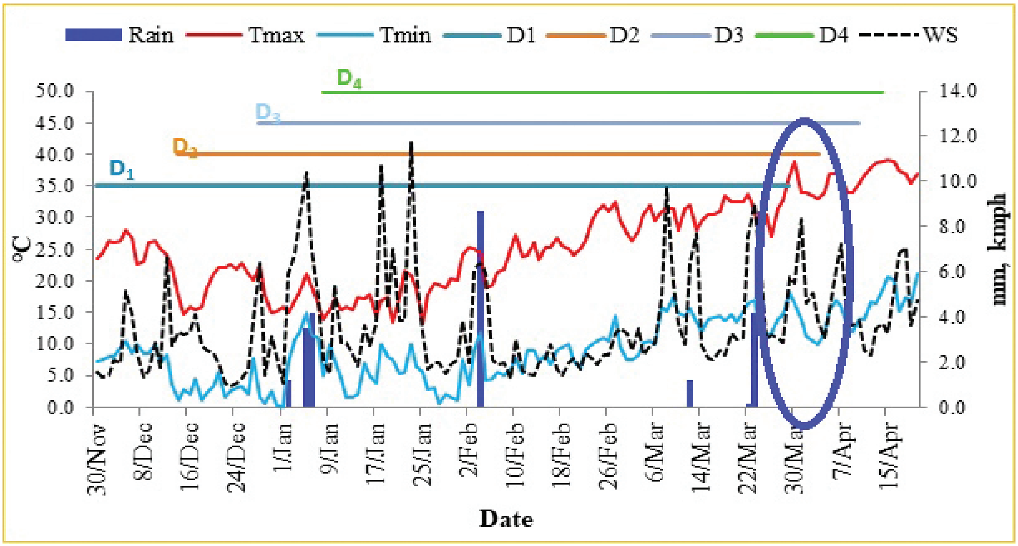


Fig.4.16: Daily weather condition during barley crop season 2020-21

Maize

Kovilpatti

In order to study the effect of micro environments on phenology, thermal requirements and grain yield of *rabi* maize hybrids under rainfed condition, experiment was conducted during *rabi* 2020-21. Four maize hybrids (S6850, NK6240, RMH3033 and COHM6) were planted on September 26, October 3, 10 and 17. The phenological observation revealed that the maize crop duration ranged from 111 to 120 days. The reduced duration of maize (112 and 113 days) was observed under delayed sowing i.e. October 17 and 10, respectively and was mainly attributed to increased maximum temperature at later reproductive phases *viz.,* milking, dough and maturity. In the case of cultivars, maize hybrids *viz.,* COHM 6 and NK6240 took minimum number of days for completion of each phenophases than other hybrids (RMH 3033 and S6850) (Table 4.46).

Table 4.46: Influence of various sowing dates and varieties on phenology of *rabi* maize

Treat-ments	Seedling	Knee high	Tasseling	Silking	Milking	Dough	Maturity	Total (days)
39th SMW (Sep 26)	14	32	12	5	15	9	33	120
40th SMW (Oct 3)	13	32	12	6	14	8	34	119
41st SMW (Oct 10)	12	31	11	5	14	8	32	113
42nd SMW (Oct 17)	12	31	11	5	14	8	31	112
Hybrids								
S 6850	13	30	12	6	16	9	33	119
NK6240	12	30	10	5	15	8	31	111
RMH 3033	13	31	10	5	16	9	32	116
COHM 6	12	30	10	5	15	8	30	110

Influence of sowing windows on yield and yield attributes of maize hybrids

Results indicated that leaf area index (LAI) (6.24), cob length (16.82 cm), cob girth (14.98 cm) and grains /row (28.84) were observed higher for 39th standard week sown crop (Sept 26) followed by 40th standard week sown crop (Oct 3) when compared to other sowing environments. Higher quantum of rainfall during early vegetative stages *viz.,* seedling and knee-high stage and even distribution of rainfall during the later reproductive stages *viz.,* tasseling, silking dough and maturity phase could be the reason for the higher growth and yield attributes *viz.,* plant height, leaf area index, grain rows/cob and grain yield for the early sown maize (39th standard week).

Among the maize hybrids evaluated COHM 6 recorded maximum LAI (6.36), cob length (16.42 cm), cob girth (16.18 cm), grains/row (28.6) and test weight (33.2 g) while the hybrid S 6850 was registered lowest growth parameters and yield under rainfed vertisol condition. The 39th standard meteorological week sown crop recorded the highest grain yield (4864 kg ha^{-1}) and stover yield (8926 kg ha^{-1}) than the other sowing windows. The lowest grain yield (3320 kg ha^{-1}) and stover yield (6278 kg ha^{-1}) was registered by the 42nd standard meteorological week sown crop (Table 4.47). Maize hybrid COHM 6 recorded the highest grain yield (4928 kg ha^{-1}) and stover yield (9115 kg ha^{-1}) than other hybrids tested. It is understood from the experiment that early sowing (39th standard meteorological week) of maize hybrid (COHM6) received with higher amount of rainfall (498.0 mm) and even rainfall distribution (31 rainy days) throughout the crop growth period led to higher growth parameters, yield attributes and yields than the other sowing windows.

Table 4.47: Influence of sowing windows on growth attributes and yield parameters of maize hybrids under rainfed condition during 2020 - 2021

Treatments	LAI at tasseling	Cob length (cm)	Cob girth (cm)	Grains / row	100 seed weight (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
Date of sowing							
39th SMW (Sep 26)	6.24	16.82	14.98	28.84	32.10	4864	8926
40th SMW (Oct 3)	6.04	15.86	12.93	26.21	31.60	4470	8320
41st SMW (Oct 10)	5.60	12.16	10.82	24.30	28.40	3860	7025
42nd SMW (Oct 17)	4.92	11.6	9.43	20.38	24.36	3320	6278
CD (5%)	0.18	0.38	0.43	0.76	0.28	148	241
Hybrids							
S 6850	5.21	10.81	11.60	22.1	31.20	3420	6725
NK6240	5.82	12.48	14.12	26.4	32.18	4460	8280
RMH 3033	5.61	12.14	13.28	24.3	31.80	4052	7650
COHM 6	6.36	16.42	16.18	28.6	33.20	4928	9115
CD (5%)	0.14	0.28	0.41	0.60	0.38	146	218

Samastipur

Influence of weather prevailed during different sowing environments (1 November, 10 November, 20 November and 30 November) on three maize varieties *viz.,* Shaktiman 4, Shaktiman 5 and 3522 Pio was studied during *rabi* 2020-21. The data related to phase duration and accumulated growing degree days (AGDD) at different phenophases of maize grown during *rabi* season of 2020-21 have been worked and furnished in Table 4.48. At germination, the highest AGDD was recorded for the crop sown on 10 November, while at knee high stage, significantly highest AGDD was associated with 1 November sown crop. The GDD accumulated at this stage by 10 and 20 November sown crops were at par. At tasseling and silking stage, 20 November sown crop accumulated highest GDD, whereas at milking, dough and maturity stages, 30 November sown crop accumulated highest GDD. There was no varietal significance with respect to both thermal days and AGDD except at germination and knee-high stage.

Table 4.48: Effect of sowing dates on different phenophases and heat unit accumulation of *rabi* maize

Treatments	Germination		Knee high		Tasseling		Silking		Milking Stage		Dough stage		Maturity	
	DAS	AGDD	DAS	AGDD	DAS	AGDD	DAS	AGDD	DAS	AGDD	DAS	AGDD	DAS	AGDD
Sowing Date														
D1 (01 Nov 2020)	7.0	112.5	40.0	461.3	105.5	812.9	116.4	925.7	138.6	1225.4	153.6	1467.4	164.1	1652.7
D2 (10 Nov 2020)	6.7	119.7	43.2	412.5	109.5	835.9	117.2	923.0	133.2	1166.2	149.4	1432.2	159.5	1615.7
D3 (20 Nov 2020)	6.6	88.9	56.1	417.8	116.4	924.0	125.5	1066.8	135.8	1237.1	153.4	1544.1	160.6	1678.8
D4 (30 Nov 2020)	9.5	97.8	59.1	349.5	110.4	871.7	119.8	1023.2	136.4	1309.5	152.0	1588.7	157.8	1688.5
CD (P=0.05)	0.44	4.84	1.68	8.26	3.50	45.09	3.67	55.7	3.39	57.85	2.58	45.87	2.66	47.39
Varieties														
V1-Shaktiman 4	7.8	107.4	50.2	411.6	110.0	858.4	120.2	995.3	136.4	1241.1	151.8	1503.8	160.0	1649.2
V2-Shaktiman 5	8.4	113.6	50.4	412.9	109.4	848.7	118.0	962.0	134.3	1205.4	151.1	1491.5	159.7	1644.9
V3- 3522 Pio	6.2	93.1	48.6	406.4	112.0	876.5	121.0	1003.5	137.4	1257.2	153.5	1532.7	161.9	1682.6
CD (P=0.05)	0.38	4.19	1.45	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

DAS- Days after sowing; AGDD- Accumulated growing degree days

Significant influence of growing environments on number of grain rows per cob, grains per cob, 1000 grain weight and grain yield were noticed. Significant higher grain yield (9971 kg ha^{-1}) was noticed for D2 sown crop (10 Nov) than other sowing dates. As far as varietal influences are concerned, significant influence was observed in case of 1000 grain weight and grain yield. Maize varieties Shaktiman 4 and 3522 Pio produced significantly higher yield than Shaktiman 5 (Table 4.49). The experiment results indicated that maize varieties Shaktiman 4 and 3522 Pio sown on Nov 10 produced higher grain yield during *rabi* season at Samastipur.

Table 4.49: Effect of sowing date on growth, yield attributes and grain yields of *rabi* maize

Treatments	Cob length (cm)	No. of grain rows per cob	Grains per cob	1000 grain weight (gm)	Grain yield ($kgha^{-1}$)
Date of sowing					
D1 (01 Nov 2020)	14.8	14.6	406.2	364.2	8949
D2 (10 Nov 2020)	16.6	14.0	432.0	341.0	9971
D3 (20 Nov 2020)	17.4	15.7	497.1	300.0	9284

Treatments	Cob length (cm)	No. of grain rows per cob	Grains per cob	1000 grain weight (gm)	Grain yield (kgha^{-1})
D4 (30 Nov 2020)	17.4	15.3	484.7	291.8	8030
CD (P=0.05)	NS	1.0	57.7	9.0	483
Varieties					
V1-Shaktiman 4	17.0	15.4	451.7	333.5	9221
V2-Shaktiman 5	15.6	14.9	444.4	313.9	8349
V3- 3522 Pio	17.0	14.3	468.9	325.4	9599
CD (P=0.05)	NS	NS	NS	7.8	418

Rabi Sorghum

Solapur

Experiment was conducted to understand the interaction between various weather parameters and consumptive use of moisture, moisture use efficiency, radiation use efficiency and grain yield of sorghum during *rabi* 2020-21. Three cultivars of sorghum were sown in four different growing environments *viz.,* Meteorological Week (MW) 36 (Sept 03-09), MW 38 (Sept 17-23), MW 40 (Oct 01-07) and MW 42 (Oct 15-21). The pooled data from the experiments conducted during 2016-20 showed that the mean CUM and MUE recorded by sorghum crop was 240 mm and 2.7 kg ha^{-1} mm (Table 4.50). The highest CUM was recorded by S_1 sown crop (282 mm) however the MUE was recorded by S_3 sown crop (3.5 kg ha^{-1}mm). This indicated that S_3 sown crop (C*hitra Nakshtra*) utilized moisture more efficiently than other dates of sowings. Among the variety M-35-1 recorded maximum mean CUM (266 mm) and MUE (3.1 ha^{-1}mm) than other varieties.

Table 4.50: CUM and MUE as influenced by different growing environments in *rabi* sorghum (2016 to 20)

Sowing Time	CUM (mm)				MUE (kg ha^{-1} mm)			
	M-35-1	Mauli	Yashoda	Mean	M-35-1	Mauli	Yashoda	Mean
S_1 MW 36 (Sept 03-09)	270	285	290	282	2.7	2.2	2.0	2.3
S_2 MW 38 (Sept 17-23)	240	268	270	259	3.4	2.7	2.6	2.9
S_3 MW 40 (Oct 01-07)	210	240	250	233	4.1	3.3	3.1	3.5
S_4 MW 42 (Oct 15-21)	185	189	192	189	2.5	2.1	2.0	2.2
Mean	226	245	250	240	3.1	2.6	2.4	2.7

Table 4.51: Pooled grain yield (kg ha^{-1}) of *rabi* sorghum as influenced by sowing dates and varieties (2016 - 20)

Treatment	2016-17	2017-18	2018-19	2019-20	2020-21	Pooled
Main=Sowing dates						
S_1 = MW 36 (Sept.03-09) *Purva nakshtra*	793.9	508.1	516.0	579.1	846.7	648.8
S_2 = MW 38 (Sept.17-23) *Uttara nakshtra*	897.4	618.2	583.3	701.6	926.9	745.5
S_3 = MW 40 (Oct. 01-07) *Hasta nakshtra*	1042.4	844.4	677.6	503.5	973.4	808.3
S_4 = MW 42 (Oct.15-21) *Chitra nakshtra*	480.9	434.0	379.9	357.2	424.2	415.1
Mean	803.7	601.2	539.2	535.4	792.8	654.4
S.E.+ (Sowing dates)	57.1	44.4	37.02	25.2	27.2	44.5
C.D. at 5%	182.6	142.1	118.45	80.7	87.1	137.1
Sub=Varieties						
V_1 = Maldandi (M-35-1)	884.3	659.1	594.3	588.5	863.6	717.9
V_2 = Mauli	770.2	573.2	514.8	534.3	801.4	638.8
V_3 = Yashoda	756.4	571.2	508.6	483.3	713.4	606.6
Mean	803.7	601.2	539.2	535.4	792.8	654.4
S.E.+ (Varieties)	33.3	23.9	22.16	19.6	23.3	10.3
C.D. at 5%	97.1	69.6	64.69	57.3	68.1	29.7
Interaction						
S.E.+ (SD X V)	66.5	47.7	44.32	39.3	46.7	20.6
C.D. at 5%	NS	NS	NS	NS	NS	NS

Among all the sowing dates, the crop sown at MW 40 (01-07 Oct) and MW 38 (17-23 Sept) produced significantly higher grain yield i.e. 808.3 kg ha^{-1} and 745.5 kg ha^{-1}, respectively when compared to the other sowing dates (Table 4.51). However, late sowing during MW 42 (15-21 Oct) resulted in significantly lower yield than other three sown crops. This could be due to moisture stress condition prevailed during reproductive growth period. Among the varieties, M-35-1 was produced significantly higher grain yield (717.9 kg ha^{-1}) over the other varieties. This might be due to M-35-1 was more effective in utilizing available moisture for its growth and development than other varieties. However, no significant interaction effect between growing environments and varieties on sorghum grain yield was noticed.

Green gram

Mohanpur

Effect of prevailing weather situation during different sowing dates on biomass and yield of green gram and variation in intercepted and absorbed PAR at different growth stages of green gram was studied during *rabi* 2020-21. Three varieties of green gram (Samrat, PM-05 and Meha) were sown on September 10 and 28 & October 09. Leaf area index was measured at initial, branching, pod development and maturity stages of the green gram crop. No significant influence was observed in LAI due to difference in date of sowing and varieties. The LAI was highest during pod development stage, both for different varieties and different dates of sowing (Table 4.52). During pod development stage LAI of D1 was highest (3.1) followed by D2 (2.7) and D3 (2.0). In the case of varieties, highest LAI was noticed for Meha (2.9) variety during pod development stage followed by Samrat (2.6) and PM05 (2.2) variety.

