All India Coordinated Research Project
on
Agrometeorology

Annual Report
2022-2023

ICAR-Central Research Institute for Dryland Agriculture
Santoshnagar, Hyderabad-500059

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Cooperating centres

S. No.	Centre	Agrometeorologist	Junior Agronomist
1	Akola	Dr Arvind Tupe	-
2	Anand	Dr M.M. Lunagaria	Dr N.J. Chaudhari
3	Anantapuramu	Dr K. Ashok Kumar	Shri K.V.S. Sudheer
4	Bangalore	Dr M.N. Thimmegowda	Dr M.H. Manjunatha
5	Bhubaneswar	Dr Tushar Ranjan Mohanty	-
6	Chatha	Dr Mahender Singh	-
7	Dapoli	Dr V.G. More	-
8	Faizabad	Dr A.K. Singh	-
9	Hisar	Dr Chandrasekhar Dagar	Dr Anil Kumar
10	Jabalpur	Dr Anay Rawat	Dr. Manish Bhan
11	Jorhat	Dr Kuldip Medhi	-
12	Kanpur	Dr S.N. Pandey	-
13	Kovilpatti	Dr Kokilavani	Dr S. Subbulakshmi
14	Ludhiana	Dr Prabhjyot K. Sidhu	Dr Sandeep Singh Sandhu
15	Mohanpur	Dr Saon Banerjee	Dr Asis Mukherjee
16	Palampur	Dr Sandeep Manuja	-
17	Parbhani	Dr Kailash K. Dakhore	-
18	Raipur	Dr J.L. Choudhary	-
19	Ranchi	Dr Pragyan Kumari	
20	Ranichauri	Dr Sumit Chaudhary	-
21	Samastipur	Dr Abdus Sattar	-
22	Solapur	Dr V.T. Jadhav	Dr Vikas Londhe
23	Thrissur	Dr B. Ajithkumar	-
24	Udaipur	Dr Jagdish Choudhary	-
25	Vijayapura	Dr. P.S. Pattar	-

Foreword

Weather plays a pivotal role in shaping the agricultural landscape of India, a country heavily reliant on farming as a primary source of livelihood and food production. The Indian agricultural sector is intricately linked with the monsoon, which delivers the majority of the country's annual rainfall. The timely arrival and distribution of monsoons are crucial for sowing and harvesting crops, making the weather a determinant of agricultural success. However, extreme weather events, such as heat waves, droughts, floods, and unseasonal rains, have become increasingly common due to climate change, posing formidable challenges. These events can devastate crops, disrupt planting schedules, and lead to yield losses, thus endangering food security and livelihoods.

Adaptation strategies, improved weather forecasting, and sustainable farming practices are essential for mitigating the adverse effects of extreme weather events on Indian agriculture. The All India Coordinated Research Project on Agrometeorology (AICRPAM), is a key player in developing both short-term and long-term strategies to improve the standard of living for our nation's farming community. The 25 AICRPAM cooperating centers, which are dispersed throughout the nation's various agroclimatic zones, are conducting research under five pertinent and distinct themes in order to identify areas that are agroclimatologically suitable for a variety of crops. They are also attempting to improve the quality of agromet advisory services for the farming community by quantifying the impact of weather elements and estimating the potential effects of climate change and variability on various crops in the years to come.

The key findings from investigations carried out at 25 AICRPAM centers during kharif 2022 and rabi 2022–23 are included in the Annual Progress Report of 2022–23. I would like to take this opportunity to thank the personnel of all 25 coordinating centers, the project coordinator, Dr Santanu Kumar Bal, and the coordinating unit team for their hard work in compiling this excellent report. I hope that the information provided in this report will immensely help students, researchers, and policymakers to regulate or mitigate the adverse effects of unusual weather circumstances.

V. K. Singh

Director

ICAR-CRIDA, Hyderabad

Acknowledgement

I wish to place deep sense of gratitude to Indian Council of Agricultural Research for its constant and generous support during the year 2022-23. The encouragement and guidance received from Hon'ble Secretary, DARE &Director General, Dr. Himanshu Pathak and Deputy Director General (NRM), Dr. Suresh Kumar Chaudhari is gratefully acknowledged. The constant guidance extended by Dr. Rajbir Singh, Assistant Director General (AAF&CC) to the project is highly appreciable. The help and encouragement received from Dr. Vinod Kumar Singh, Director, ICAR-CRIDA for the effective functioning of the project is acknowledged with sincere thanks.

The sincereefforts of the Agrometeorologists and other staff of all 25 cooperating centres are highly acknowledged for carrying out the research experiments as per the technical programand bringing out valuable informationthat made it possible to compile a comprehensive report.

Help rendered by Dr. A.V.M. Subba Rao, Dr. M.A.Sarath Chandran and Dr Timmanna for the compilation of this report are greatly acknowledged. My appreciation and thanks to Dr. Deepti Verma, Mr. A. Mallesh Yadav and Mr. Harish, for their contribution to this report.

Santanu Kumar Bal
Project Coordinator (AICRPAM)

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1. Introduction

The AllIndiaCoordinatedResearchProjecton Agrometeorology(AICRPAM)wasinitiatedby ICARinMay1983withtheestablishmentofCoordinatingCellat theCentralResearchInstitute forDrylandAgriculture,Hyderabadand12CooperatingCentresatvariousStateAgricultural Universities. Afteradetailedreviewandevaluationontheprogressmadebytheprojectand realizingtheimportanceofagrometeorologicalresearchsupport forenhancingfoodproduction, ICAR had extended the Cooperating Centres to additional13Agricultural Universities of the countryw.e.f.April1995. The25CooperatingCentresoftheAICRPAMnetworkare:Akola, Anantapur, 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). TheQuinquennial ReviewTeamhasreviewedtheresearchprogressoftheprojectin1992,1998-99,2006, 2011 and 2017. InthelastQRTReportperformanceoftheAICRPAMwasadjudgedas**VeryGood**.

1.1Objectives

- Tostudytheagriculturalclimateinrelationtocropplanningandassessmentofcrop production potentials in different agroclimatic regions
- Toestablishcrop-weatherrelationshipsforallthemajorrainfedandirrigatedcropsin different agroclimatic regions
- To study the influence of weather onthe incidence and spreadof pests and diseasesoffield crops
- To evaluate adaptation strategies in crops against weather aberrations
- To provide research support for the agromet advisory services in India

1.2TechnicalProgramfor2018-22

TheTechnicalProgramfortheyears2018-23fordifferentcentresoftheprojectanda common core program decided for all the centres with emphasis on location-specific research needs is given below.

1) Agroclimatic Characterization (Allcentres)

• Developmentofdatabase(Block/Tehsil/Mandallevel)onclimateandcropstatistics (district level)

AgroclimaticAnalysis

- Rainfall probability analysis
- Dry and wet spells
- Characterization of onset of crop season for crop planning
- Climatic and agricultural drought analysis
- Length of growing season and its variability
- Preparation of crop-weather calendars
- Consolidation of agroclimatic analysisin the form ofTechnical Reports andAgroclimatic
- Atlases
- Preparation of crop-wise manuals for weather-based decisions in crop management.
- Documentationofextremeweathereventsandtheirimpactsonagriculture

2) CropWeatherRelationships

- Development of weather-based crop yield prediction models
- Pooled analysis of crop weather data across multiple locations under AICRPAM
- Estimation of heat unit requirement of crops
- Effect of growing environment 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) CropGrowthModeling

- Calibration and validation of crop weather simulation models with new genotypes
- Exploring management options for better resource management
- Climate change impact assessment

- Development and evaluation of adaptation strategies for reducing yield losses under future climates

4) Weather Eﬀ ectsonPestsandDiseases

Thetechnicalprogramasfinalizedintheworkshopforabovethemesisgiveninتable1.1.

5) AgrometAdvisory Services(AllCentres)

- Monitoringofcropandweathersituation,twiceaweekanditsup dationonthewebsite
- Development of crop contingency plans for the aberrant weather situation
- Monitoringofextremeweathereventsandtheirimpactsonfarmingsystemsonnearreal- time basis
- Value-addition to agromet information
- Economic impact assessment

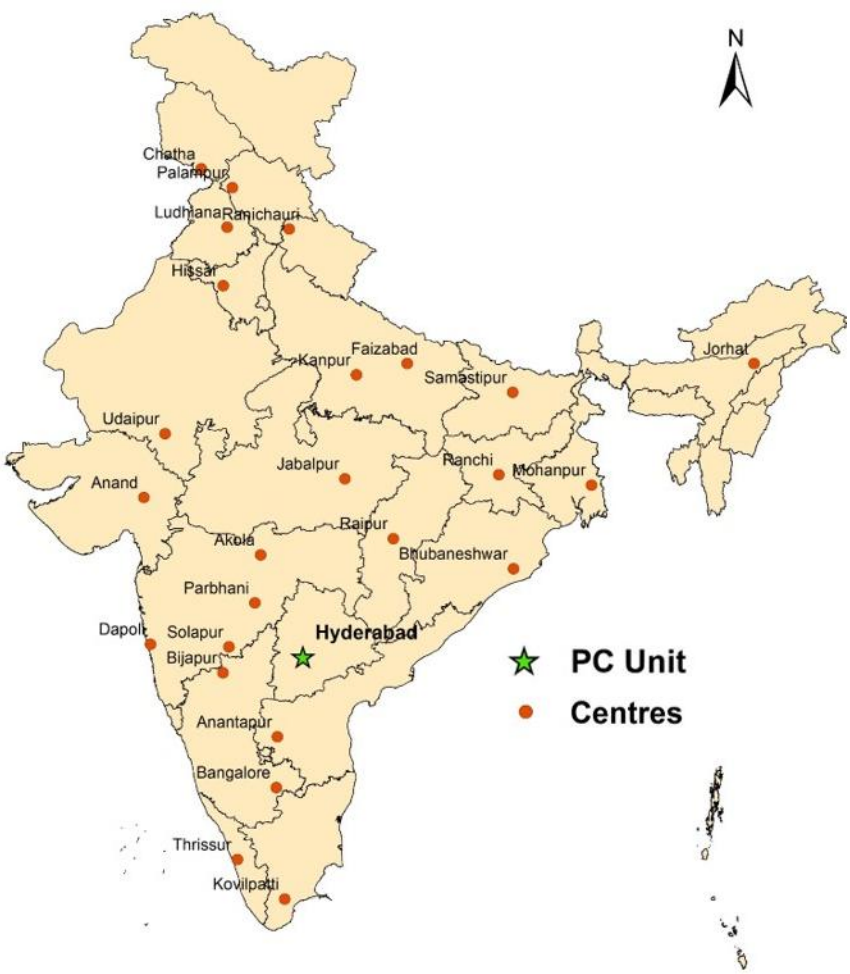


Fig. 1.1 Location map of 25 Cooperating centers and Project Coordinating Unit of AICRPAM

Table 1.1 Zone-wise technical program of AICRPAM centers for three different themes during 2018-23

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 **Chick pea:** Vijay, Digvijay, Virat	Sorghum	**Sunflower:** Thrips, Bud necrosis
		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 **Groundnut:** K6, Kadri-Harithandhra, Dharani & Anantha	**Chickpea:** JG 11, NBEG-47, NBEG-3	Groundnut	**Groundnut:** Leaf miner (DSS) **Pigeon pea:** Spotted Pod Borer
		Bengaluru	**Pigeon pea:** PRG-176, TTB-7, BRG-1 **Groundnut:** Chintamani-2, JL-24, K-6	**Mango:** Mallika	-	**Groundnut:** Leaf miner, Tikka Disease, Pod borer, Spotted pod borer **Pigeon pea:**Spotted boll worm
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
		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

S. No	Zones	Centre	Crop Weather Relationship Studies		Crop Growth Modeling	Weather Effects on Pests & Diseases
			Kharif Varieties	*Rabi* Varieties		
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
		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 2022

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 2022 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 29th May, two days earlier when compared normal date for onset (01st June 2021) and covered the entire country by 2nd July against normal date of 8th July.

Rainfall distribution during monsoon season

The seasonal rainfall (Jun-Sep) over the country as a whole was 106% of its Long Period Average (LPA 1971-2022), i.e. 920 mm rainfall against the LPA (870 mm). The seasonal rainfall was normal over Northwest India (101% of LPA) and above normal over Central India (119% of LPA). It was below normal over East & Northeast (NE) India (82% of LPA) and above normal over South Peninsula (122% of 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 2022 are given in **Table 2.1**. Out of 36 meteorological subdivisions, 12 subdivisionsreceived excess rainfall, 18 subdivisions received normal seasonal rainfall and 6 subdivisions received deficient season rainfall during the season.

A total of 12 (1 Deep Depression, 5 Depression, 2 Well Marked Low Pressure Areas, and 4 Low Pressure Areas) were formed during monsoon season.

Withdrawal of southwest monsoon

The withdrawal of monsoon commenced on 20th September from southwest Rajasthan and adjoining Kutch, against its normal date of 17th September, and withdrew from the entire country on 23rd October.

Table 2.1 Rainfall in 36 meteorological sub-divisions during 2022 southwest monsoon season

S.No.	Region	Subdivision	Actual	Normal	Deviation (%)
1	East & Northeast India	Arunachal Pradesh	1430	1675	-15
2		Assam & Meghalaya	1601	1762	-9
3		Nag-Man-Miz-Tri	943	1302	-28
4		Sub Him WB & Sikkim	1887	1890	0
5		Gangetic West Bengal	871	1167	-25
6		Jharkhand	818	1023	-20
7		Bihar	683	992	-31
8	Northwest India	East Uttar Pradesh	556	799	-30
9		West Uttar Pradesh	502	672	-25
10		Uttarakhand	1128	1163	-3
11		Haryana-Chd- Delhi	465	431	8
12		Punjab	414	440	-6
13		Himachal Pradesh	715	734	-3
14		Jammu & Kashmir	581	549	6
15		West Rajasthan	446	284	57
16		East Rajasthan	780	627	24
17	Central India	Odisha	1197	1150	4
18		West Madhya Pradesh	1192	877	36
19		East Madhya Pradesh	1146	1043	10
20		Gujarat Region	1105	928	19
21		Saurashtra & Kutch	753	540	39
22		Konkan & Goa	3136	2871	9
23		Madhya Maharashtra	942	747	26
24		Marathwada	794	643	23
25		Vidarbha	1228	937	31
26		Chhattisgarh	1276	1132	13
27	South Peninsula	A & N Island	1591	1632	-3
28		Coastal Andhra Pradesh	640	601	6
29		Telangana	1074	735	46
30		Rayalaseema	486	409	19
31		Tamil Nadu & Puduchery	477	328	45
32		Coastal Karnataka	3245	3094	5
33		Karnataka (N Interior)	651	481	35
34		Karnataka (S Interior)	1010	678	49
35		Kerala	1737	2019	-14
36		Lakshadweep	1391	1027	35
East & Northeast India			1124.8	1367.3	-18
Northwest India			594.3	587.6	1
Central India			1161.1	978	19
South Peninsula			876.1	716.2	22
Country as a whole			925	868.6	6

Northeast monsoon

The northeast monsoon rains commenced on 29th 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 119% of LPA. It was 108%, 85% and 186% of its LPA during October, November and December months, respectively. In terms of meteorological subdivisions (36), 6 received large excess rainfall, 10 received excess rainfall, 14 received normal rainfall, 4 received deficient and 2 received large deficient rainfall. During this season, Severe Cyclonic Storm MANDOUS (6 December to 10 December) formed in the post-monsoon season over the Bay of Bengal, crossed north Tamil Nadu, Puducherry and adjoining south Andhra Pradesh coasts between Puducherry and Sriharikota, close to Mamallapuram (Mahabalipuram) on 9th December as a cyclonic storm, claimed 6 lives from Tamil Nadu, Andhra Pradesh & Puducherry.

Rainfall at cooperating centers

During the year 2022, one centre of AICRPAM, Bangalore (70%) received large excess rainfall, while 10 centres received excess rainfall (+20 to +59% more than normal rainfall). Normal rainfall (-19 to +19%) was received in 12 coordinating centres while deficient rainfall (-20 to -59%) condition was experienced at Mohanpur (-41%) and Samastipur (-32%). The yearly rainfall of 25 AICRPAM centres during the year 2022 is furnished in Table 2.2.

Table 2.2 Annual rainfall received at AICRPAM centers during 2022

S. No.	AICRPAM Centre	Actual (mm)	Normal (mm)	Departure (%)
1	Akola	1162	799.0	45
2	Anand	911.5	853.0	7
3	Anantapuramu	817.9	590.0	39
4	Bengaluru	1556.8	916.0	70
5	Bhubaneswar	1466.2	1502.0	-2
6	Chatha	1398	1161.4	20
7	Dapoli	3559.5	3529.0	1
8	Faizabad	808.5	1002.0	-19
9	Hisar	667.4	507.7	31
10	Jabalpur	1490.3	1253.0	19
11	Jorhat	1812	1924.0	-6
12	Kanpur	1083.4	869.0	25
13	Kovilpatti	726.5	714.0	2
14	Ludhiana	833	733.0	14
15	Mohanpur	906.1	1539.0	-41
16	Palampur	2318.1	2332.0	-1
17	Parbhani	1080.5	881.0	23
18	Raipur	1151.4	1145.0	1
19	Ranchi	1896.3	1398.0	36
20	Ranichauri	1339.2	1270.0	5
21	Samastipur	835.4	1235.0	-32
22	Solapur	887.3	721.0	23
23	Thrissur	2495.6	2757.0	-9
24	Udaipur	749.2	601.0	25
25	Vijayapura	793.2	594.0	34

3. Agroclimatic Characterization

Characterization of crop growing environment is a pre-requisite in cropplanning andevolving strategies to overcome climate /weather inducedchanges in the meso/micro climate. Anomalies in climatic variables need tobe properly understood to make the agricultural sector resilient. Agroclimaticanalysis is used to study the climatic characteristics and crop performance in aparticular region and also to know the climatic variability/climate change and itsimpact on agriculture. Thus, historical data on climatic variables have to be analyzedusing appropriate statistical tools enabling the development of location specifictechnologies/adaptive strategies. The analysis carried out by differentcenters onthe agroclimatic characterization is reported hereunder:

PC unit

Agroclimatic onset of crop growing season in various agro-ecological regions of India

The success of rainfed crop production is highly dependent on timely sowing/planting decisions. Information on the optimum crop sowing window for the season will facilitate crop planning by farmers and other stakeholders. Daily rainfall data of 0.25° x 0.25° grid resolution from India Meteorological Department for the period 1951-2019 was used for the present study and gridded data was converted into area weighted daily rainfall data for 680 districts using Thiessen polygon method. To determine the onset of crop growing season, three methods viz., Soil Water Balance, Depth and modified Morris & Zandesta were evaluated to identify the most suitable method. Soil Water Balance (SWB) method was found to be the most suitable based on validating with observed crop sown status, false start and number of undefined onset years criteria. However, as SWB method is data-intensive, as an alternative, the onset was determined using Modified Threshold Combination (MTC) method comprising 40 combinations of threshold values viz. rainfall amount, wet spell duration, dry spell duration and dry spell search period. The onset dates determined by MTC and SWB methods were statistically compared and subsequently appropriate threshold values identified to find the onset in 19 AERs of India (Fig. 3.1).

The onset of growing season determined by SWB and MTC methods were almost similar over north-eastern parts of the country (AERs 15, 16 and 17) and west coast of India (AER 19) and also in AERs 1, 2 and parts adjacent to these regions. Due to variation in rainfall threshold, differences in onset of crop growing season were noticed in many AERs like 3, 5, 7, 8, 12 and 18. Statistical validation of onset date determined by MTC method with observed percentage crop coverage showed that it is mostly close to the observed data. This study reveal that the onset is not influenced by threshold combinations in the per-humid, humid and sub-humid regions, whereas, in semi-arid and arid regions, the critical evaluation of criteria for determining onset is vital to avoid false starts and undefined onset years.

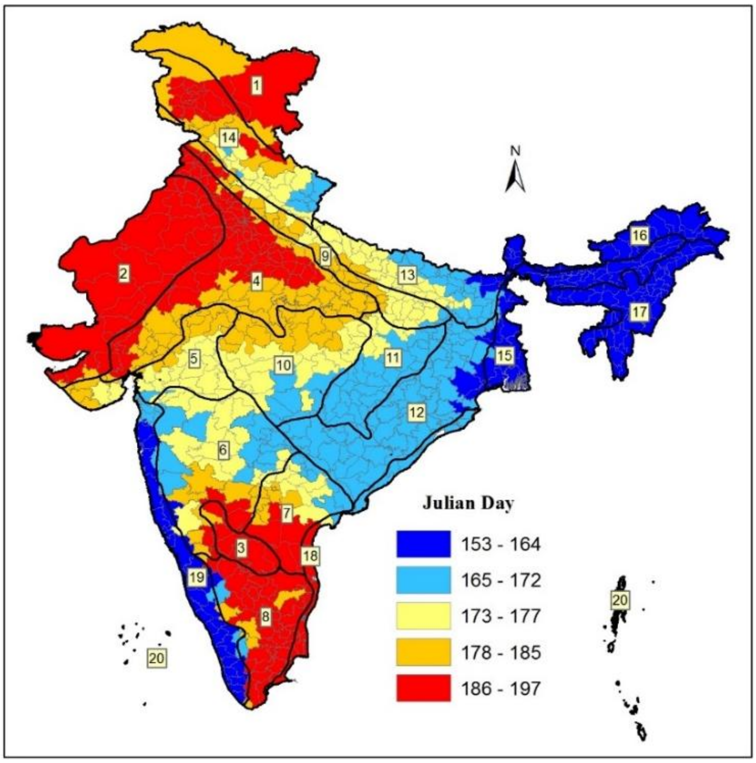


Fig. 3.1 Mean onset of growing season determined by Modified Threshold Combination method

Akola

Analysis of extreme rainfall events

Long term rainfall data (1971-2022) of 118 talukas in Vidarbha region was analyzed to work out trends in extreme rainfall events in the year and monsoon season. The Mann-Kendall test was used to evaluate the trends in rainfall, rainy days and extreme rainfall events (75<100 mm and >=100 mm). Extreme rainfall events of 75-100 mm in a year showed no significant trend in 89 percent (105) of the talukas, significant positive trend in 2% (2) of talukas and significant negative trend in 9% (11) of talukas in Vidarbha region (Fig. 3.2a). Extreme rainfall events ≥ 100 mm per year in Vidarbha region showed no significant trend in 97 percent (115) of the talukas, significant positive trend in 2% (2) of talukas and significant negative trend in 1% (1) of talukas in Vidarbha region (Fig. 3.2b). During the monsoon season, rainfall events of 75-100 mm showed no significant trend in 89 percent (105) of the talukas, significant positive trend in 3% (3) of talukas and significant negative trend in 8% (10) Vidarbha region (Fig. 3.2c). Extreme rainfall event ≥100 mm during SWM season showed no significant trend in 98 percent (116) of the talukas in Vidarbha region only 1% (1) of talukas experienced significant positive trend and 1% (1) experienced significant negative trend in Vidarbha region (Fig. 3.2d).

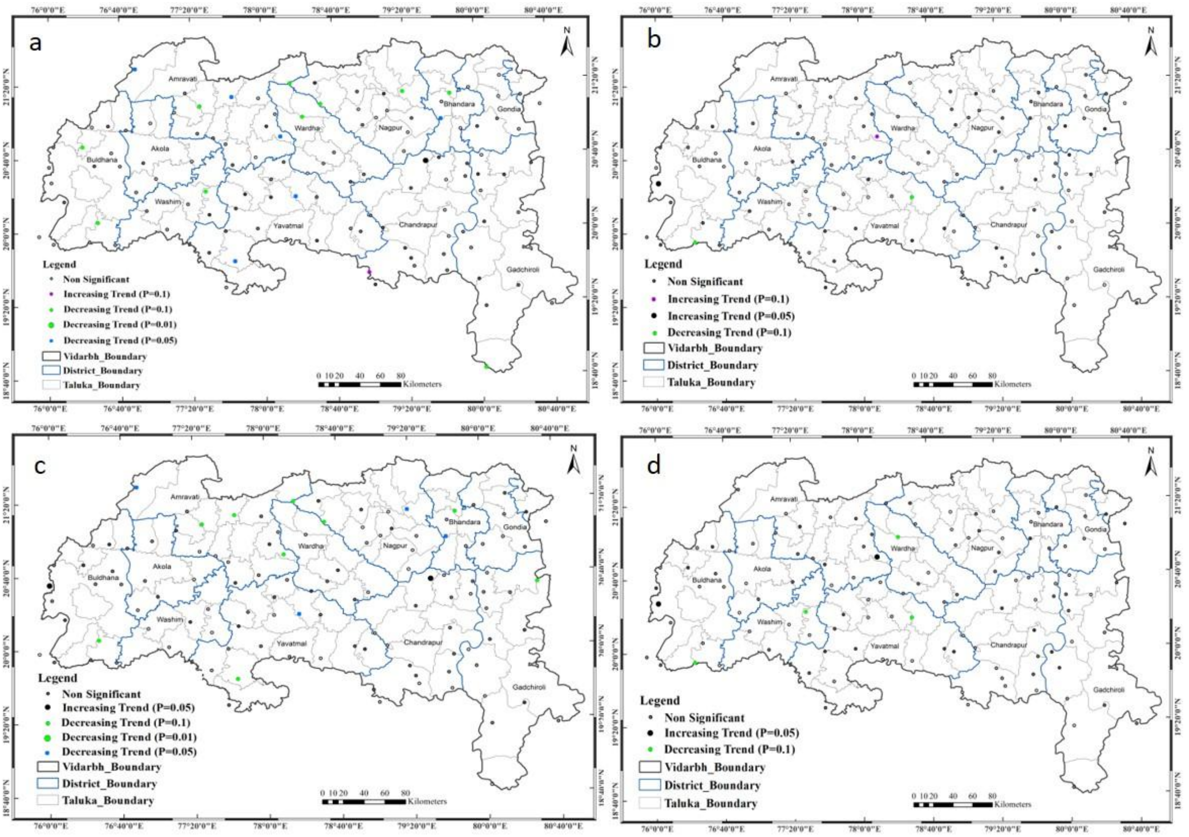


Fig. 3.2 Mann Kendall trend statistics of rainfall intensity (a) 75-100 mm on annual basis (b) ≥ 100 mm on annual basis (c) 75-100 mm during southwest monsoon and (d) ≥ 100 mm during southwest monsoon over districts of Vidarbha region, Maharashtra

B. Rainfall analysis district wise: Vidarbha districts

Recent 52 years (1971-2022) rainfall data was analyzed to work out trends of seasonal rainfall for the 11 districts (Table 3.1). None of the district showed significant increasing or decreasing trend as regards winter (January-February) rainfall, however, nine of the eleven districts indicated non-significant decreasing trend of winter rains. Almost all the districts except Gadchiroli showed an increasing trend of summer (March-May) rains. Amravati, Washim, Nagpur, Chandrapur, Gondia and Bhandara districts showed a significant increasing trend of summer rains. Except Nagpur, which showed a significant increasing trend of monsoon rainfall (June-September), none of the other districts showed significant increasing or decreasing trend of monsoon rainfall. Amravati district analyzed non-significant decreasing trend while rest of the eight districts showed non-significant increasing trend of monsoonal rains. Post monsoon rainfall (October-December), all districts showed decreasing trend and except Washim which showed non-significant increasing trend. Among the districts with decreasing trend of post-monsoon rains, Yavatmal, Wardha, Nagpur and Gondia indicated significant decreasing trend of post monsoon rainfall. Annual rainfall also did not show a significant increasing or decreasing trend. Three districts (Amravati, Yavatmal and Gondia) showed non-significant decreasing trend and eight districts (Akola, Buldhana, Washim, Wardha, Nagpur, Chandrapur, Bhandara and Gadchiroli) observed non-significant increasing trend of annual rainfall.

Table 3.1 Mann Kendall test statistic for seasonal rainfall variability during last 52 years (1971-2022) at districts of Vidarbha region, Maharashtra

District	Winter	Summer	Monsoon	Post-monsoon	Annual
Akola	-0.710 (NS)	1.034 (NS)	0.197 (NS)	-0.497 (NS)	0.292 (NS)
Amravati	-0.024 (NS)	2.438 (S 0.05)	-0.355 (NS)	-1.294 (NS)	-0.126 (NS)
Buldhana	-1.017 (NS)	0.442 (NS)	1.239 (NS)	-0.473 (NS)	0.971 (NS)
Washim	-0.268 (NS)	2.943 (S 0.01)	0.592 (NS)	0.450 (NS)	0.765 (NS)
Yavatmal	-0.852 (NS)	0.418 (NS)	0.260 (NS)	-1.791 (S 0.1)	-0.481 (NS)
Wardha	-0.758 (NS)	0.339 (NS)	1.176 (NS)	-2.644 (S 0.01)	0.387 (NS)
Nagpur	-1.073 (NS)	1.649 (S 0.1)	1.728 (S 0.1)	-2.423 (S 0.05)	0.923 (NS)
Chandrapur	-0.371 (NS)	2.446 (S 0.05)	1.286 (NS)	-1.523 (NS)	0.018 (NS)
Gondia	-0.347 (NS)	2.486 (S 0.05)	0.134 (NS)	-2.012 (S 0.05)	-0.118 (NS)
Bhandara	0.197 (NS)	2.407 (S 0.05)	0.260 (NS)	-1.460 (NS)	0.118 (NS)
Gadchiroli	0.248(NS)	-0.489 (NS)	1.334 (NS)	-1.547 (NS)	1.176 (NS)

Anand

Trend analysis of heat waves over Gujarat state

Heatwave is a marked warming of the air, or the invasion of very warm air, over a large area; it usually lasts from a few days to a few weeks (WMO-No. 182). IPCC assessed heat risk using heat wave duration index (HWDI). The HWDIs of the recent past (years 1991-2022) were considered for trend analysis. HWDI in the present study is defined as the annual count of days with at least 3 consecutive days when daily maximum temperature exceeds the 95th percentile of the reference period. The gridded daily maximum temperature data (IMD) of Gujarat state and border regions (29 grid points) for period of 1961-2022 were used in the study. Datasets were prepared for baseline period and recent period. Baseline period data were analyzed to determine the maximum temperature value at 95th percentile for each grid. The grid specific values at 95th percentile in base period were used as thresholds to compute HWDI. Linear trends of the HWDI during recent 32 years (1991-2022) were computed using simple linear regression. The trend values were tested at a significant level of 1% and 5%.

The HWDI of 62 years (1961 to 2022) timeseries at one of the grids of North Saurashtra region is depicted in Figure 3.2. The base period maximum temperature at 95th percentile had low values in Saurashtra and Kutch region (36.4 °C to 37.2 °C) and highest in middle Gujarat (41 °C) (Fig. 3.3a). HWDIs observed during recent past are higher at each grid locations compared to baseline period in Gujarat (Figure 3.3b). The trend pattern over the state during base period is depicted in Figure 4. There was no significant heatwave trend during base period at any grid locations in Gujarat. All grid locations had trend values close to zero. In North Saurashtra and Kutch region had slightly negative non-significant trends, while rest of the state had non-significant positive trend values during base period.

The trend values of recent past were high compared to base period except in east part of the state (parts of middle and north Gujarat). The trends of all grids were positive over the state. The trend values were very high (0.56 – 1.08 HWDI year^{-1}) and statistically significant in Saurashtra and Kutch region of the state (Fig. 3.2c). The trend pattern is strong evidence of increasing warming and heat extremes in these regions. The highest increasing and highly significant trend (1.08 HWDI year^{-1} **) in the state was revealed for North Saurashtra region (grid representing parts of Jamnagar, Morbi and Rajkot districts of the state) (Fig. 3.3d). The results indicated that:

- In comparison to base period (1961-1990), heatwaves during recent past (1991-2022) were prominently high with increasing trends at most parts of the state except in east part of the state (parts of middle and north Gujarat).
- The HWDI trends were very high (0.56 – 1.08 HWDI year^{-1}) and statistically significant in Saurashtra and Kutch region of the state.
- The highest increasing and highly significant trend (1.08 HWDI year^{-1} **) in the state is observed in North Saurashtra region (representing parts of Jamnagar, Morbi and Rajkot districts of the state).

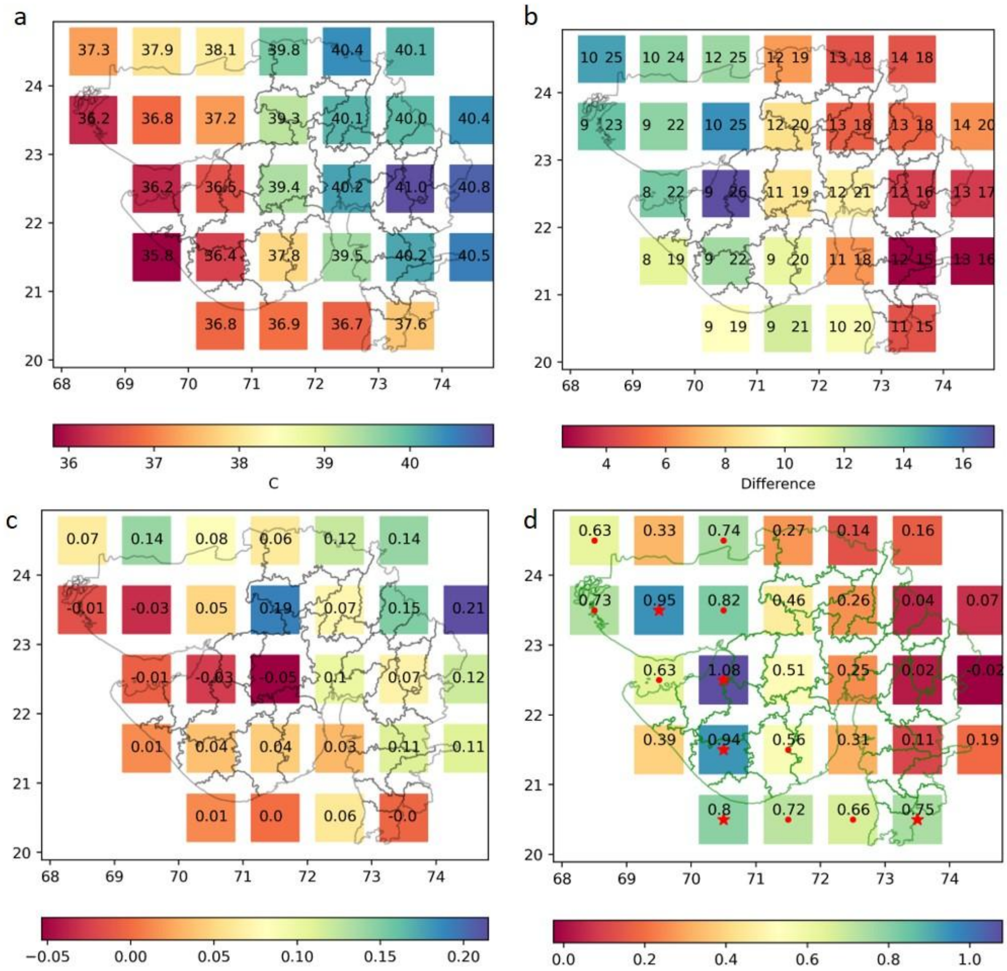


Fig. 3.3 (a) Maximum temperature values at 95th percentile of baseline period (years 1961-1990) for Gujarat, (b) Mean HWDI of baseline (left value on grid) and mean HWDI of recent past (right value on grid) for Gujarat, (c) HWDI trends over Gujarat during baseline period (years 1961-1990), (d) HWDI trends over Gujarat during recent past (years 1991-2022)

Anantapur

Dry spell Index (DSI) of various rainfed crops grown in Rayalaseema region of Andhra Pradesh

The Dry spell index (DSI), a recently formulated crop moisture stress indicator was used to quantify the cumulative impacts of dry spells on major rainfed crops during kharif season (June-September) in Rayalaseema region of Andhra Pradesh in India for the period 1998-2019. The analysis of cumulative DSI during the period 1998-2019 revealed that, out of 22 years, the number of years with DSI between 12.1 and 16.0 were maximum (9 years) in Anantapur, followed by Kadapa (5 years), Kurnool (4 years), Chittoor (2 years) and Prakasam districts (1 year).

Table 3.2 District-wise number of years under different categories of average DSI (1998-2019) in Rayalaseema region, Andhra Pradesh

	Number of years under various ranges of DSI

District	0-4	4.1-8	8.1-12	12.1 - 16	>16
Anantapur	0	3	8	9	2
Chittoor	0	10	10	2	0
Kadapa	0	2	15	5	0
Kurnool	1	6	11	4	0
Prakasam	1	7	12	1	1

The DSI was assessed for various districts in Rayalaseema region of Andhra Pradesh. The study region's average DSI for the years 1998-2019 ranged from 8.6 to 11.4. Among the various districts in the region, the highest average DSI was noticed in Anantapur district (11.4) followed by Kadapa (10.5), Kurnool (9.3) Prakasam (9.1) and Chittoor districts (8.6). On the other hand, Kurnool district had higher CV% (30.5%) for DSI, followed by Prakasam (29.0%), Chittoor (26.4%), Anantapur (24.2%) and Kadapa (22.7%) (Fig. 3.4). The percentage of crop area experiencing DSI<4 was below 5% with respect to all the crops in the study region.

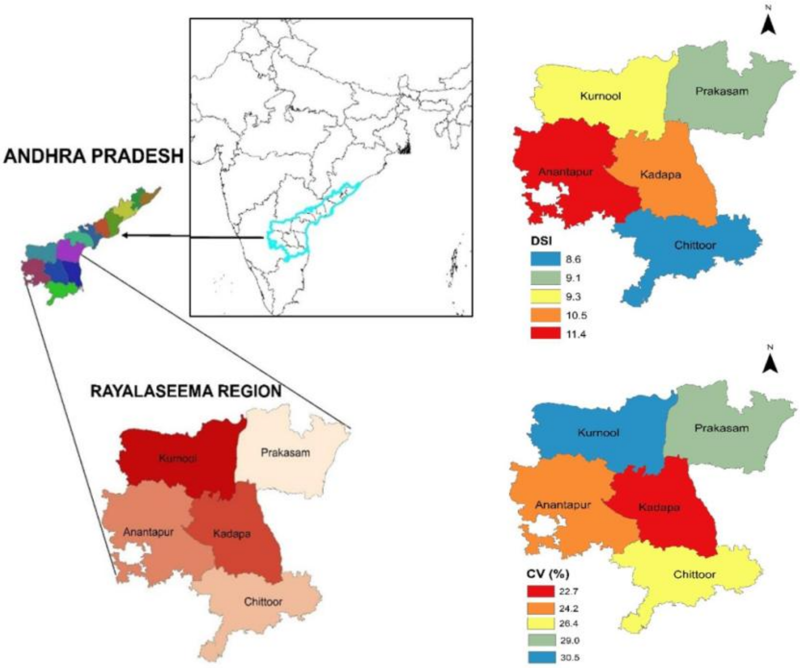


Fig. 3.4 Spatial distribution of average DSI during kharif season in various districts of Rayalaseema region of Andhra Pradesh (1998-2019)

Accuracy and variability of various PET estimation methods

The accuracy and variability of various PET estimation methods (Modified Penman Monteith, Blaney Criddle, Hargreaves, Open pan evaporimeter and Turc) was evaluated against the standard method i.e. FAO Penman-Monteith method (FAO PM). The statistical indices like Mean Bias Error (MBE), Root Mean Square Error (RMSE) and Pearson correlation coefficients were used for error estimation in the six PET estimation methods. The results revealed that the PET estimation by Christiansen method was higher, while lowest estimation was obtained with Turc method. Table 3.2 depicts the error statistics and correlation values of the six PET methods (Modified Penman Monteith, Blaney Criddle, Hargreaves, Open pan evaporimeter and Turc), used in the study against the standard FAO Penman method. The correlation coefficients of Christiansen method were higher compared to rest methods. However, the MBE and RMSE was found to be the lowest in Blaney Criddle method and highest for Turc method. The small value of RMSE and MBE depicts that the error is less between the FAO PM method and empirical method under consideration. The best model was selective first based on their orientation along the 1:1 value, the lowest value of MBE and RMSE and then correlation coefficient. Based on the cumulative performance of weekly mean PET for 32 years (1988-2019), it can be inferred that Blaney Criddle method could efficiently predict the PET pattern with least error. The Turc method under estimated the PET values followed by Open pan evaporimeter, Christiansen and Hargreaves method

Table 3.3 Error statistics and correlation between the estimated PET (Modified Penman Monteith, Blaney Criddle, Hargreaves, Open pan evaporimeter and Turc) and FAO PM method

Method	MBE	RMSE	Pearson correlation (r)
Modified Penman	0.82	0.86	0.99
Blaney Criddle	-0.13	0.66	0.91
Christiansen	0.92	0.97	1.00
Hargreaves	-0.91	1.20	0.94
Open pan evaporimeter	-1.00	1.23	0.92
Turc	-1.63	1.99	0.75

Bangalore

Shifting pattern in annual rainfall of South Karnataka

Shifting pattern analysis is important for both methodological and practical reasons including the validation, as it is an efficient tool to understand the fundamental rainfall data. A popular Likelihood-Ratio method used to understand the shifting patternoccurred indifferent districts of south Karnataka. Rainfall pattern shifting years are scattered between the time period 1984-2020, this evidently explains the dynamic nature of rainfall distribution patterns over time and space. The shifting point (year) results revealed that the average rainfall increased for all the districts as compared with before and after shifting point in rainfall (Table 3.4 and Fig. 3.5) and average annual rainfall was below normal rainfall before shifting year, but it was increased after shifting year, which was above the normal rainfall in the South Interior Karnataka. In the Malnad region, the average annual rainfall was below normal before the shifting year, and it decreased further after the shifting year in Shivamogga and Chikmagalur districts. Similar results were observed in the coastal region's Udupi district. The shifting pattern analysis provides insights into the changing rainfall patterns in the studied districts.

Table 3.4 Shifting pattern of annual rainfall (mm) data in south Karnataka

District	Shifting year	Average rainfall (mm)		Change in rainfall (mm)	Nature of shifting	Normal rainfall (mm)
		Before	After			
South Interior Karnataka (SIK)						
Bangalore Urban	2013	767.19	1107.86	340.67	↑	833.66
Bangalore Rural	2013	807.58	1107.86	300.28	↑	866.17
Chamrajnagara	2020	808.37	1310.20	501.83	↑	808.37
Chikkaballapura	2019	610.27	1359.70	749.43	↑	646.82
Chitradurga	2006	500.85	687.93	187.08	↑	569.29
Kolar	2020	689.58	1666.80	977.22	↑	713.41
Mandya	1990	693.72	814.16	120.44	↑	784.79
Mysore	2004	701.95	866.25	164.30	↑	770.07
Davanagere	2003	593.38	770.13	176.75	↑	670.98
Tumkur	2020	656.30	1109.00	452.7	↑	667.30
Ramanagara	2016	833.32	1032.26	198.94	↑	857.60
Malnad						
Shimoga	2013	1804.42	952.98	-851.44	↓	1638.29
Hassan	2018	797.85	1975.10	1177.25	↑	883.99
Chikkmagalur	1984	1708.30	1305.35	-402.95	↓	1344.67
Kodagu	2013	1609.36	3317.55	1708.19	↑	1942.66
Coastal						
Dakshina Kannada	2018	3506.35	4303.23	796.88	↑	3564.66
Udupi	2013	4255.35	3537.10	-718.25	↓	4115.21
Uttara Kannada	2018	2844.45	4253.63	1409.18	↑	2947.56

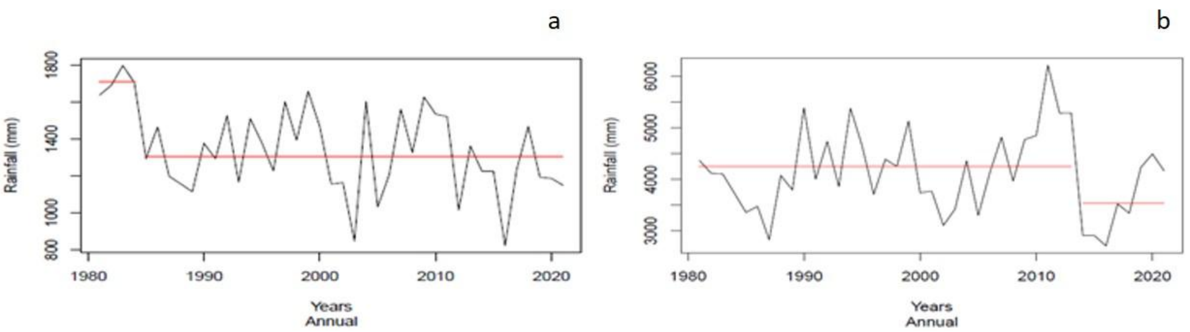


Fig 3.5 Line graphs showing annual rainfall distribution along with shifting pattern over (a) Chikmagalur and (b) Udupi districts

Rainfall variability in the Agroclimatic Zones of Karnataka

Seasonal and annual rainfall trends, as well as Sen's slope estimates, for different agro-climatic zones in Southern Karnataka presented in Table 3.5 and Fig. 3.6. No significant trend was observed in winter rainfall across all zones. All zones showed an increasing trend in pre-monsoon rainfall. The Hilly Zone did not exhibit a significant trend in South West Monsoon rainfall. The SDZ and coastal Zone showed a decreasing trend in South West Monsoon rainfall. The rest of the zones (EDZ, CDZ and STZ) exhibited an increasing trend in rainfall during the South West Monsoon season. Except for the Eastern Dry Zone (no trend), all other zones showed an increasing trend in North East Monsoon rainfall. All zones showed an increasing trend in annual rainfall. The Coastal Zone had the lowest Sen's slope estimate, indicating a relatively slower rate of increase compared to other zones. The Hilly Zone had the highest Sen's slope estimate, indicating a significant rate of increase in annual rainfall.

Table 3.5 Seasonal and annual rainfall trend and Sen’s slope estimate over different agro-climatic zones of south Karnataka

Zone	Winter (Jan-Feb)		Pre-monsoon (Mar-May)		SWM (Jun-Sep)		NEM (Oct-Dec)		Annual	
	Sen’s slope	Trend	Sen’s slope	Trend	Sen’s slope	Trend	Sen’s slope	Trend	Sen’s slope	Trend
Eastern Dry Zone	0.02	-	1.12	↑	0.12	↑	-0.1	-	1.72	↑
Central Dry Zone	0.02	-	0.61	↑	0.48	↑	0.56	↑	2.57	↑
Southern Dry Zone	0.03	-	0.35	↑	-0.64	↓	0.29	↑	1.06	↑
South Transition Zone	0.05	-	0.35	↑	0.91	↑	0.24	↑	2.48	↑
Hilly Zone	0.01	-	0.57	↑	0.07	-	0.32	↑	3.24	↑
Coastal Zone	0.01	-	0.68	↑	-5.18	↓	1.82	↑	0.54	↑

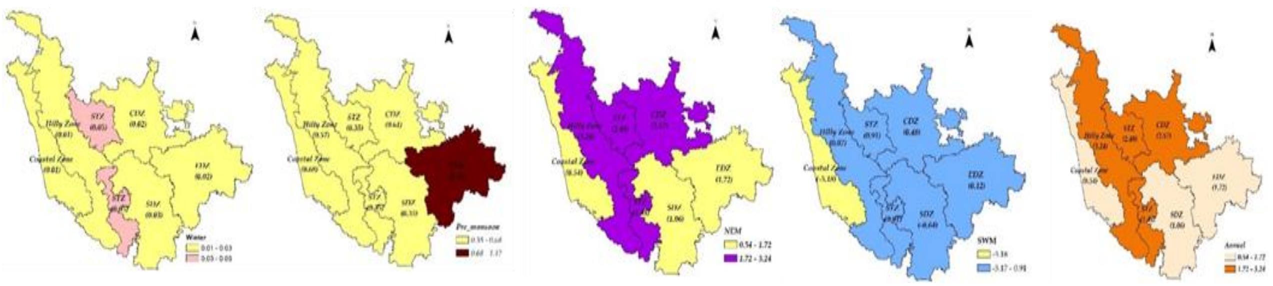


Fig. 3.6 Trends in rainfall during winter, pre-monsoon, SWM, NEM and annual rainfall in the zones of south Karnataka

Bhubaneswar

Determining Length of Growing Period for Crop Planning in East and South Eastern Coastal Plain Agroclimatic Zone of Odisha

The onset of the monsoon is considered the start of the growing season. The onset date of the monsoon was calculated by the forward accumulation of rainfall. The early onset of the monsoon was in Kendrapara district (15 June) (Table 3.6). Jagatsinghpur and khordha districts had the commencement of monsoon after 16 June. Puri district received the rainfall late (17 June) than other districts of this zone.Backward accumulation of rainfall from 15 October was done to determine the date of the recession of monsoon. The growing season terminated at around 13 October (41 SMW) in all districts of this zone (Table 3). The period of wet days during monsoon was highest in Kendrapara district (121 days) followed by Jagatsinghpur and Khordha district (120 days). The lowest wet days were in the Puri district (119 days).

Table 3.6 District-wise onset and cessation of monsoonin East and South Eastern Coastal Plain Agroclimatic Zone of Odisha

Blocks	Onset date	Cessation date	Wet Days
Jagatsinghpur	16June	13 Oct	120
Kendrapara	15 June	13 Oct	121
Khordha	16June	13 Oct	120
Puri	17 June	13 Oct	119

Total Annual Wet Period

The total wet period in a year was calculated by using LGP formula given by Sattar et.al. 2013. Jagatsinghpur, Kendrapara and Puri districts have LGP >180 days but Khordha district has 173 days (Table 3.7).The analysis revealed that the monsoon starts effectively from 24th week (15th June to 17th June) in the east and south eastern coastal plain zone and remain active up to the 41st week (13th October) Therefore, we expected good monsoon shower for about 17 weeks (24 to 41 SMW) in the region. Thus, medium-duration rice of about 120 – 135 days can easily be grown in the region with little fear of drought. The medium-duration rice can be harvested before the monsoon terminates from the region and so the chances of reduction of the yield of rice due to water stress will be low. Moreover, the residual soil moisture after the harvest of rice can be effectively utilized for raising another short-duration crop like green gram and black gram in winter.

Table 3.7 Length of Growing Period (Days) at districts of East and South Eastern Coastal Plain Agroclimatic Zone of Odisha

District	SW Monsoon Period (days)	Post-monsoon Rainfall (mm) (Oct-Jan)	AWHC (mm)	Average evaporation during the post-monsoon period (mm/day)	LGP Duration (days)
Jagatsinghpur	120	128.2	120	4.1	181
Kendrapara	121	151.6	120	3.8	192
Khordha	120	92.9	120	4.0	173

Puri	119	148.3	120	4.2	183

Crop planning based on LGP

Double cropping can be followed in Jagatsinghpur, Kendrapara and Puri districts where the length of the growing period >180 days except Khordha district where paira cropping can be followed as the length of the growing period <180 days (Tab 6). In assured irrigated situation double cropping can also be practiced in Khordha district.

Dapoli

Annual rainfall data (1971-2022) was analyzed to identify with different intensities of meteorological drought at Dapoli center and presented in Table 3.8. Out of 51 years, 88.23 per cent years (45 years) experience no drought situation and 11.76 per cent years (6 years) experience moderate drought. Dapoli center was not experience any severe drought situation. This indicates very less probability (12%) of occurrence even moderate drought at Dapoli Center.

Table 3.8 Frequency ofmeteorological drought years at Dapoli (1971-2022)

Sr. No.	Drought condition	Years	No. of Years	Percentage
1.	No. Drought	1973 to 1980, 1982 to 1985, 1988 to 2000, 2002 to 2014, 2016 to 2022	45	88.00
2.	Moderate Drought	1972, 1981, 1986, 1987, 2001,2015	6	12.00
3.	Severe Drought	-	-	-
Total			**51**	**100**

Hisar

Characterization of heat wave events over Haryana

A Heat Wave is a period of abnormally high temperatures, more than the normal maximum temperature that occurs during the summer season in the North-Western parts of India. Heat Waves typically occur between March and June, and in some rare cases even extend till July. The extreme temperatures and resultant atmospheric conditions adversely affect people living in these regions as they cause physiological stress, sometimes resulting in death.The heat wave analysis of 41 years (1980-2020) for different districts of Haryana was undertaken and the normal frequencies of heat wave occurred during March-June are plotted in GIS interface and the spatial behavior of heat wave frequency in Haryana is presented in Fig 3.7. The month of May is the hottest month to receive up to 15 heat wave episodes.

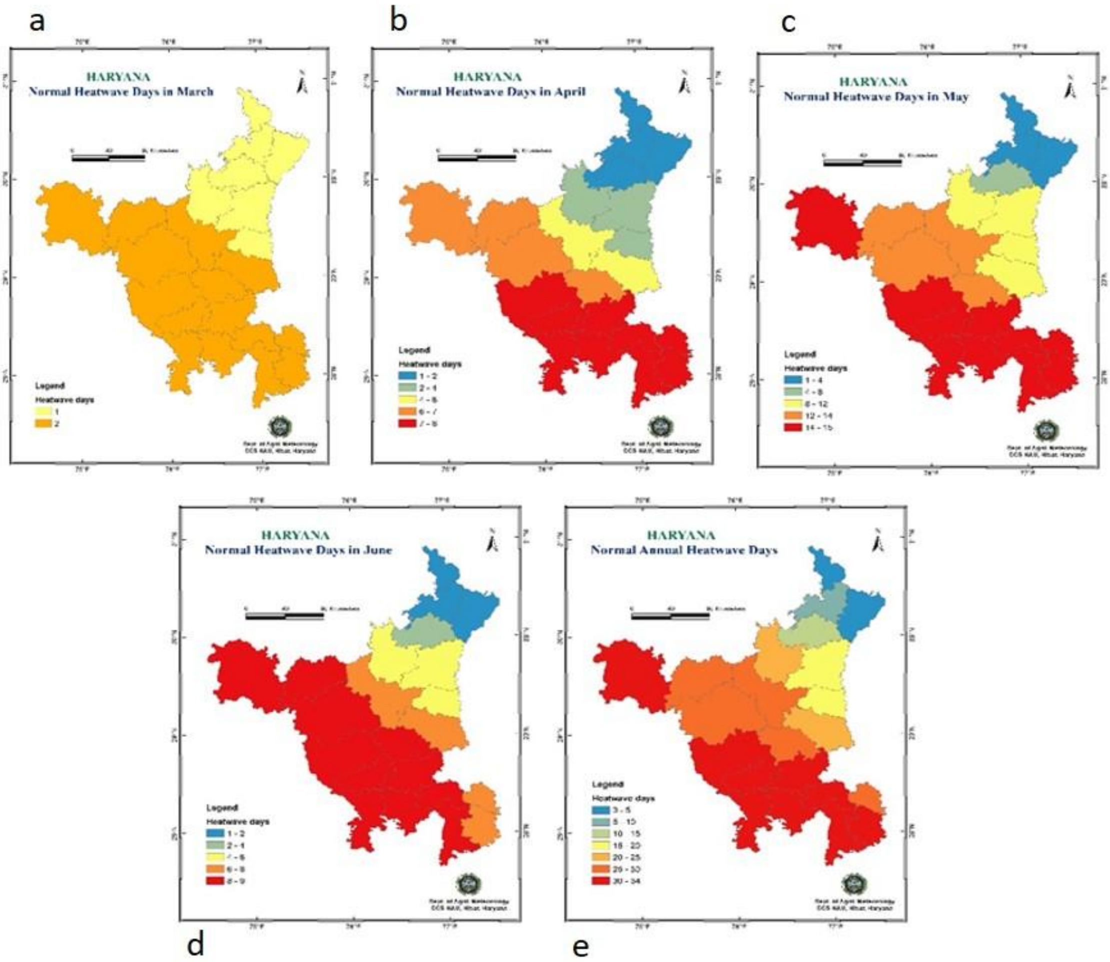


Fig. 3.7 Spatial distribution of heat wave frequency in Haryana during (a) March (b) April (c) May (d) June and (e) July

Wind pattern analysis

The daily wind speed and direction of four districts viz Ambala, Faridabad (eastern agroclimatic zone) Bhiwani and Hisar (western agroclimatic zone) were analyzed for the period of 41 years (1980-2020) and wind roses are presented in Fig 3.8. The NW direction was predominant in districts except Faridabad where southerly wind dominated. The NW direction prevailed on more than 40 % occasions and the wind speed of >10 kmph was found dominating.

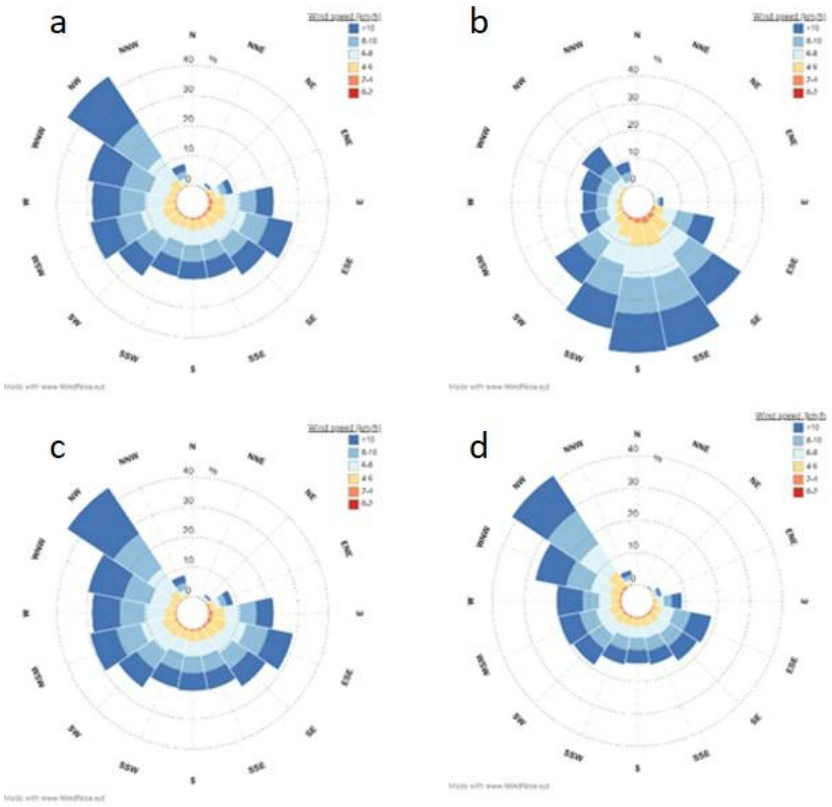


Fig 3.8 Wind rose for (a) Ambala (b) Faridabad (c) Hisar and (d) Bhiwani districts of Haryana (1980-2020)

Jorhat

The agroclimatic analysis was performed to study the distribution of rainfall and thermal regimes throughout the sali rice growing period over the districts of Upper Brahmaputra Valley Zone (UBVZ) of Assam. The sali rice growing period was initiated from June onwards till November. Generally, the growth stage of sali rice is divided into three important phases *viz*., vegetative, reproductive and ripening phase. If the crop is sown during optimum sowing window i.e., June-July in nursery, it will attain maturity by the November. The vegetative phase lasts from June to September, one month for reproductive (October) and ripening (November).

Table 3.9 Basic statistical characteristics of rainfall during winter rice growing period in different districts of UBVZ of Assam during 1991-2020

Months/phase	GOLAGHAT		JORHAT		SIVASAGAR		DIBRUGARH		TINSUKIA	
	Mean (mm)	CV (%)	Mean (mm)	CV (%)	Mean (mm)	CV (%)	Mean (mm)	CV (%)	Mean (mm)	CV (%)
June	251.3	33.8	288.7	82.5	293.6	42.1	422.4	36.24	390.2	39.3

July	310.7	32.5	377.4	87.9	368.3	27.3	486.4	19.17	458.9	31.4
August	271.5	30.7	309.2	69.4	310.4	29.9	393.9	33.15	373.7	39.8
September	196.5	39.1	239.9	84.9	231.7	38.2	317.8	39.3	297.1	52.1
Jun-Sep (Veg)	1030.4	9.3	1215.2	7.8	1204.0	9.4	1620.5	8.8	1519.9	10.6
Oct (Rep)	107.4	68.5	116.5	71.7	107.9	63.2	128.4	55.2	116.8	56.0
Nov (Mat)	20.3	115.5	17.3	85.9	21.6	82.7	10.3	86.5	18.7	94.1
Jun-Nov (GS)	1157.8	10.9	1349.0	10.5	1333.5	11.2	1767.3	11.2	1655.5	12.2

It was observed that July month received the highest rainfall in all the districts of UBVZ of Assam. The highest mean monthly rainfall was received in Dibrugarh in July (486.4mm) and the lowest was recorded in Golaghat district (310.7mm) (Table 3.9). The CV of all the months were less than 100% indicating mean monthly rainfall is highly dependable and the variation is very minimal. However, in Golaghat district, the CV in November is higher than the threshold level (100%) indicating higher variation in rainfall. During the overall winter rice growing period, maximum monthly rainfall was recorded in Dibrugarh district (1767.3mm) & minimum in Golaghat district (1157.8mm).

Table 3.10 Sen's estimator of slope of rainfall (mm/decade) during winter rice growing period in the UBVZ of Assam (1991-2020)

Months/Growing phase	Golaghat	Jorhat	Sivasagar	Dibrugarh	Tinsukia
June	-17.4	43.6**	7.6	-24.3	-36.9
July	20.5	14.5	1.7	-18.3	-27.7
August	-48.8*	-4.5	-16.1	-38.0	-24.1
September	-9.8	11.3	-1.1	-30.4	33.4**
Jun-Sep (Veg)	-5.3	-6.3	-15.4	-4.3	8.5
Oct (Rep)	-4.3	-0.8	-5.5	-1.3	-0.4
Nov (Mat)	-48.9	78.8	-30.6	-75.6	-56.0
Jun-Nov (GS)	-76.3**	57.0	-49.7	-74.6	-53.2

The trend of total rainfall during winter rice growing season was negative in all the districts except in Jorhat (57.0mm/decade) (Table 3.10). The increasing trend in rainfall during the early period of crop sowing i.e., July (43.6**) may lead to a total increase in rainfall in Jorhat district of UBVZ of Assam. The decreasing trend of rainfall during the growing season by 76.3 mm/decade in Golaghat was found statistically significant.

Kanpur

Effect of El-Nino on *Kharif* foodgrain production

The district wise average area, production and productivity of total *kharif* food grain during El Niño years compared to normal years are shown in (Fig. 3.9). The analysis indicated that the production of total *kharif* food grain in six regions of the state was reduced by 8.8 percent due to El Niño. Maximum decline in total *Kharif* food grain production (21.7 per cent) was observed in Bundelkhand zone followed by Central Plain Zone (12.4 per cent) (Fig. 3.8a). In five districts of Bundelkhand zone, a decline 18.4 per cent average yield of total *kharif* food grain, followed by Central Plain Zone (7.7 per cent) has occurred during El Niño years. The highest yield decline was noticed in Jhansi (26.2 percent) followed by Lalitpur (22.7 per cent) under Bundelkhand zone. The average area under total *Kharif* food grain decreased by 4.8 per cent in all six region of Uttar Pradesh during El Niño years. The highest decrease in total *Kharif* food grain area was observed in Bundelkhand Zone and Central Plain Zone (6.1 per cent) followed by Mid-Western Plain Zone (5.2 per cent). The production decreased by 5 to 10 percent in most of districts barring Tarai zone, Western plain zone, Mid- western plain zone and South- west semi-arid zone (Fig. 3.8b). The production declined by more than 15 per cent in Central plain zone and Bundel khand zone.

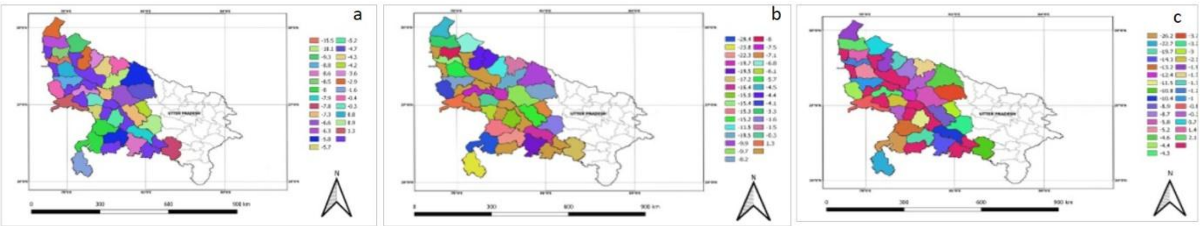


Fig. 3.9 Effect of El-Nino on per cent change in (a) area, (b) production and (c) productivity of kharif crops in west UP (1980-81 to 2017-18)

Ludhiana

In Punjab, monsoon enters normally by 1st July and withdraws by 15th September. The variability of onset and withdrawal of monsoon current and the amount of rainfall in Punjab during the last 21 years are presented in Fig. 3.10. The onset of monsoon in Punjab was delayed for eleven years, i.e., by up to 7 days during five years (2003, 2004, 2010, 2014 and 2016), by 8-14 days during two years (2006 and 2012) and more than 15 days during four years (2002, 2017, 2018 and 2019). There was early onset of monsoon for only eight years (2005, 2007, 2008, 2011, 2013, 2015, 2020 and 2021). Though the normal withdrawal of monsoon from Punjab should occur up to 15th September, there has been delayed withdrawal from Punjab during the past two decades. The very late withdrawal of the monsoon current from the state occurred in the month of October for five years (2007, 2016, 2018, 2019 and 2021).

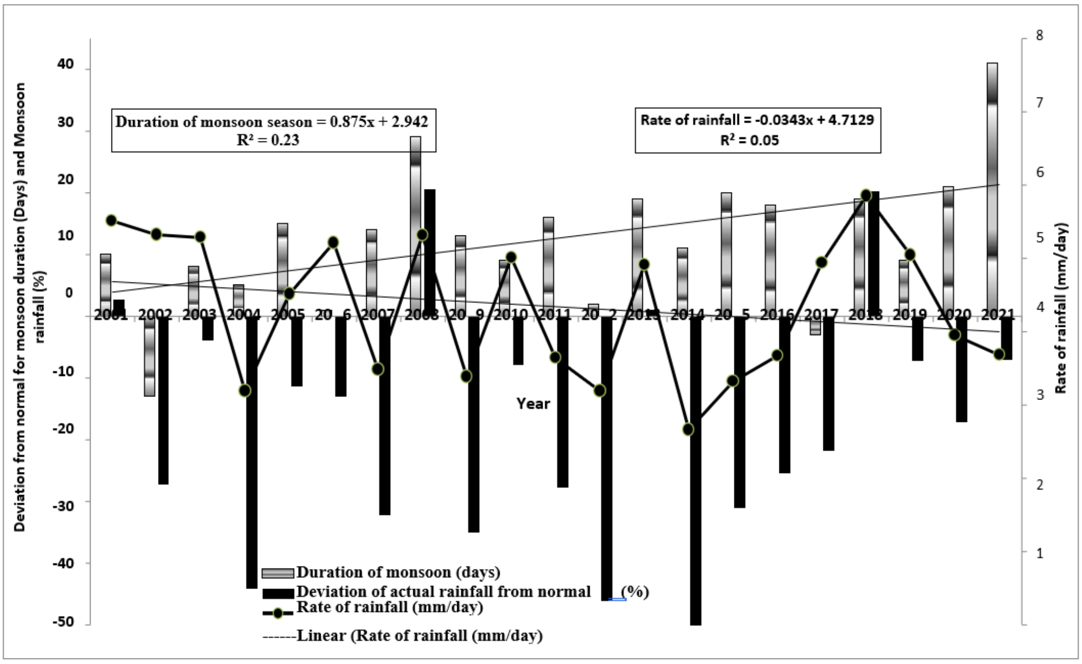


Fig. 3.10 Variability in duration of monsoon, rainfall/day and deviation of rainfall from normal in Punjab (2001 to 2021)

The normal duration of the monsoon in Punjab is 77 days (1 June to 15 September) which is increasing @0.8 day/year over the last two decades. During the last two decades, the duration of monsoon was reduced by only three years, i.e., 2002 (13 days), 2017 (03 days) and 2018 (11 days). But the monsoon rainfall was reduced by up to ~19% during nine years (2000, 2003, 2005, 2006, 2010, 2011, 2013, 2019 and 2020) and >20% during nine years (2002, 2004, 2007, 2009, 2012, 2014 to 2017). The average rate of monsoon rainfall is 6 mm/day, during the past two decades it has been less than the normal rate but more than 5 mm/day for seven years, i.e.,5.85 (2018), 5.51 (2001), 5.32 (2002), 5.31 (2008), 5.21 (2006), 5.04 (2019) and 5.01 (2010). The data on the amount of monsoon rainfall was analyzed and the percent departure from normal rainfall (Fig. 3.11) indicates that during the five decades of study, 28 years (56%) received rainfall lower than normal monsoon rainfall in the state. But during the recent two decades (2001-2020), 16 years (80%) were deficient in monsoon rainfall, though the duration of monsoon current was more than normal in the state.

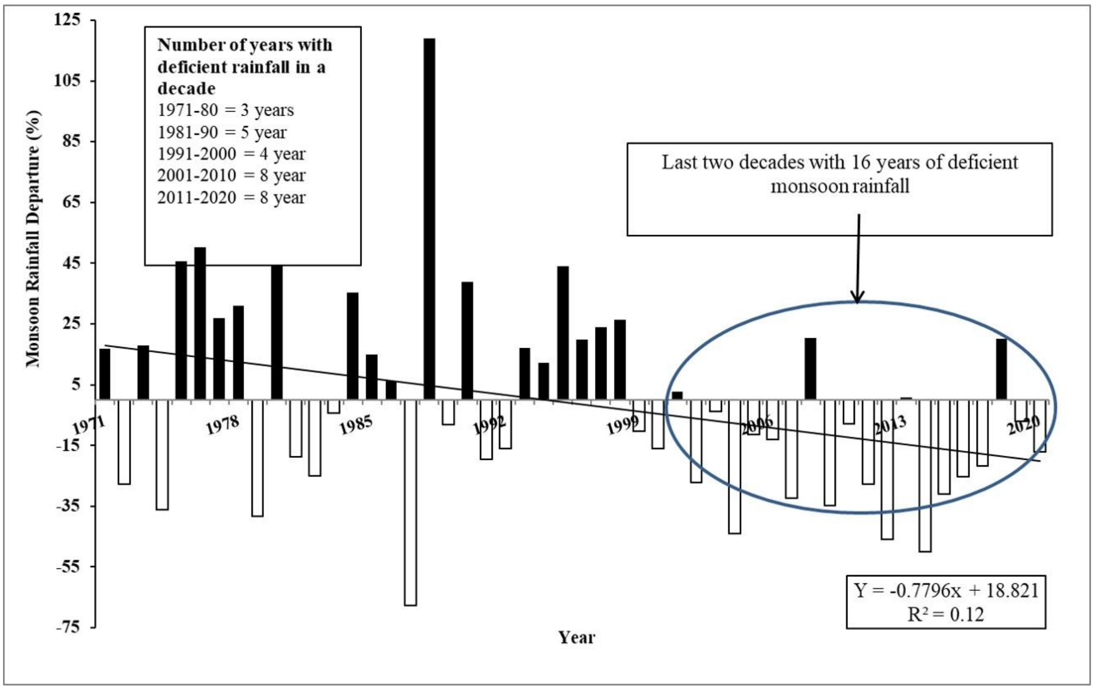


Fig. 3.11 Monsoon rainfall departure from normal rainfall over last five decades in Punjab (1971-2020)

Parbhani

Rainfall Intensities over Maharashtra

The average annual rainfall of Maharashtra is about1200 mm. In most parts of the area, the rainfall falls in the monsoon months. The diurnal rainfall for the period of 1990-2021 (32 years) generated by IMD at a grid resolution of 0.25 x 0.25 degrees, projected on the Maharashtra was processed for trend analysis. Further, the spatio-temporal variation in the frequency of rainfall events based on rainfall intensity (RI) for each season was worked out at the district level in Maharashtra state.The spatio-temporal variation in the frequency of rainfall events based on rainfall intensity (RI) for each season was worked out at the district level in Marathwada region. For doing so, the total number of rainy days in a season was broken down into different rainfall categories depending upon the daily rainfall intensity (RI) i.e., the amount of rainfall that happened in a single day and classified as light rain, moderate rain and heavy rain during different seasons. In south west monsoon 17-18% very light rain, 9-10% light rainfall, 5-6% moderate rainfall & 1-2% heavy rain possibility were occurred (Fig. 3.12).

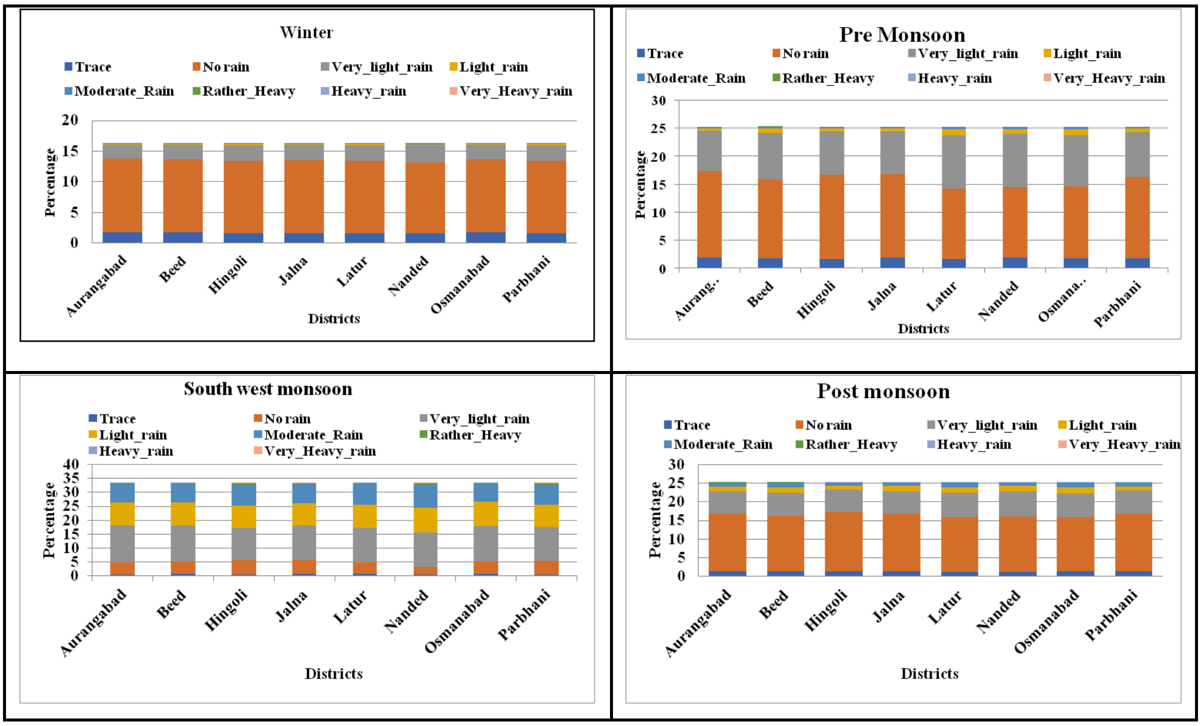


Fig. 3. 12 The long-term distribution of rainfall events expressed as a percentage of the mean number of rain days in stacked chart columns observed during winter, pre-monsoon, monsoon, and post-monsoon for a period of 32 years (1990-2021) in Marathwada.

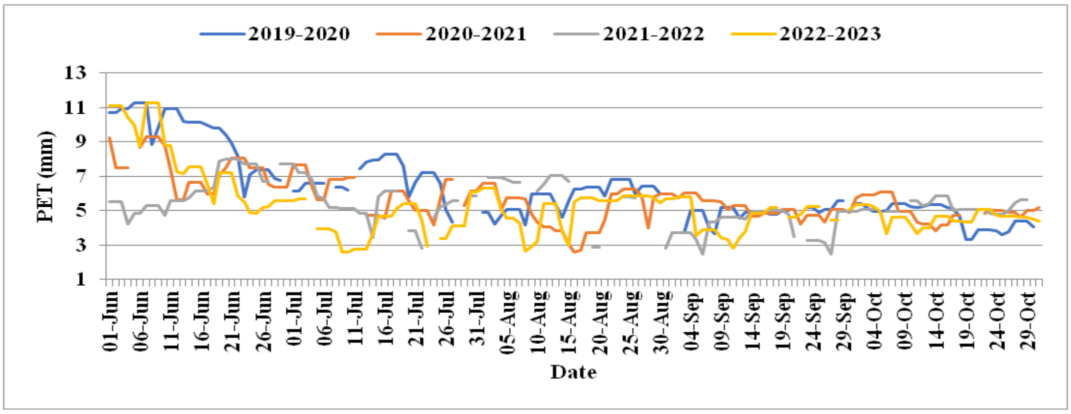


Fig 3.13 Potential Evapotranspiration of MODIS satellite from 2019 to 2022 for Parbhani district

Parbhani district area has a tropical-subtropical climate, which is under the monsoon influence. The average annual rainfall is about 937 mm. Near about 80 to 85% rainfall falls in the monsoon month. The cropping pattern in Parbhani depends upon the spatial distribution of rainfall. The daily rainfall, PET, soil moisture and NDVI data was generated over the monsoon season. The last four years (2019 to 2022) daily potential evapotranspiration (PET) & NDVI data over Parbhani (MODIS satellite and Rainfall data (INSAT) from Vedas portal SAC ISRO was collected (Figs. 3.13, 3.14 and 3.15).

The soil moisture profile and rainfall were continuously fluctuating in the entire season (Figs. 3.14 &3.15). The quantum of rainfall with well distribution was reordered in 2020-21 & 2022-23. The highest rainfall recorded in one day was 10 July in 2021 (179.1 mm) followed by 22 July 2020 (170.8 mm). Every year the August month was witness for dry spell occurrence and it was realized in the last four years when rainfall was extended up to the second and third week of October.

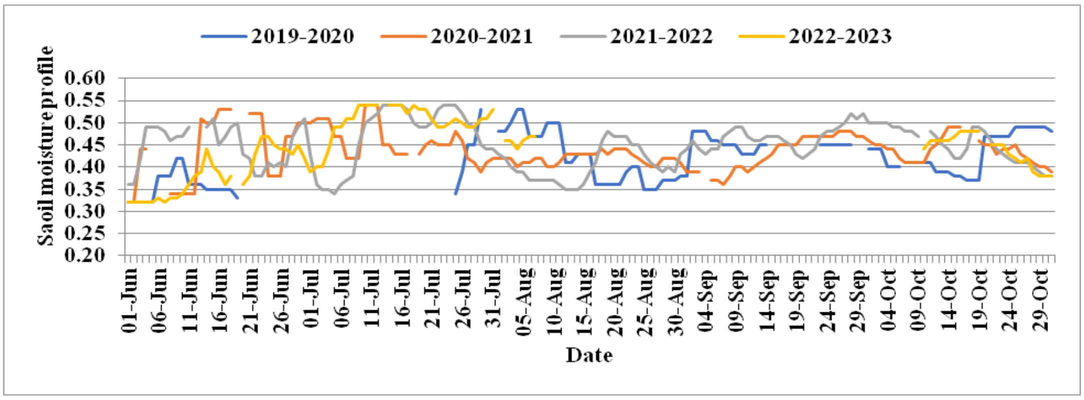


Fig 3.14 Soil moisture profile from 2019 to 2022 for Parbhani district.

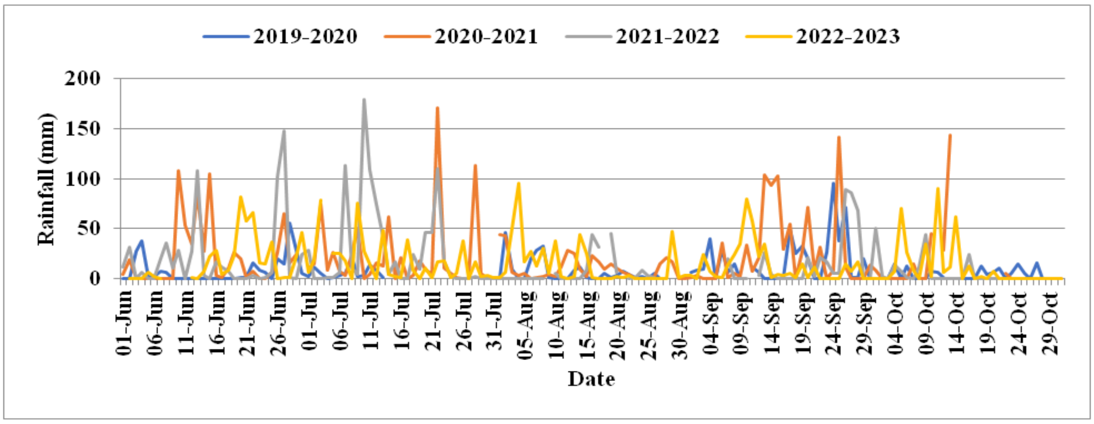


Fig 3.15 Rainfall data of INSAT satellite from 2019 to 2022 for Parbhani district.

PET rate at the start of monsoon season was more than 7 mm/day subsequently decreasing with a PET rate of 4.0 mm to 5.5 mm per day (Fig. 3.13). The highest PET rate was observed in the year 2019-20 and lowest during 2022-23. The highest Normalized Difference Vegetation Index (NDVI) recorded in the August month of 2020 and followed by 2020 (Fig 3.16). The good quantum of rainfall recorded in the September month of all year due to the healthy crop condition was reflected with more than 5.0 Normalized Difference Vegetation Index (NDVI) value.

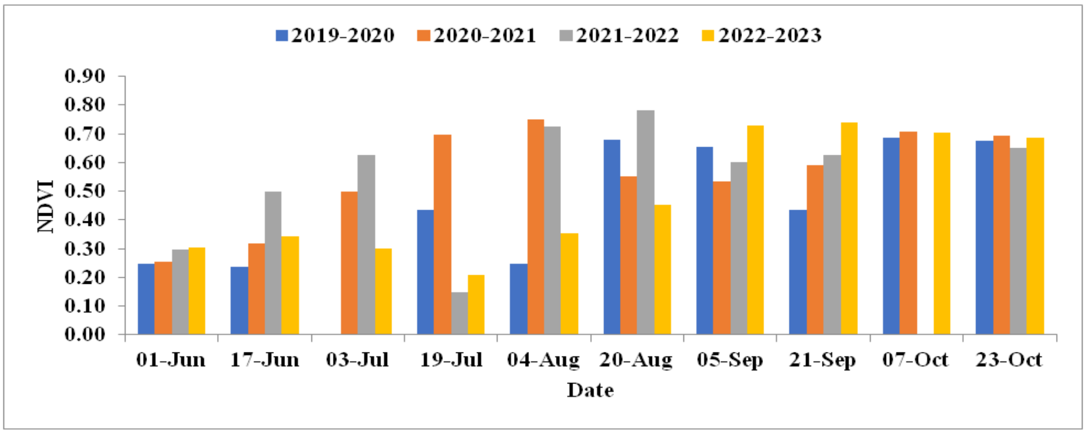


Fig. 3.16 Normalized Difference Vegetation Index (NDVI) MODIS of Parbhani district.

Samastipur

Extreme one-day rainfall events over Bihar

Daily rainfall data (1990-2019) of 10 rainfall stations located across various agroclimatic zones of Bihar were analyzed for occurrence of extreme one-day rainfall events, which shows that extreme one-day rainfall (>75 and >100 mm) during *kharif* season was found to be more frequent in Zone II (North-east alluvial plains zone) and in some pockets (Motihari, Pusa, Muzaffarpur) of Zone I (North-west alluvial plains zone) (Table 3.11).

Table 3.11 Daily rainfall events of different intensities during monsoon at different stations of Bihar (data base: 1990-2019)

Zone	Location	Number of daily rainfall events of different intensities during June to September (1990-2019)		
		>25mm	>75mm	>100mm
Zone I	Pusa	356	52	25
	Muzaffarpur	360	47	22
	Chhapra	332	43	21
	Motihari	396	57	33
Zone II	Purnia	405	78	30
	Supaul	385	79	33
Zone III	Bhagalpur	377	76	38
	Gaya	347	47	22
	Patna	338	49	21
	Rohtas	353	42	17

Evaluation of Water balance of Katihar and Supaul districts

The water balance components of Katihar and Supaul districts were worked out based on Thornthwaiteand Mather Climatic water balance model. The input components were rainfall, potential evapotranspiration (PET) and available water holding capacity (AWC) of soils. The output components are actual evapotranspiration (AET), water surplus, water deficit and soil moisture storage (SMS). In Katihar district, the humid period, *i.e.* period during which rainfall exceeds PET, extends from 22 to 40 standard met week (SMW) (Fig. 3.17a). AET greater than 0.5 PET was observed to prevail during 20-43, 20-45 and 20-47 SMW in coarse, medium and fine textured soils, respectively. Soil moisture storage (SMS) of more than 40 per cent of AWC, was recorded during 24-44 SMW in coarse, 24-46 SMW in medium and during 25-50 SMW in fine textured soils

In Supaul, the period when rainfall was more than PET consistently was 23-40 SMW. AET≥ 0.5 PET started at 21 SMW in all soils and ended at 42 in coarse, 44 in medium and 45 SMW in fine textured soils. Soil moisture storage exceeded 0.4 AWC during the periods 24-42 SMW, 25-45 SMW and 27-47 SMW in coarse, medium and fine textured soils, respectively. The variations in weekly water balance components in dominant soil (medium textured, MT) throughout a year is presented in Fig. 3.17b.

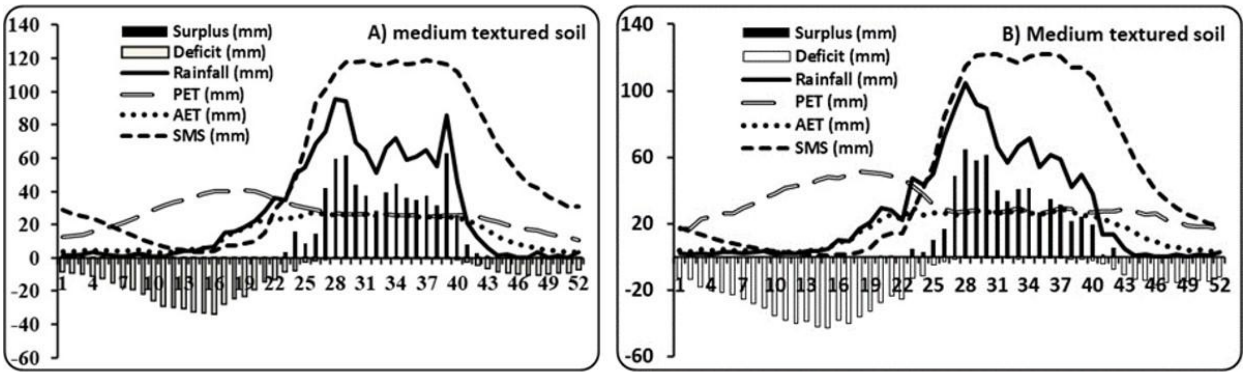


Fig. 3.17 Weekly water balance parameters in medium textured soil in A) Katihar and B) Supaul districts of Bihar (X-axis=SMW; Y-axis; surplus/Deficit/Rainfall/ PET/AET/SMS).

Solapur

Seasonal frequency analysis of heavy rainfall days in Madhya Maharashtra.

The average frequency of heavy rainfall days was estimated for Madhya Maharashtra for monsoon period as well as on annual scale. The results indicated thatduring June to September, the maximum number of heavy rainfall days ranged 6.6 to 8.0, especially in western parts of Pune, Nasik and Kolhapur districts (Fig. 3.18a). While, minimum number of Heavy rainfall days was in the range of 1 to 2 days in Solapur, Sangli, Jalgaon, some parts of Dhule, Nasik, Ahmednagar, Pune and Satara districts.During the entire year the maximum numbers of heavy rainfall days lies in the range of 7 to 8 days especially in western parts of Pune and Nasik districts (Fig. 3.18b). While, minimum number of Heavy rainfall days ranged 1 to 2 days in Solapur, Sangli, Jalgaon, some parts of Dhule, Nasik, Ahmednagar, Pune and Satara districts.