Table 4.52: Variation in LAI during different phenological stages

Treatment	Initial	Branching	Pod development	Maturity
Date of sowing				
D1	1.5	1.4	3.1	2.4
D2	0.7	1.9	2.7	2.5
D3	0.5	1.5	2.0	2.3
SEm (±)	0.09	0.12	0.28	0.22
CD (p =0.5)	0.36	NS	NS	NS
Variety				
V1	0.8	1.5	2.6	2.3
V2	0.8	1.5	2.2	2.4
V3	1.1	1.7	2.9	2.5
SEm (±)	0.10	0.16	0.27	0.18
CD (p =0.5)	NS	NS	NS	NS

Irrespective of different varieties, there was a significant statistical variation among the different dates of sowing. The highest pod yield was obtained 2236.7 kg ha^{-1} in D_2V_2. Data of mean yield showed that the D_1 sown crop gives the highest yield (2082.2 kg ha^{-1}) followed by D_2 (1881.1 kg ha^{-1}) and D_3 (1180 kg ha^{-1}). In general temperature required for optimum growth 28 -30^{o}C and in the present study the average temperature during the crop growing period was 28.5^{o}C for D_1 sown crop, which declined to 26.4°C and 24.4°C, respectively for D_2 and D_3 sown crops. This attributed for the highest yield for D_1 when compared to D_2 and D_3. During the pod development stage, the duration of BSS was highest under D_1 sown crop which led to better photosynthesis and resulted in highest yield. Among the varieties, V_2 (PM-05) performed better than other two varieties and has the highest yield (1844.4 kg ha^{-1}) followed by V_1 (Samrat) and V3 (Meha) (Table 4.53).

Table 4.53: Influence of different growing environments and varieties on green gram yield of grown in 2020-2021

Date of sowing / variety	Yield (kg ha^{-1})			
	V1	V2	V3	Mean
D1	2000.0	2133.3	2113.3	2082.2
D2	1770.0	2236.7	1636.7	1881.1
D3	1310.0	1163.3	1066.7	1180.0
Mean	1693.3	1844.4	1605.6	
Factor	SEm	CD (p=0.05)		
Date of sowing	91.5	359.1		
Variety	192.3	NS		
D X V	333.0	NS		

Seasonal evapotranspiration and water use efficiency

During the crop growing season, D_1 growing environment received 25.9 mm rainfall while D_2 and D_3 received 13.6 mm and 3.5 mm rainfall, respectively. Average soil water storage (SWS) was highest in D_1 sowing (94.3 mm) followed by D_2 (73.4 mm) and D_3 (42.4 mm). Average seasonal evapotranspiration (SET) was 120.3 mm, 107.0 mm and 65.9 mm for first, second and third date of sowing, respectively. Irrespective of variety, the highest average water use efficiency (WUE) value (1.87 kg m^{-3}) was recorded under 8 November (D_3) sown crop, which declined by 6.4% and 7.5% respectively under D_2 and D_1. WUE was increasing from first to third date of sowing (Table 4.54).

Table 4.54: Seasonal evapotranspiration and water use efficiency

Date of sowing	Variety	Rainfall (mm)	Irrigation (mm)	SWS (mm)	SET (mm)	Yield (kgha^{-1})	WUE (kgm^{-3})
D1	Samrat	25.9	0	97.5	123.4	2000.0	1.62
	PM-05	25.9	0	95.2	121.1	2133.3	1.76
	Meha	25.9	0	90.3	116.2	2113.3	1.82
D2	Samrat	13.6	20	70.9	104.5	1770.0	1.69
	PM-05	13.6	20	88.4	122	2236.7	1.83
	Meha	13.6	20	61	94.6	1636.7	1.73
D3	Samrat	3.5	20	38.3	61.8	1310.0	2.12
	PM-05	3.5	20	62	85.5	1163.3	1.36
	Meha	3.5	20	26.9	50.4	1066.7	2.12

Irrespective of date of sowing, highest average SWS and SET observed in PM-05 variety 81.9 mm and 109.5 mm, respectively followed by Samrat and Meha variety. Average WUE was highest in Meha (1.89 kg m^{-3}) followed by Samrat and PM-05 variety. Linear relation between SET and green gram yield was observed (Fig. 4.17). SET alone can describe 86% variation of yield irrespective of varieties and date of sowing. The model showed that per unit increase in SET can increase the yield by 15.3 kg ha^{-1}.

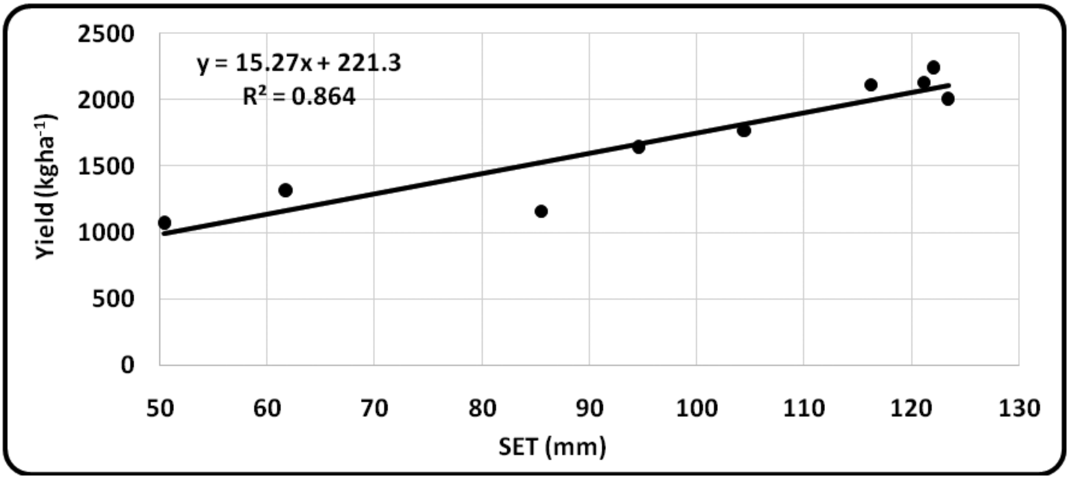


Fig.4.17: Relation between yield and seasonal evapotranspiration

Groundnut

Thrissur

Experiment on crop weather relation with groundnut variety CO-6 was conducted adopting split plot design. Four dates of sowing *viz.,* November 1 (D1), 15 (D2), December 1 (D3) and 15 (D4) were used as main plot treatments and three irrigation levels of IW/CPE ratio 0.6 (I1), 0.8 (I2) and 1.0 (I3) were used as sub plot treatments. Results indicated that shelling percentage of D1 and D3 sown crop recorded significantly higher yield than D2 and D4 sown crop. In the case of irrigation levels, I_3 showed significantly higher shelling percentage (73.1%) while I_1 and I_2 treatments were on par. Interaction between irrigation treatment and dates of planting with respect to shelling percentage was found to be non-significant. Groundnut yield was significantly influenced by the dates of planting. The highest yield (935.6 kg ha^{-1}) was recorded for D1 (November 1) planting and the lowest yield (776.9 kg ha^{-1}) was recorded during D4 (December 15) planting. Among the irrigation level treatments, the highest yield (1016.9 kg ha^{-1}) was recorded under I3 treatment and the lowest yield recorded was in I1 treatment (Table 4.55). However, the interaction between irrigation treatment and dates of planting with respect to yield was found to be non- significant.

Table 4.55: Effect of dates of planting and irrigation level on groundnut yield and yield attributes

Date of planting	Yield parameters		
	Yield (kgha^{-1})	Shelling percentage (%)	Harvest Index
1 November	935.6[a]	72.1[a]	0.36[a]
15 November	868.8[c]	70.1[b]	0.36[ab]
1 December	897.7[b]	71.5[a]	0.37[a]
15 December	776.9[d]	69.5[b]	0.34[b]
CD	26.1	1.4	0.015
I_1 (IW/CPE -0.6)	748.3[c]	69.4[b]	0.36[b]
I_2 (IW/CPE-0.8)	844.1[b]	69.9[b]	0.34[b]
I_3 (IW/CPE-1.0)	1016.9[a]	73.1[a]	0.38[a]
CD	28.4	1.3	0.02

Potato

Hisar

Effect of different weather variables prevailed during four growing environments [Oct 13 (D_1), Oct 28 (D_2), Nov 12 (D_3) and Nov 28 (D_4)] on growth, development and tuber yield of potato cultivars Kufri Bahar-V_1, Kufri Pushkar-V_2 and Kufri Lima-V_3 was studied during *rabi* 2020-21. In addition, utilization pattern of photosynthetically active radiation by potato crop at various growth stages was studied.

Planting dates and varieties did not influence to be the number of shoots per hill in potato. Growing environments have not affected the number of tubers per plant and Nov 28 (D_4) planted crop produced highest tubers (11 tubers per plant) followed by all planting dates (9 tubers per plant). However, Kufri Pushkar variety had significantly higher number of tubers per plant (12) than Kufri Bahar (9) and Kufri Lima (7) at physiological maturity. Significantly higher tuber yields *i.e.* 33090 kg ha^{-1} was recorded in Oct 28 (D_2) planted potato due to prevailing of favourable weather throughout the growing period. This was about 4.7%, 11.5% and 9.2% higher tuber yield than other planting dates, respectively (Table 4.56). Daily weather condition during D_2 potato growing season showed relatively lower temperatures which favoured tuber bulking and contributed to higher yield (Fig.4.18). Potato planted on 12 Nov (D_3) produced statistically lower tuber yield (29300 kg ha^{-1}) than other planting dates owing to heavy rain (green circle) after planting which create mechanical hindrance due to soil crusting. It was also observed that during stolonization and tuber initiation stages, D_3 experienced foliage damage due to occurrence of frost (yellow circle). Among potato varieties, Kufri Pushkar recorded significantly higher yield (32640 kg ha^{-1}) than Kufri Bahar (29450 kg ha^{-1} and Kufri Lima (30900 kg ha^{-1}).

Table 4.56: Effect of different growing environments on yield attributes and yield of potato varieties during 2020-21

Treatment	Number of shoots per hill	Number of tubers per plant	Tuber weight (g/tuber)	Tuber yield per plant (g)	Tuber yield (q/ha)	Haulm yield (q/ha)	Harvest Index (%)
Planting dates							
D_1 (13/10/2020)	5	9	58.82	363.0	300.6	144.20	67.8
D_2 (28/10/2020)	6	9	51.73	400.7	330.9	135.87	71.1
D_3 (12/11/2020)	4	9	49.46	286.8	293.0	125.64	70.0
D_4 (28/11/2020)	4	11	51.33	301.7	315.5	154.61	67.1
SE(m)	0.51	0.58	3.71	11.41	6.56	4.26	1.12
CD @ 5%	NS	NS	NS	32.97	18.96	12.30	NS
Varieties							
Kufri Bahar	4	9	43.35	282.2	294.5	126.24	69.9
Kufri Pushkar	6	12	40.06	351.0	326.4	114.57	73.9
Kufri Lima	4	7	75.09	381.1	309.0	179.44	63.2
SE(m)	1.44	0.50	2.27	9.88	5.68	3.69	0.97
CD @ 5%	NS	1.40	6.57	28.55	16.42	10.65	2.81

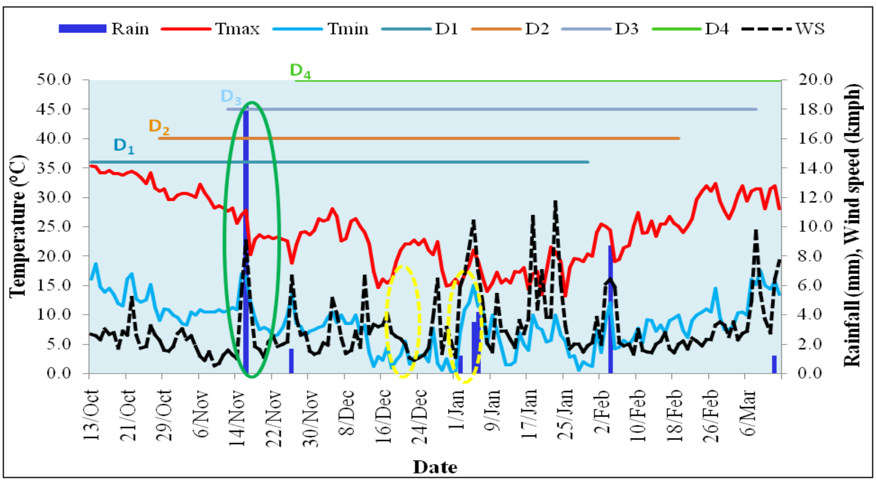


Fig.4.18: Daily weather condition prevailed during potato crop season 2020-21

5. Crop Growth Modeling

Akola

Identifying the critical irrigation requirement through soybean simulation modeling

DSSAT Soybean model was calibrated and validated for the soybean varieties JS-335, JS-9305 and AMS-1001. The model was subjected to critical irrigation application under environmental modification module to identify the date of application and amount of irrigation water to reduce or combat the adverse effect of soil moisture stress due to sowing time and duration of crops. During *kharif* 2020, wet spell conditions was prevailed owing to continuous rainfall that occurred from 25th June to 29th July. Mid-season dry spell during 31 MW (30 July-1 August) received only 8.7 mm rainfall (2 rainy days) coinciding reproductive stage of the crop. Good wet spell during critical stages of the soybean crop i.e. flowering and pod/seed development stage across different sowing environments which might have boosted the final yield performance of the crop. Protective irrigation treatments (60 mm for each irrigation) (Table 5.1) were added in DSSAT (CROPGRO Soybean) model and effect of this protective irrigation treatment on soybean yield were simulated. Comparison of simulated and observed soybean yield showed that yield gain was noticed due to the provision of protective irrigations when compared to rainfed treatment for the cultivar JS-335. However, yield increment was not observed in any sowing environments for the cultivars JS-9305 and AMS-1001 (except last sowing environment 28 MW).

Table 5.1: Effect of protective irrigation on soybean seed yield during *kharif* 2020

Sowing time	Seed yield (kg ha^{-1})				
	Observed (normal rainfed)	Simulated (normal rainfed)	Simulated (protective irrigation)		
			1 irrigation (Aug 13)	1 irrigation (Sep 8)	2 irrigations (Aug 13 & Sep 8)
JS-335					
D1 (26 MW)	2169	2359	2516 (FL-IN)	2519 (PF-SF)	2524
D2 (27 MW)	1715	1988	2153 (MVG)	2137 (PF)	2143
D3 (28 MW)	1287	1809	1977 (EVG)	1871 (FL-PI)	1945
JS-9305					
D1 (26 MW)	1708	1274	1526 (FL-IN)	1525 (PF-SF)	1528
D2 (27 MW)	1347	1053	1269 (MVG)	1271 (PF)	1273
D3 (28 MW)	1214	969	1145 (EVG)	1152 (FL-PI)	1171
AMS -1001					
D1 (26 MW)	1974	1619	1918 (FL-IN)	1915 (PF-SF)	1923
D2 (27 MW)	1662	1340	1615 (MVG)	1613 (PF)	1626
D3 (28 MW)	1257	1230	1482 (EVG)	1495 (FL-PI)	1510

Hisar

DSSAT -Potato simulation model (SUBSTOR-Potato) evaluation

SUBSTOR-Potato module of DSSAT (v4.7) was used for calibration and validation to assess the performance of the model. Two years data was collected and the model was calibrated for the year 2016-17 to derive the genetic coefficients; the model was validated with the field observations taken during the year 2017-18. For this purpose, field experiments were conducted under four planting dates *viz.* D_1 (8 Oct), D_2 (22 Oct), D_3 (5 Nov) and D_4 (23 Nov) as main plot treatments and three varieties V_1 (Kufri Bahar), V_2 (Kufri Pushkar) and V_3 (Kufri Surya) as sub-plots in split plot design with four replications. Minimum dataset was developed for the above 3 cultivars under Hisar condition. Genetic coefficients generated upon calibration is presented in the Table 5.2.

Table 5.2: Genetic coefficient of potato varieties in different sowing environments

Symbols	Description	Kufri Bahar	Kufri Pushkar	Kufri Surya
G2	Leaf area expansion rate in degree days ($cm^2/m^2/d$)	2000	2150	2000
G3	Potential tuber growth rate ($g/m^2/d$)	22.2	24.8	22.4
PD	Index that suppresses tuber growth during the period that immediately follows tuber induction (dimensionless)	0.9	0.7	0.8
P2	Index that relates photoperiod response to tuber initiation (dimensionless)	0.8	0.8	0.7
TC	Upper critical temperature for tuber initiation (°C)	23.2	22.8	21.2

Validation of SUBSTOR model

Phenology (Days taken to tuber initiation and physiological maturity)

Treatment-wise difference in days taken to tuber initiation was ranged from -4 (D_2V_1) to +4 (D_1V_1 and D_3V_1). Mean observed days to tuber initiation of potato varied from 41 (D_1V_1) to 59 (D_4V_1) among different planting dates and varieties during 2017-18, while model simulated days to tuber initiation ranged between 40 (D_1V_3) and 60 (D_4V_2) (Table 5.3). Lowest difference was recorded for first planting date as compared to other planting dates due to the prevalence of optimum weather conditions existed during that period. The simulated days for tuber initiation was in good agreement with the observed value was noticed for the statistical indices like MAE, MBE, RMSE, R^2 and PE of 0.04, 0.04, 2.52, 0.91 and 5.03, respectively. The majority of simulated values were nearer to observed values as the 1:1 line shows equal distribution of points of under estimation and over estimation.

Table 5.3: Validation of phenological events (days taken to tuber initiation and physiological maturity) with respect to sowing environments and potato varieties

Treatments	Tuber initiation (Days after planting)			Physiological maturity (Days after planting)		
	Observed	Simulated	Difference	Observed	Simulated	Difference
D_1V_1	41	45	4	97	95	-2
D_1V_2	49	51	3	102	103	1
D_1V_3	42	40	-2	76	82	6
D_2V_1	45	41	-4	102	104	2
D_2V_2	54	57	3	101	102	1
D_2V_3	50	52	2	84	82	-2
D_3V_1	49	53	4	87	90	3
D_3V_2	57	55	-2	97	91	-6
D_3V_3	51	50	-1	79	82	3
D_4V_1	59	58	-1	75	74	-1
D_4V_2	59	60	1	86	84	-2
D_4V_3	49	46	-3	70	72	2
Mean	50	51	1	88	88	0
Observed mean	50.16			87.89		
SDo	6.07			11.53		
Simulated mean	50.66			88.41		
SDs	6.52			10.92		
R^2	0.91			0.96		
MAE	0.04			0.04		
MBE	0.04			0.04		
RMSE	2.52			3.03		
PE	5.03			3.45		

SDs (Standard deviation of simulated value), SDo (Standard deviation of observed value), Mean absolute error (MAE), Mean Bias Error (MBE), Root Mean Square Error (RMSE), r (correlation coefficient) and PE (Percent Error)

Observed days to physiological maturity of potato varied from 70 (D_4V_3) to 102 (D_1V_2 & D_2V_1), while model simulated days to physiological maturity ranged between 72 (D_4V_3) and 104 (D_2V_1) (Table 5.3). The majority of treatments showed overestimated the days to physiological maturity in all the treatments. Treatment-wise difference for days taken to physiological maturity was ranged between -6 (D_3V_2) to +6 (D_1V_3). The model simulation showed good agreement with the observed values *i.e.* MAE, MBE, RMSE, R^2 and PE of 0.04, 0.04, 3.03, 0.96 and 3.45, respectively. The majority of prediction are closer to the 1:1 line which showed the over estimation of model.

Maximum LAI

The simulated maximum LAI were in good agreement with observed values. Observed maximum LAI of potato varied from 2.08 (D_4V_3) to 4.85 (D_2V_2) in planting dates and varieties during 2017-18, while model simulated maximum LAI ranged between 2.46 (D_4V_3) and 4.87 (D_1V_2). The model overestimated maximum LAI in majority of the treatments. Treatment-wise difference in maximum LAI was ranged between -0.19 (D_2V_2) and 0.49 (D_1V_3) (Table 5.4). Various model test criteria were worked out for maximum LAI *i.e.* MAE, MBE, RMSE, R^2 and PE of 0.01, 0.01, 0.21, 0.96 and 9.82, respectively. The majority of predictions are above the 1:1 line, which showed the overestimation of model and confirms the positive MBE. All prediction for maximum LAI was within ± 10% of observed values.

Table 5.4: Evaluation of SUBSTOR-Potato model with respect to growth and yield parameters of potato varieties grown in different sowing environments

Treatments	Maximum LAI			Tuber yield			Biological yield		
	Obs	Sim	Diff	Obs	Sim	Diff	Obs	Sim	Diff
D_1V_1	3.73	3.86	0.13	27875	26328	-1547	40809	44118	3309
D_1V_2	4.40	4.87	0.47	29336	26970	-2366	44697	43760	-937
D_1V_3	3.15	3.64	0.49	18438	15883	-2554	33226	33673	447
D_2V_1	4.26	4.52	0.26	33333	35999	2666	42669	48789	6120
D_2V_2	4.85	4.66	-0.19	34115	32067	-2048	46380	41857	-4523
D_2V_3	3.90	3.92	0.02	21528	25627	4099	37197	35417	-1780
D_3V_1	3.58	3.46	-0.12	23090	23968	878	38867	33758	-5109
D_3V_2	4.56	4.82	0.26	27951	25018	-2933	41909	42808	899
D_3V_3	3.33	3.23	-0.10	17361	15400	-1961	33182	35190	2008
D_4V_1	3.25	3.44	0.19	19691	16214	-3477	35251	33004	-2247
D_4V_2	4.22	4.61	0.39	21649	22431	782	36619	32221	-4398
D_4V_3	2.08	2.46	0.38	13906	14229	323	31352	35019	3667
Mean	3.77	3.96	0.19	24022	23344	-678	38513	38301	-212
Observed mean	1.77			24022.8			38513.1		
SDo	0.57			6441.6			4842.3		
Simulated mean	1.83			23344.5			38301.2		
SDs	0.43			6876.9			5579.5		
R^2	0.96			0.94			0.77		
MAE	0.01			56.5			17.7		
MBE	0.01			-56.5			-17.7		
RMSE	0.21			2391.7			3438.6		
PE	9.8			9.9			8.9		

SDs (Standard deviation of simulated value), SDo (Standard deviation of observed value), Mean Absolute Error (MAE), Mean Bias Error (MBE), Root Mean Square Error (RMSE), r (correlation coefficient) and PE (Percent Error)

Tuber and biological yield

The model predicted potato tuber yield was in good agreement with observed yield. The observed tuber yield varied from 13906 kg ha^{-1} (D_4V_3) to 34115 kg ha^{-1} (D_2V_2) during 2017-18 and the simulated yield was ranged between 14229 kg ha^{-1} (D_4V_3) and 35999 kg ha^{-1} (D_2V_1). Under D_2 planting, model simulation showed over estimation and in rest of the planting dates, model underestimated the yield. The simulated tuber yield showed good agreement with the observed values *i.e.* SDs, MAE, MBE, RMSE, R^2 and PE of 6876.9, 56.5, -56.5, 2391.7, 0.94 and 9.9, respectively (Table 5.4) and the predicted tuber yield was within ± 10% of observed values. In case of observed biological yield, it varied between 31352 kg ha^{-1} (D_4V_3) and 46380 kg ha^{-1} (D_2V_2) and the simulated biological yield ranged from 32221 kg ha^{-1} (D_4V_2) to 48789 kg ha^{-1} (D_2V_1). The simulated biological yield also showed similarity with the observed values *i.e.* SDs, MAE, MBE, RMSE, R^2 and PE of 5579.6, 17.7, -17.7, 3438.6 and 8.9, respectively (Table 5.4). The majority of prediction was far away from the 1:1 line which showed the underestimation of the model and confirms the negative MBE. The experiments results indicated that the comparison of observed and simulated days to tuber initiation and physiological maturity, maximum LAI, tuber yield and haulm yield were in satisfactory agreement. On this basis, farmers are suggested to go for potato planting in the second fortnight of October (22th Oct.) in the sub-tropical region.

Ludhiana

Management of continual heat stress in wheat through nitrogen application and sowing dates using CERES-Wheat model

The CERES-Wheat model, was calibrated for the PBW 343 wheat variety. The model was simulated to understand the impact of the continual heat stress (increase in maximum and minimum temperature by 3 °C) from sowing to harvest of the crop. Different nitrogen management options and sowing dates (Table 5.5) were tried to reduce the harmful effect of high temperature on wheat productivity. From the results it is inferred that among the three dates of sowing under normal temperature conditions, maximum wheat grain yield was obtained under 8th November. However, under continual heat stress the maximum grain yield of wheat was obtained under 15th November sowing. It was also noted that under all dates and temperature conditions increasing the number of splits of nitrogen application caused a reduction in grain yield of wheat. Further, results showed that wheat grain yield obtained in 8th November date of sowing under normal temperature and recommended dose and time of N application was 4407 kg ha^{-1} and it decreased to 3431 kg ha^{-1} (22.15%) in response to heat stress (Table 5.5). Application of 125% of recommended N in two and three [0, 30 and 60 days after sowing (DAS)] splits led to an increase in wheat productivity by 3.54 and 1.41%, respectively, under normal temperature conditions. It also helped in reducing the harmful effects of heat stress as the yield reduction was 16.04 and 21.72% with two and three splits, respectively, as compared to the recommended practice having yield reduction of 22.15%. Application of equal splits of 150% of recommended N at 0, 60 DAS; 0, 30, 60 DAS and 0, 30, 60, 90 DAS led to an increase in wheat productivity by 4.58, 4.13 and 3.13% under normal temperature conditions. Under heat stress conditions the maximum wheat productivity of 4015 kg ha^{-1} was observed with application of 150% of recommended N at 0 and 30 DAS in case of delayed sowing (15th November) and the lowest reduction in wheat productivity (8.89%) due to heat stress was also in this treatment. Thus, it may be concluded that the harmful effects of continual heat stress on wheat productivity can be reduced by sowing the wheat crop on 15th November and with additional application of nitrogen i.e.150% (188 kg/ha) of recommended N in two equal splits at 0 and 30 DAS.

Table 5.5: Effect of continual heat stress, N management and sowing dates on grain yield of wheat and its deviation from control

Treatments	Grain yield (kg ha^{-1})		Change from control (%)	
	Normal temperature	Continual heat	Normal temperature	Continual heat
Date of sowing: 1stNovember				
Recommended N (125 kg ha^{-1})				
Control, Two equal splits (0, 30 DAS)	3883	2805	-11.9	-36.4
Three equal splits (0, 30, 60 DAS)	3747	2635	-14.9	-40.2
Four equal splits (0, 30, 60, 90 DAS)	3712	2641	-15.8	-40.1
125% of recommended N (156 kg ha^{-1})				
Two equal splits (0, 30 DAS)	4219	3085	-4.3	-30.0
Three equal splits (0, 30, 60 DAS)	4073	2900	-7.6	-34.2
Four equal splits (0, 30, 60, 90 DAS)	4065	2858	-7.8	-35.2
150% of recommended N (188 kg ha^{-1})				
Two equal splits (0, 30 DAS)	4493	3324	1.9	-24.6
Three equal splits (0, 30, 60 DAS)	4344	3131	-1.4	-28.9
Four equal splits (0, 30, 60, 90 DAS)	4315	3044	-2.1	-30.9
Date of sowing: 8thNovember				
Recommended N (125 kg ha^{-1})				
Control, Two equal splits (0, 30 DAS)	4407	3431	0.0	-22.2

Treatments	Grain yield (kg ha^{-1})		Change from control (%)	
	Normal temperature	Continual heat	Normal temperature	Continual heat
Three equal splits (0, 30, 60 DAS)	4331	3117	-1.7	-29.3
Four equal splits (0, 30, 60, 90 DAS)	4120	3092	-6.5	-29.8
125% of recommended N (156 kg ha^{-1})				
Two equal splits (0, 30 DAS)	4563	3700	3.5	-16.0
Three equal splits (0, 30, 60 DAS)	4469	3450	1.4	-21.7
Four equal splits (0, 30, 60, 90 DAS)	4380	3368	-0.6	-23.6
150% of recommended N (188 kg ha^{-1})				
Two equal splits (0, 30 DAS)	4609	3931	4.6	-10.8
Three equal splits (0, 30, 60 DAS)	4589	3671	4.1	-16.7
Four equal splits (0, 30, 60, 90 DAS)	4545	3556	3.1	-19.3
Date of sowing: 15th November				
Recommended N (125 kg/ha)				
Control, Two equal splits (0, 30 DAS)	4260	3506	-3.3	-20.4
Three equal splits (0, 30, 60 DAS)	4118	3245	-6.6	-26.4
Four equal splits (0, 30, 60, 90 DAS)	3992	3178	-9.4	-27.9
125% of recommended N (156 kg ha^{-1})				
Two equal splits (0, 30 DAS)	4318	3796	-2.0	-13.9
Three equal splits (0, 30, 60 DAS)	4304	3537	-2.3	-19.7
Four equal splits (0, 30, 60, 90 DAS)	4243	3459	-3.7	-21.5
150% of recommended N (188 kg ha^{-1})				
Two equal splits (0, 30 DAS)	4320	4015	-1.9	-8.9
Three equal splits (0, 30, 60 DAS)	4319	3777	-2.0	-14.3
Four equal splits (0, 30, 60, 90 DAS)	4305	3675	-2.3	-16.6

Mohanpur

In the new alluvial zone of West Bengal, Satabdi, IR-36 and Khitish cultivar contributes the major share in rice cultivation during *kharif* season. An attempt has been made to quantify the effect of temperature and CO_2 increase on duration and the yield of these cultivars using crop growth simulation model. It has been observed from the present study that duration of the phenological stages of rice crop was not influenced due to elevated CO_2 concentration. In contrast, temperature change has profound influence on crop duration i.e. the total crop duration of Satabdi variety was reduced by 4 days, 9 days and 12 days compared to normal duration (97 days), respectively under 1 °C, 2 °C and 3 °C temperature enhanced condition. The reduction in crop duration ranged from 5 to 13 days for IR-36 (Normal 108 days) and 4 to 12 days for Khitish variety (Normal 105 days) (Fig. 5.1a).

In general temperature rise has negative impact on rice productivity. Yield of Satabdi variety decreased by 1.3, 9.4 and 19%, respectively under 1 °C, 2 °C and 3 °C temperature increase (Fig. 5.1b). In case of Khitish cultivar, 1°C temperature increase resulted 1% increase productivity. However, yield has declined by 3.9, 8.7% under 2 °C and 3 °C temperature increase. In case of Khitish variety the yield reduction will range from 2.9 to 8.1% and it indicated that under enhanced temperature scenario Khitish paddy variety would sustain its productivity compare to Satabdi variety.