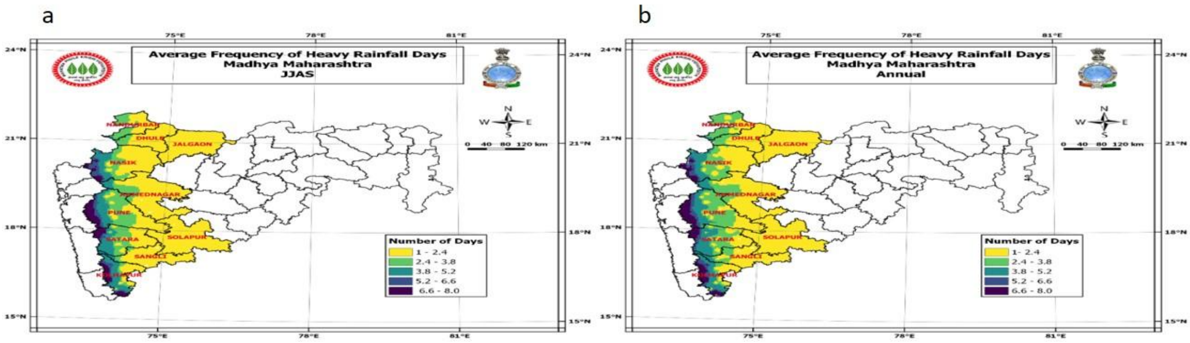


Fig. 3.18 Average frequency of heavy rainfall days on (a) monsoon period and (b) annual scale over Madhya Maharashtra

Thrissur

Shift in rainfall pattern during southwest monsoon in Kerala

The rainfall pattern change is evident and has a significant impact on livelihood and the ecosystem. Rainfall data from 1983 to 2021 was collected and pentad averages were calculated, thus 8 pentads from 1983 to 2021 were used for studying the climate variability. Rainfall data from 1983 to 2021 were used to study the trend analysis to determine climate change. During all the pentads except for the recent years, rainfall contribution was more during June and less during September. During the 1st pentad (1983-1988), 2nd pentad (1989-1993) 3rd pentad (1994-1998), 4th pentad (1999-2003), 5th pentad (2004-2008), 6th pentad (2009-2013), 7th pentad (2014-2018) and the latest years (2019-2021) contribution of June rainfall to the southwest monsoon was found to be 34%, 42%, 32%, 29%, 30%, 34%, 31% and 26% respectively in each pentad (Fig. 3.19). From the first to the last pentad, the amount of rainfall in September that contributed to the southwest monsoon was 16%, 9%, 17%, 8%, 21%, 15%, 14%, and 29%, respectively. In recent years, it was observed that the southwest monsoon during June contributed only 26% to the total southwest monsoon season. At the same time, the rainfall was found to increase in August and September *i.e.* 33% and 29% respectively. A significant decreasing trend has been observed in rainfall during the month of June while a significant increasing trend in the month of September at a significance level of 0.1. Hence a change in rainfall pattern has been observed in Kerala.

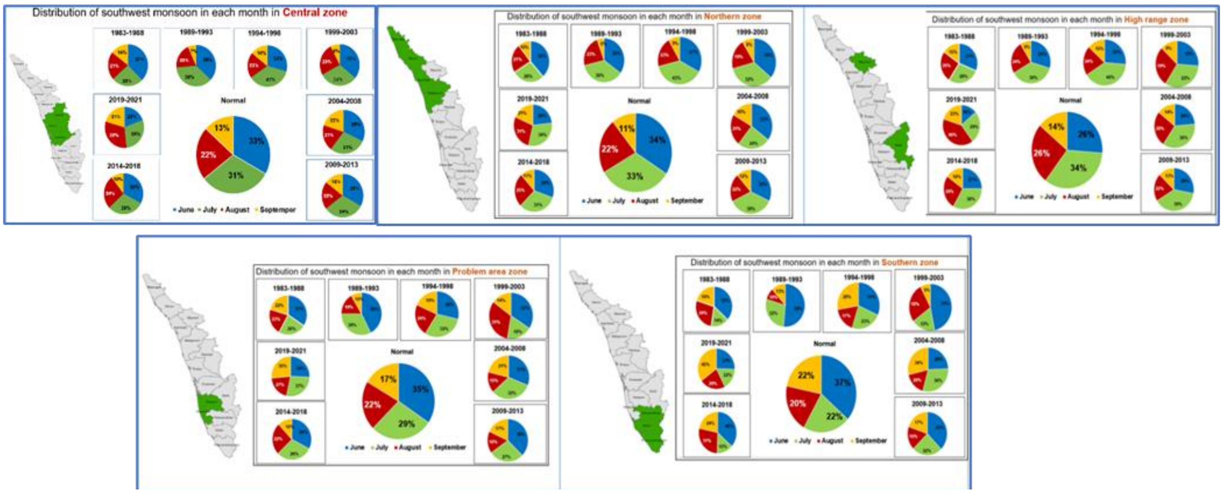


Fig. 3.19 Distribution of southwest monsoon rainfall during each month in Central, Northern, High Range, Problem Area and Southern Zones of Kerala

Future changes in southwest monsoon rainfall using GFDL-CM3 model under different RCP 4.5 and 8.5

An increase of rainfall from the base period is expected in future scenarios under both the RCPs, Under RCP 4.5 large excess and excess rainfall was expected in Kerala except in Kasargod where normal rainfall is expected in the mid and end of the century. In Alappuzha, by the end of the century, the rainfall is expected to show a normal deviation. A similar condition was observed under the RCP 8.5 where large excess and excess rainfall was expected in Kerala except in Kasargod where normal rainfall in mid and end of the century (Fig. 3.20).

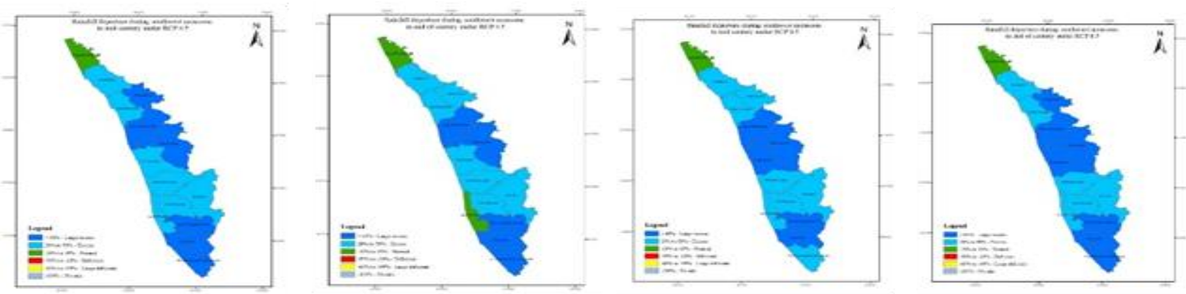


Fig. 3.20 Departure of southwest rainfall from normal under RCP 4.5 (a) mid-century (b) end of century and under RCP 8.5 (c) mid-century (d) end of century over Kerala

Change maximum temperature in Kerala using GFDL-CM3 model under different RCP scenarios

Under RCP 4.5, by mid-century, the northern and central zones show higher warming, with temperatures expected to increase by 3℃ under both RCPs. In the High Range zone, maximum temperatures are expected to decrease. In Wayanad, temperatures decreased by 1℃, while in Idukki, they decreased by 2℃ (Fig. 3.21). In the problematic and southern zones, temperatures are expected to increase by 2℃, except in Thiruvananthapuram where a small decrease of 0.01℃ is expected. By the end of the century, maximum temperatures are expected to increase in all districts except Idukki, where temperatures are projected to decrease by 0.81℃. In the northern and central zones, maximum temperatures are expected to increase by 5℃; in the southern zone, temperatures are expected to increase by 3℃. The warming was found to be higher than that under RCP 4.5, as seen in RCP 8.5. Under RCP

8.5, maximum temperatures were found to increase by 6℃ in the northern and central zones, while in the other zones, temperatures are expected to increase by 3℃.

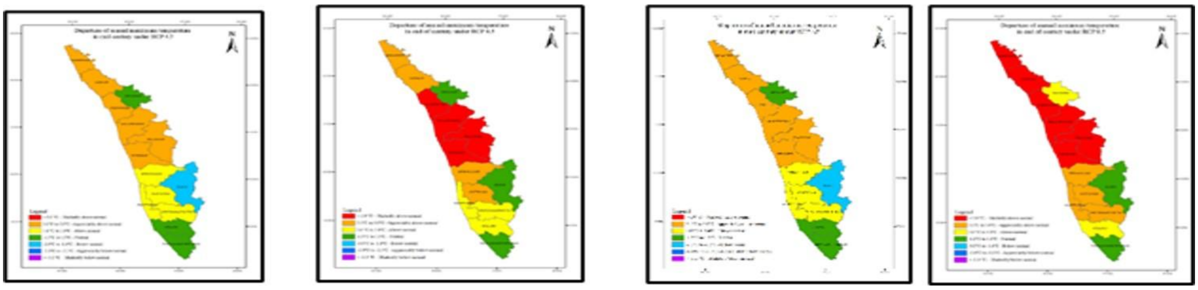


Fig. 3.21 Departure of annual maximum temperature from normal under RCP 4.5 (a) mid-century (b) end of century and under RCP 8.5 (c) mid-century (d) end of century

Minimum temperature: Under RCP 4.5, the minimum temperature has shown an increase in most parts of Kerala, except in Idukki. This trend is expected to continue in the future. In the northern and central zones of Kerala, the minimum temperature is projected to rise by 5℃ (Fig. 3.22). Within the high range zone, the Wayanad district displays an increase in the minimum temperature, while in Idukki, temperatures are expected to decrease. Similarly, in the problematic and southern zones, the minimum temperature is anticipated to increase by 3℃ compared to current conditions. Under RCP 8.5, the minimum temperature is also expected to rise, and the warming is predicted to be greater than what is observed under RCP 4.5.

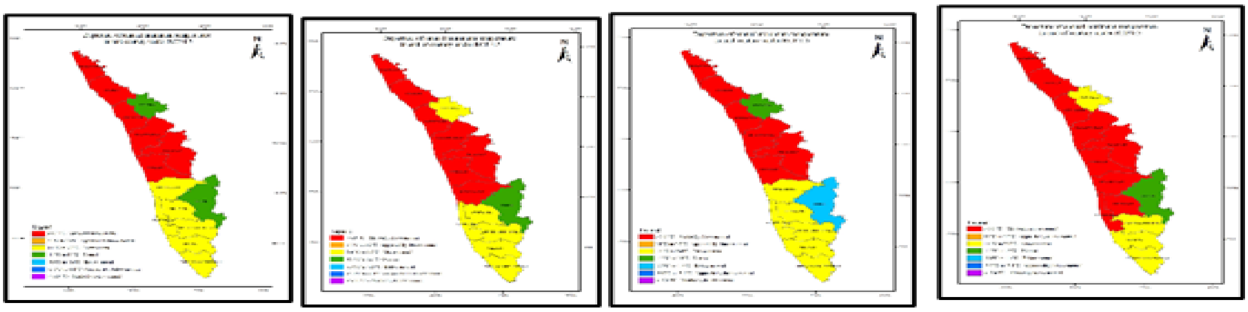


Fig. 3.22 Departure of annual minimum temperature from normal under RCP 4.5 (a) mid-century (b) end of century and under RCP 8.5 (c) mid-century (d) end of century

4. Crop Weather Relationship Studies

Many physiological processes in the crop plants are governed by themicroenvironment in which they grow. All crop growth models (dynamic /mechanistic /deterministic) inadvertently use relations between crop growthand weather elements. A better understanding of these relationships enablesscientists to estimate location specific or regional crop yields in advance. Theinformation also helps in the development of genotypes / production systemsand in the designing of management strategies both during growing seasonand post-harvest. The results of the research carried out under crop-weatherrelationships program at different centers are discussed hereunder:

Kharif 2022

Rice

Jorhat

A field experiment was conducted with four rice cultivars viz., Mahsuri, Swarna Sub-1, TTB-404 and Ranjit Sub-1 transplanted under three different microclimatic regimes viz., 26 June, 11 July and 26 July during kharif 2022. The plant height was found to differ significantly among varieties (CD is 2.18cm) as well as microclimatic regimes (CD is 1.38cm) and in their interaction effect (with CD value 2.90cm). Among the three varieties, the highest plant height was observed in Mahsuri (123.7 cm) followed by Ranjit Sub-1 (110.3cm), TTB-404 (109.6cm) and least in Swarna Sub-1 (91.3cm). Irrespective of variety, the highest plant height was observed in MR-I (112.8cm) followed by MR-II (107.9 cm) and least in MR-III (105.5 cm) (Table 4.1). The highest number of tillers per square meter was observed in Swarna Sub-1 (221) followed by TTB-404 (220) and lowest in Mahsuri (179). Maximum number of grains per panicle was observed in Ranjit Sub-1 (183). The mean panicle length was 24 cm with maximum in Swarna Sub-1 (25 cm). Among the four varieties, grain yield was found maximum in Swarna Sub-1 (4108.9 kg ha^{-1}) followed by Ranjit Sub-1 (4000.8 kg ha^{-1}), TTB-404 (3960.4 kgha^{-1}) and least in Mahsuri (3286.0 kg ha^{-1}). With delay in transplanting, there was a gradual decrease in plant height; whereas maximum effective tillers, LAI at flowering, panicles per hill and grains per panicle were highest in crop transplanted under 11 July, 2022.

Table 4.1 Yield and yield attributing characteristics of *Sali* rice grown during *kharif*, 2022 at Jorhat

Treatment	Plant height (cm)	Effective tillers per sq. meter	LAI at flowering	Panicles per hill	Grains per panicle	Panicle length (cm)	Grain Yield (kg ha^{-1})	Harvest index
Main Plot (Variety)								
Mahsuri	123.7	179.2	3.34	10.0	161.5	23.4	3286.0	0.33

Swarna Sub-1	91.3	221.3	3.40	10.2	180.1	24.5	4108.9	0.39
TTB-404	109.6	219.6	3.51	10.3	170.7	23.6	3960.4	0.38
Ranjit Sub-1	110.3	213.9	3.54	10.4	182.8	23.7	4000.8	0.38
Mean	108.7	208.5	3.44	10.2	173.7	23.8	3839.0	0.37
CD at 5%	2.18	NS	NS	NS	3.53	NS	322.6	0.012
Sub Plot (Micro climatic regimes)								
26 June. 2022	112.8	214.5	3.58	10.1	176.0	23.6	3808.5	0.36
11 July, 2022	107.9	215.5	3.62	10.3	179.1	23.9	4069.0	0.38
26 July, 2022	105.5	195.5	3.15	10.2	166.2	23.9	3639.5	0.36
Mean	108.7	208.5	3.44	10.2	173.7	23.8	3839.0	0.37
CD at 5%	1.38	NS	0.32	NS	2.94	NS	199.3	0.007
CD at 5% (V X MR)	2.90	NS	NS	NS	NS	NS	NS	NS

The interaction effect of microclimatic regimes and varieties were found to be statistically non-significant. The variability in the yield parameters can be attributed to the variability in temperature regimes under different sowing window. The mean maximum and minimum temperature throughout the growing period varied from 29.2 to 33.6 °C and 16.6 to 25.0 °C, respectively. The mean minimum temperature in early, mid and late transplanted crop varied from 21.4-24.9 °C, 18.8-25.0 °C and 16.6-24.7 °C, respectively. Likewise, the mean maximum temperature varied from 30.5-33.6 °C, 29.8-33.6 °C and 29.2-33.2 °C, respectively. The early, mid and late transplanted crop receives a mean cumulative rainfall of 1005 mm, 849 mm and 723 mm, respectively. Thus, the early and mid-transplanted crop receives relatively higher rainfall and optimum level temperature; whereas relatively less amount of rainfall was recorded when transplanted beyond first fortnight of July (i.e. D_3= 26 July). Correlation between grain yield and phasic mean meteorological parameters were worked out and the results are presented in Table 4.2.

Table 4.2 Correlation between grain yield and phasic mean meteorological parameters in *kharif* rice, 2022

Weather parameters	Phenological stages	Grain yield (kg ha^{-1})	LAI at flowering	Effective tillers m^{-2}
Tmax (mean)	Transplanting to PI	0.13	0.73**	0.22
	PI to 50% Flowering	-0.04	0.50	0.24
	50% flowering to PM	-0.20	0.49	0.02
Tmin (mean)	Transplanting to PI	0.05	0.60*	0.23
	PI to 50% Flowering	-0.01	0.58*	0.20
	50% flowering to PM	-0.13	0.55	0.11

BSSH (mean)	Transplanting to PI	0.04	0.74**	0.13
	PI to 50% Flowering	0.01	0.18	0.20
	50% flowering to PM	0.10	-0.56	-0.17
RF (cumulative)	Transplanting to PI	0.44	0.32	0.53
	PI to 50% Flowering	0.28	-0.21	0.03
	50% flowering to PM	-0.15	0.54	0.12
RH (mean)	Transplanting to PI	-0.25	-0.42	-0.26
	PI to 50% Flowering	0.16	-0.43	-0.17
	50% flowering to PM	-0.05	0.54	0.23
Evaporation (cumulative)	Transplanting to PI	0.58*	0.71**	0.68*
	PI to 50% Flowering	-0.06	0.44	0.14
	50% flowering to PM	0.04	0.04	0.22

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

Only cumulative evaporation during vegetative stage is significantly and positively (0.58*) correlated with grain yield. Here pan evaporation data defines the evaporative demand of the atmosphere during the crop growth period and as a result determines the transpiration loss of water from the crop canopy. The amount of water loss through transpiration is directly related to amount of growth. In case of other yield attributing traits *viz.*, LAI at flowering; maximum temperature (0.73**), BSSH (0.74**) and cumulative evaporation (0.71**) at vegetative stage were found to be correlated significantly and positively. Minimum temperature both at vegetative (0.60*) and reproductive (0.58*) stages were found to be correlated positively and significantly for LAI at flowering.

Mohanpur

Three transplanting environments (transplanting dates: 24.06.22, 08.07.22, and 22.07.22) were considered to establish crop weather relationship of three kharif rice cultivars (i.e., Nayanmoni, Satabdi and Swarna) in the New Alluvial Zone of West Bengal (Table 4.3). Highest plant height, GDD, HTU were observed in early rice transplanting environment. The highest yield was observed in late transplanted rice (D_3: 4347.7 kgha^{-1}) followed by 1st and 2nd transplanting environments (4033.5 kg ha^{-1} and 3936.5 kg ha^{-1}, respectively). Highest absorbed PAR (316 MJ) was observed in D_2 indicating higher vegetative growth and lowest radiation use efficiency (1.3 g MJ^{-1}) in terms of grain yield. Higher plant biomass, tiller no/ plant, panicle weight and radiation use efficiency are observed in the D_3 date of transplanting. In terms of biomass, Swarna outperformed other two varieties but in terms of grain yield it performed very poorly (3601.8 kg ha^{-1}) and subsequent lower RUE (1 g MJ^{-1}) was found. However, the Satabdi variety (4699.2 kg ha^{-1}) performed best in this situation followed by Nayanmoni (4016.6 kg ha^{-1}).

The absorption percentage of PAR varied in between ~50-75% (Fig. 4.1) where the D_2 experienced the highest variation of APAR throughout the growth period. An exponential curve was observed in D_2 while D_1 and D_3 experienced slight increments in APAR up to milking stage. This is well expressed in yield with lowest yield in D_2. APAR% in Nayanmani is abruptly lower (~55-6%) in the PI and flowering stage than Swarna and Satabdi. Poor crop stand per area may be the reason for lower APAR%. Satabdi possessed higher APAR% (milking stage->80%) reflected in yield. Transmitted radiation is high in the D_2 sowing condition which indicates poor vegetative growth than D_1 and D_3 up to flowering stage. It is clearly supported by the dry matter data observed during those phenophases (PI stage-3.2 g plant^{-1}). After the flowering stage, they maintained the same transmitting characteristics (Fig. 4.2). TPAR was higher in the tillering stage in all the varieties which indicate less growth in the earlier crop growth stages. Nayanmani canopy transmitted higher radiation in flowering stage over Satabdi and Swarna, indicating the continuation of vegetative growth in flowering stage also.

Table 4.3 Final plant height (cm), root, stem and leaf biomass, panicle weight (g), tiller number/plant, grain yield (kg ha^{-1}), Growing Degree Day (°C Day), Helio-thermal Unit (°C hour) and Radiation Use Efficiency (g MJ^{-1}) at Mohanpur

	Plant Height (cm)	Dry root / plant (g)	Dry stem / plant (g)	Dry leaf / plant (g)	Tiller Number / plant	GDD (°C Day)	HTU (°C hour)	APAR (MJ)	Panicle weight (g)	Grain yield (kg ha^{-1})	RUE (g MJ^{-1})
Date of Sowing											
D1: 24.6.22	126.3	1.37	11.94	7.4	8.4	2013	10913	279	18.13	4033.5	1.48
D2: 08.7.22	124.8	2.15	13.1	5.6	9.0	1761	9236	316	19.15	3936.5	1.30
D3: 22.7.22	122.4	2.51	12.89	7.6	9.7	1861	9995	283	25.93	4347.7	1.62
SEm (±)	0.94	0.16	0.63	0.29	0.22	-	-	-	0.61	23.03	-
CD (p=0.5)	NS	0.767	NS	1.409	NS	-	-	-	2.994	92.84	-
Variety											
Nayanmoni	118.5	1.39	8.52	4.1	9.6	1509	7805	237	27.86	4016.6	1.69
Satabdi	120.1	2.06	8.32	5.9	9.1	1801	9272	279	16.39	4699.2	1.71
Swarna	134.1	2.78	22.27	11.2	8.7	2324	13067	362	16.75	3601.8	1.00
SEm (±)	1.58	0.18	1.26	0.19	0.26	-	-	-	2.61	108.18	-
CD (p=0.5)	5.70	0.64	4.54	0.68	NS	-	-	-	9.44	337.02	-

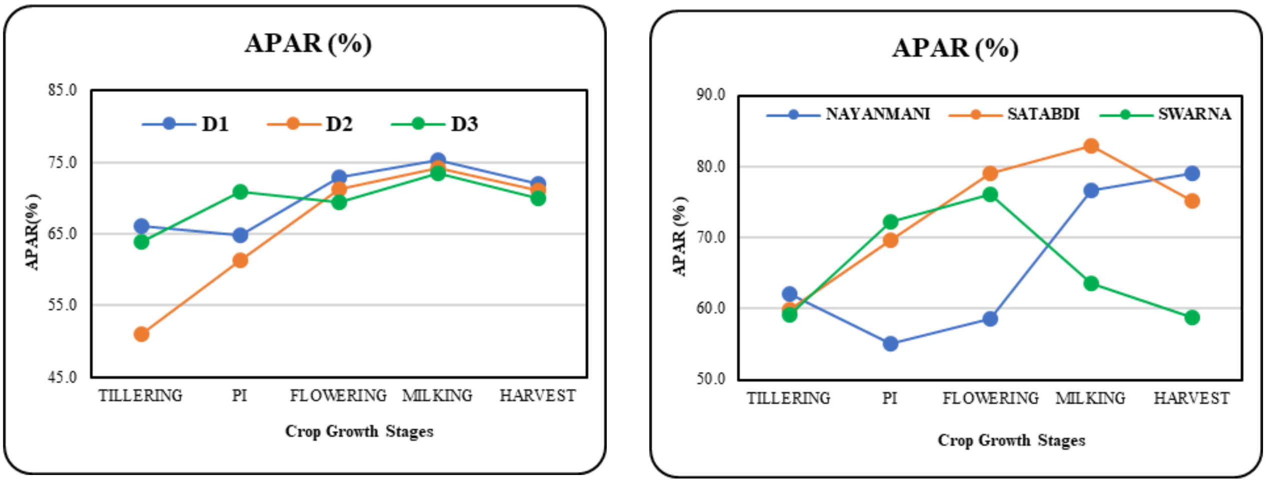


Fig. 4.1 Phenophase-wise variation of absorbed PAR in different dates of sowing and varieties at Mohanpur

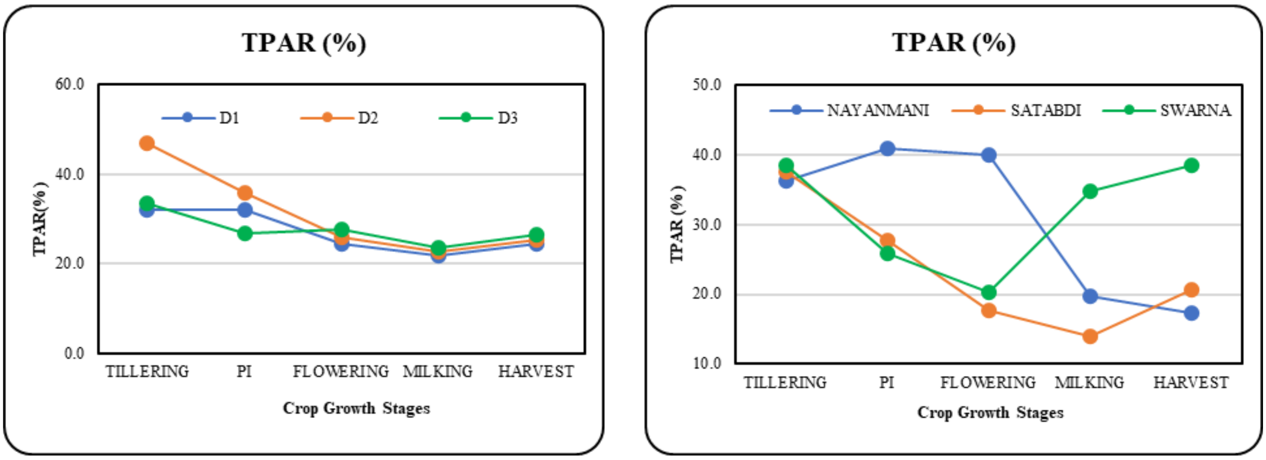


Fig. 4.2 Phenophase-wise variation of transmitted PAR in different dates of sowing and varieties

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. The number of effective tillers obtained at 5th June sown crop was significantly superior to observations under other sowing dates of 15th June and 25th June. Maximum number of fertile grains per ear were obtained when rice was normally sown (15th June) and was significantly superior to early and late sown crops (Table 4.4). Test weight for early and normal sown crops was at par and significantly superior to the late sown crop. Total dry matter recorded was highest in normally sown crop which was at par with early sown crop, but it was significantly superior to the late sown crop. Higher grain yield was recorded with

15th June sown crops (normal date) which was at par with 25th June sown crops but was significantly superior to 5th June sown crop. Harvest index in 25th June sown crops was found to be significantly higher than 5th June and 15th June sown crops.

Table 4.4 Effect of different dates of sowing and cultivars on yield and yield attributes of rice at Ranchi during *kharif* 2022

Treatments	Effective tillers m^{-2}	Fertile grain ear^{-1}	Chaffy grain ear^{-1}	1000 grain wt (g)	TDM (kg ha^{-1})	Yield (kg ha^{-1})	HI (%)
Date of Sowing							
Early	224	138	16	27	9245	3880	42
Normal	210	165	18	27	9920	4450	45
Late	207	118	18	26	8333	4030	49
S Em	4.3	3.4	1.6	0.3	2.7	1.4	0.8
C D at 5%	12.9	10.2	NS	0.9	840	430	2.4
Variety							
Sahbhagi	202	142	16	27	8015	3830	48
Naveen	222	155	17	24	10515	4460	43
MTU1010	217	124	19	29	8968	4070	46
S Em	12.9	3.4	1.6	0.3	2.7	1.4	0.8
C D at 5%	15	10.2	NS	0.9	840	430	2.4
Interaction							
S Em	7.4	5.9	2.8	0.5	4.8	2.5	1.4
C D at 5%	NS	17.6	NS	NS	NS	7.4	4.2

Chatha

A field experiment was laid out for creating variable growing environments with three dates of transplanting (T_1: 1st July, T_2: 10th July and T_3: 20th July) and three varieties of rice (V_1: Pusa 1121, $V_{2:}$ Basmati-370 and V_3: SJR-129) during *kharif*, 2022. The significantly higher yield attributes were recorded in rice crop transplanted on 1st July as compared to 10th and 20th July (Table 4.5). The significantly higher yield attributes were recorded in rice crop transplanted on 1st July as compared to 10th and 20th July. Among different varieties, the yield attributes were found significantly higher under the variety SJR-129 followed by Basmati-370, but it was observed at par with Pusa-1121. The basmati rice crop transplanted on 1st July (T_1) recorded significantly higher seed yield 3780 kg ha^{-1} than 10thJuly (3410 kg ha^{-1}) and 20th July (2730 kg ha^{-1}). The seed yield of the basmati rice crop decreased by 9.7 and 27.8 per cent, when the transplanting was delayed from 01st July to 10 and 20th July, respectively. The early transplanted (1st July) basmati crop produced significantly bold grains (24.46 g) as compared to delay the transplanting on 10th July (23.34 g) and 20thJuly (21.24 g) due to the fact that the early transplanted (T_1) basmati rice crop required more thermal time to achieve different phenological stages.

Table 4.5 Effect of different dates of transplanting on growth, yield attributes and yield of Basmati cultivars during *kharif* 2022 at Chatha

Treatments	Grain Yield (kg ha^{-1})	Biological Yield (kg ha^{-1})	Harvest Index (%)	Plant height (cm)	No. of tillers/ plant	No. of panicles/ plant	No. of grains/panicle	1000 grain wt (g)
T_1	3780	12527	30.98	124.5	10.59	8.8	51.7	24.46
T_2	3410	11074	31.21	121.5	9.1	7.22	48.5	23.34
T_3	2730	9985	27.37	111.5	7.06	6.28	46.1	21.24
CD (0.05)	196	353	1.96	2.61	1.26	1.32	5.31	0.98
SEm (±)	65	117	0.65	0.81	0.39	0.41	1.77	0.34
V_1	3320	11031	30.34	113.4	9	7.84	45.82	22.47
V_2	3010	12380	24.23	135	8.13	6.13	48.5	22.96
V_3	3590	10176	35	109.2	9.61	8.33	52	23.61
CD (0.05)	196	353	1.96	2.61	1.26	1.32	5.31	0.98
SEm (±)	65	117	0.65	0.81	0.39	0.41	1.77	0.34

Further, correlation of phenophase-wise average weather parameters with grain yield was undertaken and the result is presented in Table 4.6. The maximum and minimum temperature has significantly positive impact at seedling emergence and panicle emergence. The morning relative humidity has a significant positive impact at the Booting, Milking and Hard dough stages, while evening relative humidity is positively correlated at Tillering and Booting stages. The sunshine hour had highly negative impact at Tillering, Booting and Hard dough stages.

Table 4.6 Correlation coefficients between yield and meteorological parameters at different phenophases of transplanting basmati crop during *kharif* season 2021 and 2022.

Weather Variables → /Stages ↓	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)	EPO (mm)	Sunshine (hrs)	Morning relative humidity (%)	Evening relative humidity (%)
P_1	0.71**	0.89**	-0.49**	-0.26	-0.06	0.43	0.37
P_2	-0.03	0.35	0.03	-0.55*	-0.61**	0.07	0.55*

P_3	0.19	0.39	0.79**	0.83**	-0.77**	0.67**	0.81**
P_4	0.64**	0.64**	0.38	0.41	0.39	0.09	0.19
P_5	-0.29	0.12	0.15	-0.19	-0.34	-0.20	0.19
P_6	0.25	0.50*	0.13	-0.44	-0.32	0.58*	0.42
P_7	0.41	0.49*	-0.19	-0.19	-0.68**	0.49*	0.42
P_8	0.03	0.35	0.02	0.08	-0.47	0.004	0.41

**Significant at 0.05, **Significant at 0.01*
P_1-Seedling establishment; P_2-Tillering; P_3-Stem elongation; P_4-Panicle Emergence; P_5-Flowering; P_6-Milking; P_7-Hard dough; P_8-Physiological Maturity

Dapoli

Impact of growing environments and variety on heat use efficiency was studied using field experiment with three growing environments (early (9 June), Normal (15 June) and late (22 June)) and five varieties (Palghar-2, Jaya, Palghar-1, Swarna and Karjat-5). In case of heat units, the crop sown during the 24th week recorded the maximum heat units (2127.20 ^{o}C-day) and the crop sown on the 23rd week recorded the minimum heat units (2062.62 ^{o}C-day) (Table 4.7). Amongst the different varieties, variety Swarna required maximum heat units of 2170.55 ^{o}C-day. Similar result was observed for grain yield also, where crop sown on 24 SMW recorded highest (4215 kg ha^{-1}) and that of 25 SMW, the lowest grain yield (3051 kg ha^{-1}). The higher accumulated heat units and grain yield for crop sown on 24 SMW has recorded in the highest heat use efficiency (1.96 kg ha^{-1} °C day^{-1}), followed by crop sown on 23 SMW. Among the varieties, Jaya recorded highest HUE (2.1 kg ha^{-1} °C day^{-1}), followed by Palghar-1 (1.95 kg ha^{-1} °C day^{-1}).

Table 4.7 Effects of cultivars and growing environments on grain yield, accumulated heat use efficiency at Dapoli

Treatments	Grain yield (kg ha^{-1})	GDD (^{o}C-day)	PTU (^{o}C-day)	HTU (^{o}C-day)	HUE of seed with GDD (kg ha^{-1} °C day^{-1})
Sowing Time:					
S_1 - 23rd SMW	4050	2063	185093	5783	1.96
S_2 - 24th SMW	4215	2127	191001	6614	1.98
S_3 - 25th SMW	3051	2073	186273	6566	1.47
Varieties:					
V_1 - Palghar-2	3044	2010	181378	5606	1.51
V_2 - Jaya	4278	2037	183438	5894	2.10
V_3 - Palghar-1	4022	2066	185801	6118	1.95
V_4 - Swarna	3862	2171	194073	7056	1.78
V_5 - Karjat – 5	3655	2155	192589	6931	1.70

Thrissur

The experiment was conducted with two varieties (Jaya and Jyothi) and five dates of planting (June 5, June 20, July 5, July 20 and August 5, 2022). Effect of growing environments and varieties on dry matter accumulation was studied. Jyothi had highest dry matter accumulation compared to Jaya variety. As the maximum temperature increased the dry matter accumulation decreased in both varieties (Fig. 4.3a) while as the number of rainy days increased the dry matter accumulation also increased (Fig. 4.3b) for both varieties as shown in Table 4.8. Lowest dry matter accumulation during August 5 planting may be due to combined effect of higher maximum temperature and lower number of rainy days.

Table 4.8 Correlation results between weather parameters and dry matter accumulation.

Variety	Tmax	Tmin	RH-II	Rainy days
Jaya	-0.48*	-0.51*	0.48*	0.56*
Jyothi	-0.33	-0.06	0.15	0.16

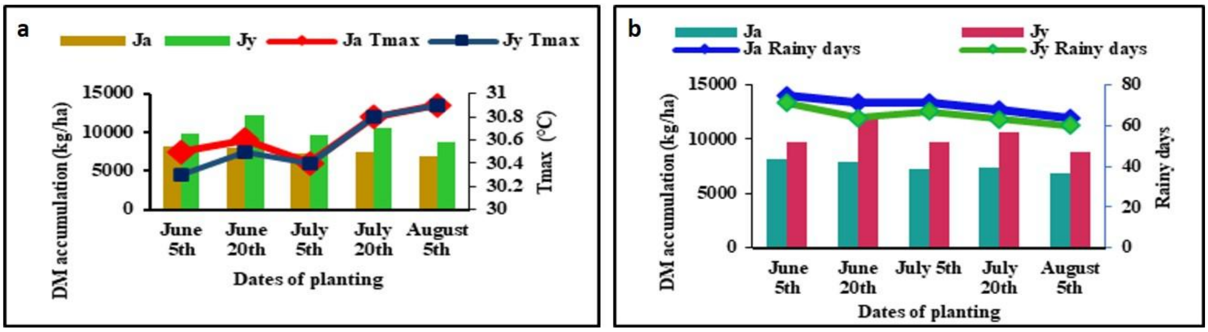


Fig. 4.3 Effect of (a) maximum temperature and (b) minimum temperature on biomass accumulation in rice at Thrissur (Ja-Jaya; Jy-Jyothi)

Jaya had highest number (86) of filled grains comparative to Jyothi (Fig. 4.4a). Jaya had highest filled grains in June 20 planting (86) while June 5 and July 5 plantings were on par. Jyothi had highest (74) number of filled grains in June 5 planting and filled grains during June 20, July 5 and August 5 plantings were found to be on par. Rainfall experienced during flowering stage had significant negative impact on filled grains production. For Jaya variety June 5 planting had highest yield and August 5 planting had lowest yield (Fig. 4.4b). For Jyothi variety, the highest yield is observed in July 20 planting and lowest yield was found in August 5 planting. It was found that increase in temperature reduced rice yield.

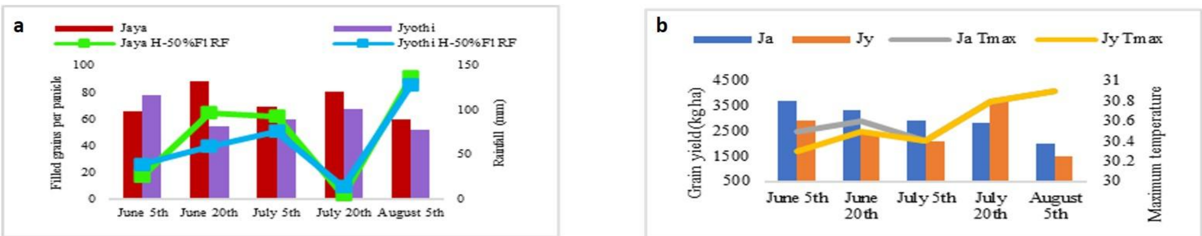


Fig. 4.4 Effect of (a) rainfall on number of filled grains and (b) mean maximum temperature on rice yield at Thrissur (Ja-Jaya; Jy-Jyothi)

Palampur

Effect of different growing environments (crop transplanted on 01st July, 10th July and 20th July) and basmati cultivars (Basmati 370, Kasturi basmati and Pusa basmati 1121) on crop phenology and grain yield was studied at Palampur.

Table 4.9 Effect of growing environments and cultivars on crop phenology, final biomass and grain yield of basmati rice at Palampur

Treatment	Days taken to achieve				Final Biomass (kg ha^{-1})	Grain yield (kg ha^{-1})
	Tillering	Panicle initiation	Heading	Physiological maturity		
$V_1 D_1$	66	86	115	147	5391	1833
$V_1 D_2$	62	80	107	141	3733	1194
$V_1 D_3$	56	75	100	136	2619	681
$V_2 D_1$	62	78	107	139	8689	3111
$V_2 D_2$	57	72	102	135	6805	2375
$V_2 D_3$	51	68	96	128	4256	1319
$V_3 D_1$	64	88	118	150	5329	1652
$V_3 D_2$	57	80	109	142	3792	986
$V_3 D_3$	50	73	102	-	3188	-
CD	2.2	3.0	4.1	4.5	505	180

It was observed that the days taken to tillering was higher in crop transplanted on 01st July and it gets reduced with subsequent dates of transplanting. Little differences were recorded among varieties for days taken to tillering phase. Days taken to panicle initiation as well as heading were also higher in first date of transplanting and they get reduced with subsequent dates. Kasturi basmati took lower number of days to panicle initiation as well as heading while higher number of days were taken to reach these phenophases in basmati 370 and pusa basmati 1121 (Table 4.9). Similar trend was observed for days taken to maturity where early transplanted crop took a greater number of days to reach maturity. The variety Pusa Basmati 1121 did not mature when transplanted on 20th July. Kasturi basmati gave satisfactory grain yield when transplanted on 01st July and 10th July while lower yield was obtained when this variety was transplanted on 20th July. The performance of other two varieties Basmati 370 and Pusa Basmati 1121 was not good with lower yields recorded in these varieties at all the dates of transplanting. Also, the yield recorded in all the varieties was higher on 01st July transplanting which declined in subsequent dates of transplanting. Pusa basmati 1121 did not give recordable yield when transplanted on 20th July.

Kharif Maize

Faizabad

Crop weather relationship study in *kharif* maize was undertaken with three growing environments (05, 15 and 25 July 2022) and thee varieties/hybrids (Kanchan, Azad hybrid-1 and Azad hybrid-2). Effect of crop growing environment and varieties on yield and HUE has been presented in Table 4.10. The results indicated that crop sown during 05 July accumulated highest heat units (1792 °C-day) and heat use efficiency (1.76 kg ha^{-1} °C-day), followed by that of 15 and 25 July sown crop. Among the varieties/hybrids, Kanchan recorded highest HUE (1.85 kg ha^{-1} °C-day), followed by Azad hybrid-1 and Azad hybrid-2.

Table 4.10 Effect of crop growing environment on yield and HUE of *kharif* Maize varieties

Treatments/Crop growing environment	Yield (kg ha^{-1})	Accumulated HU (°C-day)	HUE (kg ha^{-1} °C-day)
July 05	3340	1792	1.76
July 15	2820	1618	1.70
July 25	1970	1539	1.33
Varieties			
Kanchan	3120	1680	1.85
Azad hybrid-1	2660	1682	1.60
Azad hybrid-2	2420	1663	1.40

Ludhiana

A study was conducted to develop relationship between the weather variables and yield of maize for higher productivity in central Punjab. The maize crop was categorized into three stages i.e. vegetative, flowering stage and grain filling stage. Optimum maximum and minimum temperature respectively for better growth of maize crop during vegetative stage were in the range of 34.5 to 37.0°C and 26.0 to 27.5°C, during flowering stage were in the range of 32.0 to 35.0°C and 24.0 to 27.0°C and during grain development stage were in the range of 33.0 to 34.5°C and 26.0 to 27.5°C (Fig. 4.5). The association between rainfall and yield showed that higher yield observed in range of 400-550 mm rainfall. High yield of maize can be achieved with cumulative sunshine hours between 550 to 700 hours.

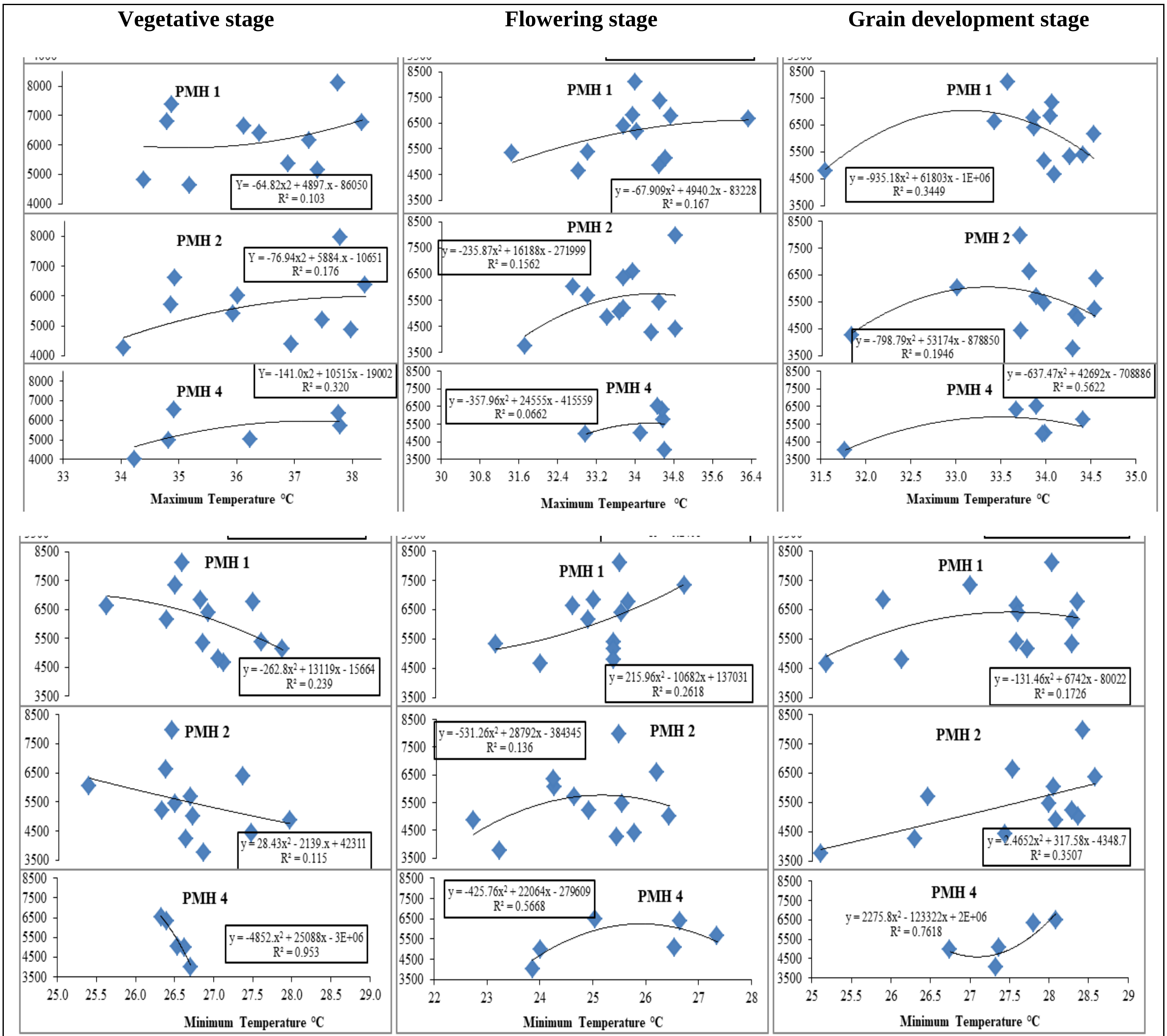


Fig. 4.5 Relationship between temperature and yield of maize cultivars at different growth stages sown during 2017 to 2022

Kanpur

Crop weather relationship studies in *kharif* maize at Kanpur was undertaken with three growing environments (21 June, 01 July and 11 July 2022) and three hybrids/cultivars viz., Azad Hyd-1, Azad Hyd-2 and DKC-7074. Effect of treatments on yield and yield attributes is presented in Table 4.11. Among growing environments, crop sown on 21 June recorded higher plant height, 100-grain weight, yield, HUE and GDD.