The sole effect of elevated CO_2 (100 to 300 ppm) on rice yield showed increase in the yield of Satabdi variety by 7.3 to 27% (Fig.5.1c). The same trend was noticed for IR-36 (12 to 32.9% increase) and Khitish variety (9.7 to 25.8% increase). Model output on combined effect of elevated temperature and CO_2 showed that the ill effect of 1°C temperature rise was nullified by increasing the ambient CO_2 concentration by 100 ppm and 5.7% increase in yield can be attributed by Satabdi variety (Fig. 5.1d). However, effect of elevated temperature by 2 °C and 3 °C on rice yield was not nullified by elevated CO_2 and resulted in overall yield reduction by 4.6 and 13.5%, respectively for Satabdi. On the other hand, 100 ppm CO_2 increase in combination with 1 °C, 2 °C and 3 °C temperature increase resulted overall yield increment by 5.8 to 12.1% and 5.4 to 12% for IR-36 and Khitish variety, respectively. CO_2 concentration increase by 200 ppm led to change in yield of Satabdi variety by 13.6%, 1.7% and 5.8%, respectively under 1 ^{o}C, 2 ^{o}C and 3 ^{o}C enhanced temperature scenario (Fig.5.1e). Under 300 ppm elevated CO_2 condition all the three varieties resulted in overall increase in rice yield under enhanced temperature condition (Fig.5.1f). Therefore, the present study results showed that Satabdi variety is more susceptible to temperature increase compare to IR- 36 and Khitish varieties. Further, the positive impact of elevated CO_2 is better attributed by IR-36 and Khitish varieties compared to Satabdi.

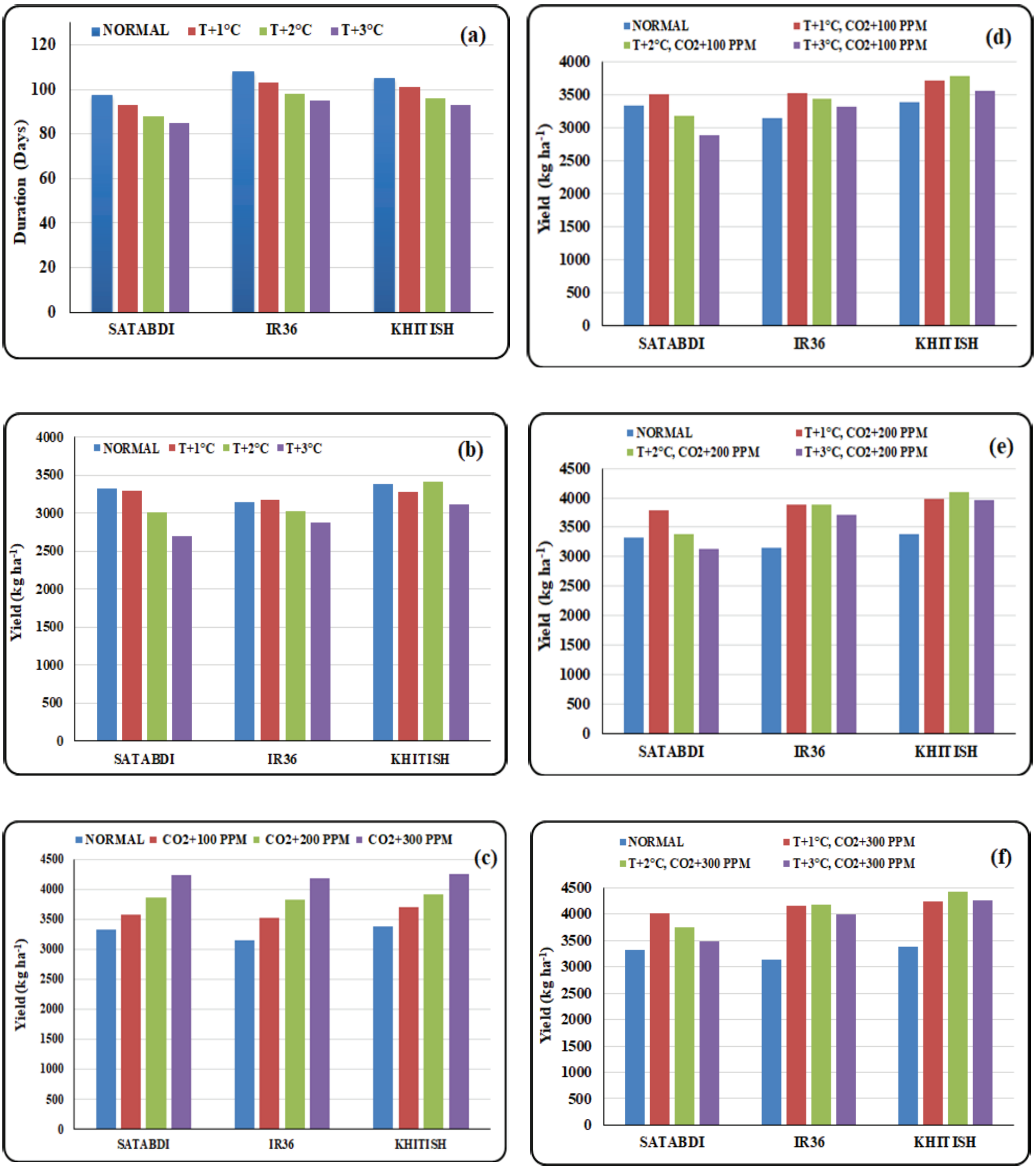


Fig. 5.1: Impact of temperature increase on duration of rice cultivars (a); impact of elevated temperature alone (b), CO_2 alone (c), combined temperature & CO_2 (d, e, & f) on yield of rice cultivars

Samastipur

Genetic coefficients of *rabi* maize variety Shaktiman 3 were worked out using weather, soil and field experimental data of Samastipur during 2011-12 and 2012-13 and the DSSAT-Maize model was validated using the experimental data for the year 2017-18. The genetic coefficients have been worked out for the variety Shaktiman 3 is furnished in Table 5.6.

Table 5.6: Genetic coefficients of maize variety Shaktiman 3

Description	Notation for Genetic coefficients	Genetic Coefficient value
Thermal time from seedling emergence to the end of the juvenile phase (expressed in degree days above a base temperature of 8 °C) during which the plant is not responsive to changes in photoperiod (°C days)	P1	320
Extent to which development (expressed as days) is delayed for each hour increase in photoperiod above the longest photoperiod at which development proceeds at a maximum rate (which is considered to be 12.5 hours), (°C days)	P2	0.79
Thermal time from silking to physiological maturity (expressed in degree days above a base temperature of 8 °C) (°C days)	P5	800
Maximum possible number of kernels per plant	G2	705
Kernel filling rate during the linear grain filling stage and under optimum conditions (mg day^{-1})	G3	9.69
Phylochron interval; the interval in thermal time (degree days) between successive leaf tip appearances (°C day tip^{-1})	PHINT	73

Performance of DSSAT-maize model using genetic coefficients for Shaktiman 3 variety was evaluated using the data of 2017-18. Comparison of observed and simulated values for phenological events and grain yield indicated that the error percentage in simulating days to anthesis and days to maturity was in the range 1.7-2.5 and 0.6-2.9, respectively. While, in the case of maize yield, error was within the range of 10% and the lowest error was noticed for 10 November sowing crop and highest error was 9.3 for 20 November sown crop (Table 5.7).

Table 5.7: Performance of DSSAT-Maize Model in simulating phenology and yield of *rabi* maize during 2017-18

Date of sowing	Days to anthesis (DAS)			Days to maturity (DAS)			Yield (kg ha^{-1})		
	Simulated	Observed	% error	Simulated	Observed	% error	Simulated	Observed	% error
1 Nov	119	116	2.5	170	167	1.8	5103	5266	3.2
10 Nov	121	119	1.7	173	168	2.9	6074	6081	0.1
20 Nov	120	122	1.7	167	166	0.6	6489	5887	9.3
30 Nov	116	118	1.7	159	158	0.6	5709	5921	3.7

Thrissur

DSSAT-CROPGRO Peanut model were calibrated using the field experimental data sets and genetic coefficients have been generated for TNAU CO-6 variety. The peanut crop was grown in four growing environments (November 1st, November 15th, December 1st and December 15th) at Instructional Farm, KAU, Vellanikkara. Results showed that the observed duration of days to germination varied between 5 to 8 days among treatments, while simulated value of days to germination was 6 days in all dates of sowing. The model simulated values of days to anthesis was 35 days under all treatments while the observed values were varied between 31 and 37 days. In case of days to attain physiological maturity, results showed that observed duration of physiological maturity varied from 142 to 149 days for all the treatments. Whereas, simulated values by model ranged between 138 and 142. The highest observed mean pod yield was recorded for the crop sown on November 1st planting in I3 treatment (1073 kg ha^{-1}). Whereas, highest simulated pod yield observed during December 1st planting in I3 treatment (1018 kg ha^{-1}). The computed error percentage between simulated and observed values that the model underestimated the phenological events and pod yield of groundnut in most of the treatments. The simulated value of phenological observations and yield of groundnut crop using DSSAT-Peanut model was in good agreement with observed value in respect of statistical indices. RMSE and D-index value for days taken for germination, anthesis and physiological maturity were 1.32, 2.21 and 6.06 and 0.42, 0.41 and 0.41, respectively (Table 5.8). The performance of the model to predict the groundnut pod yield was better when compared to predicting the phenological evens as the D-index value for the former was 0.73 while for the later it varied from 0.41 to 0.44 and hence, the model requires further refinement.

Table 5.8: Performance of DSSAT-Peanut model

Treat-ment	Days to germination			Days to anthesis			Days to physiological maturity			Pod yield (kg ha^{-1})		
	Sim	Obs	% error	Sim	Obs	% error	Sim	Obs	% error	Sim	Obs	% error
D1 I1	6	5	20.0	35	37	-5.4	138	142	-2.8	877	824.8	6.3
D2 I1	6	7	-14.3	35	33	6.1	139	146	-4.8	476	743.7	-36.0
D3 I1	6	7	-14.3	35	34	2.9	140	149	-6.0	432	780.5	-44.6
D4 I1	6	8	-25.0	35	35	0.0	140	148	-5.4	393	644	-38.9
D1 I2	6	5	20.0	35	37	-5.4	140	142	-1.4	596	908.7	-34.4
D2 I2	6	7	-14.3	35	31	12.9	145	146	-0.7	736	844.1	-12.8
D3 I2	6	7	-14.3	35	34	2.9	140	149	-6.0	781	879.3	-11.9
D4 I2	6	8	-25.0	35	33	6.1	141	148	-4.7	653	743.8	-12.2
D1 I3	6	5	20.0	35	36	-2.8	141	142	-0.7	914	1073	-14.8
D2 I3	6	7	-14.3	35	33	6.1	143	146	-2.1	1014	1018	-0.39
D3 I3	6	7	-14.3	35	31	12.9	142	149	-4.7	1018	1033	-1.4
D4 I3	6	8	-25.0	35	33	6.1	142	148	-4.1	947	943.0	0.42
Average	6	6.8	-8.4	35	33.9	3.5	140.9	146.3	-3.6	736.4	869.7	-16.7
Statistical index												
RMSE	1.32			2.21			6.06			185.2		
MAPE	18.00			5.79			3.62			17.80		
D-index	0.42			0.41			0.44			0.74		

Anand

Calibration of DSSAT-CERES-millet crop growth simulation model was carried out for *kharif* season pearl millet using the experimental data collected during 2017 at Anand centre while field experimental data for the years 2018, 2019 and 2020 were used for validating the model.

Days to anthesis and physiological maturity

Observed duration of days to anthesis varied between 49 (D_2V_1 - 2018) and 61 (D_3V_3-2018, D_1V_3-2019) days and simulated values ranged between 47 (D_3V_1-2020) and 66 (D_3V_2-2018) days (Table 5.9). Scatter plot depicts fair distribution around 1:1 line (Fig.5.2a). The simulated days to anthesis were in poor agreement with the observations (r = 0.38*, *d*r = 0.36). Relatively low MAE (3.89), low RMSE (4.67) and higher d value (0.59) indicate fairly good agreement. Model under estimated with bias value -1.67. Duration of days to physiological maturity ranged from 65 (D_2V_1-2020) to 90 (D_1V_2-2018) days and the model simulated duration varied between 69 (D_3V_1-2020) and 98 (D_1V_2-2018) days. Results showed that short duration pearl millet were slightly underestimated and long duration pearl millet were slightly overestimated by the model (Fig. 5.2b). The simulated days to maturity were in good agreement with observation. However, model slightly over estimated the days taken to physiological maturity with bias of 0.15. Index of agreement (d) and refined index of argument (d_r) were high 0.88 and 0.61, respectively.

Grain and straw yield

Recorded grain yields of pearl millet were ranged between 1866 (D_3V_1-2020) to 4223 (D_1V_3-2019) kg ha^{-1}, while simulations were in between 2156 (D_2V_1-2020) and 3654 (D_1V_3-2018) kg ha^{-1}. The grain yield simulated by model were not close to observations in three instances (Fig.5.2c) and error per cent values were high (-42.1 to 27.4). The simulated grain yield had poor agreement with the actual. Simulations had low r 0.45* and d_r (0.58) but showed good agreement with positive lower bias (57), low MAE (354 kg ha^{-1}) and low RMSE (502 kg ha^{-1}). Index of agreement (d) was fairly well with the value 0.70 (Table 5.9).

Straw yield varied from 2741 (D_2V_1-2019) to 7556 (D_1V_2-2018) kg ha^{-1}, and simulation resulted 4619 (D_3V_1-2020) to 6996 (D_1V_3-2018) kgha^{-1}. Simulated straw yields were mostly overestimated except in high production (Fig.5.2d). Error percent ranged between -14.0 to 96.0 per cent during the season. The simulated straw yield was in fairly agreement with the actual productions. It had relatively high r value (0.51**), high d value (0.64) and high d_r (0.60). Model over estimated straw yield with 803 kg ha^{-1} bias, slightly higher MAE (1068 kg ha^{-1}) and RMSE (1403 kg ha^{-1}) (Table 5.9).

Table 5.9: Validation of CERES-Millet model with respect to anthesis date, physiological maturity date, grain yield, straw yield during 2018 – 2020

Year	Treat	Anthesis (Days)			Maturity (Days)			Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
		obs	sim	dev (%)	obs	sim	dev (%)	obs	sim	dev (%)	obs	sim	dev (%)
2018	D1V1	51	58	13.7	84	90	7.1	2984	3254	9.0	6926	6855	-1.0
	D1V2	54	56	3.7	90	98	8.9	3377	3340	-1.1	7556	6988	-7.5
	D1V3	57	58	1.8	87	89	2.3	3443	3654	6.1	7148	6996	-2.1
	D2V1	49	52	6.1	84	88	4.8	2703	3012	11.4	5889	6344	7.7
	D2V2	56	56	0.0	89	96	7.9	2573	2855	11.0	6796	6455	-5.0
	D2V3	60	57	-5.0	87	87	0.0	3224	3444	6.8	7074	6641	-6.1
	D3V1	57	54	-5.3	80	86	7.5	2630	2840	8.0	6111	6411	4.9
	D3V2	60	66	10.0	82	85	3.7	2820	2856	1.3	5963	6354	6.6
	D3V3	61	65	6.6	82	85	3.7	2620	2830	8.0	6593	6988	6.0

Year	Treat	Anthesis (Days)			Maturity (Days)			Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
		obs	sim	dev (%)	obs	sim	dev (%)	obs	sim	dev (%)	obs	sim	dev (%)
2019	D1V1	52	54	3.8	76	76	0.0	3199	2389	-25.3	3877	6621	70.8
	D1V2	55	54	-1.8	77	76	-1.3	3361	2424	-27.9	4049	6618	63.4
	D1V3	61	54	-11.5	80	76	-5.0	4223	2444	-42.1	4222	6616	56.7
	D2V1	51	54	5.9	79	77	-2.5	2591	3224	24.4	2741	5372	96.0
	D2V2	52	54	3.8	81	78	-3.7	3449	3295	-4.5	3753	5408	44.1
	D2V3	58	55	-5.2	80	76	-5.0	3144	3546	12.8	4222	5703	35.1
	D3V1	52	51	-1.9	76	74	-2.6	2966	2762	-6.9	3457	5667	63.9
	D3V2	54	52	-3.7	81	75	-7.4	2968	3197	7.7	3605	6069	68.3
	D3V3	57	52	-8.8	83	75	-9.6	3036	3233	6.5	3630	6065	67.1
2020	D1V1	55	50	-9.1	69	72	4.3	2463	2882	17.0	5389	5051	-6.3
	D1V2	56	52	-7.1	70	73	4.3	2431	3097	27.4	6130	5307	-13.4
	D1V3	58	52	-10.3	73	73	0.0	2842	3125	10.0	6167	5305	-14.0
	D2V1	52	50	-3.8	65	71	9.2	2084	2156	3.5	4611	5172	12.2
	D2V2	52	50	-3.8	67	71	6.0	2290	2191	-4.3	4630	5169	11.7
	D2V3	55	51	-7.3	71	72	1.4	2293	2370	3.4	5296	5571	5.2
	D3V1	55	47	-14.5	73	69	-5.5	1866	2189	17.3	4074	4619	13.4
	D3V2	56	48	-14.3	78	70	-10.3	2239	2460	9.8	4352	4934	13.4
	D3V3	59	48	-18.6	80	70	-12.5	2213	2489	12.5	4333	4970	14.7
	Mean			-2.84			0.21			3.77			22.43
Statistical index													
Bias		-1.67			0.15			57			803		
r		0.38*			0.80**			0.45*			0.51**		
MAE		3.89			4.00			354			1068		
RMSE		4.67			4.81			502			1403		
D		0.59			0.88			0.70			0.64		
Dr		0.36			0.61			0.58			0.60		

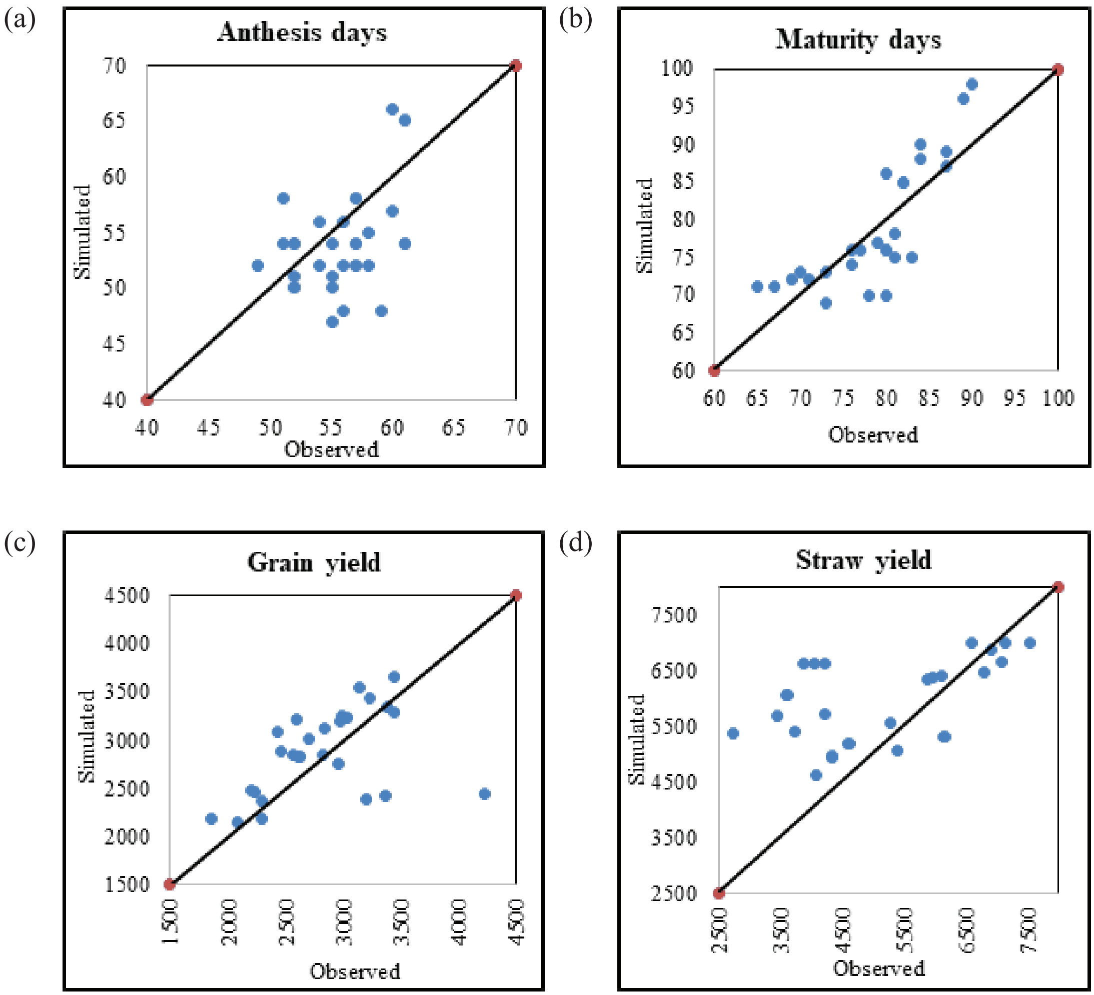


Fig. 5.2: Observed vs simulated phenology and yield variables of pearl millet (2018 - 2020)

Jorhat

Crop growth modeling study in Sali rice under RCP scenarios

Impact of climate change on growth, development and yield of Sali rice were studied based upon the Representative Concentration Pathway (RCP) scenario generated from the MarkSim DSSAT weather file generator (http://gismap.ciat.cgiar.org/MarkSimGCM/) for three future time slices i.e. 2025, 2050 and 2080.

Pattern of change in temperature and rainfall over experimentation period

In Jorhat, increase in maximum temperature is likely to be 0.3, 0.3, 0.1 and 0.3 °C during 2025 and 0.7, 1.0, 0.7 and 1.4 °C during 2050 for RCP 2.6, 4.5, 6.0 and 8.5 scenarios, respectively during the crop growing period. Projections for 2080 suggested further increase of maximum temperature in all scenarios by 0.6, 1.5, 1.6 and 3.0 °C for RCP 2.6, 4.5, 6.0 and 8.5, respectively. Like maximum temperature, the minimum temperature has also shown a likely increasing trend at Jorhat. Considering change in projections together, the likely increase in minimum temperature varied from 0.8 °C in RCP 6.0 to 1.1 °C in RCP 8.5 scenarios for 2025; 1.3 °C in RCP 2.6 to 2.1 °C in RCP 8.5 scenarios for 2050 and 1.2 °C in RCP 2.6 to 3.5 °C in RCP 8.5 scenarios for 2080 over 2017-19 (Table 5.10).

In case of rainfall, irrespective of four RCP scenarios, Jorhat is likely to receive higher amount of rainfall in all three future years relative to mean rainfall amount over the period 2017-2019. Rainfall during the crop growing period may be higher at Jorhat by 37.2, 36.9, 38.3, and 36.8% in 2025; 36.0, 43.4, 37.2 and 34.1% in 2050 and 37.6, 41.0, 34.4 and 11.8% in 2080 for RCP 2.6, 4.5, 6.0, 8.5, respectively relative to experimentation period. The end part of the 21st century *i.e.* 2080 depicted relatively less increase in percent change in rainfall amount over the experimentation period. Thus, the increase in absolute value of maximum and minimum temperature beyond 3 °C with drop in percent change in rainfall (from 41.0% in RCP 4.5 to 11.8% in RCP 8.5) may leads to higher atmospheric vapour pressure deficit causing higher rate of evapotranspiration demand from crop field.

Table 5.10: Projected variation in maximum and minimum temperature and rainfall under different RCPs over baseline period (2017-2019)

Scenarios	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Maximum temperature (°C)				
Normal value (1986-2015)	30.9			
Actual mean during experiment period (2017-19)	31.4 (0.5)			
Mean of scenario (2025)	31.7 (0.3)	31.7 (0.3)	31.5 (0.1)	31.7 (0.3)
Mean of scenario (2050)	32.1 (0.7)	32.4 (1.0)	32.1 (0.7)	32.8 (1.4)
Mean of scenario (2080)	32.0 (0.6)	32.9 (1.5)	33.0 (1.6)	34.4 (3.0)
Minimum temperature (°C)				
Normal value (1986-2015)	23.1			
Actual mean during experiment period (2017-19)	23.0 (-0.1)			
Mean of scenario (2025)	24.0 (1.0)	24.0 (1.0)	23.8 (0.8)	24.1 (1.1)
Mean of scenario (2050)	24.3 (1.3)	24.6 (1.6)	24.5 (1.5)	25.1 (2.1)
Mean of scenario (2080)	24.2 (1.2)	25.2 (2.2)	25.2 (2.2)	26.5 (3.5)
Rainfall (mm)				
Normal value (1986-2015)	1180.0			

Scenarios	RCP2.6	RCP4.5	RCP6.0	RCP8.5
Actual mean during experiment period (2017-19)	1425.0 (20.7)			
Mean of scenario (2025)	1955.5 (37.2)	1950.2 (36.9)	1970.5 (38.3)	1949.6 (36.8)
Mean of scenario (2050)	1937.7 (36.0)	2043.2 (43.4)	1954.5 (37.2)	1911.4 (34.1)
Mean of scenario (2080)	1960.3 (37.6)	2009.9 (41.0)	1915.6 (34.4)	1592.7 (11.8)

(*Figures in the parenthesis represent absolute change for temperature and per cent change for rainfall over experiment period)

Impact of climate change on rice yield

Irrespective of the RCPs, the mean percent change in projected grain yield compared to mean observed yield of Mahsuri during early (2025) and mid-part (2050) of the century varied from 9.4 to 11.5 and 8.1 to 9.2 percent, respectively (Table 5.11). While this range comes down to 4.4 to 7.3 per cent as the period shifted towards the end-part of the century *i.e.* 2080. Yield of Mahsuri is expected to decline under RCP8.5 scenario compared to other three scenarios irrespective of the transplanting dates. The mean per cent change in yield of Swarna Sub-1 also noted to increase substantially over experimentation period under different climate change scenarios and varied from 8.4 to 13.6, 6.5 to 11.7 and 5.6 to 6.3 percent under successive transplanting dates during 2025, 2050 and 2080s, respectively (Table 5.12). Similar types of observations also observed for TTB-404 cultivar. The mean projected grain yield of TTB-404 varied from 10.8 to 12.6, 7.6 to 11.1 and 4.6 to 8.3 per cent under early, mid and later part of the century under different climate change scenarios (Table 5.13).

Table 5.11: Projected rice (*cv.* Mahsuri) yield variability in Jorhat under different RCP scenarios and dates of transplanting over observed grain yield

Periods	Mean observed grain yield (kg ha^{-1}) (2017-19)	% Change in projected yield over mean observed yield				
		RCP2.6	RCP4.5	RCP6.0	RCP8.5	Mean
2025D_1	3999.7	9.3	8.4	12.76	9.3	9.9
2050D_1		10.8	7.7	9.91	8.4	9.2
2080D_1		10.6	5.0	5.71	2.4	5.9
2025D_2	3697.7	9.1	8.2	11.12	9.1	9.4
2050D_2		9.1	10.2	10.48	5.4	8.8
2080D_2		9.9	3.3	2.50	2.0	4.4
2025D_3	3474.7	11.8	11.3	11.09	11.8	11.5
2050D_3		8.7	7.8	8.53	7.5	8.1
2080D_3		8.3	6.6	6.97	7.5	7.3

(Where, D_1: 26th June, D_2: 11th July and D_3: 26th July)

Table 5.12: Projected rice (cv. Swarna sub-1) yield variability in Jorhat under different RCP scenarios and dates of transplanting over observed grain yield

Periods	Mean observed grain yield (kg ha^{-1}) (2017-19)	% Change in projected yield over mean observed yield				
		RCP2.6	RCP4.5	RCP6.0	RCP8.5	Mean
2025D$_1$	4091.0	13.1	12.2	13.42	15.8	13.6
2050D$_1$		13.6	10.3	12.66	10.3	11.7
2080D$_1$		13.3	10.2	9.02	-10.0	5.6
2025D$_2$	3872.7	12.6	11.7	8.61	12.6	11.3
2050D$_2$		8.0	8.6	7.11	6.6	7.6
2080D$_2$		7.7	7.0	5.61	4.9	6.3
2025D$_3$	3684.7	6.7	6.2	14.47	6.1	8.4
2050D$_3$		9.9	5.4	6.63	3.9	6.5
2080D$_3$		9.2	3.1	4.70	7.3	6.1

(Where, D$_1$: 26th June, D$_2$: 11th July and D$_3$: 26th July)

Table 5.13: Projected rice (*cv.* TTB-404) yield variability in Jorhat under different RCP scenarios and dates of transplanting over observed yield

Periods	Mean observed grain yield (kg ha^{-1}) (2017-19)	% change in projected yield over mean observed yield				
		RCP2.6	RCP4.5	RCP6.0	RCP8.5	Mean
2025D$_1$	4045.0	11.7	10.7	12.01	11.7	11.5
2050D$_1$		12.2	12.0	11.10	7.7	10.7
2080D$_1$		11.6	3.3	3.46	0.1	4.6
2025D$_2$	3787.0	13.0	12.0	12.73	12.9	12.6
2050D$_2$		15.3	8.2	13.57	7.4	11.1
2080D$_2$		16.3	5.2	4.57	7.2	8.3
2025D$_3$	3569.0	11.3	10.0	10.42	11.5	10.8
2050D$_3$		10.6	8.3	6.92	4.7	7.6
2080D$_3$		10.4	4.3	3.59	6.9	6.3

(Where, D$_1$: 26th June, D$_2$: 11th July and D$_3$: 26th July)

6. Weather effects on pests and diseases

Identification of the weather-related pre-disposing factors that trigger the rapid multiplication of pests or growth of pathogen beyond the economic threshold level is of great importance in pests/disease control. It is also required for devising thumb rules for pest/disease incidence, which are location specific. The issue of forewarning on the incidence of various key pests and diseases in field/orchard crops has considerable economic importance in view of the cost involved in their management through chemical measures. Thus, the development of forewarning models for various pests and diseases with sufficient accuracy and lead time has become vital for pest/disease control. The research efforts made at various centers to develop models for various pests and diseases are presented hereunder.

Kharif 2020

Anantapuramu

Correlation between spotted pod borer infestation in pigeon pea and weather parameters

Correlations between weather parameters and spotted borer incidence were studied with a field experiment conducted during 2020. The number of web and larvae/m^2 showed a negative correlation with mean temperature and sunshine hours and a positive correlation with relative humidity (Table 6.1).