Table 4.11 Effect of thermal indices and rainfall on yield of *kharif* Maize at Kanpur

Treatment	Plant height (cm)	100grain wt.(g)	Yield (kg ha^{-1})	HUE (kg ha^{-1} ^{0}C-day)	GDD (^{0}C-day)
21 June	226.6	25.9	6080.0	3.2	1923.0
1July	220.9	24.9	5850.0	3.2	1823.5
11 July	215.5	24.0	5170.0	3.0	1710.4
SE$\pm$(d)	0.46	0.19	1.44	-	-
CD at 5%	1.14	0.46	3.58	-	-
Azad Hyd-1	221.0	24.6	5750.0	3.2	1817.8
Azad Hyd-2	225.3	26.1	6190.0	3.3	1867.0
DKC-7074	216.8	24.0	5170.0	2.9	1772.2
SE$\pm$ (d)	0.35	0.14	1.12	-	-
CD at 5%	0.74	0.30	2.78	-	-

Further a pooled data analysis of experiments conducted during 2017-2022 was undertaken to characterize the phenophase-wise temperature and rainfall which contributed to above average, normal and below normal yield in maize. The result is presented in Table 4.12.

Table 4.12 Temperatures ($^\circ$C), heat unit ($^\circ$days) and rainfall during different phonological stages of three maize cultivars for obtaining three different categories of yield

Yield category	Emer.	Knee high	50% tasselling	50% silking	Milk	Dough	Maturity	Yield (kg/ha)
Maximum temperature ($^\circ$C)								
Above avg.	36.4	34.0	32.9	33.4	33.6	33.3	32.7	6619
Average	35.8	33.7	32.9	33.2	33.3	33.1	32.7	5661
Below avg.	34.4	33.0	32.9	33.5	33.2	31.9	32.9	4645
Minimum temperature ($^\circ$C)								
Above avg.	26.7	26.7	26.0	26.0	25.8	25.5	24.8	6619
Average	27.0	26.4	25.9	25.9	25.8	25.4	23.9	5661
Below avg.	26.8	26.0	25.8	25.9	25.7	24.5	22.9	4645

Soil temperature (°C)								
Above avg.	34.9	31.8	29.8	30.1	30.4	30.7	29.9	6619
Average	33.8	31.4	29.8	30.0	30.4	30.4	29.7	5661
Below avg.	31.7	30.5	29.7	30.7	30.8	29.4	29.5	4645
Rainfall (mm)								
Above avg.	28.1	318.0	183.6	38.4	46.4	86.3	44.3	6619
Average	42.9	310.3	195.9	35.0	76.2	54.7	50.7	5661
Below avg.	59.8	277.7	184.7	17.4	57.8	68.7	31.8	4645

Samastipur

To study crop weather relationship, maize crop was sown on four dates viz. 1 June (D1), 10 June (D2), 20 June (D3) and 30 June (D4) of *kharif* 2022 with three varieties viz. Pioneer 1844 (V1), Shaktiman 4 (V2) and Shaktiman 5 (V3). The effect of treatments on intercepted PAR was studied and the result in presented in Fig. 4.6.

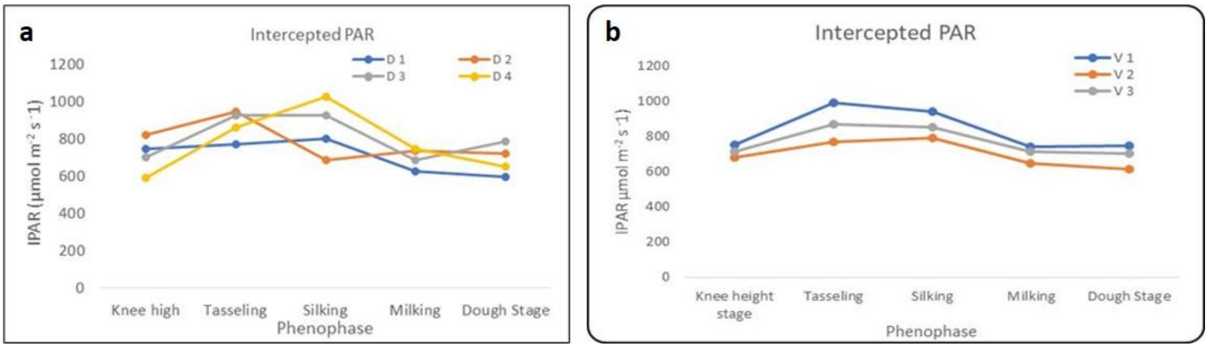


Fig. 4.6 Intercepted PAR in maize as influenced by (a) Growing environment and (b) varieties at Samastipur

The maximum intercepted PAR (1029.33 µmol m^{-2} sec^{-1}) was observed in silking stage in 4th date of sowing (30 June sown maize) and the lowest intercepted PAR of 592.81 µmol m^{-2} sec^{-1} was recorded at knee high stage in D4 (30 June) sown crop. While considering the interception by different varieties, the maximum intercepted PAR (903.58 µmol m^{-2} sec^{-1}) was associated with silking stage and the lowest of 678.61 µmol m^{-2} sec^{-1} was observed during knee high stage in Shaktiman-4 (V2). Crop sown on D1 (1 June 2022) had intercepted PAR ranging from 598 to 800.9 µmol m^{-2} sec^{-1}from knee high to dough stage. For D2 sown crop, the intercepted PAR ranged between 721.78 and 946 µmol m^{-2} sec^{-1} during its entire growing period. A variation of 687.4 to 929.8 µmol m^{-2} sec^{-1} in intercepted PAR was observed for D3 (20 June) sown maize and in D4 Intercepted PAR ranged between 592.8 and 1029.6 µmol m^{-2} sec^{-1}. D2 registered significantly higher intercepted PAR *i.e.* 822.0 and 946 µmol m^{-2} sec^{-1} at knee high stage and tasselling stage, respectively. While D4 was found to be recording significantly higher Intercepted PAR values to the tune of 1029.3 and 749.6 µmol m^{-2} sec^{-1} at knee high and tasselling stages, respectively.

Pearl millet

Anand

Field experiment consisted of three growing environments (D_1: onset of monsoon, D_2: 10 days after D_1, D_3: 20 days after D_1) and three varieties (V_1: GHB 538, V_2: GHB 558 and V_3: GHB 744). Crop weather relationship in *kharif* pearl millet was studied using experimental data of years 2017 to 2022 under rainfed condition. Optimal weather variable ranges for different phenophases of the crop determined and given in Table 4.13.

Table 4.13 Optimal weather condition for different phenophases of pearl millet for high productivity at Anand

Phase	BSS (h)	Rain (mm)	MaxT (°C)	MinT (°C)	RHm (%)	RHe (%)
Emergence-Booting	0-9.7	0-109	26-35.5	19.5-26.6	80-100	55-100
Booting-50% Flowering	0-10.1	0-13	30.2-34.4	24-26	83-100	53-85
50% Flowering-100% flowering	0-9.5	0-95	26.2-33.8	22.5-26	89-100	55-100
100% flowering-Grain filling	0-10	0-57	26.2-34.4	22.5-26	83-100	53-100
Grain filling-Phy. maturity	0-10	0-55	28.8-36.2	21.5-26.2	84-100	48-100

The phase wise weather parameters were correlated with grain yield of pearl millet for assessment of weather parameters during different phase responsible for grain yield using four years kharif season (2017-2022) data (Table 4.14). The correlation analysis revealed that the crop's production performance was negatively associated with rainfall and minimum temperature during emergence to booting phase. While the production was positively associated with morning relative humidity prevailed during same phase. Strong and statistically significant negative association (r -0.54**) with rainfall receipt during emergence to booting might be due to high rainfall events' influence on germination and initial growth of the crop. Minimum temperature till 100% flowering phase, correlated negatively. It indicates high night temperature during vegetative growth phases lowers the production 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 affect the crop up to 100% flowering.

Table 4.14 Phase wise correlation coefficient between weather parameters and pearl millet grain yield (2017-2022) at Anand (n=54)

Phase	BSS (h)	Rain (mm)	MaxT (°C)	MinT (°C)	RHm (%)	RHe (%)
Emergence- Booting	-0.20	-0.54**	-0.11	-0.28*	0.21	0.13
Booting -50% Flowering	0.05	-0.21	0.03	-0.26	-0.11	-0.15
50% Flowering-100% flowering	0.03	-0.22	0.01	-0.31*	-0.04	-0.08
100% flowering –Grain filling	-0.12	-0.12	-0.15	-0.22	0.20	0.21
Grain filling – Physiological maturity	0.19	0.24	0.21	-0.07	0.08	0.00

Solapur

The treatments of field experiment consisted of three sowing windows (2nd fortnight of June, July and August) and three varieties/hybrid (ICTP-8203, Mahyco hybrid and Dhanshakti). The crop sown in second fortnight of July (S2) produced significantly higher grain yield (1413 kg ha^{-1}) and total returns (Rs.30281 ha^{-1}) than other dates of sowing. The relationship of maximum and minimum temperature with grain yield of pearl millet was studied and the result is presented in Fig. 4.7. Both Tmax and Tmin showed non-linear relationship with grain yield. It was observed that a Tmax of 31.5 °C and a Tmin of 23.5 °C was found to be optimum for obtaining higher yield in pearl millet at Solapur.

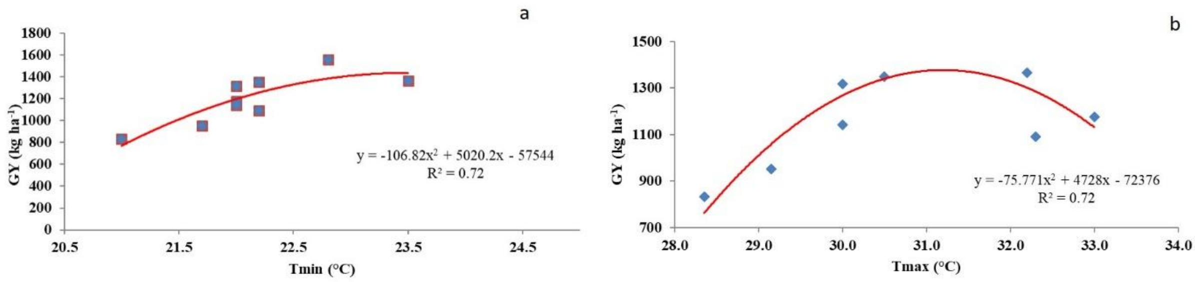


Fig. 4.7 Effect of (a) maximum temperature and (b) minimum temperature on grain yield of pearl millet at Solapur

Finger Millet

Ranichauri

Field experiment consisted of three growing environments (01 June, 10 June and 21 June 2022) and three varieties (VLM-324, PRM-2, VLM-347. The yield and yield attributes of finger millet cultivars grown under different growing environments is presented in Table 4.15.

Table 4.15 Yield attributes and seed yield of Finger millet as influenced by sowing dates and varieties at Ranichauri

Treatments	Tillers/plant at 90 DAS	Fingers/ plant	Finger length (cm) at harvest	1000- seed weight (g)	Yield (kg/ha)
Sowing date					
D1: (01.06.2022)	2.16	5.62	5.92	2.6	1134
D2: (10.06.2022)	2.60	6.01	5.93	2.83	1650
D3: (21.06.2022)	3.09	6.13	6.17	3.31	2231
SeM ±	0.08	0.14	0.04	0.07	101
CD (P=0.05)	0.25	NS	0.12	0.21	307
Varieties					
V1: (VLM-324)	2.15	5.54	5.93	2.89	1461

V2: (PRM-2)	3.04	6.63	6.16	3.00	2006
V3: (VLM-347)	2.64	5.58	5.93	2.83	1548
SeM ±	0.08	0.14	0.04	0.07	101
CD (P=0.05)	0.25	0.45	0.12	NS	307

Maximum number of tillers/plant at 90 DAS was observed with the third sowing date and it remained significantly superior over the other two sowing dates. In case of varieties, PRM-2 produced maximum tillers and remained significantly superior over the other two varieties. The interaction effect between sowing dates and varieties was found to be significant for tillers/plant. Fingers/plant was not influenced significantly by different sowing dates and varieties. However, the length of finger and 1000- seed weight was significantly influenced by sowing dates and varieties. Crop sown on the third date (21.06.2022) resulted in maximum length of both the parameters and were significantly superior over the other two dates. Among the three varieties, PRM-2 significantly recorded more finger length and maximum weight of 1000 seeds. The interaction effect of sowing dates and varieties was found to be significant for length of finger and 1000-seed weight. Seed yield was also significantly influenced by sowing dates and varieties. Sowing of crop on the third date resulted in maximum yield and it remained significantly superior over the other two dates. PRM-2 recorded maximum yield and remained significantly superior over the other two varieties.

Pigeonpea

Anantapur

A field experiment with protective irrigation and rainfed as main plot treatments, four growing environments as sub plot treatments (2nd fortnight of June, 1st fortnight of July, 2nd fortnight of July and 1st fortnight of August) and four pigeon pea cultivars (ICPL 18063, PRG 176, LRG 52 and BRG 2) was taken up during *kharif* 2022. The pigeon pea seed yield was significantly higher under protective irrigation condition. Among the varieties, PRG176 resulted in higher seed yield (698 kg ha^{-1}) compared to other varieties (Table 4.16). All pigeon pea varieties resulted in higher seed yield with early sowing (II FN June), except LRG52 and the seed yield was progressively decreased with extended time of sowing. However, BRG 2 resulted in significantly lower seed yield with I FN July sowing compared to II FN July sowing. All the varieties resulted in lower yields with late sowing (I FN August)

Table 4.16 Seed yield of pigeon pea varieties as influenced by time of sowing under rainfed and protective irrigation during 2022-23

Main plot	30.06.2022	09.07.2022	28.07.2022	15.08.2022	Mean

RF	557	599	547	342	511
PR	812	527	519	310	542
Mean	684	563	533	326	
Dates of sowing	ICPL 18063	PRG 176	LRG 52	BRG 2	Mean
RF	593	666	189	597	511
PR	624	731	142	671	542
Mean	609	698	166	634	
Varieties	ICPL 18063	PRG 176	LRG 52	BRG 2	Mean
II FN June	717	962	220	839	684
I FN July	657	732	234	628	563
II FN July	634	734	72	693	533
I FN August	426	366	136	376	326
Mean	609	698	166	634	
	I	D	V	IXD	
CD (p=0.05)	10	28	21	39	
	IxV	DxV	IxDxV		
CD (p=0.05)	30	43	60		

Green gram

Jorhat

A field experiment was conducted with four green gram cultivars as main plot treatment (SGC16, SGC20, IPM02-3 and MH 421) and three micro-climatic regimes (sown on 11 Sept, 28 Sept and 13 Oct 2022). The LAI increased gradually, reaching a peak value during the pod initiation stage. The cultivar MH 421 recorded highest LAI, measuring 1.88 during pod initiation. When compared to the crop sown on later dates (D_2: 28 September and D_3: 13 October), highest LAI was observed under the 11th of September (1.84) (Table 4.17). The better vegetative growth of the crop (emergence to budding) may be the cause of the relatively greater leaf area index measured on the first date of sowing. The crop was exposed to lower temperatures range (23.5 to 31.8 °C maximum and 10.4 to 23.4 °C minimum temperature corresponding to D_3) with delay in sowing, which impacts vegetative development and therefore lowers relative leaf expansion as well as the LAI.

Among the varieties, number of pods per plant was more in MH 421(10.57), followed by SGC 16 (10.13), SGC 20 (7.76) and least in IPM 02-3 (6.48). Likewise, among the sowing dates, maximum number of pods per plant was recorded in early (D_1) sown crop i.e., 11.55 (Table 4.17). However, with delay in sowing, number of pods per plant was found decreasing from 9.72 to 4.94 corresponding to D_2 (28 September) and D_3 (13 October), respectively. The mean pod length was maximum in IPM02-3 (7.66 cm); whereas least in SGC 16 (6.39 cm). Decrease in length of pod was observed with delay in sowing. Likewise, number of seeds per pod was found maximum when crop was sown under D_2 (9.47) followed by D_3 (9.35) and least in D_1 (9.26). Relatively, a greater number of seeds per pod was observed in mid and late sown green gram, which might be attributed to reduction in seed size when crop was exposed to low temperature during pod formation and ripening phase. Among the sowing dates, maximum test weight was observed in crop sown on 11th September (D_1) i.e., 34.16 g; and found to get reduced with delay in sowing. The weather condition pertaining to early sown crop was found optimal, thus better partitioning of photosynthates from source to sink was observed, leading to formation of bold seeds.

The yield was significantly affected by different varieties, microclimatic regimes and also by their interaction effect with CD value 17.56 kg ha^{-1}, 20.61 kg ha^{-1} and 42.02 kg ha^{-1}, respectively (Table 4.17). Among the cultivars, relatively higher seed yield was observed in MH421 (539.1 kg ha^{-1}); whereas least was observed in IPM 02-3 (432.5 kg ha^{-1}). Among the sowing dates, mean seed yield was found maximum during D_1 (545.3 kg ha^{-1}), and thereby gradually decreases with delay in sowing and becomes least in D_3 (415.8 kg ha^{-1}). The higher seed yield of the optimum sown crop might be due to the combined effects of higher values of number of pods per plant, test weight and LAI; which indirectly illustrates about the prevailing favourable weather conditions pertaining to flowering, pod-filling and maturity stages of crop sown on 11 September (D_1). However, despite of higher yield in early sown crop, less harvest index might be attributed to relative proportion of economic and biological yield corresponding to mid-sown (D_2) condition; which depicts effective partitioning of photosynthates rather than early sowing date. Furthermore, incidence of pest and disease was also found relatively more in early sown crop; which might be considered as a determining factor for early sown crop.

Table 4.17 Effect of microclimatic regimes on yield and yield attributing characteristics of *kharif* green gram during 2022 at Jorhat

Treatment	LAI at pod initiation	No. of pods per plant	Pod length (cm)	No. of seeds per pod	Test weight (g)	Yield (kg ha^{-1})	Harvest Index
Main plot treatment							
SGC16	1.63	10.13	6.39	9.18	33.16	491.2	0.25
SGC 20	1.59	7.76	6.42	9.41	32.02	470.6	0.24
IPM02-3	1.55	6.48	7.66	9.53	34.65	432.5	0.24
MH 421	1.88	10.57	6.84	9.35	34.26	539.1	0.25
Mean	1.66	8.73	6.82	9.36	33.52	483.33	0.24
CD at 5%	0.12	1.91	0.20	NS	0.14	17.56	NS
Sub plot treatment							
D_1(11 Sept.)	1.84	11.55	6.82	9.26	34.16	545.3	0.24
D_2 (28 Sept.)	1.76	9.72	6.88	9.47	33.69	488.9	0.25
D_3 (13 Oct.)	1.39	4.94	6.78	9.35	32.71	415.8	0.25
Mean	1.66	8.73	6.82	9.36	33.52	483.33	0.24
CD at 5%	0.07	1.64	NS	NS	0.11	20.61	NS
Interaction (V×D)							

CD at 5%	0.15	NS	NS	NS	0.22	42.02	NS

Groundnut

Ananthapuramu

A field experiment was taken up with two main plot treatments (rainfed and protective irrigated), four dates of sowing (Second fortnight of June, first fortnight of July, second fortnight of July and first fortnight of August) and four varieties (K6, Kadiri Harithandhra, K 1812 and TCGS 1694). The pod yield of groundnut grown under protective irrigation was significantly higher (1848 kg ha^{-1}) compared to rainfed conditions (1419 kgha^{-1}) (Table 4.18). Out of four different sowing dates (II FN June, I FN July, II FN July and I FN August), the crop sown during II FN June resulted significantly higher pod yield (2030 kg/ha) than I FN August sown crop (745 kg ha^{-1}), but was comparable with that of I FN July (1919 kg ha^{-1}) and II FN July (1840 kg ha^{-1}) sowings. Among the four varieties (K6, Kadiri Harithandhra, K 1812and TCGS 1694) evaluated, TCGS 1694 (2066 kg ha^{-1}) and K 1812 (1941 kg ha^{-1}) recorded significantly higher pod yield than Kadiri Harithandhra (1327 kg ha^{-1}) and K6 (1199 kg ha^{-1}).

Table 4.18 Yield attributes and yield of groundnut varieties as influenced by time of sowing under rainfed and protective irrigation during 2022-23.

Treatments	Filled pods/plant	Test weight (g)	Pod yield (kgha^{-1})	Haulm yield (kgha^{-1})	Biological yield (kgha^{-1})	Harvest index
Main plots (I)						
Rainfed	13.4	30.0	1419	4025	5444	0.25
Protective irrigated	14.2	31.0	1848	4349	6197	0.28
Dates of sowing (D)						
II FN June	13.8	31.8	2030	4481	6511	0.30
I FN July	14.6	30.7	1919	4498	6417	0.29
II FN July	14.2	31.3	1840	4394	6235	0.29
I FN August	12.8	28.2	745	3375	4120	0.17
Varieties (V)						
K6	10.5	30.0	1199	3801	5001	0.22
Kadiri Harithandhra	12.9	30.5	1327	3860	5188	0.24
K 1812	16.1	29.2	1941	4425	6367	0.29
TCGS 1694	15.9	32.4	2066	4660	6727	0.30
CD (p=0.05)						
I	0.44	0.8	291	158	351	0.03

D	0.74	1.8	228	148	296	0.03
V	0.72	NS	216	181	216	0.03
IXD	NS	1.2	NS	NS	NS	NS
IXV	NS	NS	306	257	306	0.04
DXV	1.44	2.5	432	NS	432	NS
IXDXV	NS	NS	NS	NS	NS	NS

The correlation studies between the pod yield and phenophase-wise weather parameters revealed that the pod yield had significant positive correlation with morning relative humidity during emergence(Table 4.19). Whereas, rainfall, rainy days, minimum temperature and growing degree days had significant negative correlation and maximum temperature and wind speed had significant positive correlation with pod yield during 50 % flowering. Significant positive correlation of rainy days, minimum temperature and afternoon relative humidity during pegging stage was evinced with pod yield of groundnut. Pod yield had a significant positive correlation with maximum, minimum temperature, sunshine, evaporation and growing degree-days and significant negative correlation with afternoon humidity during pod initiation stage.

Table 4.19 Correlation coefficients between weather parameters and pod yield of TCGS 1694 during kharif 2022 under rainfed condition at Anantapur

Weather parameters /Phenophases	Sowing – Emergence	Emergence-50% flowering	50% flowering-Pegging	Pegging - Pod development	Pod development - Maturity
RF (mm)	0.49	-0.84**	0.53	0.29	0.56
RD	0.47	-0.75**	.63*	-0.29	0.69
MAXT(C)	0.23	-0.10	0.3	0.75**	0.67
MINT (C)	0.23	0.78**	.72**	0.63*	0.71
RH1 (%)	0.58*	-0.60*	0.37	0.06	-0.79
RH2 (%)	0.29	-0.08	.74**	-0.72**	0.63
WS (kmph)	-0.20	0.61*	-0.05	0.45	0.61
SS (hr)	-0.09	-0.47	-0.29	.87**	-0.62
EVP (mm)	-0.14	0.19	-.69*	0.77**	0.61
GDD	-0.008	-0.88**	0.49	0.81**	0.123

Bangalore

Three varieties of Groundnut (viz., KCG-6, Kadri Lepakshi and K-6) were sown on two different dates of sowing (viz., 9.07.2022 and 18.7.2022). The pod and haulm yield as influenced by the treatments is presented in Table 4.20. Among the varieties, Kadri Lepakshi recorded significantly higher pod yield (1775 kg ha^{-1}) compared to K-6 (1036 kg ha^{-1}) and KCG-6 (797 kg ha^{-1}). The date of sowing had non-significant influence on groundnut pod yield. It was noticed that the first date of sowing recorded numerically higher pod yield (1307 kg ha^{-1}) as compared to the second date of sowing (1098 kg ha^{-1}). Further, interaction effect was found non-significant. The D_1V_2 (1818 kg ha^{-1}) recorded numerically higher pod yield as compared to other treatment interaction. The variety, date of sowing and interaction effects were found non-significant with the respect to haulm yield.

Table 4.20 Effect of varieties and date of sowing on pod and haulm yield of groundnut at Bangalore

Treatment	Pod yield ($kgha^{-1}$)	Haulm yield ($kgha^{-1}$)
D. Date of sowing		
D_1 (July SFN: 9.7.22)	1307	4298
D_2 (August FFN:18.7.22)	1098	4174
S.Em.±	72.48	284.8
CD (p=0.05)	NS	NS
V: Varieties		
V_1 (KCG-6)	797	4592
V_2 (Kadri Lepakshi)	1775	4305
V_3 (K-6)	1036	3811
S.Em.±	88.7	348.8
CD (p=0.05)	270.0	NS
Interaction (DXV)		
D_1V_1	957	4550
D_2V_1	638	4634
D_1V_2	1818	4475
D_2V_2	1733	4135
D_1V_3	1148	4305
D_2V_3	925	3869
S.Em.±	125.5	493.3
CD (p=0.05)	NS	NS

Soybean

Parbhani

Field experiment consisted of four growing environments (25th SMW, 26th SMW, 27th SMW & 28th SMW) and three varieties (MAUS-158, MAUS-162 & JS-335). The plant height, no. of branches/plant, yield attributes like test weight, number of pods per plant was found to be higher in MAUS-158 as compared to other varieties (Table 4.21). Among the dates of sowing higher values of these parameters were noticed in D_1 (25th SMW) as compared to other dates of sowing. MAUS-158 sown on 25th SMW was found to have the highest grain yield whereas grain yield declined in subsequent weeks sowing.

Table 4.21 Plant height, branches, yield and yield attributes of soybean during *kharif* 2022 at Parbhani

Treatments	Mean Plant Height (cm)	Mean No. of branches plant^{-1}	Mean no. of pods plant^{-1}	Test wt. (g)	Yield (kg ha^{-1})
D_1- 25th SMW	57.5	5.0	34.2	128.8	1935.1
D_{2-} 26th SMW	54.3	4.9	29.4	128.6	1628.8

D_3- 27th SMW	54.0	4.8	25.4	128.4	1402.1
D_4- 28th SMW	52.0	4.6	15.7	127.6	917.1
CD (0.05)	4.5	0.83	2.4	NS	86.2
V_1 - (MAUS-158)	58.9	4.9	28.6	128.6	1628.3
V_2-(MAUS-162)	53.5	4.8	24.6	128.3	1374.0
V_3 -(JS 335)	50.9	4.7	25.3	128.2	1410.1
CD (0.05)	4.8	NS	2.8	NS	170.8

The spectroradiometer and Leaf area meter instrument was used for the measurements of LAI & NDVI at different stages. The relation between NDVI and LAI (Fig. 4.8a) has been approximated by the fitted logarithmic curve equation $y=68.48x^2 + 661.42\ x- 136.85$ where x refers to NDVI and y to the LAI Spectroradiometer. The 'noise' in reflectance measurements certainly influenced the prediction of the vegetation optical properties and, consequently, NDVI calculation. Both NDVI and LAI measurements, however, were shown to be dependent on the stage of the vegetative growth, the denser the canopy the larger the NDVI and LAI values. The coefficient of determination of NDVI with Yield was $R^2= 0.52$ (Fig. 4.8b).

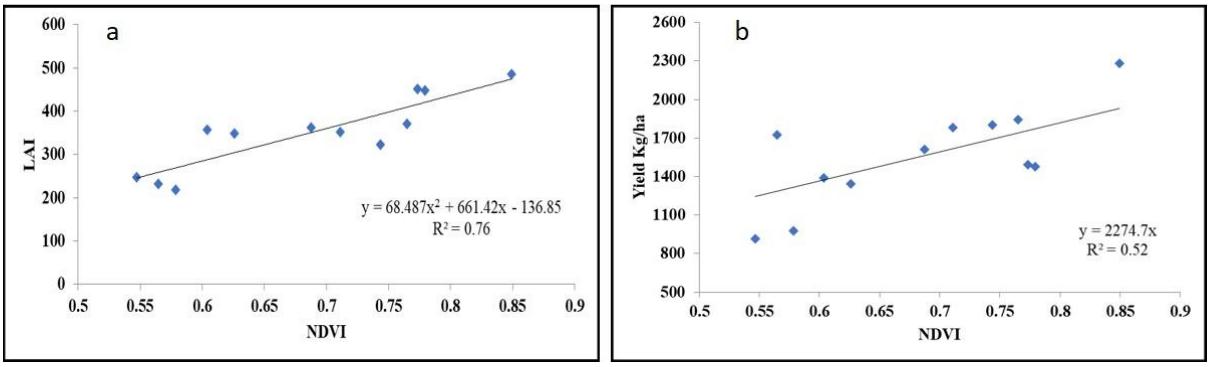


Fig. 4.8 Relationship between NDVI with (a) LAI and (b) Yield of soybean at Parbhani

Vijayapura

Crop-weather relationship study in soybean was conducted with three growing environments (08 June, 27 June and 11 July 2022) and three varieties (JS 335, DSb 21 and DSb 23-2). The data of the experiment conducted during 2016 to 2022 was pooled and statistically analysed for establishing relationships between stage-wise meteorological variables and soybean yield through correlation procedure, and the results are presented in Table 4.22. The maximum temperature, minimum temperature, minimum temperature, temperature, GDD temperature range, relative humidity range and evaporation in germination stage showed positive highly significant correlation with soybean yield, while higher values of afternoon relative humidity and rainfall were not favorable during the stage.During seedling stage, afternoon vapor pressure was negatively associated and rainfall was positively associated with final yield. During vegetative and flowering stages, only minimum temperature showed significant positive association with yield. During pod development stage, minimum temperature, morning and afternoon vapor pressure, morning and afternoon relative humidity had significant positive correlation with soybean yield, while rate of evaporation showed significant negative association.

Table 4.22 Correlation co-efficient between seed yield of soybean (all 3 varieties) and Stage-wise weather variables at Vijayapura (Pooled data of 2016-2022)

Parameter	Germination	Seedling	Vegetative	Flowering	Pod Development	Maturity
MAXT	0.56**	0.00	0.24	0.03	-0.12	-0.42**
MINT	0.49**	0.06	0.35**	0.32**	0.39**	0.26
VP1	0.43**	0.19	0.10	0.29*	0.47**	0.40**
VP2	0.04	-0.33**	0.26*	0.26*	0.57**	0.46**
RH1	-0.18	0.12	-0.03	0.21	0.54**	0.52**
RH2	-0.49**	-0.01	-0.08	0.02	0.40**	0.47**
TR	0.46**	-0.08	0.17	-0.10	-0.28*	-0.41**
RHR	0.51**	0.06	0.06	0.04	-0.21	-0.21
EVAP	0.36**	0.02	0.07	-0.26*	-0.43	-0.41**
RF	-0.34**	0.39**	-0.02	0.03	0.21	0.15
GDD	0.58**	0.13	0.18	0.13	0.21	0.19

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

Rabi 2022-23

Wheat

Palampur

A field experiment was conducted with four growing environments with the crop sown on 05th November, 20th November, 05th December and 20th December and three varieties (HD 2967, HS 490 and VL 907). wheat crop sown on 05th November produced significantly taller plants though it was at par with 20th November sowing while significantly shorter plants were observed in 20th December sowing (Table 4.23). Similar trend was observed in spike length. In case of grain yield the crop sown on 05th November, remaining at par with 20th November sowing resulted in significantly higher grain yield while significantly lower grain yield was recorded in 20th December sowing though it was at par with 05th December sowing. The straw yield and biological yield followed similar trend though the differences between 05th December and 20th December sowings were also significant.

Among varieties no significant difference was observed in plant height and spike length. Significantly higher grain yield was recorded in HS 490 though this was at par with VL 907 while HD 2967 recorded significantly lowest yield. Straw yield and biological yield also showed almost similar trend with VL 907 and HS 490 recording significantly higher values as compared to HD 2967.

Table 4.23 Plant height, Spike length, yield and yield attributes of wheat (Rabi 2022-23) at Palampur

Treatments	Plant height (cm)	Spike Length (cm)	Grain yield (kgha^{-1})	Straw yield (kgha^{-1})	Biological yield (kgha^{-1})	Harvesting index (%)
Date of sowing						
D_1: 05th Nov	106	11.1	4222	5910	10132	41.67
D_2: 20th Nov	101	10.7	4029	5927	9956	40.47
D_3: 05th Dec	93	10.1	3452	5295	8747	39.47
D_4: 20th Dec	87	9.6	3279	4871	8150	40.23
CD	8	0.8	206	285	426	1.40
Varieties						
V_1: HD 2967	94	10.0	3178	4653	7831	40.52
V_2: HS 490	97	10.5	4055	5915	9970	40.61
V_3: VL 907	99	10.6	4004	5934	9938	40.25
CD	NS	NS	160	235	355	NS

Chatha

A field experiment was conducted at Research Farm of Agrometeorology Section, SKUAST-J, Chatha, Jammu on during *Rabi* 2022-23 with the three wheat varieties (HD 2967, Raj 3077 & RSP 561) was sown on different sowing environments (05th, 20thNovember and 05th December, 2022) under randomized block design with three replications. The wheat variety (HD-2967) recorded significantly highest wheat yield (3526 kg ha^{-1}) followed by RSP-561 (3406 kg ha^{-1}) and significantly lowest in the Raj 3077 (3199 kg ha^{-1}) which may be due to highest HUE and RUE recorded by the variety HD-2967 followed by RSP-561 and Raj-3077 at all growth intervals during entire growing period (Table 4.24).

Table 4.24 Influence of different sowing environments and varieties on periodic heat use efficiency (g m^{-2} °C-day^{-1}) and Radiation use efficiency (g MJ^{-1}) in wheat crop during rabi2022-23 at Chatha

Sowing environments	Days after sowing							
	Heat use efficiency (g m^{-2} °C-day^{-1})				Radiation use efficiency (g MJ^{-1})			
	30	60	90	120	30	60	90	120
D_1- 05th Nov. 2022	0.19	0.30	0.40	0.66	0.34	0.49	0.58	0.99
D_2- 20th Nov. 2022	0.17	0.25	0.38	0.61	0.25	0.31	0.50	0.89
D_3- 05th Dec. 2022	0.16	0.22	0.35	0.58	0.24	0.29	0.49	0.86
Varieties								
V_1- HD2967	0.20	0.27	0.46	0.45	0.31	0.41	0.63	1.02
V_2- Raj 3077	0.17	0.20	0.39	0.35	0.25	0.33	0.43	0.83
V_3- RSP561	0.13	0.20	0.30	0.44	0.27	0.35	0.52	0.93

Further correlation analysis of phenophase-wise weather parameters and grain yield was carried out (Table 4.25). The jointing stage (P4) of wheat crop has significantly positive correlation with maximum temperature but negative correlation was observed with rainfall and evening relative humidity. The minimum temperature, rainfall and evaporation were significantly negatively correlated with grain yield of wheat at anthesis stage (P7). The morning relative humidity at hard dough stage and physiological maturity stage has observed positive impact, while evening relative humidity has significantly positive impact on the grain yield of wheat crop.

Table 4.25 Correlation coefficient at different growth phases between weather parameters and grain yield of Wheat during *rabi* 2015-16 to 2022-23

Weather variables → / Stages↓	Maximum Temperature (°C)	Minimum Temperature (°C)	Rainfall (mm)	EPO (mm)	Bright Sunshine hours (hrs)	Morning Relative Humidity (%)	Evening Relative Humidity (%)

P_1	0.310**	0.397**	-0.142	-0.039	0.125	-0.009	0.181
P_2	0.462**	0.538**	0.180	-0.074	-0.070	-0.099	0.140
P_3	0.490**	0.394**	-0.237*	0.067	0.443**	0.052	-0.317**
P_4	0.371**	-0.065	-0.261*	0.240*	0.273*	0.194	-0.281*
P_5	-0.241*	-0.497**	-0.244*	-0.388*	-0.217	-0.123	-0.123
P_6	-0.120	-0.331**	-0.022	-0.420**	-0.128	0.180	0.189
P_7	-0.122	-0.297*	-0.251*	-0.360**	0.071	-0.004	-0.004
P_8	-0.167	-0.285*	0.264*	-0.369**	0.104	-0.034	0.097
P_9	-0.162	-0.048	-0.065	-0.469**	-0.355**	0.175	0.314**
P_{10}	-0.213	-0.212	-0.044	-0.365**	-0.333**	0.141	0.297*

***Correlation is significant at the 0.01 level (2-tailed), * Correlation is significant at the 0.05 level (2-tailed)*
P_1- Emergence; P_2- CRI; P_3-Tillering: P_4-Jointing: P_5-Flagleaf; P_6-spike emergence; P_7-Anthesis; P_8-Milking; P_9-Hard dough; P_{10}-Physiological Maturity

Ludhiana

The meteorological parameters averaged for different growth stages of wheat cv PBW869 were computed for early, timely and late son wheat at Ludhiana (Table 4.26). Highest and lowest yield of wheat was achieved with maximum/minimum temperature during vegetative stage was within 14.6-28.6/ 6.3-15.6 ^{o}C and 19.0-27.3/ 7.3-12.7 ^{o}C, respectively, during flowering stage was within 16.4-23.0/ 6.2-9.8 ^{o}C and 23.6-30.0/ 13.5-15.5 ^{o}C, respectively and during grain development stage was within 25.6-27.9/ 10.7-15.3 ^{o}C and 26.2-32.9/ 14.3-15.7 ^{o}C, respectively.

Table 4.26 Relationship between meteorological parameters and yield of wheat cv. PBW 869, *rabi*2022-23 at Ludhiana

Phenological events	Grain yield (kgha^{-1})	Temperature (^{o}C)		Relative humidity (%)		Sunshine hour (hrs)	Rainfall (mm)
		Maximum	Minimum	Morning	Evening		
Early sowing: October 26, 2022							
Comp. emergence - CRI	6992	28.6	15.6	87.0	40.4	2.7	0.0
CRI-Jointing		22.3	8.3	93.1	43.9	6.3	0.6
Jointing- flag leaf		14.6	6.3	94.1	68.6	1.9	0.0

Flag leaf-booting		16.4	6.2	91.3	52.9	4.1	0.0
Booting-Heading		19.7	7.8	92.1	56.7	6.1	32.1
Heading-Anthesis		23.0	9.8	87.7	46.3	7.2	0.0
Anthesis- milking		25.6	10.7	89.5	42.2	7.7	0.0
Milking- Soft dough		27.2	13.1	88.8	41.0	9.3	2.8
Soft dough-Hard dough		27.9	15.3	88.1	46.8	7.6	19.2
Timely sowing: Nov 9, 2022							
Comp. emergence - CRI		25.7	8.8	93.2	29.7	8.3	0.0
CRI-Jointing		18.3	7.0	93.4	54.6	4.6	0.6
Jointing- flag leaf		19.0	8.1	91.8	58.3	5.0	32.1
Flag leaf-booting		22.6	9.0	89.3	47.1	7.6	0.0
Booting-Heading	6240	25.6	10.7	89.2	42.3	7.5	0.0
Heading-Anthesis		26.7	11.8	90.2	39.7	8.7	2.8
Anthesis- milking		28.0	13.8	88.5	41.3	10.0	0.0
Milking- Soft dough		27.2	15.4	88.4	49.1	7.0	19.2
Soft dough-Hard dough		26.3	15.4	86.7	50.8	7.7	35.6
Late sowing: Nov 30, 2022							
Comp. emergence-CRI		19.01	7.31	93.40	54.33	5.07	0.00
CRI-Jointing		18.52	7.37	91.25	55.30	5.08	32.70
Jointing- flag leaf		27.31	12.70	90.57	43.14	7.59	2.80
Flag leaf-booting		27.71	13.54	88.71	42.57	10.20	0.00
Booting-Heading	4472	30.19	15.43	87.71	39.29	9.84	6.00
Heading-Anthesis		23.60	15.50	89.75	61.50	3.00	13.20
Anthesis- milking		26.15	14.35	88.38	49.50	9.00	33.00
Milking- Soft dough		26.30	15.75	84.75	51.88	7.05	25.00
Soft dough-Hard dough		32.89	15.66	76.00	23.29	11.59	0.00

Kanpur

Maximum temperature regimes during growth and development periods influenced the yield of wheat varieties viz. K-307, K-9107, and HD-2967 sown at three dates of sowing viz., 23rd Nov., 8th Dec., and 23rd Dec. during *Rabi* 2022-23. It was observed that 23rd Nov. sown crop received lower maximum temperature during Jointing, PI, flowering, anthesis, dough and maturity stage i.e. 20.2, 24.3, 27.6, 30.9, 28.8 and 32.5 °C, respectively was congenial and favorable for growth and development of crop. The lowest temperature during reproductive stages of early sown crop (23 Nov) was more congenial for mineralization of soil nutrients and their uptake which might be responsible for higher yield (3250 kg ha^{-1}) as compared to delayed sowing of 8th Dec (2930 kg ha^{-1}) and 23rd Dec (2530 kg ha^{-1}). The data has been through graphical representations in Fig. 4.9. A 1.0 °C increase in maximum temperature during reproductive stage caused a yield reduction of 433.3 kg ha^{-1}(Fig. 4.9b).

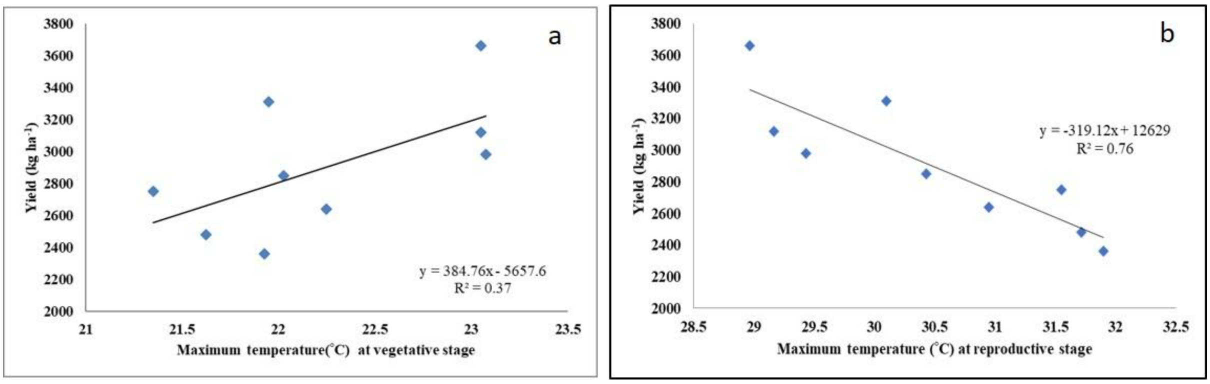


Fig. 4.9 Effect of maximum temperature during (a) vegetative and (b) reproductive stages of wheat on grain yield at Kanpur

Similarly, in the case of minimum temperature, it was noted that in early sown crop (23rd Nov.) lower minimum temperature prevailed during jointing, PI, flowering, anthesis, milking, dough and maturity stages i.e. 6.9, 10.1, 11.3, 12.2, 15.0, 16.0 and 16.5 °C, respectively was favourable for crop growth and development. The lowest minimum temperature during reproductive stages was more congenial for mineralization of soil nutrients and their uptake which resulted higher grain yield 3250 kg ha^{-1}in 23rd Nov. sowing as compared to delayed sowing of 8th Dec (2930 kg ha^{-1}) and 23rd Dec (2530 kg ha^{-1}). A 1.0 °C increase of minimum temperature during reproductive stage caused a yield reduction of 577.8 kg ha^{-1}(Fig. 4.10).

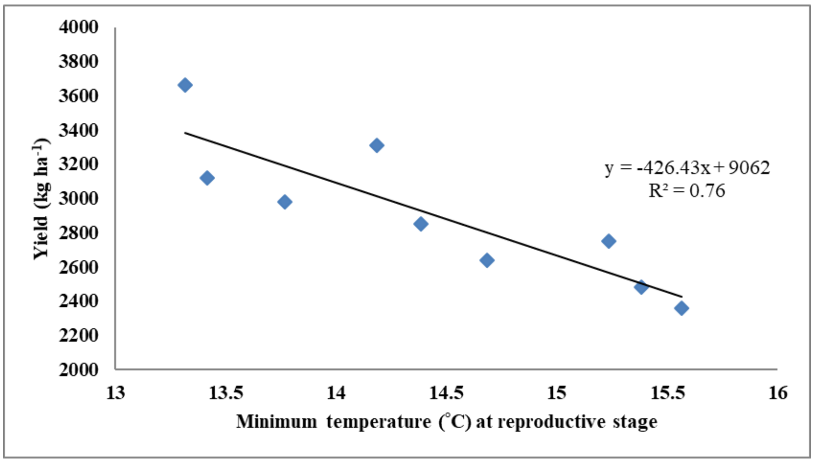


Fig.4.10 Effect of minimum temperature during reproductive stages of wheat on grain yield at Kanpur

Ranichauri

The experiment was conducted in a randomized block design (RBD) having treatment combinations of three dates of sowing (D1: November 01, D2: November 15 and D3: November 30, 2022) and three varieties *i.e.* VL-892, UP-2572 and HD-2967 under three replications. The influence of sowing dates was found to be non-significant for all the parameters given in Table 4.27.

Table 4.27 Yield attributes and yields of wheat as influenced by varieties at Ranichauri

Treatments	Plant population m^{-2}	1000-seed weight	Grain Yield (kg ha^{-1})	Biological Yield (kg ha^{-1})	Harvest index (%)
Varieties					
VL-892	266.9	35.187	927.8	2,435.19	37.9
UP-2572	202.9	36.655	873.6	2,328.24	38.2
HD-2967	152.4	33.255	534.3	1,630.56	33.3
SEm±	21.0	0.945	97.5	337.5	2.9
CD(P=0.05)	63.6	NA	295.0	589.2	NA

The data pertaining to yield attributing characters and yields *viz*. Plant population/m^2, 1000-seed weight, Grain Yield (kg ha^{-1}), Biological Yield (kg ha^{-1}) & harvest index is presented in Table 2. The influence of growing environment was found to be non-significant for all these parameters. VL-892 recorded maximum grain yield and biological yield and remained significantly superior over HD-2967 and at par with UP-2572. The harvest index was not influenced significantly by sowing dates and varieties. The interaction between the parameters were also found to be non-significant.

Rabi Maize

Kovilpatti

Field experiment consisted of three growing environments (29September, 06October, 13Octoberand 20October 2022) and four varieties (S 6850, NK 6240, RMH 3033 and Co H (M) 6). The yield, yield attributes, plant height and LAI as affected the treatments are presented in Table 4.28. Growth parameters, yield attributes and yields of maize hybrids were significantly influenced by sowing windows except 100 grain weight. Higher growth parameters *viz.*, plant height (237.4 cm), leaf area index (LAI) (5.1), rows / cob (14.2) and grains /row (29.4) grain yield (3949 kgha^{-1}) were observed during 39th SMW sown crop but was on par with 40th SMW sown crop. Among the maize hybrids evaluated, NK 6240 recorded maximum plant height (242.7 cm), LAI (5.1), rows/cob (13.9), grains /row (30.1) and test weight (29.2 g), grain yield (3881 kgha^{-1}) and this was followed by COHM 6.

Table 4.28 Influence of different sowing window and hybrids on yield and yield attributes of rabi maize at Kovilpatti

Treatments	Plant height (cm)	LAI at tasselling	Rows per cob	Grains per row	100 seed weight (g)	Grain yield (kgha^{-1})
Sowing window						
39 SMW	237.4	5.1	14.2	29. 5	29.4	3949
40 SMW	234.9	4.9	13.9	29.3	29.3	3936
41 SMW	234.5	4.9	13.7	29.4	28.7	3837
42 SMW	229.1	4.7	12.7	28.6	27.9	3456
CD (0.05)	3.84	0.12	0.29	NS	0.46	18
Hybrids						
S 6850	222.1	4.8	13.1	28.7	28	3588
NK6240	242.7	5.1	13.9	30.1	29.2	3881
RMH 3033	224.4	4.7	13.2	28.4	28.4	3674
COH (M) 6	241.9	5.0	13.6	29.4	29	3829
CD (0.05)	7.46	0.12	0.36	0.64	0.73	85

Barley

Hisar

The field experiment on barley was conducted during *Rabi* 2022-23 at Hisar with four growing environments (D_1: 9th Nov, D_2: 24th Nov, D_3: 9th Dec and D_4: 24th Dec) and four varieties (V_1: BH 393, V_2: BH 902, V_3: BH 946 and V_4: BH 885). The yield and yield attributes as influenced by the treatments are presented in Table 4.29. Growing environments and varieties showed significant effect on barley grain yield during 2022-23. The higher grain yield was recorded in D_1 (4910 kg ha^{-1}) as compared to other dates. Among the barley varieties, BH 393 recorded higher grain yield (4660 kgha^{-1}). This was at par with BH 902 (4580 kg ha^{-1}). Lower grain yield was recorded in BH 885 (4190 kg ha^{-1}) as this is two-row variety and the rest of varieties were six row varieties.

Table 4.29 Effect of growing environments and varieties on yield attributes and yield of barley at Hisar during rabi 2022-23

Treatment	ET	GS	SL	TW	GY	SY	HI
Main plot (growing environments)							
D_1 (9 Nov 22)	1113	46.6	9.22	44.9	4910	6910	0.42
D_2 (24 Nov 22)	993	50.9	9.24	46.0	4430	7100	0.39
D_3 (9 Dec 22)	853	50.8	9.82	40.3	4530	7660	0.37
D_4 (24 Dec 22)	685	47.9	9.49	38.9	3900	8060	0.34
SE(m)	29.7	1.5	0.19	1.6	120	520	0.02
CD (A) at 5%	104.9	NS	NS	5.5	427	NS	NS
Sub plot (Varieties)							
V_1 (BH 393)	855	56.6	9.66	38.8	4660	6990	0.38
V_2 (BH 902)	989	56.8	9.63	45.3	4580	8820	0.35
V_3 (BH 946)	911	57.0	9.34	41.5	4390	6510	0.43
V_4 (BH 885)	889	25.7	9.14	44.5	4190	7400	0.37
SE(m)	26.2	1.4	0.26	1.1	120	180	0.01
CD (B) at 5%	76.8	4.2	NS	3.3	357	370	0.03

ET – Effective tillers per m^2, GS – No. of Grains per spike, SL – Spike length (cm), TW – Test weight (g), GY – Grain Yield (kgha^{-1}), SY – Straw Yield (kgha^{-1}), HI – Harvest Index.

The canopy and air temperature difference (Tc-Ta) measured with the infra-red thermometer at different growth stages and presented in Table 4.30. It is evident that the crop didn't face any moisture stress up to milking stage but thereafter the moisture stress was experienced with the prevalence of high temperatures during the month of March and resulted in reduced grain yield.

Table 4.30 Crop canopy and air temperature difference (Tc-Ta, °C) at noon under different growing environments and varieties in Barley during 2022-23 at Hisar

Treatment	Tc-Ta (°C)				
	Tillering	Jointing	Anthesis	Dough	PM
Main Plot (Planting dates)					
D_1 (9 Nov 22)	-5.17	-5.61	-5.19	2.38	3.28
D_2 (24 Nov 22)	-5.34	-5.00	-4.61	2.82	3.38
D_3 (9 Dec 22)	-5.16	-4.73	-4.85	3.11	3.64

D_4 (24 Dec 22)	-4.97	-4.97	-4.83	2.94	3.57
SE(m)	0.042	0.048	0.042	0.049	0.044
CD at 5%	0.149	0.170	0.150	0.173	0.156
Sub plot (Varieties)					
V_1 (BH 393)	-4.93	-4.88	-4.80	2.70	3.60
V_2 (BH 902)	-5.08	-4.93	-4.78	2.97	3.57
V_3 (BH 946)	-5.23	-5.15	-4.90	3.01	3.45
V_4 (BH 885)	-5.40	-5.37	-5.00	2.57	3.27
SE(m)	0.049	0.060	0.053	0.060	0.047
CD at 5%	0.143	0.171	0.155	0.176	0.139

Rabi Sorghum

Kovilpatti

A field experiment was conducted with three growing environments (sown on 39 SMW, 41 SMW and 43 SMW) and four sorghum genotypes (K-12, K-8, CSV-20 and CO-30) during *rabi* 2022-2023. Effect of sowing windows on plant height, yield parameters and yield of sorghum varieties under rainfed condition during 2022-2023 is presented in Table 4.31. Higher plant height of 245.3 cm, LAI (7.05), 1000 seed weight (16.5 g) and yield (3301 kg ha^{-1}) were recorded by 41st standard week sown crop (which was on par with 39th standard week sown sorghum) than 43rd standard week sown crop. Sowing of sorghum variety CSV 20 registered significantly increased growth and yield attributes *viz.*, higher plant height (243.4 cm), leaf area index (6.78), ear head length (21.2 cm), 1000 seed weight (16.5 g), which ultimately reflected in increased grain yield of 3060 kg ha^{-1}.

Table 4.31 Effect of growing environments and varieties on growth, yield and yield attributes of Sorghum at Kovilpatti

Treatments	Plant height (cm)	LAI	Earhead Length (cm)	1000 seed weight (g)	Grain yield (kg ha^{-1})
Date of sowing					
D_1 : 39thSMW	241.3	6.65	20.83	16.4	3012
D_2: 41st SMW	245.3	7.05	21.33	16.5	3301
D_3: 43rdSMW	134.4	4.78	16.87	12.7	1229
SEd	6.38	0.27	0.30	0.27	124

CD (5 %)	17.71	0.74	0.82	0.76	346
Sorghum varieties					
V_1: K 12	209.9	6.52	20.31	15.2	2482
V_2: K 8	182.4	5.34	17.40	14.0	2242
V_3: CSV 20	243.4	6.78	21.17	16.5	3060
V_4: CO 30	192.1	5.99	19.82	15.1	2270
SEd	8.97	0.26	0.30	0.18	66
CD (5%)	18.85	0.55	0.63	0.37	139
M at S SEd	14.89	0.47	0.54	0.38	159
M at S CD (5%)	33.13	1.09	1.24	0.93	400
S at M SEd	15.54	0.45	0.52	0.31	114
S at M CD (5%)	32.64	0.95	1.09	0.64	240

Chickpea

Raipur

Chickpea crop was sown during r*abi* 2022-2023 with three varieties V_1- Vaibhav, V_2- JG-14 (ZC), and V_3- JG-16. There were three growing environments D_1-10/11/2022, D_2-25/11/2022, D_3-10/12/2022. Heat stress limits chickpea growth and vigor at all phenological stages, but the reproductive phase is considered more sensitive to temperature extremes than the vegetative stage. Heat stress during reproduction generally reduces flower number, increases flower abortion, alters anther locule number decrease, causes pollen sterility with poor pollen germination, reduces fertilization and stigma receptivity, causes ovary abnormalities, reduces the remobilization of photosynthates to seeds, and reduces seed number, seed weight and seed yield. Heat stress is a major factor limiting growth of cool season crops in the transitional and warm climatic regions.
Heat Susceptibility Index (HSI) in Chickpea was worked using the formula

Heat Susceptibility Index (HSI) = (1-YL/YN)/(1-XL/XN)

Where,
YL= Mean seed yield of a line under late sown conditions;
YN= Mean seed yield of a line under normal sown conditions; XL= Mean seed yield of all line under late sown conditions; XN= Mean seed yield of all line under normal sown conditions.

Heat Susceptibility Index Range
HSI< 0.5 were considered as heat tolerant,
HSI 0.5 to 0.99 were considered as moderately heat tolerant and HSI >1.0 were considered as heat susceptible.

The results are presented in Table 4.32. JG-14 and JG-16 varieties were found heat susceptible and Vaibhav variety was found moderately heat tolerant variety.

Table 4.32 Yields and heat susceptibility index (HSI) of different varieties of chickpea under normal (N) and late (L) sown conditions

Varieties	D_1- 10/11/2022 (Normal Sowing)	D_3-10/12/2022 (Late Sowing)	HSI Value
V1- Vaibhav	1296.97	1005.05	0.87
V2- JG 14	1100.94	797.84	1.06
V3- JG 16	1480.52	1071.43	1.07
Total mean	1292.81	958.1	

Ranchi

Experiment was conducted at Ranchi centre with three varieties of chickpea viz., JG14, GNG 1581 and Birsa Chana 3 which were sown on 10th Nov (Early), 25th Nov (Normal) and 10th Dec (Late) to find out the response of chickpea to varied weather conditions. Yield and yield defining characters were significantly influenced by varied thermal regimes as well as varietals differences. Average performance of chickpea sown by 25th Nov (Early) was significantly higher (1701 kg ha^{-1}) than crop sown on 10th Nov (1115 kg ha^{-1}) and 10th Dec. (1012 $kgha^{-1}$) during 2022-23 (Table 4.33). Among the varieties, significantly higher yield was recorded by BirsaChana3 (1416 $kgha^{-1}$) with 49 % harvest index followed by JG 14 (1288 kg ha^{-1}) and GNG 1581 (1125 $kgha^{-1}$). Although 100 seed weight of JG 14 variety was higher than Birsa Chana 3 and GNG 1581 other yield attributing character viz. no. of seed per pod was found lower than BirsaChana3, which reduced the yield of JG 14.

Table 4.33 Effect of dates of sowing and cultivars on yield and yield attributes of chick pea at Ranchi during rabi 2022-23

Treatments	No. of filled pod/plant	No. of seed/pod	100 seed wt (g)	TDM (kg ha^{-1})	Yield (kg ha^{-1})	HI (%)
			Date of sowing			
Early	31	1.4	17.2	3075	1701	55
Normal	30	1.2	17.5	2475	1115	45
Llate	22	1.4	17.4	2316	1012	44
S Em	1.8	0.05	0.14	75	48	1
C D at 5%	5.4	NS	NS	226	145	4.3
			Variety			
JG 14	27	1.1	23.7	2617	1288	49
GNG 1581	25	1.6	14.6	2431	1125	46
BirsaChana3	31	1.3	13.8	2818	1416	49
S Em	1.8	0.05	0.14	75	48	1
C D at 5%	NS	0.17	0.4	226	145	NS
Interaction						
S Em	3.1	0.09	0.2	130	83	2.5
C D at 5%	NS	NS	NS	392	251	NS

Vijayapura

Chickpea varieties JG-11, BGD -111-1, Jaki -9218, BGD -103 and Vijay were grown under four growing environments to study the crop weather relationships. Field experiment data during 2017-2022 was pooled and correlation of phenophase-wise weather parameters with seed yield was undertaken. The data indicate significant association of yield with weather parameters mainly in flowering and pod development stages. Maximum temperature during flowering to maturity stages had negative correlation with seed yield (Table 4.34). During flowering stage, correlation of minimum temperature, morning vapor pressure, afternoon vapor pressure, afternoon relative humidity, cumulative sunshine duration, morning and afternoon cloud cover, and growing degree days with yield was positive. During the pod development stage, yield was positively influenced by cumulative sunshine duration, rainfall and growing degree days, but negatively associated with evaporation and daily sunshine duration. The most influencing parameter over all stages was cumulative sunshine duration with high positive significance.

Table 4.34 Correlation co-efficient between seed yield of chickpea (mean of all 5 varieties) and stage wise agrometeorological variables at Vijayapura (2017-2022)

Parameter	Germination	Seedling	Vegetative	Flowering	Pod Development	Maturity
MAXT	-0.08	0.24*	0.00	-0.55**	-0.34**	-0.30**
MINT	-0.10	0.11	0.15	0.39**	0.16	-0.12
VP1	-0.09	0.05	0.08	0.40**	0.26*	0.07
VP2	0.01	0.02	0.00	0.41**	0.18	0.05
RH1	-0.04	-0.13	-0.12	0.22*	0.30**	0.21*
RH2	-0.03	-0.06	-0.02	0.51**	0.24*	0.14
TR	0.05	-0.01	-0.15	-0.51**	-0.25*	-0.10
RHR	-0.17	-0.07	-0.05	-0.57**	-0.11	0.13
CUMSUNS	0.76**	0.76**	0.78**	0.75**	0.75**	0.74**
CC I	-0.07	-0.11	0.20	0.58**	0.28**	0.10
CC II	-0.27**	-0.06	0.09	0.50**	0.26*	0.27**
EVAP	0.05	0.09	-0.23*	-0.76**	-0.53**	-0.34**
BSS I	0.09	0.07	-0.23*	-0.74**	-0.33**	-0.15
RF	-0.10	-0.22*	-0.07	0.24*	0.31**	-0.10
GDD	0.15	0.43**	0.38**	0.49**	0.29**	0.07

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

Anantapur

The field experiment consisted of three growing environments (Second fortnight of October, first fortnight of November and second fortnight of November 2022) and three chick pea varieties (JG-11, NBeG-3 and NBeG-49). The mean seed yield with II FN of October was higher (1005 kg ha^{-1}) as compared to I FN of November (931kg ha^{-1}) and II FN of November (939kgha^{-1}). Among the varieties, the mean seed yield with all three varieties (JG-11, NBeG 3 and NBeG 49) evaluated NBeG 49 has recorded highest seed yield (1112 kg ha^{-1}) followed by JG-11 (907 kg ha^{-1}) (Table 4.35). The variation in seed yield of chickpea was not significant with respect to sowing dates and varieties evaluated.

Table 4.35 Yield and yield attributes of chickpea as influenced by sowing environment and varieties during *rabi* 2022-23 at Anantapur

Treatments	No. of branches per plant	Days to 50% flowering	Days to maturity	No. of pods perplant	Yield (kg ha^{-1})
Sowing date					
II FN October	11.1	42	90	25.3	1004
I FN November	6.5	40	89	17.7	931
II FN November	9.6	40	89	20.0	939
CD (p=0.05)	1.6	NS	NS	2.2	NS
Variety					
JG-11	8.7	39	88	20.9	906
NBeG-3	10.2	42	90	22.8	856
NBeG-49	8.3	41	91	21.3	1112
CD (p-0.05)	NS	1	NS	NS	NS

Solapur

A field experiment with four growing environments [S_1- MW 38 (Sept 17-23), S_2- MW 40 (Oct. 01-07), S_3 - MW 42 (Oct. 15-21), S_4 - MW 44 (Oct. 29- Nov.04)] and two varieties V_1- Vijay, V_2- Dig Vijay) was undertaken. The impact of growing environments and cultivars on yield of chick pea was studied by pooled analysis of experiments conducted during rabi 2016-17 to 2022-23. The results indicated that among the growing environments, crop sown during 38 SMW recorded highest yield (913 kg ha^{-1}), followed by SMW 40 (Table 4.36). Among the cultivars, Digvijay recorded higher yield compared to Vijay.

Table 4.36 Pooled yield (kg ha^{-1}) of*rabi* chickpea as influenced by various sowing dates and varieties at Solapur (2016-17 to 2022-23)

Treatment	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	Pooled	SYI
Main-Sowing dates									
S_1 = MW 38	1255.8	660.0	564.5	712.5	1061.2	832.4	1305.6	913.14	0.47
S_2 = MW 40	1113.1	510.6	467.1	507.9	880.3	1164.2	1166.14	829.91	0.42
S_3 = MW 42	985.6	483.2	413.3	396.5	769.0	881.2	1011.60	705.77	0.42
S_4= MW 44	812.3	354.5	310.3	342.7	465.9	683.1	711.26	525.72	0.41
Mean	1041.7	502.1	438.8	489.9	794.1	890.2	1063.65	745.78	0.43
Sub-Two varieties									
V_1 = Vijay	937.1	433.9	371.6	439.7	751.6	839.1	972.09	677.87	0.44
V_2= Digvijay	1146.3	570.3	506.0	540.1	836.6	941.3	1155.22	813.69	0.47
Mean	1041.7	502.1	438.8	489.9	794.1	890.2	1063.55	745.78	0.45
S.E.± (Sowing dates)	25.2	29.1	26.7	40.4	41.4	32.1	36.7	33.09	
C.D. at 5 %	80.6	93.1	85.4	129.2	132.3	102.8	109.2	104.66	
S.E.± (Varieties)	20.1	19.2	15.7	26.7	27.5	25.4	8.0	20.37	
C.D. at 5 %	62.0	59.2	48.3	82.2	84.8	78.1	23.4	62.57	
S.E.± (SD X V)	40.2	38.5	31.3	53.4	55.0	50.7	16.0	40.73	
C.D. at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	

Green gram

Mohanpur

Series of green gram experiments were conducted in the rabi season of AICRPAM Mohanpur center starting from the year 2017 to 2021. Response surface methodology is applied to develop a green gram yield prediction model. Samrat, PM-05 and Meha varieties are considered in this study and for regression purposes they are coded as 1, 2 and 3, respectively. In this study a second order model was developed using diurnal temperature variation and rainfall to understand the dynamics of the two-input variable considering the variety effect. Then a first order model was developed to check the feasibility of the model across any variety of green gram (Table 4.37). The “rsm” package from R software was used to perform the regression.

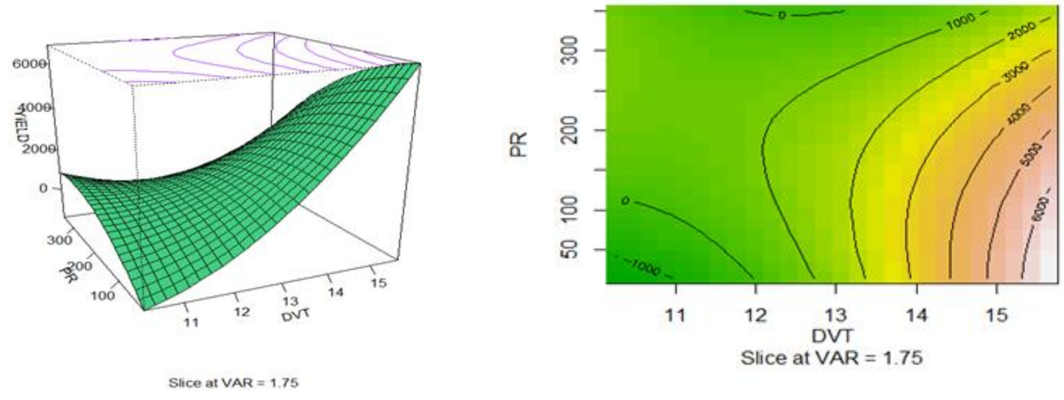
Table 4.37 Variables selected and performance evaluation of two response surface models for green gram yield prediction at Mohanpur

	MODEL-1		MODEL-2	
Linear variables	Variety		Rainfall, Diurnal temperature variation	
Non-linear variables	Rainfall, Diurnal temperature variation		-	
	Calibration	Validation	Calibration	Validation
MAE	48.99	117.93	116.82	195.27
RMSE	62.81	150.09	156.28	236.02
NRMSE %	14.9	38.3	37.1	60.3
NSE	0.98	0.84	0.86	0.61
d	0.99	0.97	0.96	0.91
R2	0.98	0.94	0.86	0.71
bR2	0.98	0.88	0.85	0.69
KGE	0.98	0.79	0.9	0.79

With the second order ‘rsm’ model developed with diurnal variation of temperature and rainfall with the yield of green gram performed exceptionally well with an adjusted r^2 of 0.98 in calibration process and 0.88 in the validation period. This indicates that the linearity-maintained variety wise and combination of second power polynomials of diurnal variation of temperature and rainfall have a significant effect on yield. Though the nRMSE value of the model performance is high (38%) while Kling Gupta efficiency was found 0.79 during the validation period which is quite reliable.

$$YIELD = 1333.8 + 19.2 \times VAR + 682.2 \times DVT - 7.1 \times PR - 4.0 \times DVT \times PR + 183.9 \times (DVT)^2 - 0.03 \times (PR)^2$$

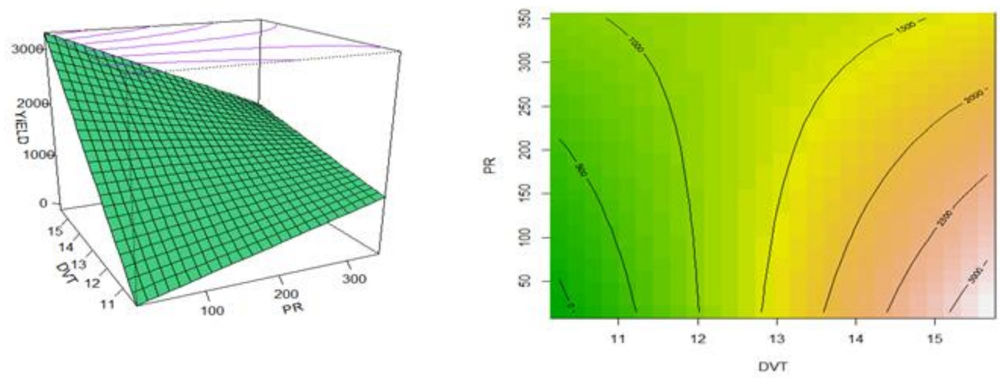
$$YIELD = 1387.5 + 309.9 \times DVT - 1.01 \times PR - 1.5 \times DVT \times PR$$



a. **b.**

Fig. 4.11 Varietal Response of green gram yield with respect to diurnal variation of temperature and rainfall: (a) 3d response diagram, and (b) contour plot

In Fig.4.11, the green gridded surface is the ultimate response of yield imparted by diurnal temperature variation and rainfall considering linear varietal effect. It is clearly visible that with increased diurnal variation in temperature the yield is expected to increase. On the other hand, rainfall has a relatively lower impact on green gram yield. From the contour plot Fig. 3.b, we can visualize the response of the variables in the upper surface of the cube through contour lines. It is simulated that ~13°C of diurnal temperature variation combined with 200 mm rainfall yields 1000 kgha^{-1} of green gram.



a. **b.**

Figure 4.12 Response of green gram yield with respect to diurnal variation of temperature and rainfall: (a) 3d response diagram, and (b) contour plot

In the Fig. 4.12, the response of green gram yield was captured irrespective of variety to create a generalized model for green gram. The figure indicates that decreasing rainfall with increased diurnal temperature variation increases the yield of green gram. The two-way linear rsm model performed well in the calibration period with an adjusted r^2 of 0.85 and relatively higher nRMSE value (37.1%). Though the adjusted r^2 value and nRMSE value of validation period is 0.69 and 60.3%, the d-index (0.91) and kling-gupta efficiency (0.79) indicates its predicting capability. The two models clearly indicated that the rainfall has a detrimental effect on rabi green gram yield. Diurnal temperature variation greater than 13 °C associated with rainfall less than 200 mm can generate yield more than 2000 kg ha^{-1}.

Potato

Hisar

The field experiment on potato was conducted during *Rabi* 2022-23 at Hisar with four growing environments (D1: 8th Nov, D2: 18th Nov, D3: 28th Nov and D4: 8th Dec) and three varieties (V_1: Kufri Bahar, V_2: Kufri Pushkar and V_3: Kufri Lima). The tuber yield is influenced by different growing environments and are presented in Table 4.38. The crop sown on November 18 (D_2) produced a greater yield of 37640 kg ha^{-1}. It was followed by crops sown on December 8 (D_4), (November 28 (D_3) and November 8 (D_1) which produced tuber yields of 29620 kg ha^{-1}, 28650 kg ha^{-1} and 23820 kg ha^{-1}, respectively. Under various growth conditions, tuber yield varied significantly. In terms of variety, Kufri Pushkar had the highest tuber yield (35120 kgha^{-1}), followed by Kufri Lima (27150 kgha-1), and Kufri Bahar (25460 kg ha^{-1}). During the crop season the potato crop encountered the two episodes of frost occurrences (15-18 Jan and 27-28 Jan 2023) which affected the D_1 crop more adversely as it was in tuber bulking stage and did not have sufficient time to recover from the damage by the frost.

Table 4.38 Effect of growing environment on yield of potato varieties at Hisar

Yield attributes				
Treatment	No. of tubers per plant	Tuber yield per plant (g)	Tuber yield (kg ha^{-1})	Haulm yield (g plant^{-1})
Factor A (Growing environments)				
D1 (8th Nov)	6.0	285.8	23820	141.0
D2 (18th Nov)	10.0	451.7	37640	161.6
D3 (28th Nov)	9.0	343.8	28650	158.7
D4 (8th Dec)	8.0	355.4	29620	150.0
SE(m) ±	0.31	25.41	2117	3.86
CD at 5%	0.99	82.44	6870	12.52
Factor B (Varieties)				
V1 (Kufri Bahar)	8.0	307.3	25610	150.5
V2 (Kufri Pushkar)	11.0	425.3	35440	155.1
V3 (Kufri Lima)	7.0	344.9	28740	152.9
SE(m) ±	0.27	12.45	1038	2.63
CD at 5%	0.78	36.56	3046	NS

The spectral reflectance pattern (spectral signature) of the Kufri Pushkar variety under different growing environments at tuber bulking (maximum canopy) stage is presented in Fig. 4.13. The Kufri Pushkar variety showed that the late sown crop i.e. 8th Dec has highest reflectance in all wavelength bands and 18th Nov sown crop has lowest reflectance in visible band and the 28th Nov sown crop recorded lowest reflectance in NIR band. The lowest reflectance in visible region of electromagnetic spectrum shows higher radiation absorption by chlorophyll by crop sown on 08 Dec. This might be one of the reasons for higher tuber yield of crop sown during 08 Dec.

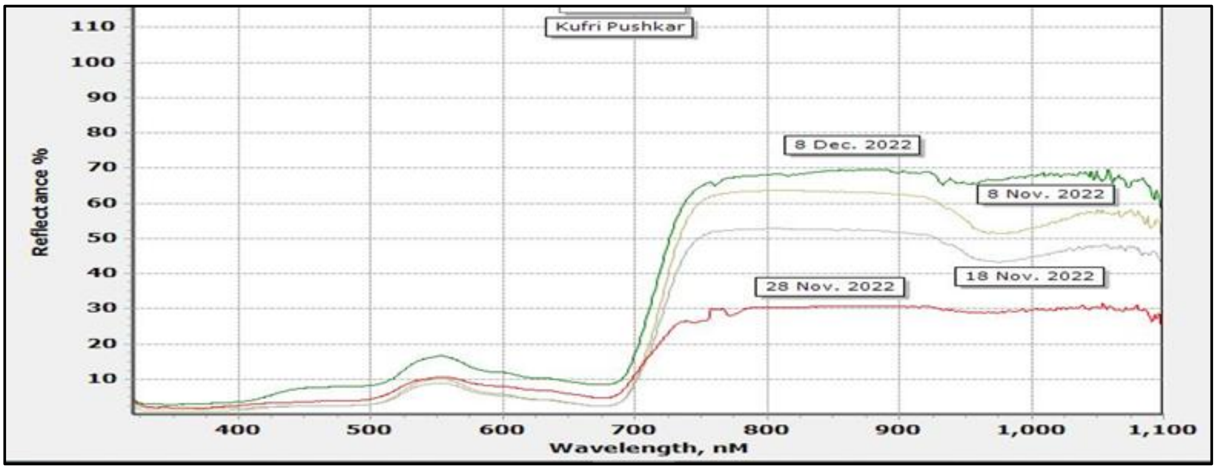


Fig. 4.13 Spectral reflectance pattern of potato variety Kufri Pushkar under growing environments at Hisar

Mustard

Palampur

A field experiment was conducted with three growing environments (crop sown on 20th October, 30th October and 10th November 2022) and three genotypes (HPN-1, GSL-1 and ONK-1) during 2022-23. It was found that, 8-12 days were taken to complete emergence in all the dates of sowing. Accordingly, crop sown on third date got 16-17 days lesser for maturity compared to first two sowing dates (Table 4.39). It was the main reason for lower yield by the crop sown on 10 Nov. Higher seed yield of *gobhi sarson* was recorded when the crop was sown on 20th October followed by 30th October sowing and 10th November sowing in that order (Table 4.40). Among the varieties, the yield of HPN-1 and GSL-1 was on par and was higher than that of ONK-1.

Table 4.39 Influence of growing environments and varieties on phenology of mustard at Palampur during rabi 2022-23

Treatment	Days to	Days to	Days to 50%	Days to 90% pod	Days to physiological

	emergence	first flower	flowering	formation	maturity
Varieties					
V_1: GSL 1	10.33	100.67	110.33	120.33	160.00
V_2: HPN 1	9.33	102.00	110.67	122.33	160.33
V_3: ONK 1	9.67	100.67	111.33	121.33	159.67
CD	NS	NS	NS	NS	NS
Date of sowing					
D_1: Oct 20	8.67	107.33	117.00	128.33	168.00
D_2: Oct 30	9.67	101.67	110.67	121.67	160.33
D_3: Nov 10	11.00	94.33	104.67	114.00	151.67
CD	0.82	6.13	6.20	6.48	7.02

D_1: 20 Oct; D_2: 30 Oct; D_3: 10 Nov; V_1: GSL-1; V_2:HPN-1; V_3: ONK-1

Table 4.40 Influence of growing environments and varieties on phenology, final biomass and seed yield of mustard at Palampur during rabi 2022-23

Treatment	Emergence	50% Flowering	Physiological maturity	Final biomass (kg ha^{-1})	Seed yield (kg ha^{-1})
$V_1 D_1$	9	117	168	4535	1247
$V_1 D_2$	10	110	160	4249	1137
$V_1 D_3$	12	104	152	3713	1005
$V_2 D_1$	9	116	168	3980	1219
$V_2 D_2$	9	111	161	3764	1150
$V_2 D_3$	10	105	152	3148	1047
$V_3 D_1$	8	118	168	3555	1191
$V_3 D_2$	10	111	160	3384	1027
$V_3 D_3$	11	105	151	3248	934
CD	1.41	10.7	12.2	260	80

Faizabad

A field experiment with three growing environments (25 Oct, 04 Nov and 14 Nov 2022) and three varieties (NDR-8501, Bio-902 and Varuna) was undertaken at Faizabad. Number of siliquae plant^{-1}, Length of siliqua (cm.), No of Seeds siliqua^{-1}, Test weight (g) as affected by growing environment and varieties have been presented in Table 4.41. Different crop growing environment had influenced significantly to all the yield attributes except test weight. Higher value of yield attributes was recorded in 25th October sowing which was significant over 4th Nov. and 14th Nov. sowing. Among the varieties, NDR-8501 recorded higher values of yield attributes compared to other varieties under study. The highest yield was recorded when crop was sown on 25th Oct. Higher yield was recorded with NDR-8501 variety, which was significant over the yield of Varuna and Bio-902.

Table 4.41 Yields attributes of mustard as affected by growing environment and varieties at Faizabad

Treatments	No of Siliquae plant^{-1}	Length of siliqua (cm)	No of Seeds siliqua^{-1}	Test weight (g)	Seed yield (kg ha^{-1})	Biological yield (kg ha^{-1})
Crop Growing environment						
25 Oct.	282.4	7.4	14.2	4.4	1920	8510
04 Nov.	271.5	7.5	12.2	4.2	1830	6750
14 Nov.	243.6	6.4	11.3	4.5	1560	5810
SEm±	4.14	0.15	0.23	0.03	333	159
CD at 5%	12.13	0.32	0.74	NS	985	451
Varieties						
NDR-8501	295.1	7.2	14.3	4.2	1820	8160
Bio-902	270.2	6.3	13.7	4.3	1650	7150
Varuna	242.3	6.4	11.6	4.7	1760	6240
SEm±	4.14	0.13	0.23	0.04	331	151
CD at 5%	12.16	0.32	0.74	NS	985	456

Anand

A field experiment was conducted with four growing environments (D_1- 10th October, 2022, D_2- 20th October, 2022, D_3- 30th October, 2022, D_4- 10th November, 2022) and three mustard varieties (V_1**:** Bio 902, V_2**:** GM 3, V_3**:** GDM 4) during *rabi* 2022-23. Crop weather relationship mustard was studied using field experimental data of *rabi* seasons of years 2017-18 to 2022-23. The phase wise average weather parameters were correlated with yield of mustard using six years' rabi season (2017-18 to 2022-23) data. Maximum temperature, minimum temperature and morning relative humidity prevailed during early growth stages (up to flowering initiation) of mustard have strong positive association with seed yield (Table 4.42). Sunshine hours and afternoon relative humidity of initial growth phases were not associated to crop yield. Only maximum of all phases had statistically significant with productivity. BSS and temperatures of pod initiation to maturity had negative association to yield which agrees with the nearly linear drop in crop yields with delay in sowing. Afternoon relative humidity of this phase was positively associated to the crop yield. 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.

Table4.42 Phase wise correlation coefficient between weather parameters and mustard pod yield (2018-2023) at Anand. (*n*=72)

Phase	BSS (h)	MaxT (°C)	MinT (°C)	RHm (%)	RHe (%)
Emergence – Early vegetative	0.04	0.65**	0.37**	0.55**	0.21
Early vegetative -Flowering initiation	0.01	0.58**	0.26*	0.50**	-0.03
Flowering initiation – Pod initiation	0.06	0.20	0.00	0.10	-0.02
Pod initiation – Seed development	-0.13	0.24	0.07	0.08	0.04
Seed development – Physiological Maturity	-0.36**	-0.32**	-0.28*	0.10	0.32**

The statistical analysis yield and yield attributes are given in Table 4.43. Results showed that yield and all yield attributing characters were significantly influenced by growing environments (started from different dates of sowing), except plant population. Significantly higher grain yield, straw yield, number of siliquae per plant, number of grains per silique, grain weight per plant and test weight were recorded under variety V_2 (GM 3). Maximum plant height was recorded in D_1 sowing and variety V_2. Leaf partitioning was recorded higher during vegetative growth in all the dates of sowing and varieties, which declined during reproductive phase. Partitioning of stem was increased with growing period in all the dates of sowing and varieties. Partitioning of root was low during early growth, slightly increased during middle stage and then declined during late growth stages in all treatments.

Table 4.43 Seed yield, straw yield, harvest index, siliquae plant^{-1}, seeds silique^{-1} seed weight plant^{-1}, test weight and plant population per meter row length of mustard as influenced by different sowing environment and variety at Anand

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha-1)	HI (%)	Number of siliquae plant-1	Number of grains silique-1	Grain weight plant^{-1} (g)	Straw weight plant^{-1} (g)	Test Weight (g)	Plant popu-lation per meter row
Mean for date of sowing									
D_1	1677	6905	19.5	564	12.5	26.9	38.5	5.71	9.00
D_2	1616	6503	20.0	506	12.3	25.9	36.3	5.44	9.25
D_3	1450	6403	18.5	485	12.0	24.5	35.6	5.24	9.42
D_4	1203	5294	18.6	433	11.3	21.4	29.1	4.79	9.42
S.Em.±	40	179	0.3	14	0.2	0.9	1.3	0.16	0.22
C.D. at 5%	129	571	1.0	44	0.7	2.8	4.2	0.51	NS
C. V. %	9.39	9.87	5.63	9.63	6.20	12.21	13.06	10.43	8.19
Mean for variety									
V_1	1484	6303	19.1	491	12.0	25.1	35.5	5.23	9.25
V_2	1544	6528	19.1	539	12.4	26.3	34.8	5.59	9.44
V_3	1431	5998	19.3	460	11.7	22.6	34.4	5.07	9.13
S.Em.±	27	135	0.5	18	0.2	0.9	0.8	0.12	0.22
C.D. at 5%	79	394	NS	52	0.6	2.5	NS	0.34	NS
C. V. %	7.29	8.62	9.31	14.44	6.35	13.82	9.45	8.88	9.56
Significant interaction	Combination		Parameter						
	D x V		Number of grains per siliquae, Test weight						

Horticultural Crops

Mango

Dapoli

An attempt was made to develop a weather base statistical model for forecasting of meteorological week for emergence of vegetative flush in mango cv. Alphonso by using step down multiple regression equations. Data regarding weather parameters and actual meteorological week of vegetative flush recorded at Dapoli center during the period of 1997-98 to 2020-21 (22^{nd} Years) were used and developed prediction model was tested for two years at Dapoli, Phondaghat, Mulde, Rameshwar and Vengurla locations of South Konkan region and Palghar location of North Konkan region by using data of respective center. The step-down multiple regressions of meteorological week of vegetative flush as a dependent character and weather components as independent character for twenty-two years are presented in Table 4.44.

Table 4.44 Step down multiple regression equation for predicting time of appearance of vegetative flush in mango at Dapoli

Regression equation	R^2	F value
MW for Veg. flush = 21.102+0.949*TMAX-0.421*TMINI (Weather during vegetative flush)	0.71**	23.77
MW for Veg. flush = 26.040+0.831*TMAX-0.458*TMINI (Weather one week before vegetative flush)	0.75**	28.37
MW for Veg. flush = 7.571+1.128*TMAX (Weather two weeks before vegetative flush)	0.65**	40.70
MW for Veg. flush = 31.600+0.757*TMAX-0.551*TMINI (Weather before three weeks vegetative flush)	0.75**	28.06
MW for Veg. flush = 26.848+1.110*TMAX-0.768*TMINI (Weather four weeks before vegetative flush)	0.64**	16.48

** significance at 1 %

It is revealed from step down multiple regression equation of meteorological week for emergence of vegetative flush, that the weather parameters, maximum temperature and minimum temperature were contributed to variability for emergence of vegetative flush in mango and its applicability was 71, 75, 65, 75 and 64 percent in the same week, at one week, two weeks, three weeks and four weeks before emergence of vegetative flush, respectively.

The prediction model for forecasting of meteorological week for vegetative flush in mango cv. Alphanso is as under;

Meteorological week for vegetative flush emergence in mango cv. Alphonso (3 weeks before) = 31.600+0.757*TMAX-0.551*TMINI (R^2 = 0.75**)

Meteorological week for vegetative flush emergence in mango cv. Alphonso (4 weeks before) = 26.848+1.110*TMAX-0.768*TMINI (R^2 = 0.64**)

The trigger values of weather parameters influencing emergence of vegetative flush in mango cv. Alphonso are presented in Table 4.45.

Table 4.45 Trigger values of weather parameters influencing emergence of vegetative flush in mango at Dapoli

Sr. No.	Period	Weather parameters			
		Maximum temperature	Significance	Minimum temperature	Significance
1.	Three weeks before	25.8 to 34.7	1%	15.2 to 23.7	5%
2.	Four weeks before	26.9 to 34.6	1%	19.6 to 24.1	N.S.

The data regarding validation of prediction model for meteorological week of vegetative flush in mango cv. Alphonso, three and four weeks before vegetative flush are presented in Table 4.46. The data revealed that the error percent in predicting meteorological week of vegetative flush in mango cv. Alphonso, three and four weeks before vegetative flush at different locations in Konkan region, was in the range of 1.15 to 9.52 per cent in both the years of validation with RMSE value of 1.07 to 3.09 per cent. This means the models developed for predicting meteorological week of vegetative flush in mango cv. Alphonso, three and four weeks before vegetative flush is predicted to the correction of 90 per cent and above and model is accepted for prediction of meteorological week of vegetative flush in mango cv. Alphonso, three and four weeks before vegetative flush.

Table 4.46 Error percentage of predication model for forecasting meteorological week for emergence of vegetative flush in mango at Dapoli

Location	Error in predicting meteorological week for emergence of vegetative flush (%)											
	2021-22						2022-23					
	Before Three week			Before Four week			Before Three week			Before Four week		
	Error	S.D.	RMSE	Error	S.D.	RMSE	Error	S.D.	RMSE	Error	S.D.	RMSE
Dapoli	1.69%	1.14	1.30%	3.64%	1.70	1.91%	1.99%	1.91	1.41%	3.08%	3.60	1.75%
Phondaghat	2.82%	1.06	1.68%	1.19%	1.18	1.09%	1.15%	0.82	1.07%	2.49%	1.60	1.58%
Mulde	3.80%	2.72	1.95%	6.92%	4.01	2.63%	1.38%	0.93	1.18%	4.51%	2.17	2.12%
Rameshwar	4.59%	0.48	2.14%	7.78%	0.69	2.79%	4.58%	0.55	2.14%	9.52%	0.80	3.09%
Vengurla	3.40%	1.32	1.84%	7.46%	1.97	2.73%	-	-	-	-	-	-
Palghar	4.73%	2.83	2.17%	5.53%	2.04	2.35%	5.80%	2.52	2.41%	5.09%	2.58	2.26%

Cashew

Dapoli

The phonological observations of cashew were collected from 15-25-year-old trees (10 plants) at weekly intervals on 20 shoots per tree (5 shoots tagged each direction). Out of 10 selected plants, five plants of variety Vengurla-4 and five local type plants were selected for experiment. Correlation between mean weather parameters with different phonological stages was studied from June 2019 to May 2022 and significant results are presented in Table 4.47.