Table 6.1: Correlation between weather parameters and spotted pod borer incidence in Pigeon pea under rain fed situation during 2020-21

Weather Parameters	06/25/2020		07/10/2020		07/24/2020		08/11/2020	
	No. of webs m^{-2}	*NOLL m^{-2}	No. of webs m^{-2}	NOLL m^{-2}	No. of webs m^{-2}	NOLL m^{-2}	No. of webs m^{-2}	NOLL m^{-2}
T Max	-0.521	-0.359	-0.721	-0.534	-0.351	-0.664	-0.764	-0.519
T Min	0.028	-0.107	0.299	0.136	-0.395	-0.050	0.630	0.078
RH 1	0.700	0.512	0.805	0.628	0.660	0.768	0.365	0.370
RH 2	0.353	0.178	0.599	0.442	0.094	0.421	0.769	0.347
RF	-0.032	-0.166	0.218	0.132	-0.226	0.053	0.614	0.130
WS	-0.112	-0.359	-0.391	-0.496	-0.497	-0.304	0.666	0.011
SH	-0.152	-0.119	-0.363	-0.160	0.222	-0.132	-0.680	-0.298
EVP	-0.708	-0.470	-0.774	-0.596	-0.551	-0.681	-0.785	-0.440

*NOLL – Number of larvae

Hisar

Relationship of key pest infestation in cotton with weather parameters

Correlation between the infestation of whitefly and jassids in two cotton varieties *viz.,* HS-6 and RCH-650 were studied. The data on jassids in during 1999-2020 and that of whitefly during nine crop seasons (2007, 2008 and 2012-2020) was used to estimate the correlation with weather parameters.

Table 6.2: Correlation coefficient between weather parameters and infestation of Jassid and Whitefly in cotton

Variety	Pest	T_{max} (°C)	T_{min} (°C)	RH_m (%)	RH_e (%)	WS (kmph)	SSH (hr.)	Ep (mm)	Rf. (mm)	Acc. Rf. (mm)
HS-6	Jassid	-0.10	0.38*	0.19*	0.45*	0.15*	-0.27*	-0.11	0.13	-0.06
	White fly	-0.06	0.04	0.22*	0.11	-0.12	0.03	-0.14		0.01
RCH-650	Jassid	-0.09	0.38*	0.17*	0.42*	0.14	-0.25*	-0.10	0.13	-0.05
	White fly	-0.07	0.07	0.23*	0.14	-0.12	0.03	-0.14		0.01

*Values are significant at 0.05 probability level (N=195)

Maximum temperature, pan evaporation and accumulated rainfall showed non-significant and sunshine hours showed significant negative correlation with jassids population in HS-6, whereas, minimum temperature and evening relative humidity showed significant positive correlation (Table 6.2). In RCH-650, Sunshine hours showed significant negative correlation with jassids population, whereas, minimum temperature and relative humidity showed significant positive correlation. Data on white fly infestation on HS-6 showed non-significant negative correlation with Maximum temperature, sunshine hour and pan evaporation, whereas morning and evening relative humidity, accumulated rainfall, wind speed showed positive correlation. On RCH-650, white fly population showed non-significant negative correlation with maximum temperature, wind speed and pan evaporation, whereas morning and evening relative humidity, sunshine hours accumulated rainfall and showed a significant positive correlation.

Rabi 2020-21

Anand

A correlation analysis was performed between aphid population number and weather parameters. The results showed no significant association (Table 6.3). Congenial weather parameters' ranges were too broad because of higher variability in seasons of 18 years. The parameter ranges were not useful to predict the occurrence of aphids in the mustard and mostly aphids were observed to occur during flowering to pod initiation stages of the crop. Correlation between two days' average of weather parameter of lead time to first occurrences was explored, considering the lead time of 1 to 15 days from occurrence. There wasn't a significant association of aphid intensity to any parameter that prevailed during lead periods, but it was found that the correlation coefficient reduces with longer lead time.

Table 6.3: Correlation between two days average weather parameter of lead time to first occurrences (n=17)

Lead days	BSS	Tmax	Tmin	RH1	RH2
1	0.22	0.24	-0.16	0.04	0.10
2	0.23	0.15	-0.28	0.27	0.02
3	0.30	0.12	-0.35	0.33	-0.06
4	0.18	-0.04	-0.32	0.30	-0.10
5	0.13	0.06	-0.26	0.33	0.05
6	0.18	0.16	-0.23	0.09	-0.07
7	0.13	0.10	-0.20	-0.05	0.08
8	0.16	-0.06	-0.20	-0.15	0.18
9	0.12	-0.25	-0.32	-0.19	0.02
10	-0.11	-0.33	-0.36	-0.19	-0.03
11	-0.47	-0.34	-0.24	-0.01	-0.03
12	-0.31	-0.30	-0.27	0.30	-0.04
13	-0.09	-0.23	-0.36	0.40	-0.02
14	-0.07	-0.22	-0.28	0.24	0.08
15	0.04	-0.24	-0.25	-0.08	0.18

Among the weather parameters, minimum temperature shows a consistent association with the aphid index at first occurrence, though the correlation wasn't statistically significant. Low minimum temperature, more sunshine hours and high morning relative humidity prevalence for 2-5 days might be responsible initiation of aphid infestation in the mustard crop during the flowering to pod initiation phase. Correlation coefficients with two days' temperature of 11-12 lead days also show that more sunshine hours and the high temperature lowers aphid intensity/ infestation which occurs after 11-12 days in mustard.

Further, the relationship between aphid index (flowering to seed development) and seed yield recorded under four dates of sowing during 15 years was studied and presented in the form of a scatter plot in Fig. 6.1. Seed yields of mustard were found higher ($\geq$ 1500 kg ha^{-1}) when aphid intensities were lower than 1.7.

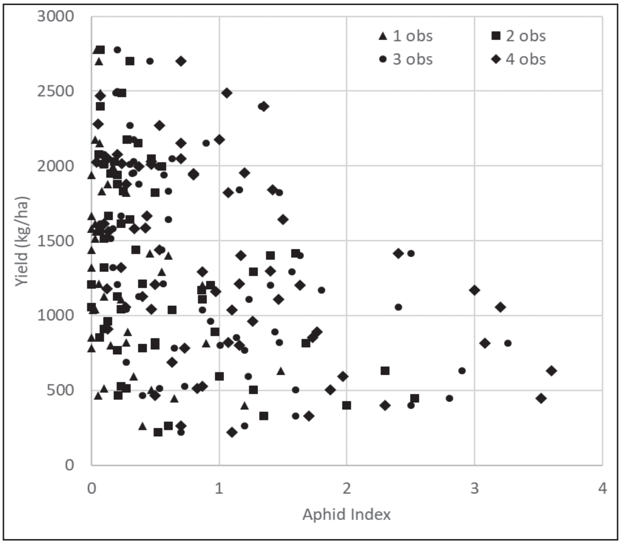


Fig.6.1: The relationship between aphid intensity at different observations during flowering to seed development and mustard seed yield at Anand (Data of 15 years)

Hisar

Prediction equations for Karnal bunt disease incidence in wheat using multiple linear regression

Thirty-five years Karnal bunt disease data for Karnal (1981-82 to 2015-16, 35 seasons), 36 years for Hisar (1980-81 to 2015-16, 36 seasons), 27 years for Rewari (1989-90 to 2015-16, 27 seasons) and 20 years for Sirsa (1997-98 to 2015-16, 20 seasons) were used for the development of multiple regression models for different regions with significant meteorological parameters during 6 to 12 SMWs and is presented in Table 6.4.

Table 6.4: Models developed for predicting incidence of Karnal bunt disease using multiple linear regression

Stations/ Regions	Multiple regression models	R^2
Hisar	Y_H=0.197+0.0130*Rf_9-0.069*EP_{10}-0.0028*$Tmax_{11}$+0.0485*RD_{12}+ 0.005273*RHe_{12}	R^2=0.69
Karnal	Y_K=0.110+0.0413*RD_6+0.0325*$Tmin_8$-0.0144*$Tmax_9$+0.052*RD_{11}+0.0283*RD_{12}	R^2=0.64
Rewari	Y_R=-0.637+0.195*$Tmax_6$+0.0205$Tmin_6$+0.0231*SSH_{10}-0.02407*Rf_{11}+0.895*RD_{11}	R^2=0.66
Sirsa	Y_S=0.3485+0.0022*$Tmax_4$-0.020*Ep_6+0.033*RD_6+0.101*RD_{10}-0.140*WS_{11}+0.014*Rf_{11}	R^2=0.84

The models developed were used to predict Karnal bunt disease incidence during 201617 to 2019-20 seasons and the percent deviation from the observed was worked out (Table 6.5). The results showed that these regression models predicted the Karnal bunt disease incidence with acceptable accuracy, except in Sirsa due to the non-availability of evaporation data. It has been observed that during 6-12 SMWs, a temperature range of 16 – 23.8 °C; one or two rainy days and a morning relative humidity of 91-96% during 1-5 SMWs causes the development of the disease.

Table 6.5: Validation of the developed models for prediction of Karnal bunt disease

District	Description	2016-17	2017-18	2018-19	2019-20
Karnal	Predicted	0.180	0.086	0.396	0.216
	Observed	0.164	0.076	0.413	0.323
	% deviation	9.8	13.2	-4.1	-35.5
Hisar	Predicted	0.064	0.108	0.358	0.178
	Observed	0.065	0.100	0.434	0.171
	% deviation	-1.1	8.0	-17.6	4.1
Rewari	Predicted	0.173	0.106	0.249	0.519
	Observed	0.140	0.101	0.284	0.450
	% deviation	23.4	4.6	-12.3	15.3
Sirsa	Predicted	0.027	0.002	0.013	----
	Observed	0.024	0.003	0.012	----
	% deviation	12.5	33.3	13.4	

Jabalpur

Relationship between gram pod borer infestation in chickpea and weather elements

Weather insect-pest relationship between *Helicoverpa armigera* (Gram pod borer) and weather parameters among different chickpea species (desi, gulabi and kabuli types) sown at different sowing dates was studied. The larval population was collected at metre row length, five times per plot two times in a week (Tuesday and Friday). No pesticide application was undertaken in the plots.

The population increased from 50th-11th SMW as an increase in larvae per meter row length was recorded. The larval population reduced during 6th - 7th SMW due to a reduction in minimum temperatures. It increased again with the increase in both maximum and minimum temperatures from 8th SMW onwards.

Association between weather parameters and larval population in chickpea varieties are presented in Table 6.6. Due to low rainfall during *kharif* season 2020, a temperature remained high during *rabi* season of 2020-21 thereby causing more larval population since, when the crop was at vegetative stage. A significant and positive correlation existed between larval population and bright sunshine hours in JG14 desi variety. Other weather parameters and varieties did not show a significant relation with the larval population

Table 6.6: Pearson's correlation coefficient between *Helicoverpa armigera* and weather parameters in chickpea species

Chickpea species Tmax		Larval population (Numbers/m row length)										
		Tmim	SSH	Rainfall	RHm	RHe	W S	VapM	VapE	Eva	Rainy days	
Desi (JG-14)	Pearson Correlation	0.149	-0.211	.613*	0.057	-0.184	-0.366	0.132	-0.305	-0.434	0.331	0.18
	Sig. (2-tailed)	0.612	0.47	0.02	0.846	0.528	0.198	0.654	0.289	0.121	0.248	0.539
Kabuli	Pearson Correlation	0.08	-0.173	0.09	0.026	-0.233	-0.355	-0.253	-0.131	-0.409	0.197	0.151
	Sig. (2-tailed)	0.785	0.555	0.759	0.929	0.423	0.213	0.382	0.655	0.146	0.5	0.606
Desi (JG-36)	Pearson Correlation	-0.352	-0.405	-0.107	-0.414	-0.054	0.067	-0.299	-0.286	-0.332	-0.261	-0.377
	Sig. (2-tailed)	0.217	0.15	0.717	0.142	0.856	0.82	0.299	0.321	0.246	0.368	0.183

* Correlation is significant at the 0.05 level (2-tailed)

Kovilpatti

Correlation of powdery mildew disease incidence index in black gram with weather parameters

A field trial was conducted in Agricultural Research Station, Kovilpatti during the North-East monsoon period under the rainfed situation to study the influence of weather variables on powdery mildew disease in black gram. The black gram variety VBN 6 was sown on 11.10.2020 and was harvested on 14.01.2021. The receipt of Northeast monsoon rainfall was 421.4 mm with 17 rainy days and it was 6% more than normal rainfall during the crop growing period. The results showed that the minimum temperature has contributed much to the spread of colonies of powdery mildew pathogen in the host plant. The disease incidence was observed from 47th standard meteorological week onwards. From the analysis, it was found that a reduction in minimum temperature was found to increase the powdery mildew disease spread (Table 6.7).

Table 6.7: Correlation of powdery mildew disease index in black gram with weather parameters

RF (mm)	Max.T (°C)	Min.T (°C)	RH (%)	SSH/day
-0.288	-0.599*	-0.871**	0.511	0.265

A similar study was done in the case of leafhopper infestation in cotton. The crop variety KC 3 was sown in the black soils of Agricultural Research Station, Kovilpatti. The crop was maintained without any plant protection measures. Observations on the leafhopper population were made in numbers per leaf at weekly intervals. The weather variables *viz.,* maximum and minimum temperature, morning and afternoon relative humidity, wind velocity and rainfall were measured with Class B observatory located near the field. Infestation by leafhopper was observed from 41 SMW onwards. The correlation study showed that, maximum temperature, sunshine hours, wind velocity and evaporation had negatively influenced the leafhopper population significantly (Table 6.8). At the same time, relative humidity (significant) and rainfall (non-significant) had a positive impact on population build-up.

Table 6.8: Correlation of leaf hopper population in cotton with weather parameters in Kovilpatti

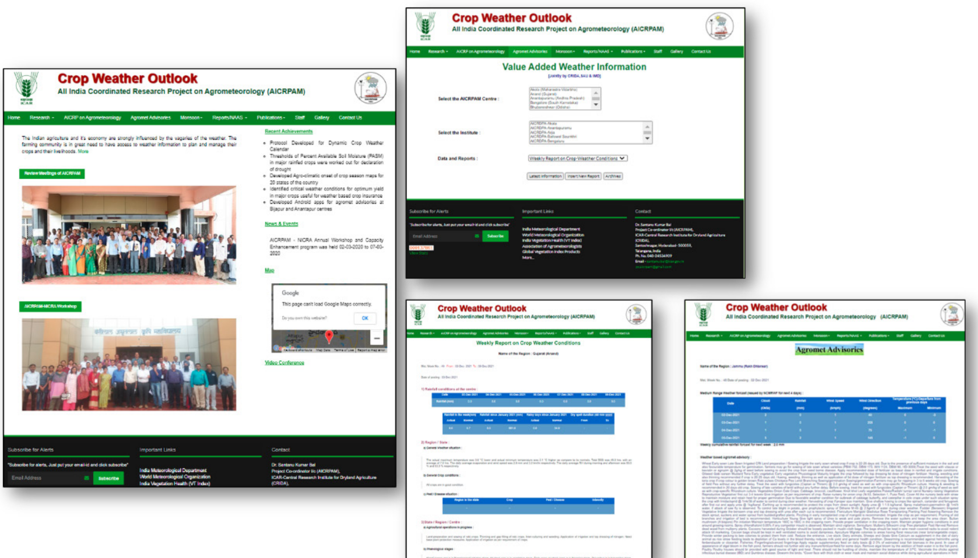
Max.T (°C)	Min.T (°C)	SSH	WV	RH-I (%)	RF (mm)	EVP
-0.822**	-0.310	-0.547**	-0.688**	0.647*	0.381	-0.812**

** Correlation is significant at the 0.01 level. * Correlation is significant at the 0.05 level.

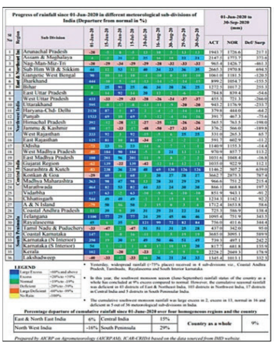
7. Agromet Advisory Services

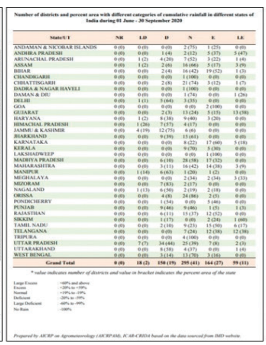
Kharif crop season starts with the onset of southwest monsoon rains and their distribution, which governs the entire gambit of the Agriculture and economy of India. Extreme events such as heavy and unseasonal rainfall, flash floods, droughts, heat and cold waves, frost and hailstorms are the other factors affecting the production and productivity of field and horticultural crops. At this point of time, a farmer requires timely and accurate weather forecasts and advisories information to plan the operations and remedial measures to reduce the losses in farm produce due to aberrant weather conditions. Agromet advisories issued in time can save inputs (seeds, fertilizers, plant protection chemicals etc.) as well as the entire crop (especially at the maturity stage). Agromet Advisory Service (AAS) is a part of extension Agrometeorology and is defined as "Agrometeorological and agro-climatological information that can be directly applied to improve and/or protect the livelihood of farmers".

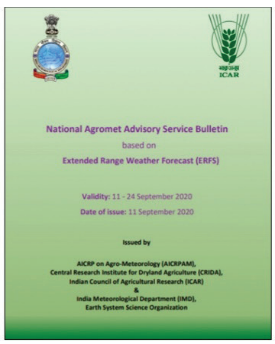
AICRPAM with the help of its cooperating centers across the country is involved in issuing AAS bulletins twice a week, in vernacular languages. The dynamic web portal "Crop weather outlook" hosted by AICRPAM-CRIDA updates daily and weekly weather & crop information and Agromet advisories of the 25 states, where the AICRPAM centers are located in. Apart from this, the coordinating unit at CRIDA plays a major role in issuing daily sub-divisional rainfall charts, weekly Agromet advisories based on Extended Range Weather Forecasts, and monthly crop and weather bulletins for "NITI Aayog" on status of monsoon, progress in *kharif* sowing and AAS for deficit/excess rainfall areas of the country during the southwest monsoon.

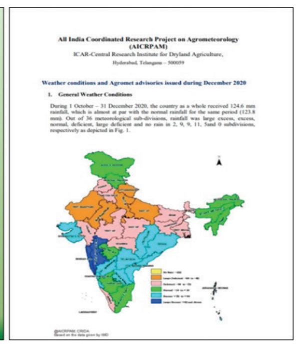


All the above information uploaded dynamically on the crop weather outlook website hosted by AICRPAM from ICAR-CRIDA. The information flow on long-range weather forecasts starts from the South Asian Climate Outlook Forum (SASCOF) during April of every year on the ensuing southwest monsoon. Though the spatial resolution of the forecast is low, it gives a broad idea about the general performance of the monsoon and probable regions of the country with likely get excess, normal and deficit. The project Coordinating Unit of AICRPAM has overlaid the state and district boundaries on the SASCOF's forecast map to generate state and district-specific information. This information on district-wise and state-wise forecast of rainfall during 2020 Southwest monsoon was shared with state government authorities during interface meetings on preparedness for monsoon 2020. At the AICRPAM unit, daily bulletins are prepared on monsoon onset and rainfall progress at the met subdivision level, based on the data provided by India Meteorological Department (IMD) from June 1 to September 30, 2020. Weekly weather and crop bulletins on the status of monsoon, progress in *kharif* sowing and Agromet advisories for deficit/excess rainfall areas of the country were prepared with inputs from cooperating centers of AICRPAM. Further, weekly 'National Agromet Advisory Services' (NAAS) bulletins were prepared in collaboration with IMD. This bulletin provides realized weekly weather conditions over last week and Extended Range Weather Forecast (ERFS) for the next two weeks. AICRPAM provides the Agromet advisories prepared for major crops for the coming week by getting the information from AICRPAM centers across the country during *kharif* season and reported to officials of ICAR, Ministry of Agriculture and Farmers Welfare and other stakeholders across the country. Apart from this, AICRPAM had also provided weekly bulletins on 'Status of monsoon, *kharif* sowings progress and Agromet advisories for excess/ deficit rainfall districts'.









In order to automate the Agromet advisories, AICRPAM has conceptualized Dynamic Crop weather Calendar, prepared a methodology worked with different crops and generated DCWCs for different centers. Centers are developing Android Apps for disseminating the Agromet Advisories to the farmers at an ease and in time. This is helping in saving the crop from damage as well as getting benefits to farmers.

Mobile application - 'Mewar Ritu' (Agromet Services for Sourthern Rajasthan Disticts)

AICRPAM centre Udaipur developed a new mobile application 'Mewar Ritu' for the benefit of farmers in seven southern Rajasthan districts (Udaipur, Rajsamand, Pratapgarh, Chittorgarh, Bhilwara, Dungarpur, and Banswara) under the jurisdiction of Maharana Pratap University of Agriculture and Technology (MPUAT). Vice-Chancellor of MPUAT, Udaipur, Dr. Narendra Singh Rathore launched the mobile app and told that this mobile app is very important to farmers for getting information about the weather condition to prevail in the next five days and value-added agro-met advisory which would help them to plan and take agricultural activities in time and reduce the crop/livestock loss due to weather hazards (Fig. 7.1). The app is being updated twice a week (every Tuesday and Friday).

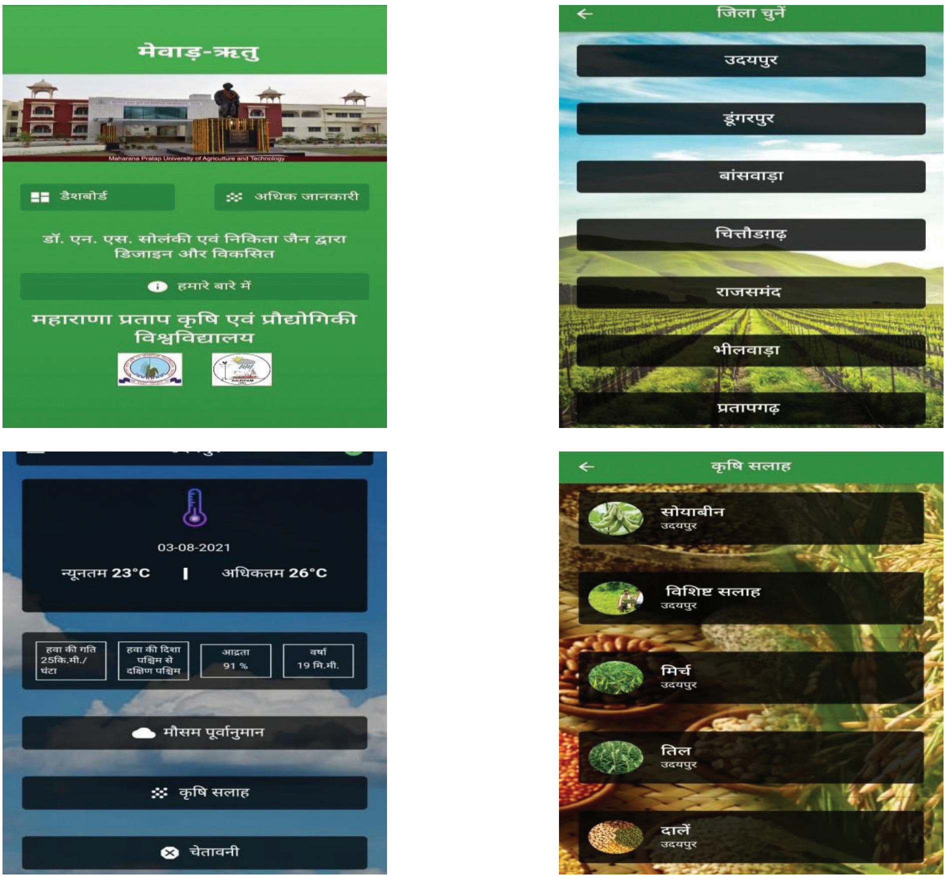


Fig.7.1: Screenshots of "Mewar Ritu" app

'Mewar Ritu' App is available in the google play store (https://play.google.com/store/apps/details?id=com.mewarritu&hl=en_IN&gl=US).

8. Summary

Agro-climatic characterization

- Trend analysis of one-day extreme rainfall using Mann-Kendall test for 118 tehsils located in the Vidarbha region, Maharashtra during 1971-2020 was carried out. Results showed that on annual basis, two tehsils (Mangrupir in Washim and Koparna Gadchiroli district) showed significant positive trend and 12 tehsils showed significant negative trend in one-day rainfall event of 75-100 mm. In the case of one-day rainfall events > 100 mm on annual basis, two tehsils showed significant positive trend and two tehsils showed significant negative trend. During southwest monsoon, same result was observed.
- Magnitude and variation in meteorological drought incidence during monsoon (June-September) period was computed using drought indices like SPI and SPEI at selected locations in the Gujarat state (Anand, Bhuj, Junagadh, Navsari and SK Nagar). Results indicated that use of SPEI or SPI does not have marked different in quantification of the severity of the drought at most part of the state and hence in Gujarat state, SPI should be preferred as it requires only rainfall data than SPEI.
- During south west monsoon season, the average rainfall recorded was below normal in most of locations of Jammu region under the influence of El Niño episodes except Batote, Banihal and Rajouri districts, which showed the slightly increase in rainfall. The decrease in rainfall was highest (25.1%) in Kathua district.
- Monthly PET values using three methods *viz.,* Hargreaves-Samani, Turc and Makkink were estimated for new alluvial zone of West Bengal during 2010-2020. Results indicated that all the three methods estimated the highest PET during May, though there was a difference in the magnitude. In general, the highest mean monthly PET was recorded by Hargreaves-Samani method, followed by Turc and Makkink methods.
- Trend in number of dew days at Palampur, Himachal Pradesh during the period 1985-2020 showed a linear increase with a high R^2 value of 0.69.
- Climatic water balance was calculated for ten locations in Western Maharashtra using daily weather data for the period 1961-2015 to identify the length of growing season. The length of the growing season is the highest in Kohapur and Nashik (22 weeks) and lowest in Jalgon and Nandurbar (16 weeks).
- The initial and conditional probability for getting weekly rainfall of 25 mm was worked out for Vellanikkara, Thrissur using Weathercock software. More than 50% probability to get 25 mm rainfall in a week was noticed from 20 SMW to 45 SMW and during this period land preparation/sowing/transplanting and rice cultivation without irrigation is possible.

- Mann-Kendall trend analysis was carried out using block level rainfall data of 30 years (1991 – 2020) of Deogarh district of Odisha. The annual rainfall showed increasing trend in two blocks namely Barkote & Reamal while Tileibani block showed declining trend. At the same time, Deogarh district as a whole showed non-significant increasing trend during the study period.
- Analysis of monsoon rainfall data for the past 120 years (1901-2020) at Ludhiana showed seasonality with a slight increasing trend of 1.3 mm/year. Results showed that there was below normal monsoon rainfall during 64 years and in many occasions extended period (> 2 years) with below normal monsoon was experienced. In this region, both excess or deficit monsoon rainfall is one of the major abiotic components responsible in determining the water resources and crop productivity.
- Probabilities of having dry spell of successive two weeks during *kharif* season in different districts of Bihar have been worked out. Analysis revealed that the probability for two consecutive weeks of dry spells are less during July and August (1-6%) and higher during June (1-30%) and September (0-19%). Compared to the western districts, the probability for dry spells are higher in eastern districts of Bihar.

Crop weather relationship studies

Kharif 2020

Rice

- Crop weather relationship between effect of three sowing environments (10 June, 25 June and 10 July) and three basmati rice cultivars (Pusa-1121, SJR-129, Basmati 370) was conducted at Chatha, Jammu. The maximum RUE (0.73 gm/ MJ^{-1} m^{-2}) was found in crop sown on 10 June and for Basmati 370 cultivar. Results also indicated that rainfall had significant positive relation during the milking and hard dough stage.
- At Mohanpur centre, effect of different dates of sowing (19 June, 3 July 17 July and 31 July) and cultivars (Nayanmani, Satabdi and Swarna) on absorbed PAR and radiation use efficiency was studied. It was observed that the absorption percentage of PAR increased (25%) from tillering to Panicle initiation stage for all the dates of transplantations, except 19 June. Crop transplanted on 19 June recorded highest grain yield (5422 kg ha^{-1}) and RUE (0.45 g MJ^{-1}).
- Correlation between phenophase-wise mean weather parameters and grain yield of rice cultivars MTU-1010, Rajesshwari and CG Sugandhit Bhog was undertaken at Raipur centre. Results revealed that mean Tmax and BSS during the milking to maturity phase showed a significant positive correlation with grain yield while rainfall and RH-2 had significant negative relation.

Maize

- Impact of growing environments (5 July, 15 July and 25 July) and maize cultivars (Kanchan, Azad hybrid-1 and Azad hybrid-2) on yield and heat use efficiency in maize was studied at Faizabad centre. The results indicated that the crop sown on 05 July and maize cultivar Kanchan recorded highest yield and HUE.

Pearl millet

- At Anand centre, a stepwise regression model was fitted between phase-wise mean weather parameters and *kharif* pearl millet yield was studied. Results showed that the stepwise regression model (adjusted R^2=0.88) retained rainfall, maximum temperature and relative humidity during emergence to booting phase, sunshine hours during 50%-100% flowering and rainfall during 100% flowering to grain filling.
- Experiment to understand the effect of different sowing environments and cultivars on chlorophyll concentration index (CCI) of *kharif* pearl millet was conducted at Hisar. From the results it was observed that both growing environments and cultivars did not significantly influence the CCI at all growth stages.

Sunflower

- Effect of dates of sowing on radiation use efficiency (RUE) of sunflower using pooled data analysis (2015-2020) was carried out at Solapur. Results indicated that crop sown on 2nd fortnight of June had higher RUE during the vegetative stage while crop sown on 2nd fortnight of July recorded higher RUE during the reproductive stage. Among the cultivars, Phule Bhaskar recorded higher RUE under all three dates of sowing.

Turmeric

- At Thrissur, a field experiment was conducted to find the effect of different mulching conditions (white polythene, black polythene, Paddy straw and Green leaves) on turmeric yield. It was noticed that turmeric yield was on par under paddy straw and green leave mulch treatments and the least yield was recorded in black polythene mulch.

Guava

- Multiple regression models to predict the guava yield for rainy, winter and spring seasons using experimental data of 2013-14 to 2019-20 and the models were validated with an observed yield of 2020-21. The model for the rainy season underestimated (-13.1%) the guava yield, whereas, for winter and spring season model overestimated the yield by 8.8 and 15.5%, respectively.

Rabi 2020-21

Wheat

- Influence of different sowing environments on wheat yield at Kanpur centre showed that significantly higher grain yield was recorded for the crop sown on 25th November (4560 $kgha^{-1}$) and delay in sowing time resulted in a decline in wheat grain yield by 16.9% and 26.5%, when crop was sown on 10 and 25 December, respectively.