Table 4.47 Significant correlation between weather parameter and different phenological stages of Cashew at Dapoli (at 1% level)

Stage	Local		Vengurla -4	
	Positive	Negative	Positive	Negative
Vegetative stage	RH II - 0.87 (56-94 %) RF - 0.75 (1.0-506.7mm) RH I - 0.69 (88-97 %) Tmin- 0.66 (18.2-23.9 ^{o}C)	BSS - 0.82 (1.0-8.6 hrs) Tmax - 0.74 (28.0-33.4^{o}C) Epan - 0.72 (1.0-3.8 mm)	RH II - 0.86 (56-94%) RF - 0.74 (0.0-506.7 mm) Tmin - 0.68 (18.3-23.9 ^{o}C) RH I - 0.65 (85-97 %)	BSS - 0.80 (0.0-8.9 hrs) Epan - 0.71 (1.0-5.6 mm) Tmax - 0.70 (28.0-33.8 ^{o}C)
Flowering	RH II - 0.55 (46-94 %) Tmin - 0.46 (12.0-23.9 ^{o}C) RH I - 0.37 (85-97 %)	BSS - 0.53 (1.0-9.7 hrs) Tmax - 0.50 (28.0-35.0 ^{o}C)	RH II - 0.55 (46-94 %) Tmin - 0.46 (12.0-23.9^{o}C) RH I - 0.37 (85-97 %)	BSS - 0.54 (1.0-9.7 hrs) Tmax - 0.49 (16.0-35.0 ^{o}C)
Flower drop	WS - 0.48 (2.1 to 9.3 km hr^{-1}) Epan - 0.38 (1.0-5.7 mm) Tmin - 0.36 (12.1-23.9^{o}C)	-	WS - 0.46 (2.1 to 9.3 khr^{-1}) Epan - 0.36 (1.0-5.7 mm)	--
Fruiting	Epan - 0.79 (3.3-5.7 mm) Tmax - 0.70 (30.7-35. ^{o}C) BSS - 0.54 (5.8-9.7 hrs)	RH I - 0.67 (85-93 %) RH II - 0.57 (45-71%) RF - 0.40 (0-71.5 mm)	Epan - 0.79 (3.3-5.7 mm) Tmax - 0.70 (30.7-35.1 ^{o}C) BSS - 0.55 (5.8-9.7 hrs)	RH I - 0.68 (85-93 %) RH II - 0.58 (45-71 %) RF - 0.40 (0-71.5 mm)

Guava

Hisar

Hisar-Safeda, the popular existing guava variety in CCSHAU orchard was studied in relation to prevalent weather parameters using appropriate correlation techniques. The plant age was 13 years and the planting density was 275 plants ha^{-1}. The correlation between fruit quality and weather parameter with the pooled data (2013-14 to 2022-23) is presented in Table 4.48. The average fruit weight (g/fruit) was significantly and positively correlated with RH_m (r=0.79), RHe (r=0.49) and water use efficiency (r=0.72), whereas T_{max} (-0.67), T_{min} (-0.50), BSS (-0.58), SVPm (-0.40) & SVPe (-0.37), wind speed (-0.63) and maximum possible sunshine hours (-0.78) showed negative correlation. The yield was found to be positively correlated and significant with minimum temperature, saturated vapor pressure and rainfall. The relative humidity had significant positive correction with fruit quality i.e. higher TSS (higher value of relative humidity favours the sweetness) and lower acidity.

Table 4.48 Correlation of guava quality with weather parameter under Hisar condition (pooled data analysis, 2013-14 to 2022-23)

Weather parameters	Yield & quality parameters			
	Average fruit weight (g/fruit)	Yield ($kgha^{-1}$)	TSS (%)	Acidity (%)
T_{max} (°C)	-0.67*	0.29	-0.18	0.34
T_{min} (°C)	-0.50*	0.40*	-0.02	0.20
SVPm (mm of Hg)	-0.40*	0.46*	0.06	0.14
SVPe (mm of Hg)	-0.37*	0.44*	0.09	0.11
RH_m (%)	0.80*	-0.01	0.54*	-0.47*
RH_e (%)	0.49*	0.29	0.51*	-0.45*
WS ($kmhr^{-1}$)	-0.63*	0.23	-0.25	0.35
BSS (hr)	-0.58*	0.06	-0.21	0.43*
Ep ($mmday^{-1}$)	-0.17	0.35	0.01	0.35
Rf ($mmday^{-1}$)	-0.19	0.40*	0.07	0.12
RD (day)	-0.26	0.51*	0.11	0.20
Accu RF ($mmseason^{-1}$)	0.07	-0.33*	-0.10	-0.23
PAR (MJm^{-2} day^{-1})	-0.05	-0.01	0.11	0.44*
Max. possible sunshine hours (hr)	-0.78*	0.22	-0.33	0.47*
Et (mm)	-0.11	0.16	0.05	0.46*
WUE (kg ha^{-1} mm^{-1})	0.72*	0.25	0.52*	-0.19

**Significant at 0.05 probability level, n= 30*

The guava yield prediction model based on weather parameters was developed using eight years pooled data analysis (2013-14 to 2020-21). The multiple regression model was developed for winter seasons crop and are given below:

Multiple Regression model for guava yield (winter season)	R^2	Adj. R^2
Yield (kg/ha)=17287.1-268.51*Et-3526.2*Tmin+3990.51*SVPm-21.74*AccuRF-174.94*WUE	0.97	0.92

T_{min}= Av. Minimum temperature (°C), WUE= Av. Water use efficiency (kg/ha/mm), Accu.RF=Seasonal accumulated rainfall (mm), Et=Crop reference evapotranspiration (mm).

The guava yield model predictions were validated with observed yield of 2021-22 & 2022-23 (not included in model development) and are presented in Table 4.49.

Table 4.49 Validation of winter season guava yield prediction during 2021-22 & 2022-23 at Hisar

Crop season	Observed yield (kgha^{-1})	Predicted yield (kgha^{-1})	Deviation (%)
2021-22	5500	3880	-29
2022-23	6050	5108	-16

Ginger

Thrissur

The experiment was carried out in a split plot design, with the main plot treatment consisting of four distinct planting dates (viz. 1st June (D1), 15th June (D2) and 1st July (D3) and 15th July (D4)) and the sub plot treatment consisting of three different types of mulches (green leaves (M1), paddy straw (M2) and dry coconut leaves (M3) with three replications. June 1st planted crop reportedly had higher yield while July 15th planted crop had the lowest yield. Early planting yielded higher yields than late planting, which had lower yields (Fig. 4.14a). The treatment with paddy straw mulch showed significantly higher yields over the other mulches viz. green leaves mulch and dry coconut leaves mulch (Fig 4.14b). The high yield per plant obtained can be because of the combined effect of favourable environmental conditions and micrometeorological conditions from mulching treatments like moderate soil temperature and soil moisture experienced by the crop.

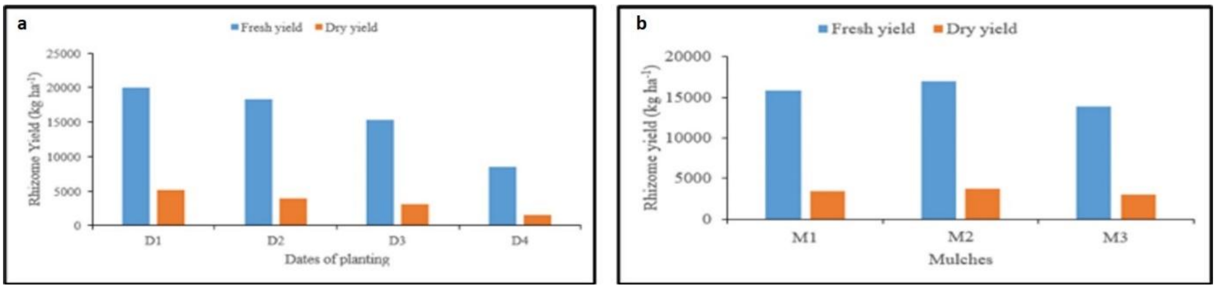


Fig. 4.14 Ginger fresh and dry rhizome yield under (a) growing environments and (b) various mulches at Thrissur

Higher soil temperature fluctuations at the same depth have a negative impact on crop. Among various mulches, dry coconut leaves caused the highest weekly average soil temperature variation at 5 cm and 15 cm depths, followed by green leaves mulch, with paddy straw mulch showing the least variation (Fig. 4.15a).

a

b

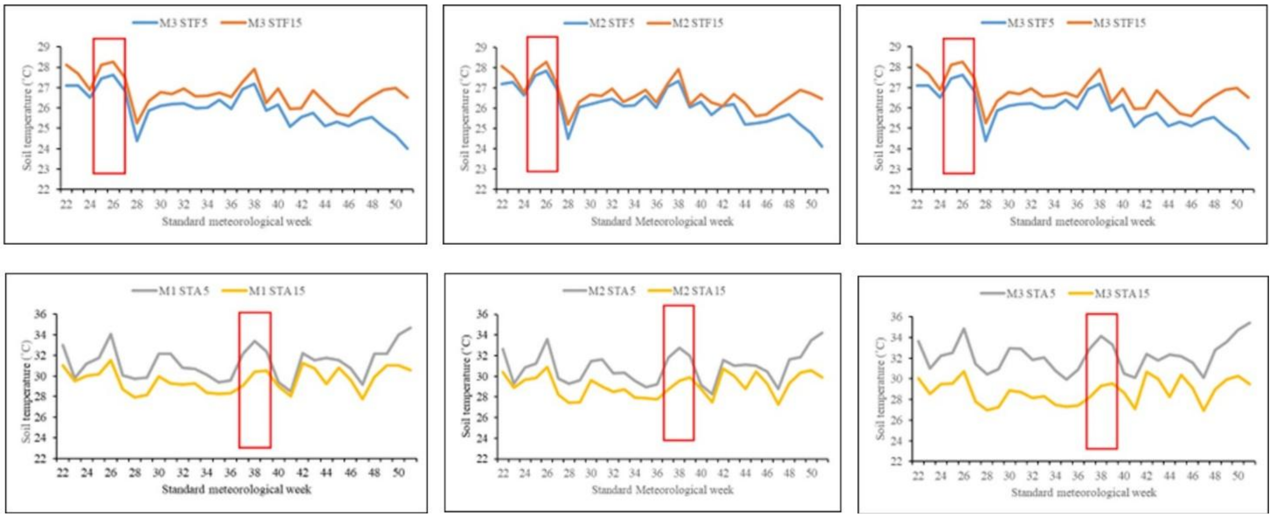


Fig. 4.15 Observed average weekly soil temperature at different depths (5cm and 15cm) at (a) forenoon hours and (b) afternoon hours in M1: Green leaf mulch, M2: Paddy straw mulch, M3: Dry coconut leaves

Increase in accumulated growing degree days and accumulated photothermal units resulted in increased rhizome yield (Fig. 4.16).

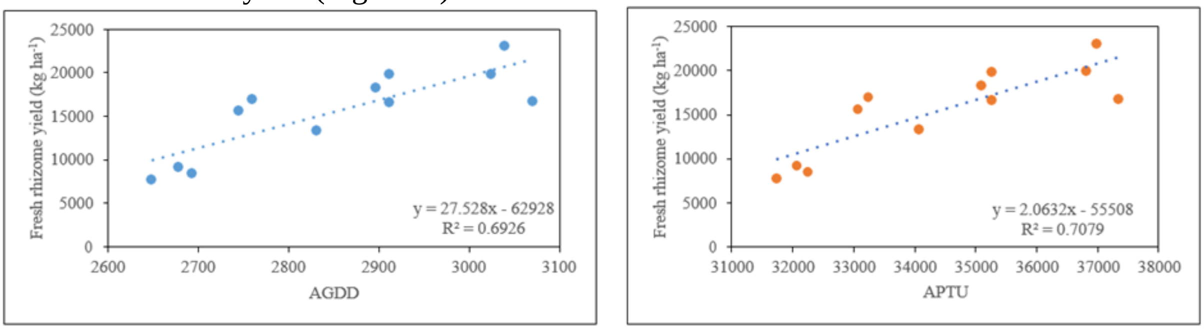


Fig. 4.16. Effect of (a) accumulated growing degree days and (b) accumulated photothermal units on rhizome yield of ginger at Thrissur

Turmeric

Thrissur

The crop weather relationships in turmeric was studied with four different dates of planting (viz. 1st June (D_1), 15th June (D_2) and 1st July (D_3) and 15th July (D_4)) and three different mulching treatments (green leaves (M_1), paddy straw (M_2) and dry coconut leaves (M_3)) with three replications. Fresh yield and dry yield of the crop was higher in both June1st and June 15th dates of plantings. Plots mulched with paddy straw produced more yield compared to other two mulching treatments. Detrimental effect was found between yield and rainfall during third phenophase of turmeric (Fig. 4.17a). With an increase in maximum temperature, it was found that there was a decrease in yield (Fig. 4.17b).

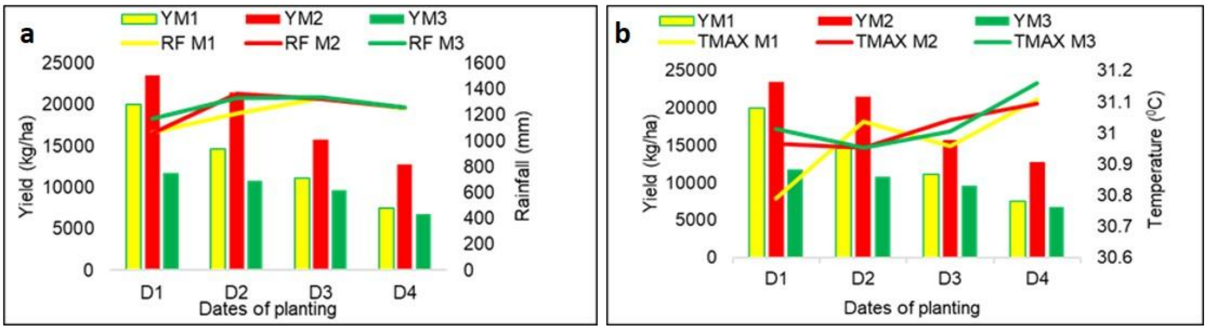


Fig. 4.17 Effect of (a) rainfall and (b) temperature during various growing environments on turmeric yield at Thrissur

Yield of turmeric under various organic mulches during different phenophases were predicted using Principal Component Analysis in each phenophases *i.e.* P1 (planting to germination), P2 (germination to initiation of active tillering), P3 (active tillering to bulking) and P4(bulking to physiological maturity). It was found that the error percentage was less in P4 (Fig. 4.18). The equations created with principal components are presented in Table 4.50.

Table 4.50 Regression equations developed using principal components for yield prediction of turmeric at Thrissur

Mulches	Regression equation developed
Green leaf mulch	Y=13336.54-29.6093X1-3198.6X2
Paddy straw mulch	Y=18392.27-22.133X1-14460.6X2
Coconut dry leaves mulch	Y=9770.643-12.4525X1+5913.054X2

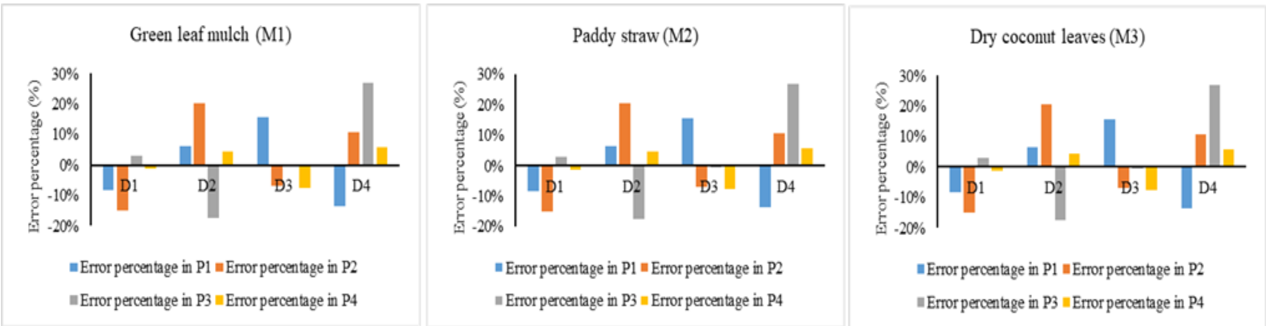


Fig. 4.18 Comparison of predicted and observed yield of turmeric in green leaf mulch (M1), paddy straw mulch (M2) and dry coconut leaf mulch (M3)

5. Crop Growth Modeling

Crop growth models are being used widely to understand crop responsesto environmental / nutrient / water stress. Yield estimation at site specific /regional scales is also being attempted by several researchers. The applicability ofexogenous crop growth models for Indian conditions has been studied at variouslocations and the results of those studies are reported hereunder:

Akola

Calibration and validation of DSSAT Soybean model

The field data of crop phenological development, leaf area index, canopy height, by product and yield were estimated. The genetic coefficients of varieties (JS-335, JS 9305 and AMS-100-39) were generated and used in the analysis of the model were estimated using GLUE coefficient estimator embedded in the DSSAT v 4.5 model with the experimental field data as well as weather collected. Model was calibrated to simulate phenology, seed yield and environmental modification output accurately. Adequate model validation has been done using Root Mean Square Error (RMSE), Percentage Error (PE) and the Degree of agreement (D).

Phenology

Anthesis day

Data pertaining to anthesis day is given in Table 5.1. The observed and predicted mean number of anthesis day was 48 and 48; 43 and 46 and 44 and 47 for the varieties JS-335, JS-9305 and AMS-100-39, respectively. The degree of agreement was 1.00, 0.99 and 0.99 the varieties JS-335, JS-9305 and AMS-100-39, respectively. The percentage error (PE) was 3.47, 8.91 and 9.95, respectively for JS-335, JS-9305 and AMS-100-39 across different sowing management. Therefore, the days for anthesis predicted was well matched with observed days.

Table 5.1 Error per cent by simulated days to anthesis, first pod, first seed and physiological maturity from observed

Cultivar/Date of sowing	Anthesis day			First pod day			First seed day			Physiological maturity		
	O	S	Error %	O	S	Error %	O	S	Error %	O	S	Error %
JS-335												
D_1- 26 MW	51	48	-5.88	59	61	3.39	69	75	8.70	101	109	7.92
D_2- 27 MW	49	49	0.00	56	60	7.14	65	73	12.31	97	107	10.31
D_3- 28 MW	48	49	2.08	54	60	11.11	63	72	14.29	92	106	15.22
D4- 29 MW	43	44	2.33	49	54	10.20	58	66	13.79	86	100	16.28
Mean	**48**	**48**	**-0.37**	**55**	**59**	**7.96**	**64**	**72**	**12.27**	**94**	**106**	**12.43**

SD			**3.82**			**3.49**			**2.53**			**3.98**
RMSE			**1.66**			**4.50**			**7.83**			**11.79**
PE			**3.47**			**8.26**			**12.28**			**12.54**
D			**1.00**			**0.99**			**0.99**			**0.99**
JS-9305												
D_1- 26 MW	44	47	6.82	50	59	**18.00**	59	72	22.03	88	106	20.45
D_2- 27 MW	44	47	6.82	50	59	18.00	59	71	20.34	85	105	23.53
D_3- 28 MW	42	48	14.29	47	59	25.53	55	70	27.27	81	103	27.16
D4- 29 MW	41	43	4.88	46	53	15.22	54	63	16.67	78	97	24.36
Mean	**43**	**46**	**8.20**	**48**	**58**	**19.19**	**57**	**69**	**21.58**	**83**	**103**	**23.88**
SD			**4.16**			**4.43**			**4.41**			**2.76**
RMSE			**3.81**			**9.42**			**12.44**			**19.81**
PE			**8.91**			**19.52**			**21.92**			**23.86**
D			**0.99**			**0.99**			**0.99**			**0.99**
AMS-100-39												
D_1- 26 MW	47	48	2.13	53	60	13.21	62	72	16.13	92	106	15.22
D_2- 27 MW	44	48	9.09	49	60	22.45	58	71	22.41	86	104	20.93
D_3- 28 MW	42	49	16.67	47	60	27.66	55	70	27.27	81	103	27.16
D4- 29 MW	41	44	7.32	46	54	17.39	54	63	16.67	79	97	22.78
Mean	**44**	**47**	**8.80**	**49**	**59**	**20.18**	**57**	**69**	**20.62**	**85**	**103**	**21.52**
SD			**6.02**			**6.26**			**5.27**			**4.95**
RMSE			**4.33**			**10.04**			**11.99**			**18.22**
PE			**9.95**			**20.59**			**3.79**			**5.67**
D			**0.99**			**0.99**			**1.00**			**1.00**

First pod day

The observed and predicted mean number of first pod day was 55 and 59; 48 and 58 and 49 and 59 for the varieties JS-335 JS-9305 and AMS-100-39, respectively (Table 3.1). The degree of agreement was 0.99 in all the varieties. The percentage error (PE) was 8.26, 19.52 and 20.59, respectively for JS-335, JS-9305 and AMS-100-39 across different sowing management. As the PE is less than ten per cent the prediction is acceptable.

First seed day

Relevant data on first seed day is presented in Table 5.1. The observed and predicted mean number of first seed day was 64 and 72; 57 and 69; and 57 and 69 for the varieties JS-335, JS-9305 and AMS-100-39, respectively. The degree of agreement was 0.99. The percentage error (PE) was 12.28, 21.92 and 3.79 respectively for JS-335, JS-9305 and AMS-100-39 across different sowing management. As the PE is less than ten per cent, therefore the prediction was well matched with observed values.

Physiological maturity

The data on physiological maturity is presented in Table 5.1. The observed and predicted mean number of physiological maturities was 94 and 106; 93 and 103; 95 and 10392 for the varieties JS-335, JS-9305 and AMS-100-39, respectively. The degree of agreement was 0.99. The percentage error (PE) was 12.54, 23.86 and 5.67, respectively for JS-335, JS-93-05 and AMS-100-39 across different sowing management. Therefore, the prediction was well matched with observed values.

Seed yield

Relevant data on error percent by simulated seed yield from observed one is presented in Table 5.1. Observed and predicted mean seed yield across sowing management was 1551 and 1807; 1406 and 1775; and 1376 and 1665 for the varieties JS-335, JS-9305 and AMS-100-39, respectively. The degree of agreement was 0.99, 0.98 and 0.99. The percentage error (PE) was 17.04, 14.01 and 10.97, respectively for JS-335, JS-9305 and AMS-100-39 across different sowing management. Therefore, the prediction was well matched with observed values for all varieties particularly in AMS-100-39 and JS 9305 followed by JS 335.

Sensitivity analysis of DSSAT-CROPGRO-Soybean model to temperature and CO_2

Tropical countries are more vulnerable to climatic effects in agricultural productivity. A sensitivity analysis was conducted by selecting options (increase / decrease) maximum temperature (+ 1 to 5 °C), minimum temperature (± 1 to 5 °C) and concentration of carbon dioxide (+100, +200 and +300 ppm). The yield variations were compared as percent increase or decrease of model output under normal weather conditions. The impact of ± 1 to 5 °C maximum and minimum temperatures on simulated seed yield of soybean and its per cent change of yield from model output under normal weather conditions are presented in Table 5.2. Sensitivity of CROPGRO (DSSAT) model simulated seed yield under growing environment from S1 (26 MW) to S4 (29 MW) showed decrease in seed yield. The increase in maximum and minimum temperatures gradually decreased the yield by -19.4 to -23.1% under S1 (26 MW). The magnitude of yield reduction was to a greater degree with delayed sowing with 29 MW sowing recording 11.8 to 38.0% reduction with upscaling of temperatures from 1°C to 5°C.

Table 5.2 Sensitivity of CROPGRO soybean model to maximum and minimum temperature (°C)

Sowing Window	**1**	**2**	**3**	**4**	**5**	**Normal Yield (kg/ha)**	**-1**	**-2**	**-3**	**-4**	**-5**
S1	2126	2108	2074	2069	2027	**2637**	2295	2287	2256	2203	2120

(26MW)	***-19.4***	***-20.1***	***-21.3***	***-21.5***	***-23.1***		***-17.2***	***-17.5***	***-18.6***	***-20.5***	***-23.5***
S2 (27MW)	1957	1881	1820	1781	1760	**1614**	2061	1995	1934	1868	1770
	21.2	***16.5***	***12.8***	***10.3***	***9.1***		***-19.0***	***-21.6***	***-24.0***	***-26.6***	***-30.5***
S3 (28MW)	1598	1529	1457	1356	1349	**1267**	1633	1606	1566	1482	1355
	26.2	***20.7***	***15.0***	***7.0***	***6.5***		***-23.4***	***-24.7***	***-26.5***	***-30.5***	***-36.4***
S4 (29MW)	1257	1187	1111	1052	1019	**911**	1276	1265	1179	1143	1026
	38.0	***30.3***	***21.9***	***15.4***	***11.8***		***-23.6***	***-24.3***	***-29.4***	***-31.6***	***-38.6***

Figures in parenthesis are % deviation

The downscaled maximum and minimum temperatures increased the yield across different sowings. The magnitude of yield increase was more with later growing environments. As such the average maximum and minimum temperature during *kharif* soybean growing period was 32.0 and 23.1°C and the applied downscaling might not affect the crop growth and development as to a degree that of upscaling putting the temperatures beyond the normal favourable range of crop growth and development. The results clearly indicated that increased temperature variation (+1 to 5°C) likely to impact seed yield of soybean as compared to down scaled maximum and minimum temperatures.

Anand

Validation of DSSAT-CERES-Millet model for Pearl millet

Crop simulation model CERES-millet was calibrated using data of year 2017 and validation was done using the data of years 2018, 2019, 2020, 2021 and 2022.

Days to anthesis

Observed duration of days to anthesis varied between 49 (D_3V_1 - 2021) and 62 (D_2V_3-2022) days and simulation ranged between 44 (D_3V_1-2020) and 60 (D_1V_1, D_1V_2, D_1V_3-2019) days. The error per cent on observations were between -23.7 and 15.4 per cent. Scatter plot (Fig. 5.1a) depicts lower side of 1:1 line. The simulated days to anthesis were not in good agreement with the observations (r = 0.08, dr = -0.20). Also, relatively high MAE (6.67), high RMSE (7.66) and lower d value (0.38) indicate not good agreement. Model underestimated with bias value -5.78.

Days to maturity

Duration of days to physiological maturity ranged from 65 (D_2V_1-2020) to 90 (D_1V_2-2018) days and their simulation has range between 67 (D_3V_1-2020) and 86 (D_1V_3-2019) days.

The error per cent on observations were between -12.5 and 10.5 per cent. Figure 5.1 (b) shows that short durations were slightly underestimated and long durations were slightly overestimated by the model. The simulated days to maturity were in good agreement with observation. There was high r value (0.67), low MAE (3.69) and low RMSE (4.77). Model slightly under estimated maturity days with bias of -1.38. Index of agreement (d) and refined index of argument (d_r) were high 0.78 and 0.62, respectively.

Maximum leaf area index

Observed peak leaf area index in treatments varied from 2.8 (D_2V_1-2020) to 5.8 (D_3V_3-2022) and simulation was 2.7 (D_3V_1-2020) to 5.0 (D_1V_2-2022). In most cases maximum leaf area index was under estimated as well as overestimated [Fig. 5.1 (c)]. Deviation ranged from -38.8 to 56.1 per cent. Low r value (0.27), low MAE (0.48) and high RMSE 0.65 indicate not good agreement with the observations. Model simulations of maximum LAI were slightly underestimated. Lower values of d (0.58) and d_r (0.45) indicated poor performance of model.

Grain yield

Recorded grain yields of pearl millet were ranged between 864 (D_2V_1-2019) to 3443 (D_1V_3-2018) kg ha^{-1}, while simulations were in between 1925 (D_3V_1-2020) and 3319 (D_2V_3-2019) kg ha^{-1}. The grain yield simulated by model were not close to observations in three instances [Fig. 5.1 (d)] and error per cent values were high (-13.2 to 221.0). The simulated grain yield had poor agreement with the actual. Simulations had r 0.00 and d_r (0.46). Grain yield also showed poor agreement with positive higher bias (437), high MAE (548 kgha^{-1}) and low RMSE (857 kg ha^{-1}). Index of agreement (d) was also poor with the value 0.45.

Straw yield

Straw yield varied from 2741 (D_2V_1-2019) to 7743 (D_1V_3-2022) kg ha^{-1}, and simulation resulted 4656 (D_3V_1-2020) to 8988 (D_1V_2-2019) kg ha^{-1}. Simulated straw yields were mostly underestimated except in high production [Fig. 5.1 (e)]. Error percent ranged between -30.0 to 163.0 per cent during the season. The simulated straw yield was in poor agreement with the actual productions. It had negative r value (-0.43), low d (0.19) and d_r (0.37) value. Model overestimated straw yield with 339 kg ha^{-1} bias, higher MAE (1483 kg ha^{-1}) and RMSE (2028 kg ha^{-1}).

Total dry matter production

Total above ground dry biomass of various treatments recorded between 3605 (D_2V_1-2019) kg ha^{-1} to 10710 (D_1V_2-2018) kg ha^{-1}, while its simulation ranged between 6581 (D_3V_1-2020) kg ha^{-1} to 11745 (D_1V_3-2019) kg ha^{-1} (Fig. 5.1f). Error per cent were very high in some cases (-22.0 to 174.3). The simulated above ground biomass had poor agreement with the observed. There was negative r (-0.45), low d (0.25) and d_r (0.45) values. Also showed poor agreement with high bias (825 kg ha^{-1}), high MAE (1822 kg ha^{-1}) and RMSE (2745 kg ha^{-1}).

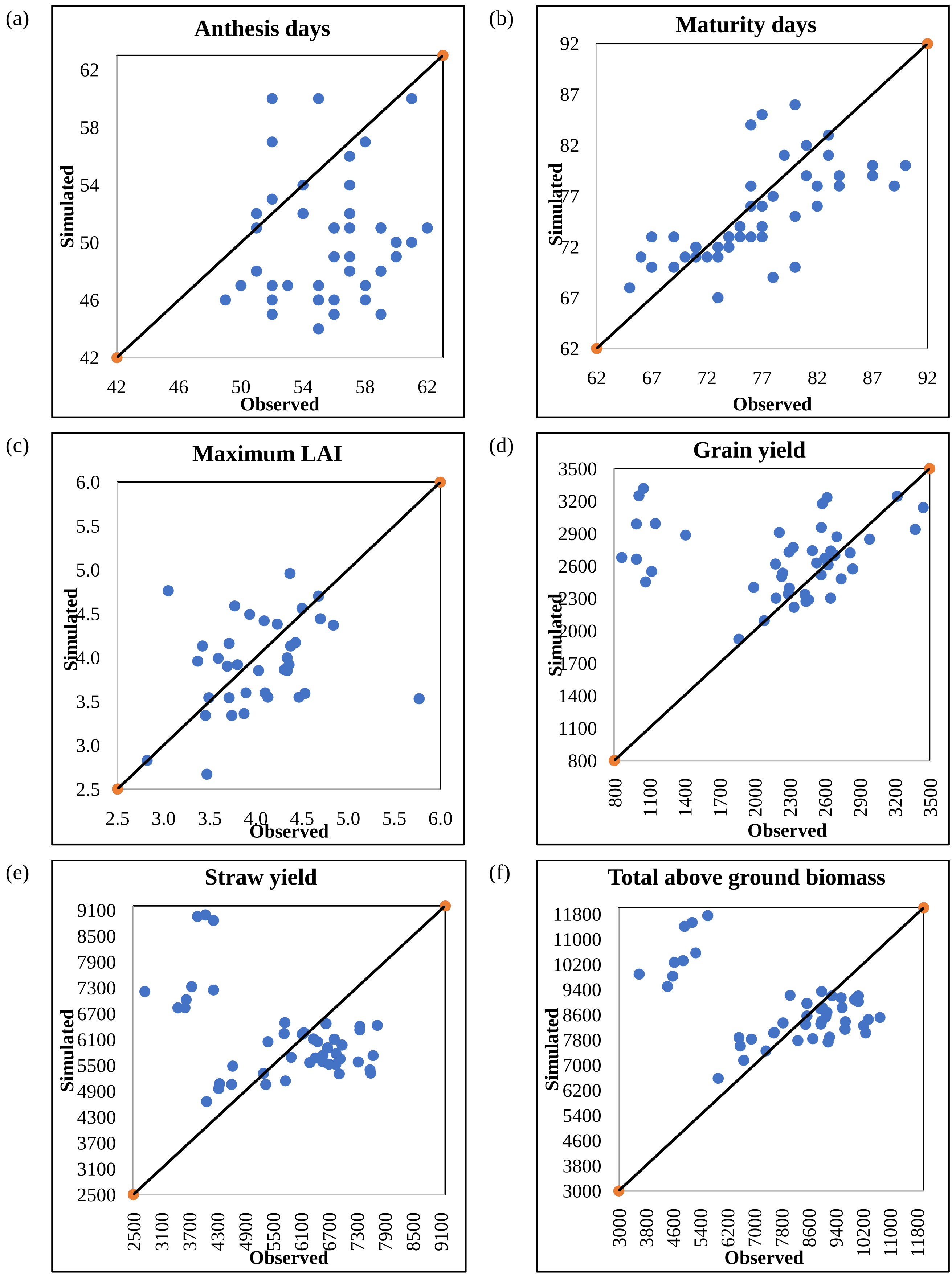


Fig. 5.1 a-f Observed vs simulated growth and yield variables of pearl millet (2018 - 2022)

Chatha

Model development and evaluation for Wheat yield prediction (Statistical)

Wheat yield prediction models were developed for the three sowing environments and evaluated with various weather parameters, which influence the seed yield of the crop with the help of eight experimental data sets of different crop seasons (*rabi*, 2015-16 to 2022-23) (Table 5.3).

Table 5.3 Regression model for wheat seed yield prediction

Regression model	R^2	Adj R^2	SEm
First Growing Environment (D_1)			
Y= 38.012+ 2.80($MaxT_3$)+.139($MaxT_4$)+0.011 ($MaxT_6$) -0.288 (Min T_1)- 0.162 (RHe_6) -0.341 (RHe_7) -0.372 RHe_8) +0.036 (RF_6)-0.017(RF_7)– 0.018(RF_9) -0.575 (SS_3) -4.366 (SS_4) +0.084 (SS_6)	0.92	082	2.61
Second Growing Environment (D_2)			
Y= -31.65+0.303 ($MaxT_2$)+0.114($MaxT_7$)-0.102($MinT_9$) +0.670 (RHm_2) - 0.012(RHe_2) -0.084(RHe_5) + 0.074 (RF_2) -0.025(RF_7) -0.014(RF_8) - 0.003(EP_4)	0.76	0.58	3.19
Third Growing Environment (D_3)			
Y= -33.65 +0.719 ($MaxT_3$) +2.259 ($MaxT_4$) + 0.527 ($MaxT_6$) +1.929($MinT_1$) -0.036 (RHe_6) -0.247 (RHe_7) +0.015(RF_6) -0.013(RF_7) - 0.728(SS_3) +0.171(SS_4)	0.82	0.68	2.60

$MaxT_2$ - CRI stage; $MaxT_3$ - Tillering stage; $MaxT_4$ - Jointing stage; $MaxT_6$- Head emergence stage; $MaxT_7$ - Anthesis stage; $MinT_1$ - emergence stage; $MinT_9$ - Hard dough stage; RHm_2 - CRI stage; RHe_2 - CRI stage; RHe_5- Flag leaf stage; RHe_6- Head emergence stage; RHe_7 - Anthesis stage; RHe_8 - Milking stage; SS_3 - Tillering stage ; SS_4 - Jointing stage; SS_6 Head emergence stage; SS_9- Hard dough stage; EP_4- Jointing stage; RF2- CRI stage; RF6- Head emergence stage;RF7- Anthesis stage; RF8- Milking stage; RF9- Hard dough stage;MaxT- Maximum Temp; MinT-Minimum Temp ; RHm-Morning relate humidity; RHe-Evening relative humidity; SS- Sunshine hrs; EP-Evaporation; RF-Rainfall

Multiple regression equations were developed for estimation of yield of different wheat cultivars using the significant weather variables. Maximum temperature along with minimum temperature, relative humidity, sunshine hours and rainfall of different periods together explained the variability in wheat yield up to 92 per cent in first growing environment (D_1) and 76 per cent in second growing environment (D_2) and 82 per cent in third growing environment (D_3) wheat crop. The regression model for growing environment indicate significant relationship of maximum and minimum temperature, precipitation, relative humidity morning and evening, sunshine hours and evaporation with wheat yield. The regression equation for first growing environment (D_1) indicates that the average maximum temperature along at tillering stage, jointing and head emergence is positively related to wheat yield while a negative relation was observed with minimum temperature at emergence, sunshine hours at tillering and jointing stage, relative humidity and rainfall at head emergence, anthesis and hard dough stage.

For second growing environment (D_2), the regression equation indicates the positive relation of wheat yield with maximum temperature, relative humidity morning and rainfall at

CRI stage while a negative relation was observed with minimum temperature at hard dough stage, relative humidity evening, rainfall at anthesis, and milking stage. The regression equation for third growing environment (D_3) indicates that the minimum temperature at emergence stage, maximum temperature at tillering, jointing and head emergence stage, sunshine hours at jointing and rainfall at head emergence stage were positively related to wheat yield while rainfall at anthesis stage and relative humidity evening at head emergence and anthesis stage.

Ludhiana

Determinationofsowingwindowforwheatusing CERES-wheatmodel

ThesimulationstudyforthetwowheatcultivarsthatareHD2967andPBW725wasperformedby considering six sowing dates during the late October and early, mid and late November for twoconsecutive years 2019-20 and 2020-21 using the recommended package and practices of PAU Ludhiana.The input files for crop, soil and weather were extracted as per the model (DSSAT v4.7.5) format and thecultivar specific parameters (CSPs) were also determined on the basis of the crop cultivars. The calibratedand validated DSSAT CERES-wheat model was used to simulate yield and biomass for the consideredsowing window of Wheat in Punjab *i.e.*mid October to late November which helped in deciding theoptimumdates forwheatsowingandwhat wouldbe the resultsof late sowingofwheat. The sensitivity analysis of both the wheat cultivars showed the P1V and P1D CSPs to be the mostsensitivewhilethecalibrationresultsdepictedsimilarCSPswithnotmuchdifferenceforthetwoc ultivars. The statistical results depicted strong coefficient of determination (R^2) for anthesis (0.93, 0.90),maturity (0.74, 0.94), yield (0.74, 0.71) and biomass (0.89, 0.75), respectively for HD2967 and PBW725 (Table 5.4).The normalized root mean square error (NRMSE) was excellent (<10%) for anthesis (3.18%, 4.32%);maturity (2.93%, 2.04%), yield (0.86%, 0.90%) and biomass (10.3%, 9.3%) of HD2967 and PBW725,respectively. All the evaluation measure gave good results thus depicting the model to be accurate forfurther applications. The simulated sowing window on the basis of the calibrated and validated model was20th Octoberto 9th Decemberwith observeddeviation ofgrain yield from themean atearly sowing(before 20th October) to be -3.86% and delayed sowing (after 9th December) to be -1.94% for HD2967.The wheat cultivar PBW725 observed the grain yield depreciation from the mean by -20.2% at earlysowing(before 20thOctober) and by-6.7% atdelayedsowing(after 14thDecember).

Table 5.4 StatisticalmeasuresforevaluationofCERES-Wheatv4.7.5simulationperformance

Parameters	HD2967		PBW725	
	Observed	Simulated	Observed	Simulated
Anthesis				
Mean(DAS)	112	108	109	105
Ratio	0.97		0.96	
StandardDeviation	4.79	4.78	3.39	4.07
R^2	0.93		0.90	
RMSE(DAS)	3.56		4.71	
d-stat	0.88		0.73	
NRMSE(%)	3.18		4.32	
Modelefficiency	0.45		-0.93	
Maturity				

Mean(DAS)	153	156	150	153
Ratio	1.02		1.02	
StandardDeviation	6.82	6.11	5.68	6.01
R^2	0.74		0.94	
RMSE(DAS)	4.49		3.05	
d-stat	0.88		0.93	
NRMSE(%)	2.93		2.04	
Modelefficiency	0.57		0.71	
Grainyield				
Mean(kg/ha)	5397	5334	5089	5062
Ratio	1.00		0.99	
StandardDeviation	645.0	386.2	350.5	464.9
R^2	0.74		0.71	
RMSE(kg/ha)	375.61		253.2	
d-stat	0.86		0.90	
NRMSE(%)	6.96		4.98	
Modelefficiency	0.66		0.48	
Biomassyield				
Mean(kg/ha)	14356	13038	13708	13331
Ratio	0.90		0.97	
SD	1568.2	1909.7	764.2	1828.7
R^2	0.89		0.75	
RMSE(kg/ha)	1482.2		1282.7	
d-stat	0.84		0.75	
NRMSE(%)	10.3		9.3	
Modelefficiency	0.11		-1.82	

Mohanpur

The onset and the withdrawal of monsoon largely determine the success of rainfed Agriculture. Late onset of monsoon delays sowing of crops leading to poor yield. Similarly, early withdrawal of rains affects the yield due to moisture stress especially when the *kharif* crops are at critical growth stage of grain formation, grain development and finally the productivity. Abnormalities in weather parameter compelled farmers to grow the rice in different season and delay transplanting dates, so that the harvesting will also be delayed. Intermittent dry spell of monsoon during various phenological phases is becoming more detrimental to the overall crop production. Swarna (long duration) and Satabdi (medium duration) are one of the most important rice varieties which grown different parts of the country along with West Bengal. In the new alluvial zone of West Bengal, Satabdi as well as Swarna cultivar contributes considerable share in rice cultivation during kharif season. In crop growth simulation study, attempt has been made to identify the effect of dry spell (no rainfall) on productivity of these two rice cultivars. In west Bengal condition almost everywhere transplanting is generally recommended to be completed within the week of July. To assess the stress situation imparted due to late transplanting, different artificial situation was simulated and respective effect on biological parameters were studied. To work out the exercise virtual experiment was carried out in DSSAT4.7 platform, considering the following treatments.

1) No stress: There has been be no dearth of nitrogen and irrigation throughout the growing season.

2) Rainfed: Crop grown under normal rainfall situation. No additional irrigation was applied.

3) **Environmental modification:** Prefixed dry spells exerted during the crop growing period.

4) EM+1 irrigation: Environmental modification with one supplemented irrigation.

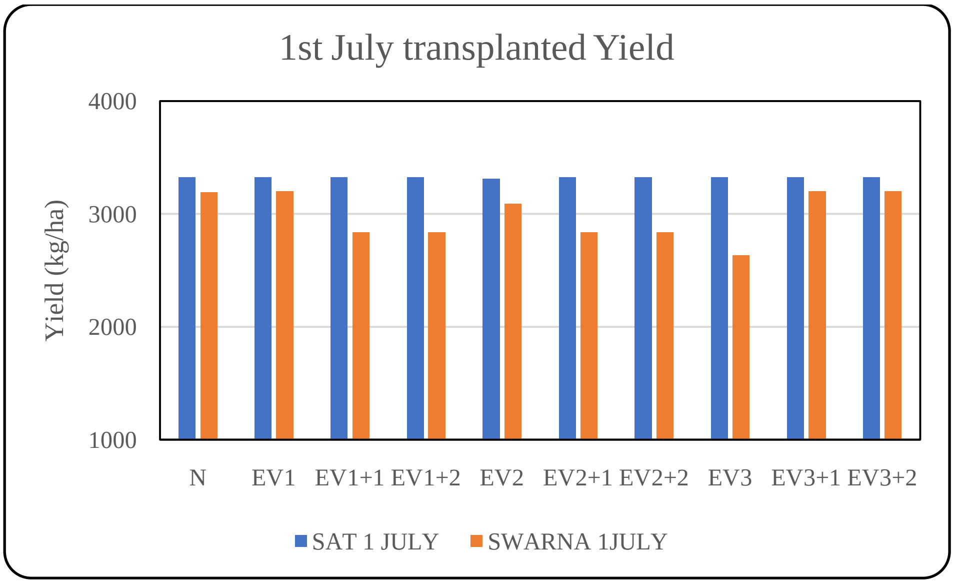
5) EM+2 irrigation: Environmental modification with two supplemented irrigation.