Barley

- At Hisar, it was observed that significantly higher barley grain yield was recorded in early sown crop i.e. Nov 30 and for the barley variety BH 946.

Maize

- Effect of micro environments on phenology, thermal requirements and grain yield of *rabi* maize hybrids under rainfed condition was studied at Kovilpatti. Yield and yield attributes were significantly higher for the maize hybrid COHM6 and the early sowing environment (39 SMW) when compared to later sowing environments and hybrids.
- The experiment on crop weather relationship showed that maize varieties Shaktiman 4 and 3522 Pio sown on Nov 10 produced higher grain yield during *rabi* season at Samastipur.

Sorghum

- At Solapur, study on the interaction between consumptive use of moisture, moisture use efficiency, radiation use efficiency and grain yield of *rabi* sorghum indicated that crop sown during C*hitra Nakshtras* (Oct 1-7), utilized the moisture more efficiently than other dates of sowings.

Chickpea

- An experiment on the influence of different sowing environments on chickpea phenology, heat use efficiency and yield at Akola revealed that the seed, biomass yield of chickpea as well as heat use efficiency was significantly higher for the crop sown on November 03 and for the JAKI-9218 cultivar.
- At Ranchi, an experiment was conducted to find out the response of chickpea to varied weather conditions on heat and radiation use efficiency. The results showed that the highest heat and radiation use efficiencies were noticed in early sowing crop (Nov 10) and for the cultivar Birsa Chana 3.

Green gram

- Linear relation between seasonal evapotranspiration and green gram yield was observed at Mohanpur centre. It alone can explain green gram yield variation up to 86% irrespective of varieties and dates of sowing and per unit increase in seasonal evapotranspiration can increase the yield by 15.3 $kgha^{-1}$.

Mustard

- Crop weather relationship in the mustard crop was carried out at Anand and it was observed that sowing mustard crop on 10 October provided favourable growing environment and the mustard yield declined linearly with delay in sowing. The stepwise regression model (adjusted R^2=0.74) indicated morning relative humidity during emergence to early vegetative, maximum temperature during early vegetative to flowering initiation phase and pod initiation to seed development had been used to predict the mustard yield.

Crop growth modeling

- SUBSTOR-Potato module of DSSAT (v4.7) was used to find the optimum sowing date for potato at Hisar. The model simulated phenological events and tuber yield were in satisfactory with the observed values and it was found that second fortnight of October is optimum for potato planting in sub-tropical region.
- Simulation study was carried out at Ludhiana using the CERES-Wheat model (for PBW343 cultivar) and results showed that the harmful effects of continual heat stress on wheat productivity can be reduced by sowing the wheat crop by 15th November and with additional application of nitrogen i.e.150% (188 kg ha^{-1}) of recommended N in two equal splits at 0 and 30 DAS.
- At Mohanpur, DSSAT-CERES simulation model was used to quantify the effect of temperature and CO_2 increase on duration and the yield of popular rice cultivars *viz.,* Satabdi, IR-36 and Khitish. Results showed that duration was not influenced by elevated CO_2 alone. However, duration of Satabdi, IR 36 and Khitish varieties was reduced by 4-13 days under 1 °C, 2 °C and 3 °C temperature enhanced condition. Further, Satabdi variety is more susceptible to temperature increase compare to IR- 36 and Khitish varieties. The positive impact of elevated CO_2 is better attributed by IR-36 and Khitish varieties compared to Satabdi.
- Genetic coefficients of *rabi* maize variety Shaktiman 3 were worked out at Samastipur through DSSAT Maize model.
- DSSAT-CROPGRO Peanut model were calibrated and genetic coefficients have been generated for TNAU CO-6 variety at Thrissur centre. Statistical analysis indicated that performance of the model was better to predict the groundnut pod yield when compared to predicting the phenological evens and hence the model requires further refinement.
- AT Jorhat, impact of climate change on growth, development and yield of Sali rice cultivars Mahsuri, Swarna Sub-1 and TTB-404 were studied under different Representative Concentration Pathway (RCP) scenarios. Results revealed that irrespective of the RCPs, the grain yield of Mahsuri cultivar varied from 9.4-11.5%, 8.1-9.2% and 4.4-7.3% during

early (2025), mid-part (2050) and end-part of the century (2080), respectively. Similar types of observations observed for Swarna Sub-1 and TTB-404 cultivars.

Weather effects on pests and diseases

- Correlation between weather parameters and pigeon pea spotted borer incidence were studied at Anantapuramu centre. It was noticed that the number of web and larvae/m^2 showed negative correlation with mean temperature and sunshine hours and positive correlation with relative humidity.
- Hisar - Correlation between infestation of white fly and jassids in two cotton varieties *viz.,* HS-6 and RCH-650 was studied.
- Correlation analysis between mustard aphid population and weather parameters at Anand centre revealed that there wasn't significant association of aphid intensity to any weather parameter that prevailed during lead periods. However, it was found that correlation coefficient reduces with longer lead time. Further, seed yields of mustard were found higher (≥ 1500 kg ha^{-1}) when aphid intensities were lower than 1.7.
- Multiple regression models were developed to predict the Karnal bunt disease of wheta using 35 years data for Karnal (1981-82 to 2015-16, 35 seasons), 36 years for Hisar (1980-81 to 2015-16, 36 seasons) and 27 years for Rewari (1989-90 to 2015-16, 27 seasons). Results indicated that during 6-12 SMWs, a temperature range of 16 – 23.8 °C; one or two rainy days and a morning relative humidity of 91-96% during 1-5 SMWs causes development of the disease.
- At Jabalpur, study on weather insect-pest relationship between gram pod borer and weather parameters among different chickpea species (desi, gulabi and kabuli types) sown at different sowing dates was carried out. A significant positive correlation existed only between larval population and bright sunshine hours in JG14 desi variety.
- The correlation study between cotton leaf hopper and weather elements showed that, maximum temperature, sunshine hours, wind velocity and evaporation had negatively influenced the leaf hopper population significantly. At the same time, relative humidity (significant) and rainfall (non-significant) had positive impact on population build up.

Agromet advisory services

- New mobile application 'Mewar Ritu' was developed by AICRPAM-Udaipur centre for effective dissemination of Agromet Advisory Bulletins for the benefit of farmers of Rajasthan state.

9. Research Publications 2020-21

PC Unit, Hyderabad

Paper in Peer Reviewed Journals

Bal, S.K., Dhakar, R., Mishra, A., Vijaya Kumar, P., Sandeep, V.M., Pramod, V.P., Sarath Chandran, M.A., Subba Rao, A.V.M., Gill, K.K. and Rajendra Prasad (2021). Developing frost prediction models using multivariate statistical techniques for two diverse locations of Northern India. *Theoretical and Applied Climatology,* 146: 1097-1110. https://doi.org/10.1007/s00704-021-03786-8

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Vijaya Kumar, P., Bal, S.K., Dhakar, R., Sarath Chandran, M.A., Subba Rao, A.V.M., Sandeep, V.M., Pramod, V.P., Malleswari, S.N., Sudhakar, G., Solanki, N.S., Shivaramu, H.S., Lunagaria, M.M., Dakhore, K.K., Londhe, V.M., Kumari, P., Singh, M., Subbulakshmi, S., Manjunatha, M.S. and Chaudhari, N.J. (2021). Algorithms for Weather Based Management Decisions in Major Rainfed Crops of India: Validation Using Data from Multi-location Field Experiments. *Agronomy Journal*, 113: 1816-1830. https://doi.org/10.1002/agj2.20518

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AICRPAM Centres Publications

Anand

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Jadav, M.G., Lunagaria, M.M., Patil, D.D. and Patel, H.R. (2021). Sensitivity analysis to study the effects of temperature, carbon dioxide and solar radiation on sunflower under middle Gujarat Agro climatic region. *Journal of Agrometeorology*, 23(1):141-143.

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Ashok Kumar, K. and Swain, D.K. (2021). Nutrient management strategy for improving chemical and biological properties of lateritic soil. *Agronomy Journal*, 113:135-146.

Ashok Kumar, K., Indu, C., Nanda Kumar Reddy, J., Baby, M., Dinesh Kumar, P. and Ramana, C. (2021). Effect of organic and inorganic mulches on soil properties and productivity of chilli (*Capsicum annuum* L.) crop grown on alfisols. *Pantnagar Journal of Research*, 19(1):21-27.

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Bengaluru

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Chatha

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Hisar

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Jorhat

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Kanpur

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Kovilpatti

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Ludhiana

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Mohanpur

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Raipur

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Ranchi

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Samastipur

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Thrissur

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Udaipur

Paper in Peer Reviewed Journals

Kadam, S.S., Solanki, N.S., Mohd., A., Dashora, L.N. and Upadhyay, B. (2020). Growth, yield and economics of dual-purpose oats (Avena sativa L.) as affected by sowing time, cutting schedules and nitrogen levels. *Range Management and Agroforestry* 41: 87-93.

Vijayapura

Paper in Peer Reviewed Journals

Raghavendrsa Achari, Venkatesh, H. and Hiremath J.R. (2020). Farmers' preparedness to manage grape diseases through agromet advisories based on weather based forecast models, *Journal of Agrometeorology*, 22:136-140.

Awards and Recognitions

- Dr. Abdus Sattar (AICRPAM centre Samastipur) was honoured with the 'Distinguished Scientist Award-2020' from Agricultural & Environmental Technology Development Society (AETDS), US Nagar, Uttarakhand.
- Dr. S. N. Pandey (AICRPAM centre Kanpur) and his team were honoured with the 'Best Innovation Award' for their outstanding contribution to the development of the mobile app (Mewar Ritu) at CSAU & T, Kanpur in 2021.
- Kuldip Medhi (AICRPAM centre Jorhat) and the team received the best paper award in the virtual National conference on "Strategic reorientation for climate-smart agriculture" organized by Punjab Agriculture University, Ludhiana during 17-19 March, 2021.
- Dr. Prabhjyot-Kaur (AICRPAM centre Ludhiana) and her team secured the first best oral presentation award in the virtual National conference on "Strategic reorientation for climate-smart agriculture" organized by Punjab Agriculture University, Ludhiana during 17-19 March, 2021.
- Best poster presentation award was given to S.G. Birajdar, V.T. Jadhav, V. M. Londhe, J.D. Jadhav and P.B. Pawar (AICRPAM centre Solapur) in the virtual National conference on "Strategic reorientation for climate smart agriculture" organized by Punjab Agriculture University, Ludhiana during 17-19 March, 2021.
- CASCC (AICRPAM centre Samastipur) Kisan Mela Stall in the Kisan Mela held during 7-9 February, 2021 at RPCAU, Pusa received Third Prize for demonstrating agromet products and other climate-smart technologies to the farmers.
- Dr. V.M. Londhe (AICRPAM centre Solapur) and his team secured 3rd position in the oral presentation category in the International Web Conference on "Food Security through Sustainable Agriculture (FSSA) Vakasana-2020 held during 21-22 September 2020 organized by Shri Vaishnav Vidyapeeth, Indore, M.P., India.
- V.T. Jadhav (AICRPAM centre Solapur) and his team received a consolation prize in the oral presentation category in the International Web Conference on "Food Security through Sustainable Agriculture (FSSA) Vakasana-2020 held during 21-22 September 2020 organized by Shri Vaishnav Vidyapeeth, Indore, M.P., India.

Staff position at cooperating centers during 2020-21
(AICRP on Agrometeorology)

Positions Sanctioned and Filled (F) / Vacant (V)				
Centre	**Agrometeorologist**	**Junior Agronomist**	**Meteorological Observer**	**Field Assistant**
Akola	F	–	V	V
Anand	F	F	F	F
Anantapuramu	F	F	F	F
Bengaluru	F	F	F	F
Bhubaneswar	F	–	V	F
Chatha	F	–	F	F
Dapoli	F	–	F	V
Faizabad	V	F	F	F
Hisar	F	F	F	F
Jabalpur	F	F	V	F
Jorhat	F	–	F	F
Kanpur	F	–	F	F
Kovilpatti	F	F	F	F
Ludhiana	F	F	F	F
Mohanpur	F	F	F	F
Palampur	F	–	V	V
Parbhani	V	–	F	V
Raipur	F	–	F	F
Ranchi	V	F	V	F
Ranichauri	V	V	V	V
Samastipur	F	–	V	F
Solapur	F	F	F	F
Thrissur	F	–	F	F
Udaipur	F	–	V	V
Vijayapura	F	–	F	F
Post Filled	**21**	**11**	**17**	**19**
Post Sanctioned	**25**	**12**	**25**	**25**

Center-wise and Head-wise RE allocation (Plan): FY 2020-21

(AICRP on Agrometeorology)

(Amount In Rupees)

S. No.	Centre	RE 2020-21									
		Salary	Grant-in-aid General				Grant-in-aid Capital		SC-SP		Grand Total
			TA	Res. Exp.	Opr. Exp.	HRD	IT	Equipment	General	Capital	
1	Akola	1500000	35000	77000	210000	0	72375	440000	0	0	2334375
2	Anand	3450000	94262	100000	300000	0	6000	0	0	0	3950262
3	Anantapuramu	3075000	45000	50000	210000	0	3000	250000	90000	11500	3734500
4	Bengaluru	3669900	70000	100000	220000	0	3000	160000	100000	11500	4334400
5	Bhubaneswar	1616800	60000	60000	250000	0	77000	580000	0	0	2643800
6	Chatha	3300000	70000	80000	240000	0	85000	0	73000	11500	3859500
7	Dapoli	1950000	30000	50000	150000	0	60000	50000	0	0	2290000
8	Faizabad	810000	40000	50000	220000	0	85000	0	0	0	1205000
9	Hisar	3250000	76000	30000	300000	0	23000	100000	72664	11500	3863164
10	Jabalpur	2500000	56000	69000	230000	0	6000	100000	0	0	2961000
11	Jorhat	1705000	40000	75000	250000	0	3000	0	0	0	2073000
12	Kanpur	3150000	50000	60000	160000	0	190000	175000	130000	11500	3926500
13	Kovilpatti	3833087	40000	120000	220000	0	115000	100000	96941	11500	4536528
14	Ludhiana	3495000	50000	60000	230000	0	80000	600000	210000	23000	4748000
15	Mohanpur	3996762	35000	80000	190000	0	3000	0	62300	11500	4378562
16	Palampur	2250000	35000	50000	230000	0	75000	0	49595	0	2689595
17	Parbhani	957256	10000	90000	250000	0	4000	600000	0	0	1911256
18	Raipur	2575000	25000	50000	150000	0	60000	129125	0	0	2989125
19	Ranchi	800000	45000	50000	210000	0	3000	275000	116500	11500	1511000
20	Ranichauri	356999	41881	66857	125000	0	6000	0	0	0	596737
21	Samastipur	173920	51000	500000	390000	0	3000	180000	0	0	1297920
22	Solapur	3454571	39000	60000	160000	0	3000	0	0	0	3716571
23	Thrissur	1403705	35000	71000	180000	0	60000	125000	143000	12000	2029705
24	Udaipur	2600000	30000	68000	160000	0	3000	0	0	0	2861000
25	Vijayapura	2750000	55000	50000	190000	0	7500	50000	0	0	3102500
26	**PC Unit**	**0**	**0**	**0**	**573000**	**0**	**50000**	**0**	**0**	**0**	**623000**
	Total	**58623000**	**1158143**	**2116857**	**5998000**	**0**	**1085875**	**3914125**	**1144000**	**127000**	**74167000**

Field activities at AICRPAM Centres

Field activities at AICRPAM Centres