Irrigation dates:

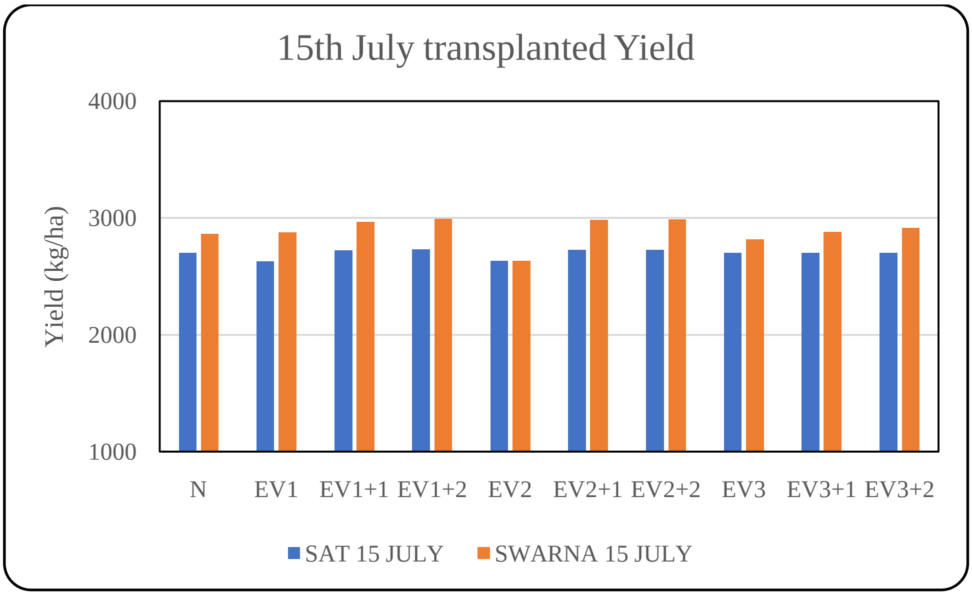
Stress Situation	Irrigation no.	Dates
EM1	1	25^{th} July
(15^{th} July-15^{th} Aug)	2	25^{th} July + 4^{th} August
EM2	1	5^{th} August
(15^{th} July -31^{st} Aug)	2	5^{th} August + 20^{th} August
EM3	1	25^{th} August
(15^{th} Aug-15^{th} Sep)	2	25^{th} August + 5^{th} September

Date of transplanting: 1^{st} July and 15^{th} July

Yield: Virtual experiment was executed to check the drought escaping capability of two rice cultivars; i.e., Satabdi and Swarna with two transplanting dates, each 15 days apart. The experiment depicted that the 1^{st} July transplanted Satabdi and Swarna performed better than the 15^{th} July transplanted kharif rice.



a.



b.

Fig. 5.2 Effect of different treatments on two rice cultivar yield; a) 1st July transplanted b) 15th July transplanted

With the delay in 15 days transplanted yield is reduced by 18% and 10% in Satabdi and Swarna respectively (Fig. 5.2). The rainless period (water scarcity simulated) during 15th July to 15th August impacted the 15th July transplanted rice drastically, 21% and 10% of yield decrease was identified in Satabdi and Swarna variety respectively with respect to 1st July transplanted. This indicate that the Satabdi variety is best suited for early transplanting condition where the delay in transplanting decrease the drought mitigating capability of the cultivar. Similar pattern was identified in the stress period imparted during 15th July to 31st Aug. In case of environmental modification during 15th August to 15th September the yield was observed higher in late transplanted Swarna variety than early transplanting condition while 18% yield reduction is associated with Satabdi variety than early transplanting situations. This indicates that the late transplanted Swarna can cope with late season drought situation. With the application of one or two irrigation during early and mid-season simulated drought situation can increase the yield of late transplanted Swarna cultivar by 3-4.5% than the normally grown situation. While in late transplanted Satabdi variety, application of irrigation during early and mid-drought situations has relatively no effect in yield. As Satabdi variety is shorter in duration the third environmental stress situation started after the crucial water requirement stages and there is no change in the virtual yield is observed over normal situation. While Swarna cultivar yield increased by 21% in early transplanted and 2-3.5% in late transplanted EM3 stressed condition with the application of one or two irrigation. This indicate that application of one or two irrigation in late season drought in early transplanted Swarna variety can boost the yield. In case of early transplanted Swarna variety the application of irrigation in EM1 and EM2 showed decrease in yield while in EM3 condition application of irrigation enhanced the yield. This may be due to the washing out of the crucial nutrients applied for the plant growth and no stress was encountered due to the absence of water.

LAI: 1st July transplanted Swarna and Satabdi variety LAI values are depicted in the Fig. 5.3. The Swarna variety simulated a LAI_{max} of 5.38 while Satabdi have a relatively lower maximum canopy cover with sharp blade like leaves with LAI_{max} value of 4.5 under normal situation. In case of Swarna variety the LAI is seen flat after 30 days up to 60 DAT in EM1 condition. After that increase in LAI was observed up to 75 DAT and gradually deceased thereafter. Application of one or two irrigation has similar effect on LAI_{max} (6.8). From these results we can conclude that one irrigation during 25th July to 5th august for early season drought can mitigate stress situation in early transplanted rice. However, the LAI value was greatly reduced in long term mid-season drought (Swarna- EM2: 4.5, Satabdi- EM2: 3.7) and late season drought (Swarna- EM3: 4.7, Satabdi- EM3: 3.9) than the early season drought (EM1) like situation. Application of one irrigation is successful in mitigating mid-season drought but showed relatively lower LAI_{max} value in late season drought in Swarna variety. Though the value of LAI_{max} is higher in 1st July transplanted (5.83) than the 15th July transplanted (4-5) when application of irrigation was done in late season drought like situation. This result follows the similar trend with yield. Early transplanted Satadbi on the other hand is resilient to early season water stress imparted on it depicted through LAI values.

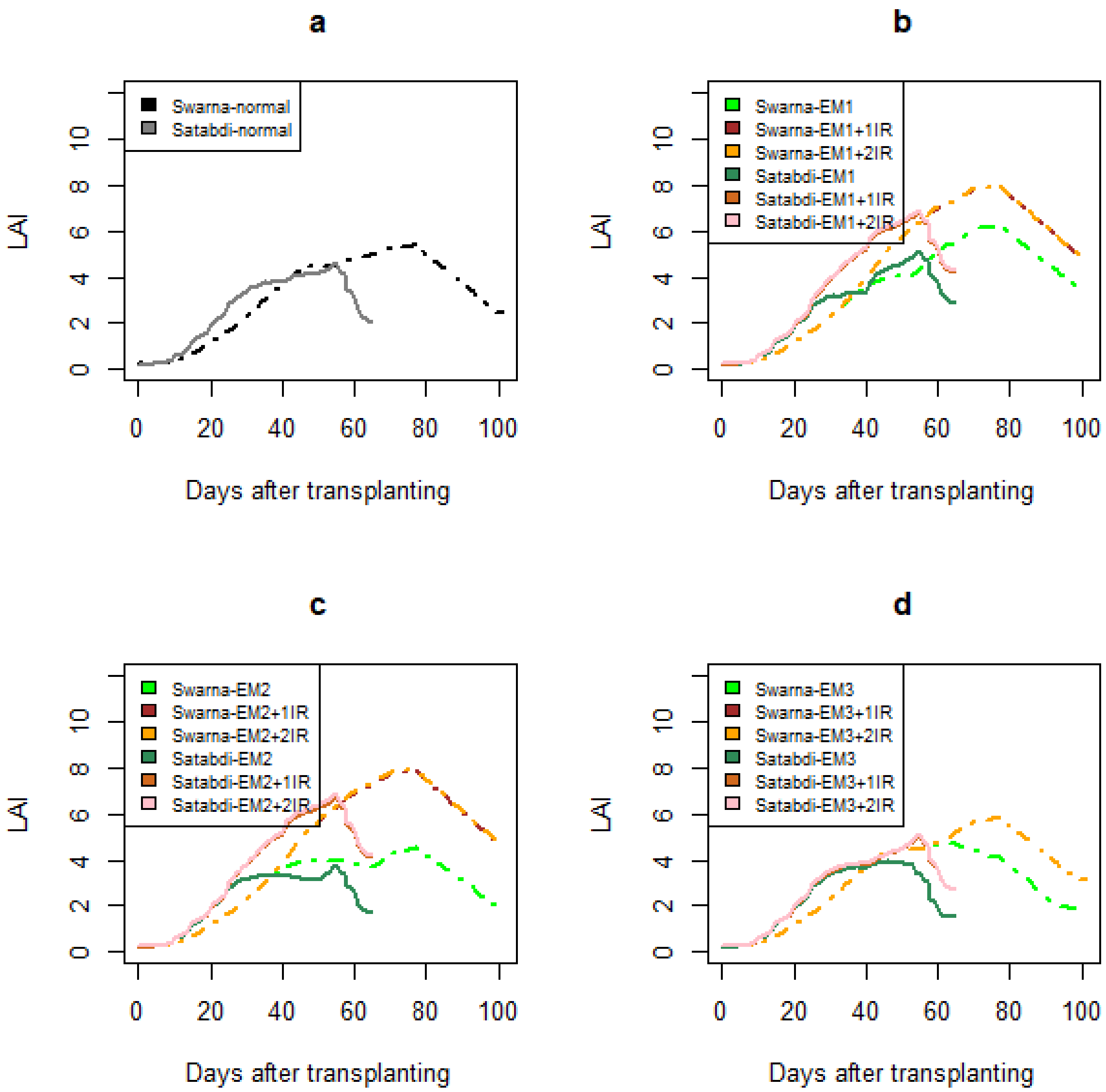


Fig. 5.3 Effect of different environmental modification treatments on LAI of 1st July transplanted two rice cultivars; a) normal condition and no-stress condition, b) 15th July to 15th August water stress with one and two irrigation application, c) 15th July to 31st August water stress with one and two irrigation application, and d) 15th August to 15th September water stress with one and two irrigation application.

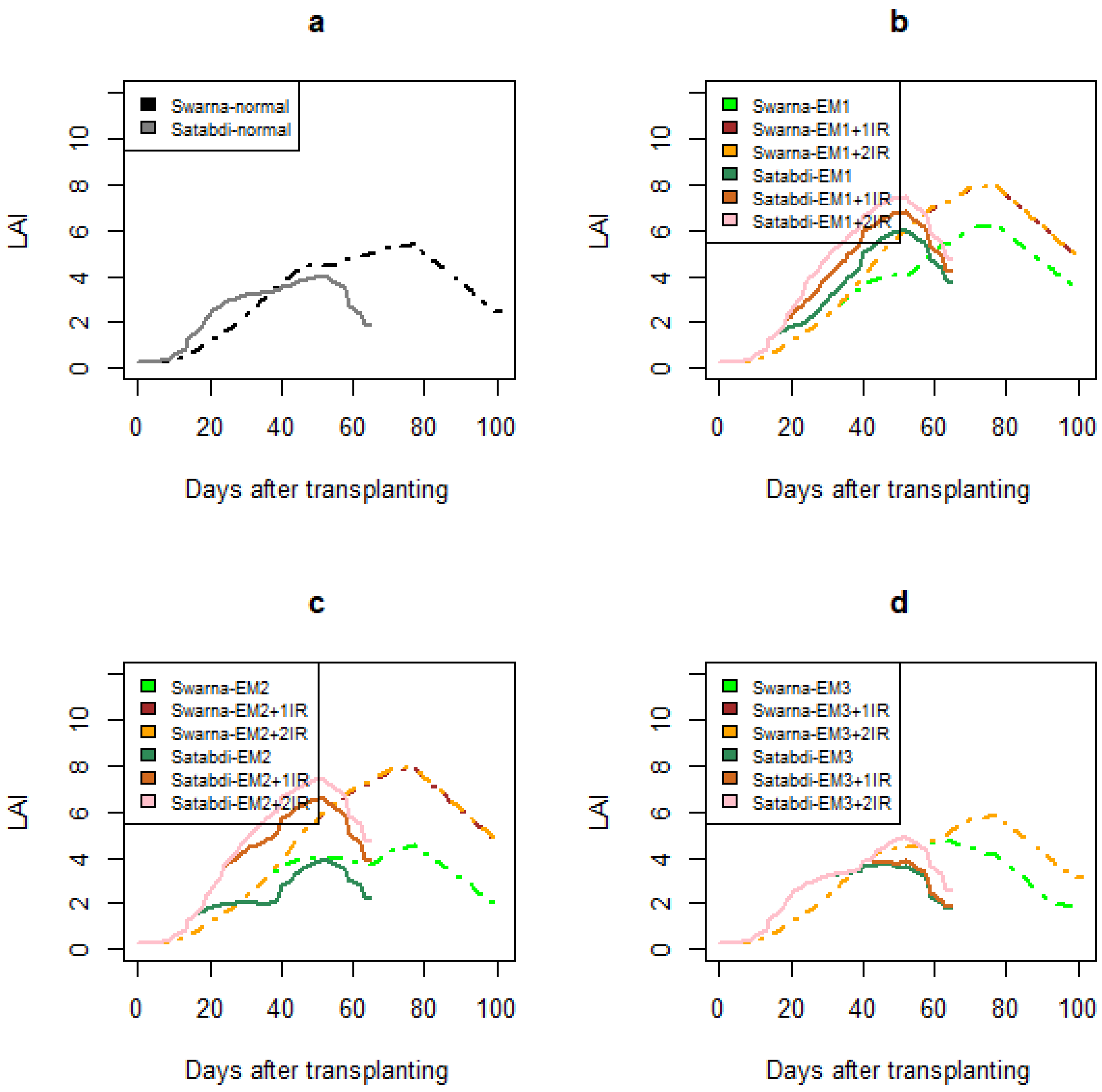


Fig. 5.4 Effect of different environmental modification treatments on LAI of 15th July transplanted two rice cultivars; a) normal condition and no-stress condition, b) 15th July to 15th August water stress with one and two irrigation application, c) 15th July to 31st August water stress with one and two irrigation application, and d) 15th August to 15th September water stress with one and two irrigation application.

Among 15th July transplanting scenario the highest LAI_{max} was observed 4.14 in Swarna variety followed by Satabdi cultivar (4) under normal condition (Fig. 5.4). The mid and late season drought (EM2 & EM3) impacted the Swarna cultivar badly. With application of one irrigation increased the LAI_{max} by 5 to 64% and with application of two irrigation increased the LAI_{max} by 32 to 85%. In Satabdi variety application of one irrigation increased the LAI_{max} by 5 to 68% and with application of two irrigation increased the LAI_{max} by 32 to 90% (in three EM condition). From the above study it is clear that the application of one irrigation in late transplanted Swarna mid-season drought situation can increase its yield and overall growth while in late transplanted Satabdi, application of one or two irrigation during early to mid-season drought situation enhances its performance.

Raipur

Sensitivity analysis of wheat yield in different CO_2 concentration and changing temperature conditions

Attempts were made to make simulations runs for the wheat variety CG-1013 which is the popular wheat variety in Chhattisgarh state (Table 5.5). Experimental data for the year 2022-23 were used for validation purpose and there seems to be scope of improvement in genetic coefficients of this variety. If the error percentage between simulated and observed is within the accepted limit of 10%, genetic coefficients can consider to be in fine-tuning stage.

It can be very well seen that except in isolated incidences, increased temperature by +1.0 °C, +1.5 °C and 2.0 °C will lead to the wheat production losses. However increased concentration upto the level of 550 ppm can compensate these losses in isolated cases. There may be production increase in 550 ppms even with expected temperature increase. The production losses are as per present varietal and environmental temperature conditions. However, with development of climate resilent agriculture and practices, situation may change in future. There is need of identification of suitable planting dates and CSM can play a big role in sustainable agriculture.

Table 5.5 Combined effect of elevated CO_2 concentration and increasing temperature on grain yield of wheat variety (CG1013) for different growing environment under sensitivity analysis of model for different districts of Chhattisgarh

		450 ppm						500 ppm						550 ppm					
District	**Tem.**	**D1**	**Error%**	**D2**	**Error%**	**D3**	**Error%**	**D1**	**Error%**	**D2**	**Error%**	**D3**	**Error%**	**D1**	**Error%**	**D2**	**Error%**	**D3**	**Error%**
Raipur	**1**	3023	-6.48	3263	4.84	2944	-2.24	3050	-4.03	2887	-2.53	2887	0.9	3269	2.94	2978	0.6	3311	**13.59**
	1.5	2925	-10.05	2855	-8.76	2712	-10.99	2755	-15.17	2635	-12.33	2609	-9.66	2820	-12.52	2703	-9.51	2932	**2.42**
	2	2800	-14.96	2759	-12.54	2633	-14.32	2418	-14.22	2263	-10.8	2413	-18.57	2615	-21.34	2556	-15.81	2395	-19.46
Baster	**1**	2915	-2.71	2813	-2.74	2775	-0.65	2972	-0.74	2880	-0.35	2881	3.05	3021	0.89	2920	1.03	2893	**3.46**
	1.5	2762	-8.4	2665	-8.44	2645	-5.6	2740	-9.27	2685	-7.64	2722	-2.61	2881	-3.92	2781	-3.92	2755	-1.38
	2	2620	-14.27	2524	-14.5	2520	-10.83	2518	-18.9	2576	-12.19	2515	-11.05	2691	-11.26	2630	-9.89	2571	-8.63
Dhamtari	**1**	3256	-0.77	3111	-1.93	3061	0.62	3376	2.81	3181	0.31	3180	4.34	3356	2.23	3310	4.2	3182	**4.4**
	1.5	3120	-5.16	3090	-2.62	2915	-4.36	3143	-4.39	2985	-6.23	2915	-4.36	3212	-2.15	3205	1.06	3017	-0.83
	2	2943	-11.48	2880	-10.1	2772	-9.74	3073	-6.77	2870	-10.49	2796	-8.8	3142	-4.42	3018	-5.07	2840	-7.11
Koria	**1**	3015	-13.96	3223	-2.39	3091	-5.34	3104	-10.7	3026	-9.05	2906	-12.04	3244	-5.92	3132	-5.36	3250	-0.18
	1.5	2905	-18.28	3162	-4.36	2908	-11.97	2985	-15.11	2872	-14.9	2765	-17.76	3112	-10.41	1991	-15.75	3099	-5.07
	2	2800	-22.71	3981	17.11	2871	-13.41	2711	-26.74	2704	-22.04	2614	-24.56	2823	-21.71	2810	-17.44	2863	-13.73
Surguja	**1**	2985	-14.07	3152	-7.55	2921	-15.13	3015	-12.94	2825	-20	2813	-19.55	3150	-8.1	2950	-14.92	3216	-4.57
	1.5	2872	-18.56	2810	-20.64	2805	-19.89	2910	-17.01	2616	-29.59	2622	-28.26	2915	-16.81	2771	-22.34	3015	-11.54
	2	2065	-14.89	2643	-28.26	2612	-28.75	2663	-27.86	2326	-25.74	2510	-26.98	2725	-24.95	2623	-29.24	2950	-14
Janjgir-champa	**1**	3156	-1.52	3289	5.17	3026	-2.35	3095	-3.52	2915	-7	2911	-6.39	3305	3.06	3010	-3.62	3374	8.21
	1.5	2910	-17.01	3053	-11.04	2821	-19.21	2815	-20.96	2750	-23.27	2772	-21.32	3170	-7.41	2844	-19.2	3120	-7.79
	2	2771	-22.88	2820	-20.21	2605	-29.1	2710	-15.65	2641	-18.36	2582	-10.25	2955	-15.23	2624	-29.19	3072	-9.47
Jashpur	**1**	3285	-8.77	3650	4.19	3492	3.52	3480	-2.67	3460	-1.07	3326	-1.29	3692	3.22	3511	0.4	3508	3.96

	1.5	3051	-17.11	3463	-0.98	3163	-6.51	3310	-7.95	3244	-7.8	3210	-4.95	3471	-2.94	3346	-4.51	3211	-4.92
	2	2905	-22.99	3122	-12.01	3076	-9.53	3200	-11.66	3052	-14.58	3072	-9.67	3345	-6.82	3161	-10.63	3005	-12.11
Bilaspur	**1**	3220	2.7	3351	9.79	3156	5.93	3110	-0.74	3017	-0.2	3056	2.85	3415	8.26	3122	3.17	3405	12.8
	1.5	3011	-4.05	3105	2.64	2911	-1.99	2844	-10.16	2861	-5.66	2981	0.4	3200	2.09	2905	-4.06	3212	7.57
	2	2887	-8.52	2862	-5.63	2725	-8.95	2651	-18.18	2641	-14.46	2720	-9.15	3015	-3.91	2711	-11.51	3046	2.53
Durg	**1**	3132	-0.03	3291	6.38	2891	0.69	3062	-2.32	2881	-6.94	2816	-1.95	3250	3.6	2991	-3.01	3316	13.42
	1.5	2805	-11.69	2845	-8.3	2705	-6.14	2806	-11.65	2591	-18.91	2743	-4.67	2870	-9.16	2771	-11.19	2743	-4.67
	2	2511	-14.77	2672	-15.31	2515	-14.16	2662	-17.69	2361	-18.5	2522	-13.84	2666	-17.52	2544	-21.11	2811	-2.13
Rajnandgaon	**1**	3120	-1.28	3272	10.09	2881	0.62	3067	-3.03	2822	-4.25	2805	-2.07	3191	0.97	2961	0.64	3362	14.84
	1.5	2816	-12.22	2835	-3.77	2715	-5.45	2899	-9	2541	-15.78	2642	-8.36	2850	-10.88	2751	-6.94	3192	10.31
	2	2563	-23.29	2634	-11.69	2510	-14.06	2660	-18.8	2350	-25.19	2508	-14.15	2611	-21.03	2640	-11.44	2877	0.49
Kabirdham	**1**	3050	-4.13	3261	4.94	2880	-6.6	3051	-4.1	2863	-8.28	2855	-7.53	3145	-0.99	2991	-3.64	3371	8.93
	1.5	2814	-12.86	2833	-9.42	2705	-13.49	2861	-11.01	2548	-21.66	2656	-15.59	2840	-11.83	2763	-12.2	3182	3.52
	2	2670	-18.95	2595	-19.46	2516	-22.02	2643	-20.17	2391	-29.65	2511	-22.26	2593	-22.48	2645	-17.2	2866	-7.12
Mahasamund	**1**	3110	-3.09	3220	3.73	3140	2.23	3391	5.46	3245	4.47	3251	5.57	3430	6.53	3126	0.83	3345	8.22
	1.5	2981	-7.55	3115	0.48	2856	-7.49	3160	-1.46	3090	-0.32	3122	1.67	3235	0.9	2905	-6.71	3211	4.39
	2	2750	-16.58	2840	-9.15	2752	-11.56	2952	-8.6	2865	-8.2	2963	-3.61	3163	-1.36	2711	-14.35	2972	-3.3

6. Weather Effects on Pests and Diseases

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 intheir management through chemical measures. Thus, development of forewarningmodels for various pests and diseases with sufficient accuracy and lead time isvital. The research efforts made at various centers to develop models for variouspests and diseases are presented hereunder:

Akola

Interaction between insect pests of mustard and weather

The incidence of *S. litura* and semilooper in soybean grown under four micro-environments of four different dates of sowing from 26 to 29 SMW [D1 (26), D2 (27), D3 (28), D4 (29)] was studied. Population dynamics were analyzed using correlation and regression based on the dataset of 2018 to 2022 (five years). The occurrence of *S. litura* was noted at 31 SMW (3.0 larvae/mrl/week) and maximum *S. litura* larvae /mrlwasrecorded in sowing D2 followed by D4, D3 and D1 at 36 SMW. Whereas, the occurrence of semilooper larvae/mrl was noted at 30 SMW (3.3 larvae/mrl/week) and maximum semilooper larvae/mrlwasrecorded in sowing D4 followed by D2, D3, and D1 at 36 SMW

Correlation between weather parameters and *S. litura*

Correlations between *S. litura* population and weather parameters during the current week of incidence, 1, 2, 3, and 4 week lag periods (Table 6.1) showed a significant negative correlation of *S.litura* (weekly with maximum temperature at all the lag periods and with a mean temperature of the preceding 1, 3 and 4 weeks. Relative humidity (instant and lag) encouraged the buildup of the *S. litura* population. These results showed that lower maximum and mean temperatures and higher humidity conditions are congenial for *S. litura* population on soybean crops.

Table 6.1 Correlation between the population of pests of soybeanwithweather parameters (2018-2022)

Lag - Period week	T_{max} (^{0}C)	T_{min} (^{0}C)	Mean T (^{0}C)	RH-I (%)	RH-II (%)	Mean RH (%)
Spodoptera						
Current week	-0.31	0.43	0.49	0.56	0.23	0.67
1st Week	-0.57	0.29	-0.02	0.46	0.41	0.12
2nd Week	-0.81	0.26	0.01	0.36	0.69	0.01
3rd Week	-0.82	0.03	-0.11	0.45	0.82	0.05
4th Week	-0.68	0.11	-0.26	0.47	0.73	0.30
Semilooper						
Current week	-0.40	0.84	0.50	0.57	0.30	0.67
1st Week	-0.64	0.74	0.38	0.41	0.48	0.12
2nd Week	-0.87	0.91	0.32	0.40	0.77	0.01
3rd Week	-0.86	0.82	0.34	0.49	0.87	0.05
4th Week	-0.72	-0.12	-0.52	0.55	0.78	0.37

Correlation between weather parameters and semilooper

Correlations between the semilooper population and weather parameters during the current week, 1, 2, 3, and 4-week lag periods showed a significant negative correlation of the semilooper with maximum temperature at all the lag periods and with mean temperature of the preceding 4 weeks. Relative humidity (instant and lag) was found to encourage the buildup of the semilooper population. These results showed that lower maximum and mean temperatures and higher humidity conditions are congenial for the semilooper population on soybean crops.

Anand

Effect of weather on insect pests of mustard

The field experiments were conducted to study the influence of weather on insect pests of mustard (cv GM 2) under four sowing windowsfrom 10 October to 10 November. The correlation analysis revealed that there is no statistically significant association between weather parameters prevailing during infestation and aphid population. Congenial weather parameters' ranges were too broad because of higher variability in seasons of 20 years. The correlation between two days' average of weather parameters of lead time to first occurrences was explored, considering a lead time of 1 to 10 days from occurrence. There was no significant association of aphid intensity to any of the weather parameter that prevailed during lead periods, but it was found that the correlation coefficient reduces with longer lead time (Fig. 6.1).Among the weather parameters, minimum temperature shows a consistent negative association with 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 to 5 days might be responsible for the initiation of aphid infestation in mustard crops during the flowering to pod initiation phase.

The data of aphid index of flowering to seed development phase and seed yield recorded in four sowings for twenty years. Seed yields of mustard were found higher (≥ 1500 kg ha^{-1}) when aphid intensities were lower than 1.7. Vice versa when aphid intensity increases more than 1.7 during the flowering to seed development phase, the seed yield of mustard drops (Fig. 6.2).

Lead days	BSS	Tmax	Tmin	RH1	RH2
1	0.1	0.17	-0.08	0.08	0.16
2	0.11	0.13	-0.16	0.32	0.15
3	-0.06	0.0	-0.2	0.4	0.09
4	-0.26	-0.2	-0.17	0.33	0.17
5	-0.18	-0.18	-0.15	0.33	0.3
6	-0.11	-0.11	-0.16	0.12	0.23
7	-0.11	-0.04	-0.13	0.02	0.3
8	-0.05	-0.04	-0.1	-0.12	0.27
9	0.12	-0.18	-0.21	-0.24	0.0
10	-0.09	-0.23	-0.28	-0.22	-0.05

Fig. 6.1: Correlation between two days average weather parameter of lead time to first occurrences (n=19)

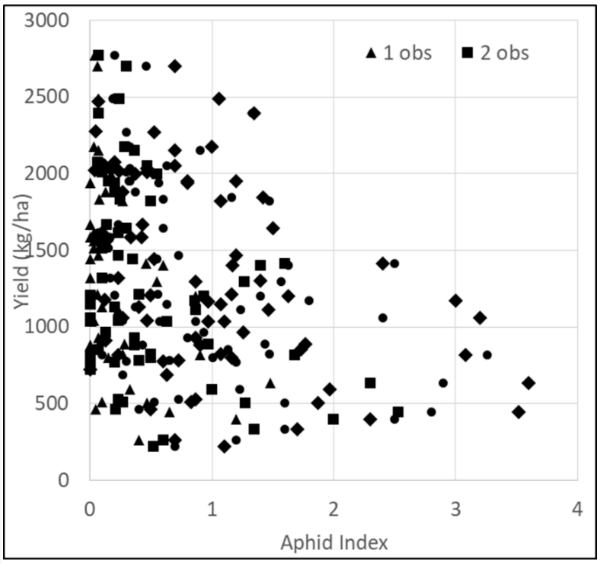


Fig. 6.2: Aphid intensity during flowering to seed development (21 years x 4 dates of sowing)

Anantapur

Effect of weather on insect pests of pigeon pea

Field experiments were conducted to establish the relationship between weather parameters and the incidence of spotted borer in pigeon pea in the kharif season from 2017-18 to 2022-23. The pigeon pea (var. PRG 176) was sown at different sowing environments (II FN June, I FN July, II FN July and I FN August). The data on the incidence of webs and larvae for five years (2017-18, 2019-20, 2020-21, 2021-22 and 2022-23) was correlated with the weather parameters that prevailed during the same period. The pest incidence was not noticed during 2018-19 and hence, five years of data were considered for correlation studies. The results showed that there was a significant positive correlation between the webs/m ^{2} and minimum air temperature, morning relative humidity and wind speed. Further, it was observed that there was a significant positive correlation between larvae/m^2 and morning and afternoon relative humidity. However, larvae/m^2 had a significant negative correlation with maximum air temperature and evaporation (Table 6.2).

Table 6.2 Correlation between weather parameters and spotted pod borer incidence during 2017-18 to 2022-23 (pooled data)

Weather parameter	**Webs/m^2**	**Larvae/m^2**
T_{max} (C)	-0.10	-0.30**
T_{min}(C)	0.17*	0.06
RHI(%)	0.28**	0.35**
RH II (%)	0.05	0.21**
WS (kmph)	0.34**	0.00
RF (mm)	-0.07	-0.08
SS (hr)	0.04	-0.13
EVP (mm)	-0.11	-0.20*

* significant at the 0.05 level** significant at the 0.01 level

A linear regression model was developed for predicting the number of webs and larvae of spotted pod borer in pigeon pea as below

Webs/m^2=-69.087-2.788 MAXT+1.366MINT+1.298RH1-0.136 RH2+3.105WS-0.094RF+1.256SS+1.474EVP

Larvae/m^2=-31.067-0.904 MAXT-0.155MINT+0.552RH1+0.162 RH2+0.581WS-0.079RF+0.23SS+0.924 EVP

Bangalore

Effect of weather on insect pests and diseases of mango

The effect of insect pests and disease incidence in mango crop was studied under two conditions (M_1: Control and M_2: with plant protection sprays) having a sample size of five plants each in two orchards.

Table 6.3 Correlation and regression between pests and disease in mango and weather parameters (Pooled data 2020 to 2022)

Weather parameters	Powdery mildew	Leaf Hopper	Fruit fly
Tmax (^oC)	-0.33	0.16	0.58*
Tmin (^oC)	-0.65**	-0.45**	0.52*
Average RH (%)	0.01	-0.46*	-0.48
WS ($kmhr^{-1}$)	0.16	0.12	-0.65**
SSH (hrs)	0.48*	0.59**	-0.03
Rainfall (mm)	-0.34	-0.46*	-0.01

Powdery mildew incidence was positively correlated with average relative humidity and wind velocity (0.011 and 0.160, respectively). The pooled analysis revealed a significant positive influence with sunshine hours (0.488*) and a significant negative influence with minimum temperature (-0.655**), maximum temperature (-0.330) and rainfall (-0.340). Similarly, The leaf hopper population during the mango growing period was positively correlated with maximum temperature and wind speed (0.166 and 0.129, respectively). The pooled analysis revealed a significant positive correlation with sunshine hours (0.598**) and a significant negative relationship with minimum temperature (-0.455**), relative humidity (-0.462*), and rainfall (-0.469*) (Table 6.4).

Fruit fly collection exhibited a significant positive correlation with maximum and minimum temperature (0.586* and 0.529*, respectively), whereas, average relative humidity (-0.486) and wind velocity (-0.658**), sunshine hours (-0.032) and rainfall (-0.012) shown negative correlation with fruit fly catches (Table 6.4).

Table 6.4 Multiple regression equation for diseases, pests and, weather parameters

Disease/pests	Regression equation	R^2
Powdery mildew	$Y= 426.62-6.68\ X_1-1.206\ X_2-3.135\ X_3+0.347\ X_4+1.020\ X_5+0.117\ X_6$	0.70
Hoppers	$Y= 69.13-0.118\ X_1-1.264\ X_2-0.671\ X_3+1.354\ X_4-0.321\ X_5+0.015\ X_6$	0.79
Fruit fly	$Y= -53.72+4.11\ X_1+6.09\ X_2-1.67\ X_3-0.88\ X_4-2.15\ X_5+0.26\ X_6$	0.67

Note: X_1: maximum temperature X_2: minimum temperature X_3: average relative humidity X_4: wind speed X_5: sunshine hours X_6: rainfall

The results of multiple regression between powdery mildew, hoppers population, fruit fly, and weather parameters showed a positive relationship. The coefficient of determination (R^2) of regression between powdery mildew with weather parameters was 70 %, hopper population was 79 %, and fruit fly was 67.5 % (Table 6.4).

Bhubaneshwar

Incidence of brinjal shoot and fruit borer and their correlation with abiotic factors

The infestation of brinjal shoot and fruit borer (BSFB) on shoots of brinjal crop transplanted on 16/06/2021 was noticed from the 27th standard meteorological week SMW (4 June - 10 July) to 45th SMW (7-13 November) and its occurrence ranged from 4.77% to 38.44%. The infestation by BSFB on the shoots increased gradually and reached the peak (38.44%) during the 34th SMW (22- 28 August) and declined gradually. The mean atmospheric temperature, mean relative humidity, bright sunshine hour (BSH) and rainfall were 29.5°C, 92%, 6.6 hr/day, 0.0 mm respectively, during the peak period of incidence. The mean temperature, rainfall and BSH showed positive correlation with shoot infestation whereas, relative humidity was found to be negatively correlated.Similarly, **i**nfestation by BSFB on fruits was noticed from 30th SMW (25-31 July) to 45th SMW (7-13 November) and its occurrence ranged from 4.65%to 47.55 % The infestation on fruits by BSFB increased rapidly, reached a maximum of 47.55 % at 39th SMW (26-Septmber - 2 October) and thereafter, it started to decline. At the peak period of incidence, the mean atmospheric temperature, mean relative humidity, rainfall was 29.5°C, 97% and 0.0 mm, respectively. The infestation of fruits by BSFB showed positive correlation with rainfall (r = 0.18), RH (r = 0.28) and BSH (r = 0.19) whereas it was found to be negatively correlated with temperature ((Table 6.5).

Table 6.5 Correlation of BSFB infestation with weather parameters

	Shoot damage (%)	Fruit damage (%)
Mean Atmospheric Temperature (°C)	r = 0.16	r = -0.11
Mean Relative Humidity (%)	r = -0.13	r = 0.28
Total Rainfall (mm)	r = 0.13	r = 0.18
Bright sunshine hour(hrs)	r = 0.32	r = 0.19

Chatha

Crop weather pest relationship in mustard

The field experiment was conducted to establish pest and weather relationships on mustard crops at SKUAST-J, Chatha, Jammu during *Rabi* 2022-23. The three mustard varieties (RSPR-01, RSPR-69, and RSPR-03) were sown on different sowing dates (08th, 18th& 28th November 2022) in randomized block design with replications. The correlation coefficients derived between the aphid population and different meteorological parameters observed during the preceding ten days revealed a significant positive correlation with minimum temperature. The mean temperature and mean relative humidity have significant positive relationships with the aphid population. The humid thermal ratios (HTR) are negatively correlated with aphid population (Table 6.6).

Table 6.6 Correlation between aphid and weather parameters in mustard *rabi* 2022-23

Maximum Temperature	0.25
Minimum Temperature	0.50**
Mean Temperature	0.55**
Morning Relative Humidity	0.31
Evening Relative Humidity	0.25
Mean Relative Humidity	0.35*
Rainfall	0.07
Sun Shine hrs	0.04
Humid Thermal Ratio	-0.11

** significant at the 0.01 level, * significant at the .05 level

The aphids usually became visible during the 8th Standard Meteorological Week (SMW). Thereafter, the temperature increases along with dry conditions rendered congenial conditions for aphid multiplication and at the threshold level when the maximum temperature ranged between 29.0 to 34.4 °C, the minimum temperature ranged between 11.4 to 20.6 °C, mean temperature ranged between 20.2 to 26.5 °C coupled with morning and evening relative humidity ranged from 83 to 96 and 41 to 57 %, respectively (Fig 6.3).

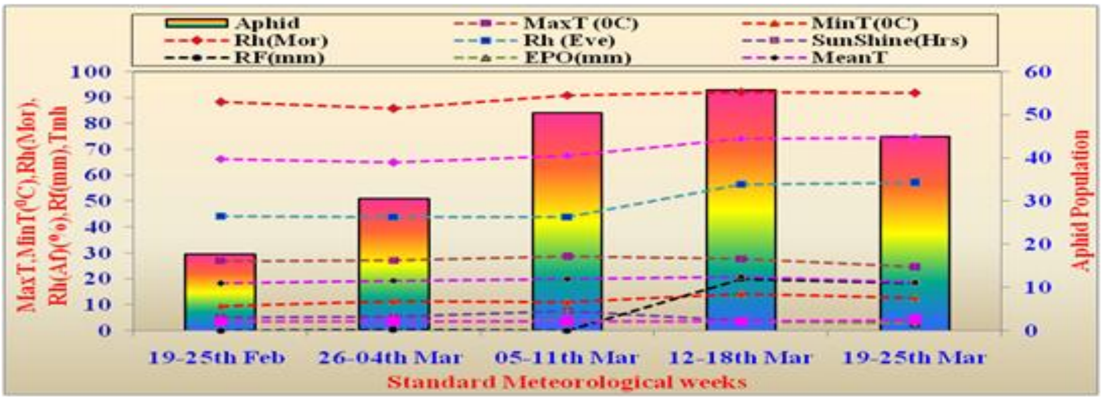


Fig 6.3 Mustard aphid population at different standard meteorological weeks

Hisar

Quantification of the weather-pest relationship of key pests in cotton

Field experiments were conducted to study the influence of weather parameters on key pests of cotton at the Department of Entomology, CCSHAU, Hisar.Data on *Jassid* (Leaf hopper) of cotton HS-6 variety from 1999 to 2022 was correlated with the weather parameters. The sunshine hours (-0.27) and rainfall showed a significant negative correlation with *jassid* population, whereas, minimum temperature (0.41), morning (0.15) and evening relative humidity (0.42), and wind speed (0.19) showed a significant positive correlation.Twelvecropping season (2007-08 and 2012-2022) data on jassid in cotton (RCH650) was correlated with the weather parameters. Sunshine hours (-0.24) showed a significant negative correlation with *jassid* population at RCH 650, whereas, minimum temperature (0.39), morning (0.14) and evening relative humidity (0.39) and wind speed (0.17) showed a significant positive correlation (Table 6.7).

Table 6.7 Influence of weather on the population of jassids and whitefly in cotton

Pest	Var	T_{max} (°C)	T_{min} (°C)	RH_m (%)	RH_e (%)	WS (Kmph)	SSH (hr.)	Ep (mm)	Rf. (mm)
Jassid	HS-6	-0.04	0.41*	0.15*	0.42*	0.19*	-0.27*	-0.05	-0.14*
	RCH650	-0.04	0.39*	0.14*	0.39*	0.17*	-0.24*	-0.06	-0.12
whitefly	HS-6	-0.05	0.05	0.25*	0.13*	-0.09	0.01	-0.12	-0.01
	RCH650	-0.07	0.07	0.23*	0.15*	-0.08	0.01	-0.12	-0.01

*n=236, *5% significant level*

Data of whitefly on cotton HS-6 variety from 1999 to 2022 was correlated with the weather parameters. The morning (0.25) and evening (0.13) relative humidity showed a positive correlation. Twelve years of crop season whitefly weekly data (2007-08 and 2012 to 2022) on cotton (RCH650) was correlated with the weather parameters. The morning (0.23) and evening (0.15) relative humidity and sunshine hours (0.01), showed a positive correlation.

The equation developed to use 5-season whitefly data

A stepwise multiple linear regression equation was carried out to identify best-suited model for the predictability of the whitefly population using the above weather variables. The variability in the occurrence of whitefly population of RCH650 of Hisar zone was explained up to 45% with the help of weekly significant weather parameters.

Table 6.8 Multiple regression equation for whitefly population prediction (RCH 650)

Multiple regression models	**R^2**
Ywf=-621.011+8.54*Tmax-0.88*Tmin+4.15*RHm+407*RHe-3.28*WS+5.68*Sunshine+0.92*Ep-0.043* RF	R^2=0.45

Simple weather-disease models for prediction of cotton leaf curl virus disease (CLCuD)

The weekly disease incidence of cotton leaf curl virus disease in susceptible variety HS-6 was recorded under natural conditions by the cotton section, CCSHAU, Hisar.The percent disease index (PDI) of cotton leaf curl virus disease data (2016 to 2022) was correlated with the meteorological parameters. The maximum temperature (-0.60), minimum temperature (-0.65), wind speed (-0.72), and rainfall (-0.18) showed a significant negative correlation with PDI, whereas morning relative humidity (0.52) showed a significant positive correlation. The optimum range of weather parameters with the progression of maximum PDI value from 22 to 45 SMWs was analyzed as optimum T_{max} for the disease development was noted to be between 31.4 to 35.5°C, minimum temperature 17.9 to 25.1 °C and relative humidity morning (RHI) 82 to 94 percent and wind speed 2.2 to 6.3 kmph with the occurrence of rainfall. The wind speed showed a highly significant negative correlation with disease development which may be favorable for whitefly vector migration.

Table 6.9 Relationship between PDI and weather parameters (pooled)

	PDI	Tmax	Tmin	RH I	RH II	WS	SSH	Rainfall
PDI	1.00							
Tmax	-0.60*	1.00						
Tmin	-0.65*	0.55	1.00					
RH I	0.52*	-0.77	-0.16	1.00				
RH II	-0.04	-0.47	0.38	0.72	1.00			
WS	-0.72*	0.54	0.69	-0.40	0.15	1.00		
SSH	0.10	0.36	-0.11	-0.37	-0.52	-0.10	1.00	
Rainfall	-0.18*	-0.22	0.19	0.32	0.50	0.05	-0.32	1.00

* Significant at 5% p level, n= 140

PDI prediction model (Cotton leaf curl virus disease)

A stepwise multiple linear regression equation was carried out to identify the best-suited model using weather variables. The multiple regression model used 6 years (2016-2021) data and the developed model was validated with an independent data set of 2022 (Fig 6.4).

PDI= -49.73+1.17Tmax-2.65Tmin+1.51RHmor-2.85WS-5.58RD (R^2=0.85)

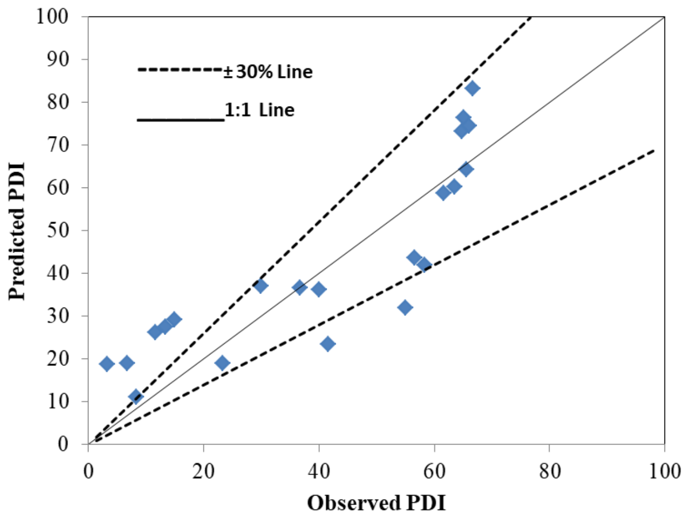


Fig 6.4: Scatter plot of observed vs predicted PDI to validate the model for the year 2022

Jabalpur

Effect of weather on insect pests of chickpea

Weather insect-pest relationship between pod borer, *Helicoverpaarmigera* and weather parameters among different chickpea varieties (desi, gulabi and kabuli) were sown at different dates. Larval population was recorded at meter row length two times a week (Tuesday and Friday).

Larval population: During the rabi season 2022-23, the overall population of pod borer was less till 50 SMW. The population increased from 51stto 12th SMW with an increase in larvae per meter row length.The larval population was reduced during 2nd SMW with minimum temperatures. It rises with the increase in both maximum and minimum temperatures from 7th SMW.

Influence of sowing dates of chickpea on population of *H. armigera*

Among the sown dates, D1 observed more larval population per plant followed by D2 and D3 sown dates. Among chickpea varieties, the desi variety observed a larger larval population than the remaining other varieties thereby suggesting that Desi have more occurrence whereas Kabuli and Gulabi species with no effect on larval numbers with the chickpea species.

Correlation studies

The association between weather parameters and larval population in chickpea varieties revealed that, due to the short time of minimum temperature in this season, the larval population emerged early in the season. The desi variety was more sensitive to pod borer than the other varieties. A maximum temperature exhibited a positive association with the larval population whereas evening relative humidity showed a negative correlation in the desi variety (Table 6.10).

Table 6.10 Pearson's correlation coefficient between *Helicoverpaarmigera* and weather parameters in chickpea

		T_{max}	T_{min}	Sun Shine hrs	RF (mm)	RH I %)	RH II (%)
JG14	Pearson Correlation	0.57*	0.29	0.46	-0.04	-0.41	-.55*
	Sig. (2-tailed)	0.01	0.25	0.06	0.85	0.09	.022
JGK1	Pearson Correlation	0.44	0.28	0.27	0.17	-.22	-.33
	Sig. (2-tailed)	0.07	0.27	0.28	0.50	0.37	0.19
JGG 1	Pearson Correlation	0.50	0.15	0.51	-0.20	-0.35	-0.48
	Sig. (2-tailed)	0.04	0.56	0.03	0.43	0.15	0.05

** significant at the 0.01 level, * significant at the .05 level

Influence of weather on larval population at different sown dates in chickpea

In early sown chickpea crop, the larval population in chickpea increased after 510 SMW, and remained high till 8 SMW. The maximum temperature increases with the increase in larval population and exhibited a positive association of larval population with maximum temperature. It suggests a range of maximum temperature of 20-30 °C; minimum temperature of 6-14 °C; sunshine hours of 6-9 hours; morning relative humidity of 85 - 93 % and evening relative humidity of 30-50 %, respectively.

In the late-sown chickpea crop, the larval population declined after 10thSMW. The population increases when the maximum temperature is in a range of 25-30°C, minimum temperature of 8-16 °C, sunshine hours by 7-9 hours, morning and evening relative humidity of 70-85 % and 30-45 % ,respectively.

Jorhat

Effect of weather on severity of Cercospora leaf spot disease in green gram

The Cercospora leaf spot disease symptom was initially observed in IPM 02-3 during 41st SMW (1.11%) under early sown situation (D_1: 11 Sept). The mean highest PDI of Cercospora leaf spot in SGC16 (18.0%), SGC20 (14.17%), IPM02-3 (20.56%) and MH421 (10.83%) were observed during the 45 SMW. Overall, the highest PDI of cercospora leaf spot disease was recorded in IPM02-3 when sown on 28 September (D_2: 28 Sept). The highest PDI of cercospora leaf spot was observed in IPM 02-3 and least in MH 421 throughout the crop growing season when sown under delayed (D_3) conditions. Overall, maximum and minimum temperatures in the range of 29.4 -31.8 °C and 15.1-23.4 °C, mean relative humidity >81%, and light to moderate level of rainfall (49.1 mm) with mean BSSH of 7.2 hours were found favorable for Cercospora leaf spot development, corresponding to early sown kharif green gram. Late sown crop in *kharif* season was less favorable for the incidence of diseases since the temperature at that time dropped below 10°C and conidia do not grow.

Similarly, substantial variations in PDI were observed among sowing dates during the reproductive (0.52%) and ripening (0.59%) phases of crop with a maximum PDI of 5.62% (D_2) and 13.71% (D_1), respectively. Among three sowing dates and cultivars, the relatively highest PDI of Cercospora leaf spot was observed in the early-sown IPM 02-3 (20.56%) cultivar of green gram (Table 6.11).

Table 6.11 Effect of sowing dates on Cercospora leaf spot disease development in different varieties of green gram during *kharif*, 2022

	Vegetative	Reproductive	Ripening
Main plot treatment			
SGC 16	1.24(1.29)	4.02(2.00)	7.31(2.54)
SGC 20	1.57(1.25)	5.78(2.40)	8.56(2.84)
IPM 02-3	2.34(1.41)	6.84(2.59)	12.31(3.38)
MH 421	0.27(1.38)	1.71(1.10)	4.26(1.64)
Mean	1.36(1.33)	4.59(2.02)	8.11(2.60)
$CD_{(0.05)}$	NS	0.70	0.65
Sub plot treatment			
D_1	1.04(1.29)	5.16(2.29)	13.71(3.70)
D_2	2.11(1.39)	5.62(2.32)	7.56(2.63)
D_3	0.92(1.32)	2.98(1.46)	3.05(1.47)
Mean	1.36(1.33)	4.59(2.02)	8.11(2.60)
$CD_{(0.05)}$	NS	0.52	0.59
Interaction (V×D)			
CD	NS	NS	NS

Correlation between cercospora leaf spot with weather variables reveals that in *kharif* season, maximum (0.81**) and minimum temperature (0.80**) exhibited significant and positive correlation in the ripening phase only. In case of the overall disease observation period (cumulative), a significant negative correlation was observed with rainfall (-0.48**), wind speed (-0.46**) and afternoon RH (-0.44**); whereas a significant positive correlation was observed with BSSH (0.49**) and pan evaporation (0.42*). Afternoon relative humidity had positive association at ripening (0.70*) (Table 6.12).

Table 6.12 Correlation between weather parameters and Cercospora leaf spot in green gram at different growth stages during *kharif*, 2022

Crop phases	Kharif, 2022							
	Tmax	Tmin	RH-I	RH-II	RF	WS	BSSH	PANE
Vegetative	0.1	-0.11	-0.1	-0.26	-0.17	-0.13	0.26	0.39
Reproductive	0.36	0.28	-0.29	0.25	0.14	0.1	-0.13	0.36
Ripening	0.81**	0.80**	-0.79**	0.70*	0.00	0.23	0.61*	-0.51
Cumulative	0.01	-0.33	0.17	-0.44**	-0.48**	-0.46**	0.49**	0.42*

** significant at the 0.01 level, * significant at the .05 level

The best predictive model for Cercospora leaf spot has been found integrating maximum temperature for the ripening phase and morning BSSH for the total disease observation period, with a coefficient of determination (R^2) of 0.65 and 0.25, respectively (Table 6.13).

Table 6.13 Development of regression model (step-wise) for diseases of green gram observed during *kharif*, 2022

	Predictive Model	R^2
Vegetative	No variables entered	-
Reproductive	No variables entered	-
Ripening	Y = -17.25 + (0.69 × Tmax)	0.65
Total period	Y= 0.72 + (0.19 × BSSH)	0.25

Effect of weather on aphid population dynamics in green gram

The aphid attack was not observed in the early sown green gram during the *kharif* season of 2022, while in mid-and late sown green gram, aphid was recorded in all cultivars. In case of mid-sown situation (D_2), aphid was initially observed in IPM02-3 during the 47th SMW. The mean peak population of aphid in SGC-16 (126.5), SGC-20 (59.5), IPM-02-3 (157) and MH-421 (49) were recorded during 48th and 49th SMW in mid-sown green gram. Overall, highest aphid population throughout the crop growth season was observed in IPM-02-3 and lowest in MH-421 when sown on 28 Sept. (D_2). In late sown green gram; aphid was observed during 47th SMW (19th Nov.) in SGC-20. The mean peak population of aphids in SGC-16 (169), IPM-02-3 (141.75) and MH-421 (59.5) were recorded on 10th Dec. (50th SMW); whereas in SGC-20 (109) it was recorded in 3 Dec. (49th SMW). In late sown green gram, the highest aphid population throughout the crop growth season was observed in SGC-16 and lowest in MH-421. Among all the microclimatic regimes and cultivars, aphid population was most abundant in late-sown green gram and in IPM-02-3. A mean maximum temperature of 28.5-25.9 ^{0} C, 14.7-11.6 ^{0} C minimum temperature, >75% mean relative humidity with 8.3 hours of sunshine was found favorable for the aphid population corresponding to the late sown green gram.

The mean number of aphids was highest in IPM 02-3 throughout the reproductive and ripening phases. Statistically significant variations in a number of aphids were observed among sowing dates during the reproductive (0.89) and ripening (1.81) phase of *kharif* sown crop with a maximum aphid population of 69.62 (D_2) and 76.24 (D_3) corresponding to ripening phase. Aphid infestation was not observed in early sown green gram and throughout the vegetative phase of crop (Table 6.14).

Table 6.14 Effect of sowing dates on aphid population dynamics in different varieties of green gram during *kharif*, 2022

	Vegetative	Reproductive	Ripening
Main plot treatment			
SGC 16	0	0.95 (0.46)	68.60 (6.17)
SGC 20	0	5.87 (1.06)	30.00 (4.35)
IPM 02-3	0	3.91 (1.02)	69.74 (6.46)
MH 421	0	0.91 (0.46)	22.99 (3.72)
Mean	0	2.91 (0.75)	48.65 (5.18)
$CD_{(0.05)}$	-	NS	NS
Sub plot treatment			
D1	0	0.0 (0.71)	0.0 (0.71)
D2	0	0.0 (0.71)	69.62 (7.49)
D3	0	8.75 (2.26)	76.24 (8.05)
Mean	0	2.91 (0.75)	48.65 (5.18)
$CD_{(0.05)}$	-	0.89	1.81
Interaction (V×D)			
$CD_{(0.05)}$	-	NS	NS

The aphid population was significantly and negatively correlated with minimum temperature (-0.65*). However, it was significantly and positively correlated with morning relative humidity (0.61*) and evaporation (0.71**). It was observed that the afternoon relative humidity for the total insect observation period was found to contribute significantly to predicting aphids in green gram during *kharif* season with a coefficient of determination 0.67. Whereas, no variable was selected by the model when run for reproductive and ripening phases (Table 6.15).

Table 6.15 Correlation between weather parameters and aphid population in green gram *kharif*, 2022

Crop phases	*Kharif*, 2022							
	Tmax	Tmin	RH-I	RH-II	RF	WS	BSSH	PANE
Vegetative	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Reproductive	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ripening	-0.13	-0.13	0.13	0.13	0	-0.13	-0.13	-0.13
Cumulative	-0.38	-0.65*	0.61*	0.18	0	-0.48	-0.22	0.71**

** significant at the 0.01 level, * significant at the .05 level

Kanpur

Influence of weather parameters on maize stem borer

The infestation of maize stem borer, *C. partellus* observed during Kharif -2022, was 1.37% during the 27th week in the early date of sowing. The maximum and minimum temperature and relative humidity that prevailed during the initial infestation were 35.8 °C and 27.9 °C, 80.4 & 64.8 % at morning and noon respectively, the bright sunshine hours 6.1 hrs, and 47.4 mm rainfall was recorded during the week. The pest population increased gradually and reached to peak on 37th SMW i.e. with a formation of mean number of dead hearts i.e. 10.25 percent. The maximum, and minimum temperature and relative humidity prevailed during the peak period was 31.3 °C and 24.4 °C, 93.1 and 80% morning and noon, while total rainfall was observed at 156.2 mm, and sunshine hours (4.6 hrs) was recorded during this week. Thereafter, the pest population decreased gradually in all three maize varieties from 38th SMW to 39 SMW, very low dead hearts were seen in the 39 SMW where the maximum and minimum temperatures were recorded 32 °C and 23.4 °C, respectively, along with 86.9 and 72.1% relative humidity, 13.2 mm rainfall and sunshine hours 2.8 hrs. in early sown (21st June) maize crop. The highest larval population and dead heart formation in maize on 21st June sowing followed by 1st July and 11th July sowing. Among the varieties, the highest infestation of maize stem borer was found in Azad hybrid -2 followed by Azad hybrid -1 and DKC-7074

Table 6.17: Correlation between weather parameters and stem borer in maize during *kharif*, 2022

Weather Parameter	Timely sowing (21.06.2022)	Mid sowing (01.07.2022)	Late sowing (11.07.2022)
Tmax.	-0.44*	-0.44*	-0.05
Tmin.	-0.36*	-0.42*	-0.14
Tmean	-0.43*	-0.44*	-0.08
RH I	0.42*	0.41*	0.18
RH II	0.38*	0.43*	0.12
RH mean	0.40*	0.44*	0.15
RF	0.22	0.20	-0.08
BSS	0.10	-0.03	0.06

** significant at the 0.01 level, * significant at the .05 level

Correlation coefficients on weekly weather parameters such as maximum, minimum, and mean temperature, and mean relative humidity, weekly cumulative rainfall and bright sunshine hours with per cent mean number of dead hearts of maize during different sowing dates were worked out. Relative humidity morning, evening and mean relative humidity positive correlation was found between all sowing dates but maximum temperature, minimum temperature, and mean temperature, was observed with negative correlation all sowing dates. The rainfall showed a positive correlation between 21st June and 1st July sowing, but on 11th July sowing, a negative correlation. The sunshine hours showed a positive correlation for the increasing number of larval populations at 21st June and 11th July sowing but 01st July showed a negative correlation with a number of larval (Stem borer) populations.

The correlation matrix indicated a significant negative correlation for maximum, minimum and mean temperature with 21st June & 1st July sowing (r -0.44*, -0.36*, -0.43* & -0.44*, -0.42*, -0.44*), relative humidity morning, noon and mean shows significant positive correlation with 21st June & 1st July sowing (r 0.42*, 0.38*, 0.40* and 0.41*, 0.43*, 0.443*) with maize stem borer infestation. The incidence of stem borerhas a non-significant positive correlation with rainfall, and sunshine hours at all sowing (Table 6.17).

Table 6.18 Multiple regression equation for maize stem borer and weather parameters

Insects	Sowing Time	Regression equation	R^2
Maize Stem borer	Early (21.06.2022)	$Y=-127.51-9.85X_1-12.45X_2+22.78X_3+7.53X_4+7.24 X_5-13.56 X_6-0.04 X_7+2.59 X_8$	0.79
	Mid (01.07.2022)	$Y=-116.42-3.51X_1-6.76X_2+10.89X_3+15.66X_4+15.86X_5-30.47 X_6-0.03 X_7+2.14 X_8$	0.68
	Late (11.07.2022)	$Y=-88.59-7.96X_1-13.41X_2+21.17X_3+14.42X_4+15.12 X_5-28.63 X_6-0.03 X_7+2.50 X_8$	0.68

Note: X1: maximum temperature X2: minimum temperature X3: average temperature X4: morning relative humidity X5: noon relative humidity X6: mean relative humidity X7: rainfall X8: sunshine hours

The results of multiple regressions between maize stem borer and weather parameters show a positive relationship. The coefficient of determination (R^2) of regression between maize stem borer with weather parameters at early sown 79%, mid-sown and late sown 0.68 % (Table 6.18).

Kovilpatti

Effects of weather conditions on powdery mildew disease in black gram

The weekly disease incidence of powdery mildew disease was recorded in VBN 8 variety under natural field conditions in the black gram crop at ARS, Kovilpatti. The percent disease index (PDI) of powdery mildew disease data was correlated with the meteorological parameters. The maximum temperature (-0.19), wind speed (-0.56), sunshine hours (-0.44) and dew (-0.36) showed significant negative correlation with PDI, whereas minimum temperature (0.60), morning relative humidity (0.36) and rainfall (0.57) showed a significant positive correlation (Table 6.19). The optimum range of weather parameters with the maximum PDI value from 42 to 2 SMWs was analyzed as optimum maximum for the disease development was noted to be between 30.3 to 32.3 °C, minimum temperature 18.3 to 21.9 °C and relative humidity (morning) 88 to 91 percent and wind speed 1.0 to 2.1 kmph with the occurrence of rainfall.

Table 6.19 Correlation between Powdery mildew and weather parameters

	PDI	Tmax	Tmin	Rh	WS	SSH	RF	Dew
PDI	1.00							
Tmax	-0.19*	1.00						
Tmin	0.60*	-0.18	1.00					
RH	0.36*	0.05	0.85	1.00				
WS	-0.56*	0.18	-0.81	-0.55	1.00			
SSH	-0.44*	0.66	-0.78	-0.49	0.80	1.00		
Rainfall	0.57*	-0.02	0.44	0.45	-0.41	-0.34	1.00	
Dew	-0.36*	-0.07	0.40	0.58	0.65	0.53	0.62	1.00

A stepwise multiple linear regression model developed for powdery mildew is given below.

PDI = (-128.59) -0.99 RF -12.21 Tmax + 33.38 Tmin -3.34 RH + 39.19WS + 14.01SSH + 54.52 Dew   ($R^2 = 0.85$)

Effect of weather conditions on leafhopper in cotton

The weekly pest incidence of leaf hopper was recorded in KC 3 cotton under natural field conditions at ARS, Kovilpatti. The number ofleaf hopper data was correlated with the meteorological parameters. The maximum temperature (-0.78), maximum temperature (-0.25), wind speed (-0.66), sunshine hours (-0.23) and evaporation (-0.61) showed a significant negative correlation with LHI, whereas rainfall (0.06) showed a significant positive correlation.The optimum range of weather parameters with the maximum LHI value from 39 to 11 SMWs was analyzed. As optimum maximum temperature for the leaf hopper development was noted to be between 34.7 to 37.5 °C, minimum temperature 21.2 to 24°C and relative humidity (morning) 76 to 80 percent(Table 6.20).

Table 6.20 Correlation between leafhopper and weather parameters

	LHI	RF	Tmax	Tmin	SSH	WV	RH-1	Evp
LHI	1.00							
RF	0.05	1.00						
Tmax	-0.78	-0.10	1.00					
Tmin	-0.25	0.42	0.20	1.00				
SSH	-0.23	-0.34	0.45	-0.46	1.00			
WV	-0.66	0.29	0.84	0.11	0.45	1.00		
RH-1(%)	0.57	0.39	-0.84	0.14	-0.62	-0.84	1.00	
Evp(mm)	-0.61*	-0.22	0.90	0.03	0.56	0.82	-0.94	1.00

A stepwise multiple linear regression model developed for leaf hopper has given below.

LHI = 0.00 RF -2.7 Tmax 0.07 Tmin 0.14 +SSH + 0.14WS -0.52 RH -0.04 Evo (R² = 0.68)

Ludhiana

Effects on weather parameters on citrus psyllid (*Diaphorina citri* Kuwayama)

The weather and pest data for eight years from 2007 to 2015 (except 2012) were used for the development and validation of the citrus psylla population prediction model and four-year data from 2016 to 2019. To identify the weather parameter having a significant impact on psylla population the coefficient of determination (R^2) was worked out (Table 6.21). The weekly (seven days preceding to the day on which psylla data was recorded) weather data from 2007 to 2015 and corresponding psylla data at 15-dayintervalswere used for the calculation of R^2. The values of R^2 were greatly increased after applying the log transformation to the psylla count. In the log-transformed data, the impact of temperature (both maximum and minimum), bright sunshine hours, morning relative humidity, and THI on psylla count was found to be statistically significant (Table 6.21). The temperature-humidity index (THI) was calculated following:

$$THI = (0.8 \times T) + [(RH/100) \times (T - 14.4)] + 46.4$$

where T -Temperature (°C), RH -Relative humidity (%)

Table 6.21 Coefficient of determination (R^2) between various weather parameters and citrus psylla population

T_{max} (°C)	T_{min} (°C)	Bright sunshine hours	RF(mm)	RH II (%)	RH I (%)	THI
Non transformed						
0.22	0.34	0.04	0.08	0.02	0.03	0.33
After Log transformation [log (x+10)]						
0.41	0.52	0.10	0.02	0.00	0.12	0.52

Development of psylla population prediction model

The multiple regression analysis between Log transformed citrus psylla population data (as dependent variable) and maximum and minimum temperatures, duration of bright sunshine, morning relative humidity, and THI (as independent variables) resulted in the following model:

Y=0.02892-0.03304*Tmax+0.00797*Tmin+0.03791*SSH-0.0028625*RHm+0.03203*THI

Validation of the developed model

The multiple regression model between Log transformed citrus psylla population data (as dependent variable) and maximum and minimum temperatures, duration of bright sunshine, morning relative humidity and THI (as independent variables) was validated by using four years (2016 to 2019) weather and psylla data.

Table 6.22 Validation of the citrus psylla population prediction model

Statistics	Year				Average
	2016	2017	2018	2019	
Number of observations	24	24	24	24	
Observed mean	38.42	32.91	34.88	33.59	34.95
Predicted mean	36.28	38.57	34.92	33.93	35.93
Percent deviation	-5.56	17.20	0.13	1.02	2.80
RMSE	9.91	10.60	10.84	7.97	
R^2	0.52	0.38	0.52	0.85	
F value	11.38	6.43548	11.38	59.50000	

Mohanpur

Rice yellow stem borer and weather relationship in Gangetic plains of West Bengal

Five pheromone lure traps were installed in the experimental kharif rice field of the AICRPAM Mohanpur centre from 2016-22. The daily catch was counted from each trap and averaged. The daily count values along with respective weather parameters were identified where the pest count exceeds 3. Daily maximum, minimum temperature and morning and afternoon relative humidity were considered as the governing weather factors. Artificial neural networks were used to identify the most critical weather variable.

Artificial Neural Network (ANN)

A 4-68-1 ANN model was developed to establish the pest-weather relationship. The minT was considered the most important variable for pest prediction followed by RH1, maxT, and RH2 respectively (Fig. 6.5).

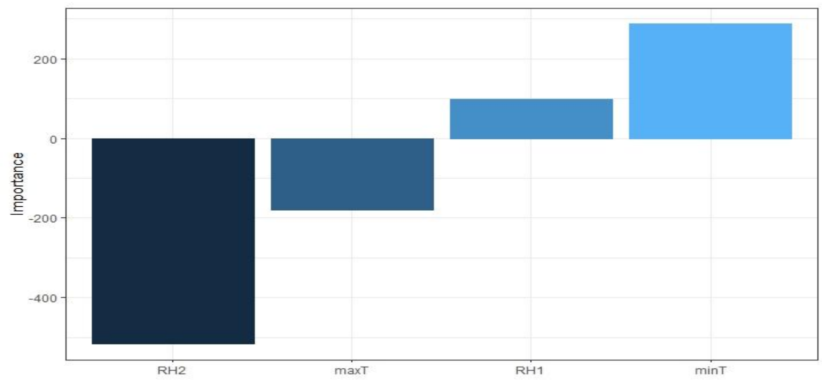


Fig. 6.5 Relative importance of the variables

For the calibration period, the ANN model performed moderately with an adj. R^2 of 0.44 with an efficiency of 53%. But performed quite efficiently in prediction with an efficiency of 67% in the validation period with an adj. R^2 of 0.55. According to the Artificial neural network (Fig. 6.6.) an increase in the maximum temperature causes a decrease in the rice stem borer count. The lethal temperature is >32°C. Rice stem borer count increases with an increase in minimum temperature from 16-20 °C. Within the range of 20-22 °C the increase in minimum temperature causes a decreased count data. 60 to 80% morning relative humidity can cause rice stem borer outbreaks. Afternoon relative humidity of less than 40% favours rice stem borer infestation.

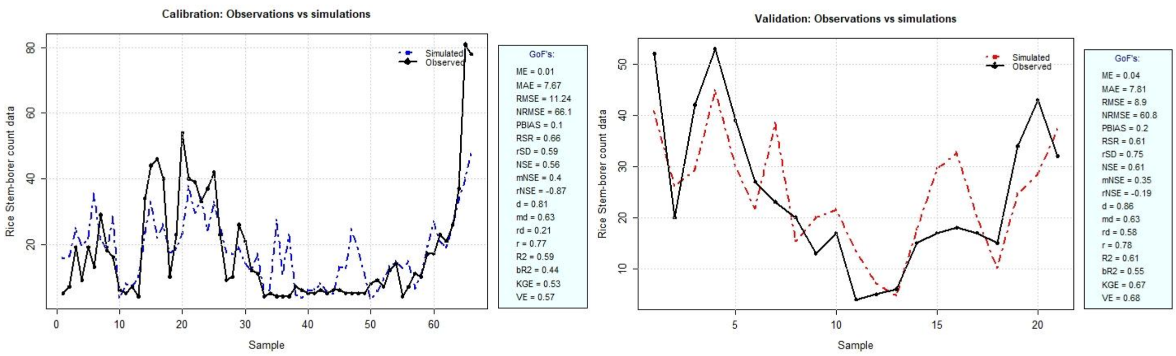


Fig. 6.6 Visualization of calibration and validation of the ANN model

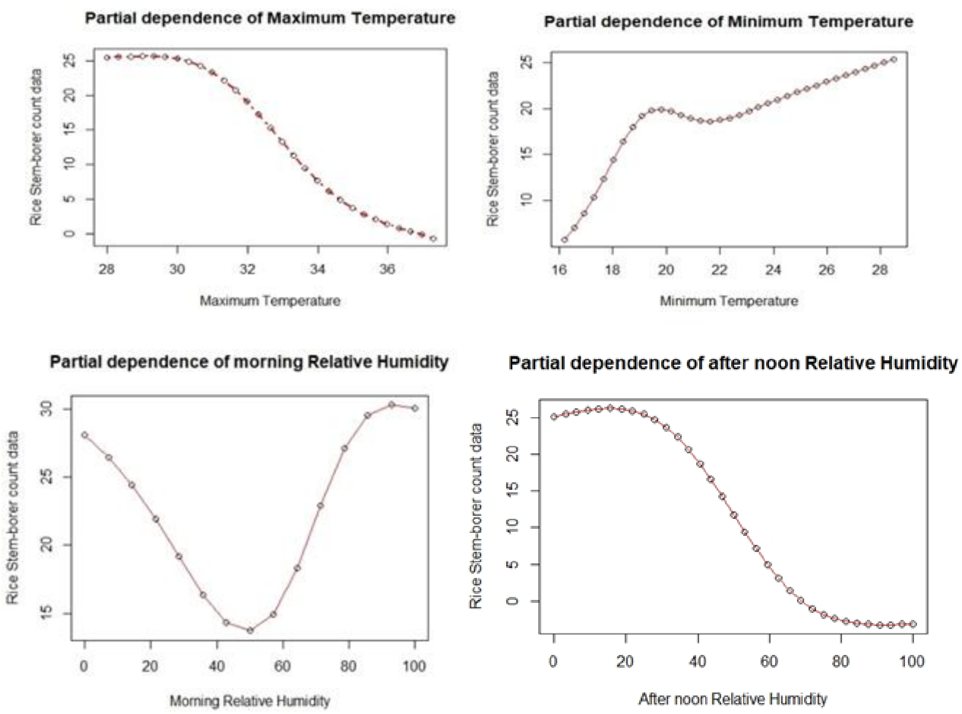


Fig. 6.7 Partial dependence of the input variables of the ANN model

As this location experiences more than 32°C and 20°C maximum and minimum temperature respectively during kharif season so the impact of temperature is subdued. Hence the morning relative humidity is the key factor in determining stem-borer infestation in the hot and humid region of West Bengal. Morning and afternoon relative humidity of 92-97% and 50-57% respectively are favourable for rice stem borer outbreak.

Parbhani

Insect pests in soybean crop

The relationship between weather and the incidence of pests on soybean was established under rainfed conditions at Parbhani during Kharif 2022-23. A total nine pheromone traps were installed in the soybean trial i.e 3 traps of each lure. The weekly observation of moth per pheromone was recorded. Table 1. data shows that *Spodoptera litura* moth trap was observed during 33 SMW and the infestation was continuously increased up to the 39 SMW. Highest moth recorded i. e. 21.0 *S. litura* / 3 traps was observed in 39 SMW, Highest moth recorded i. e. 4 *Helicoverpa armigera* / 3 traps was observed in 35 SMW & highest moth recorded i. e. 8 / 3 traps were observed in 40 SMW. The correlation analysis indicated a significant positive correlation with maximum temperature and minimum temperature, whereas a significant negative correlation with relative humidity and wind speed of *H. armigera* was observed. The correlation analysis indicated a significant positive correlation with morning relative humidity, while significant negative correlation with a minimum temperature of *S. litura* was observed.

Table 6.23 Correlation between soybean pests with weather parameters kharif 2022-23

	RF (mm)	**T_{max} (^oC)**	**T_{min} (^oC)**	**RH-I (%)**	**RH-II (%)**	**EVP (mm)**	**BSS (hrs)**	**WS (kmph)**
H. armigera	-0.255	0.326*	0.394*	-0.615**	-0.464*	0.140	0.225	-0.593**
S. litura	0.217	0.087	-0.437**	0.461**	0.258	-0.025	0.051	-0.229

* Significant at 5% level ** Significant at 1% level

Raipur

Development of weather-based forewarning model for Green Leaf Hopper in rice

Understanding the pest-weather relationship is of paramount impact for effective pest suppression. The nymph and adults of GLH cause direct damage to rice crop by sucking sap from leaf sheath and blades. Real-time forecasting of the pest population would be useful to the farming community for the judicious use of pesticides. The correlation analysis was worked out between the long-term population of GLH (2000-19) and weather parameters to meet this objective. In this study, weeks with a significant correlation between weather parameters and green leaf hopper population were selected for further analysis. Forewarning models were developed by multiple regression techniques. The prediction model as obtained by stepwise regression for each week with significant weather parameters is shown in Table. Other weeks were omitted due to the lack of a significant relationship between weather parameters and the population of GLH.

Table 6.24 Prediction equations for green leaf hopper obtained by stepwise regression

SMW	Pheno-phase	Model Equations	R^2
26	Initial	Y_{26} = -1.338+0.495*RF (1-week lag)	0.32*
33	Stem Elongation	Y_{33} = -2.389+0.31*RF (2 weeks lag)	0.38**
34	Stem Elongation	Y_{34} = -1.323+ 0.477*RF (3 weeks lag)	0.62**
35	Booting/ Heading	Y_{35} = -16.384+ 0.9336*RF (4 weeks lag)	0.66**
37	Flowering	Y_{37} = 5292.3+166.32*T_{max} (3 weeks lag)	0.32*
43	Flowering	Y_{43} = 5532.14-586.25*SSH (corresponding week)	0.35**
45	Dough	Y_{45}=2615.06+501.06*RF (corresponding week)-238.45*SSH (2 weeks lag)	0.52**
46	Maturity	Y_{46} = 12590.86-136.51* RH I (corresponding week)	0.22*
47	Maturity	Y_{47} = 3326.82+334.81*RF (2-week lag) - 354.49*SSH (corresponding week)	0.69**
48	Maturity	Y_{48} = 215.64+ 478.81*RF (3 weeks lag)	0.76**

* Significant at 5% level ** Significant at 1% level

Samastipur

Insect pests weather relationships in maize

A model of pest weather relation for the incidence of fall armyworm for its larval population and leaf damage (%) in rabi maize was developed using the data of larval population and percent leaf damage recorded during 2017-18, 2018-19 and 2019-20.Multiple linear regression and the Poisson model were developed. The model was validated using population and percent leaf damage data for 2020-21. ThePoisson model was found to perform better in predicting the incidence and damage of fall armyworms in rabi maize (Table 6.25).

Thresholds of maximum temperature, minimum temperature and relative humidity were identified, which can be used for predicting the incidence of fall armyworm and giving advisories. It was observed that a maximum temperature of 26.5-30 ^{o}C, minimum temperature of 13.2-15.6 ^{o}C, and relative humidity range of 84-87 during the morning and 59-63 percent during afternoon hours helped peak infestation of the pest.

Table 6.25 Multiple linear regression and Poisson model

Population	Coefficients	
	Multiple Linear Regression (MLR) Model	Poisson Model
Intercept	-0.46	1.34
T_{max}	0.21	1.07
T_{min}	-0.28*	0.89
RH I	0.00	1.00
RH II	0.02	1.00
Leaf damage (%)	Coefficients	
Intercept	-0.03	0.09
T_{max}	0.01	1.08
T_{min}	-0.02*	1.12
RH I	-0.00	0.99
RH II	0.00	1.00

7. Agromet Advisory Services

8. Summary

AGROCLIMATIC CHARACTERIZATION

- Agroclimatic onset of crop growing season was worked out for 680 districts of the country using three different methodsviz., Soil Water Balance, Depth and modified Morris & Zandesta. The onset was determined using Modified Threshold Combination (MTC) method comprising 40 combinations of threshold values.
- Long term rainfall data (1971-2022) of 11 districts in Vidarbha region was analysed to work out trends in seasonal rainfall.Nine of the eleven districts indicated non-significant decreasing trend of winter rains. Almost all the districts except Gadchiroli showed an increasing trend of summer (March-May) rains.
- Trend analysis of heat wave duration index (HWDI) at gridded level over Gujarat was carried out using the daily temperature data during 1991-2022. The HWDI trends were very high (0.56 – 1.08 HWDI year^{-1}) and statistically significant in Saurashtra and Kutch region of the state.
- The accuracy and variability of various PET estimation methods (Modified Penman Monteith, Blaney Criddle, Hargreaves, Open pan evaporimeter and Turc) was evaluated against the standard method i.e. FAO Penman-Monteith method at Ananthapuramu centre.Based on the cumulative performance of weekly mean PET for 32 years (1988-2019), Blaney Criddle method could efficiently predict the PET pattern with least error.
- Study on length of growing period (LGP) in East and South Eastern Coastal Plain Agroclimatic Zone of Odisha indicated that double cropping can be followed in Jagatsinghpur, Kendrapara and Puri districts where the length of the growing period >180 days except Khordha district where paira cropping can be followed as the length of the growing period <180 days.
- The daily wind speed and direction of four districts viz Ambala, Faridabad (eastern agroclimatic zone) Bhiwani and Hisar (western agroclimatic zone) were analyzed for the period of 41 years (1980-2020) and wind roses were prepared by Hisar centre.
- Effect of El Nino episodes on area, production and productivity of kharif crops in West Uttar Pradesh was studied by Kanpur centre. In five districts of Bundelkhand zone, a decline 18.4 per cent average yield of total *kharif* food grain, followed by Central Plain Zone (7.7 per cent) has occurred during El Niño years. The production declined by more than 15 per cent in Central plain zone and Bundelkhand zone.
- Variability induration of monsoon over Punjab was studied using the data during 2001-2021.During the last two decades, the duration of monsoon was reduced by only three years, i.e., 2002 (13 days), 2017 (03 days) and 2018 (11 days) against the normal value of 77 days.But the monsoon rainfall was reduced by up to ~19% during nine years.
- The water balance components of Katihar and Supaul districts were worked out based on Thornthwaiteand Mather Climatic water balance model by Samastipur centre. Soil moisture storage (SMS) of more than 40 per cent of AWC, was recorded during 24-44 SMW in coarse, 24-46 SMW in medium and during 25-50 SMW in fine textured soils.
- Projected changes in maximum temperature over Kerala was studied using GFDL-CM3 model by Thrissur centre. By the end of the century, maximum temperatures are expected to increase in all districts except Idukki, where temperatures are projected to decrease by 0.81℃. In the northern and central zones, maximum temperatures are expected to increase by 5℃; in the southern zone, temperatures are expected to increase by 3℃.

CROP WEATHER RELATIONSHIP STUDIES

Kharif 2022

Rice

- At Jorhat, grain yield was found maximum in Swarna Sub-1 (4109 kg ha^{-1}) followed by Ranjit Sub-1 (4001 kg ha^{-1}), TTB-404 (3960 $kgha^{-1}$) and least in Mahsuri (3286 kg ha^{-1}). With delay in transplanting, there was a gradual decrease in plant height; whereas maximum effective tillers, LAI at flowering, panicles per hill and grains per panicle were highest in crop transplanted under 11 July.
- At Mohanpur, crop-weather relationships in transplanted rice was undertaken using three growing environments (24 June, 08 July and 22 July 2022) and three varieties (Nayanmoni, Satabdi and Swarna). The highest yield was observed in late transplanted rice (D_3: 4347.7 $kgha^{-1}$) followed by 1st and 2nd transplanting environments (4033.5 kg ha^{-1} and 3936.5 kg ha^{-1}, respectively). Highest absorbed PAR (316 MJ) was observed in D_2 indicating higher vegetative growth and lowest radiation use efficiency (1.3 g MJ^{-1}) in terms of grain yield.
- Significantly higher yield and yield attributes were recorded in rice crop transplanted on 1st July as compared to 10th and 20th July at Chatha.Among different varieties, the yield attributes were found significantly higher under the variety SJR-129 followed by Basmati-370, but it was observed at par with Pusa-1121.
- The higher accumulated heat units and grain yield for crop sown on 24 SMW has recorded in the highest heat use efficiency (1.96 kg ha^{-1} °C day^{-1}), followed by crop sown on 23 SMW at Dapoli. Among the varieties, Jaya recorded highest HUE (2.1 kg ha^{-1} °C day^{-1}), followed by Palghar-1 (1.95 kg ha^{-1} °C day^{-1}).
- Crop weather relationship studies on basmati cultivars at Palampur indicated that crop transplanted on 1st July recorded highest yield and among the cultivars, Kasuri Basmati recorded highest yield compared to Basmati 370 and Pusa Basmati 1121.

Maize

- At Faizabad, crop sown during 05 July accumulated highest heat units (1792 °C-day) and heat use efficiency (1.76 kg ha^{-1} °C-day). Among the varieties/hybrids, Kanchan recorded highest HUE (1.85 kg ha^{-1} °C-day), followed by Azad hybrid-1 and Azad hybrid-2.
- Optimum maximum and minimum temperature respectively for better growth of maize crop during vegetative stage were identified to be in the range of 34.5 to 37.0°C and 26.0 to 27.5°C, during flowering stage were in the range of 32.0 to 35.0°C and 24.0 to 27.0°C

and during grain development stage were in the range of 33.0 to 34.5°C and 26.0 to 27.5°C at Central Punjab.

- At Samastipur, the maximum intercepted PAR (1029.33 μmol m^{-2} sec^{-1}) was observed in silking stage in 4^{th} date of sowing (30 June sown maize) and the lowest intercepted PAR of 592.81 μmol m^{-2} sec^{-1} was recorded at knee high stage in D_4 (30 June) sown crop. While considering the interception by different varieties, the maximum intercepted PAR (903.58 μmol m^{-2} sec^{-1}) was associated with silking stage and the lowest of 678.61 μmol m^{-2} sec^{-1} was observed during knee high stage in Shaktiman-4.

Pearlmillet

- The phase wise weather parameters were correlated with grain yield of pearl millet for assessment of weather parameters during different phase responsible for grain yield using four years kharif season (2017-2022) data at Anand.Minimum temperature till 100% flowering phase, correlated negatively. It indicates high night temperature during vegetative growth phases lowers the production of pearl millet.
- At Solapur, study on the relationship of maximum and minimum temperature with grain yield of pearl millet indicated that a Tmax of 31.5 °C and a Tmin of 23.5 °C was found to be optimum for obtaining higher yield

Finger millet

- At Solapur, sowing of crop on the 21 June resulted in maximum yield (2231 kg ha^{-1}) and it remained significantly superior over the other two dates. PRM-2 recorded maximum yield (2006 kg ha^{-1}) and remained significantly superior over the other two varieties.

Pigeonpea

- At Anantapur, the pigeon pea seed yield was significantly higher under protective irrigation condition. Among the varieties, PRG176 resulted in higher seed yield (698 kg ha^{-1}) compared to other varieties. All pigeon pea varieties resulted in higher seed yield with early sowing (II FN June), except LRG52.

Green gram

- At Jorhat, relatively higher seed yield was observed in MH421 (539.1 kg ha^{-1}); whereas least was observed in IPM 02-3 (432.5 kg ha^{-1}). Among the sowing dates, mean seed yield was found maximum during D_1 (545.3 kg ha^{-1}), and thereby gradually decreases with delay in sowing and becomes least in D_3 (415.8 kg ha^{-1}).

Groundnut

- The correlation study between the pod yield and phenophase-wise weather parameters at Anantapur revealed that the pod yield had significant positive correlation with morning relative humidity during emergence. Rainfall, rainy days, minimum temperature and growing degree days had significant negative correlation and maximum temperature and wind speed had significant positive correlation with pod yield during 50 % flowering.

- At Bangalore, Kadri Lepakshi recorded significantly higher pod yield (1775 kg ha^{-1}) compared to K-6 (1036 kg ha^{-1}) and KCG-6 (797 kg ha^{-1}). The first date of sowing recorded higher pod yield (1307 kg ha^{-1}) as compared to the second date of sowing (1098 kg ha^{-1}).

Soybean

- The relation between NDVI and LAI was approximated by the fitted logarithmic curve equation at Parbhani. Both NDVI and LAI measurements, were shown to be dependent on the stage of the vegetative growth, the denser the canopy the larger the NDVI and LAI values.
- Pooled data analysis of experiments conducted during 2016-22 at Vijayapura revealed that During pod development stage, minimum temperature, morning and afternoon vapor pressure, morning and afternoon relative humidity had significant positive correlation with soybean yield, while rate of evaporation showed significant negative association.

***Rabi* 2022-23**

Wheat

- At Palampur, crop sown on 05th November resulted in significantly higher grain yield while significantly lower grain yield was recorded in 20th December sowing.Significantly higher grain yield was recorded by HS 490 and the lowest by HD 2967.
- At Chatha, wheat variety (HD-2967) recorded significantly highest wheat yield (3526 kg ha^{-1}) followed by RSP-561 (3406 kg ha^{-1}) and significantly lowest in the Raj 3077 (3199 kg ha^{-1}).This may be due to highest HUE and RUE recorded by the variety HD-2967 followed by RSP-561 and Raj-3077 at all growth intervals during entire growing period.
- The meteorological parameters averaged for different growth stages of wheat cv PBW869 were computed for early, timely and late son wheat at Ludhiana. Highest and lowest yield of wheat was achieved with maximum/minimum temperature during vegetative stage was within 14.6-28.6/ 6.3-15.6 ^{o}C and 19.0-27.3/ 7.3-12.7 ^{o}C, respectively, during flowering stage was within 16.4-23.0/ 6.2-9.8 ^{o}C and 23.6-30.0/ 13.5-15.5 ^{o}C, respectively.
- A 1.0 °C increase in maximum temperature during reproductive stage caused a yield reduction of 433.3 kg ha^{-1} at Kanpur.
- At Ranichauri, VL-892 recorded maximum grain yield and biological yield and remained significantly superior over HD-2967 and at par with UP-2572.

Maize

- At Kovilpatti, among the maize hybrids evaluated, NK 6240 recorded maximum plant height (242.7 cm), LAI (5.1), rows/cob (13.9), grains /row (30.1) and test weight (29.2 g), grain yield (3881 kgha^{-1}) and this was followed by COHM 6.

Barley

- Growing environments and varieties showed significant effect on barley grain yield during 2022-23 at Hisar. The higher grain yield was recorded in D_1 (4910 kg ha^{-1}) as compared to other dates. Among the barley varieties, BH 393 recorded higher grain yield (4660 kgha^{-1}).

Sorghum

- Higher plant height of 245.3 cm, LAI (7.05), 1000 seed weight (16.5 g) and yield (3301 kg ha^{-1}) were recorded by 41st standard week sown crop at Kovilpatti. sorghum variety CSV 20 registered significantly increased growth and yield attributes *viz.*, higher plant height (243.4 cm), leaf area index (6.78), ear head length (21.2 cm), 1000 seed weight (16.5 g), which ultimately reflected in increased grain yield of 3060 kg ha^{-1}.

Chickpea

- Chickpea cultivars Vaibhav, JG-14 and JG-16 were evaluated for heat susceptibility using an index at Raipur. JG-14 and JG-16 varieties were found heat susceptible and Vaibhav variety was found moderately heat tolerant variety

- Yield and yield defining characters were significantly influenced by varied thermal regimes as well as varietals differences at Ranchi. Average performance of chickpea sown by 25th Nov (Early) was significantly higher (1701 kg ha^{-1}) than crop sown on 10th Nov (1115 kg ha^{-1}) and 10th Dec. (1012 kgha^{-1}). Among the varieties, significantly higher yield was recorded by BirsaChana3 (1416 kgha^{-1}) with 49 % harvest index followed by JG 14 (1288 kg ha^{-1})

- Field experiment data during 2017-2022 was pooled and correlation of phenophase-wise weather parameters with seed yield was undertaken at Vijayapura.During the pod development stage, yield was positively influenced by cumulative sunshine duration, rainfall and growing degree days, but negatively associated with evaporation and daily sunshine duration.

- At Anantapur, the mean seed yield with crop sown during II FN of October was higher (1005 kg ha^{-1}) as compared to I FN of November (931kg ha^{-1}) and II FN of November (939kgha^{-1}). Among the varieties, the mean seed yield with all three varieties (JG-11, NBeG 3 and NBeG 49) evaluated NBeG 49 has recorded highest seed yield (1112 kg ha^{-1}) followed by JG-11 (907 kg ha^{-1}).

- At Solapur, among the growing environments, crop sown during 38 SMW recorded highest yield (913 kg ha^{-1}), followed by SMW 40. Among the cultivars, Digvijay recorded higher yield compared to Vijay.

Greengram

- The response surface model developed with rainfall and temperature with green gram yield at Mohanpur performed exceptionally well with an adjusted r^2 of 0.98 in calibration process and 0.88 in the validation period.

Potato

- Kufri Pushkar had the highest tuber yield (35120 kgha^{-1}), followed by Kufri Lima (27150 kgha-1), and Kufri Bahar (25460 kg ha^{-1}) at Hisar.

Mustard

- At Palampur, higher seed yield of *gobhi sarson* was recorded when the crop was sown on 20th October followed by 30th October sowing and 10th November sowing in that order (Table 4.40). Among the varieties, the yield of HPN-1 and GSL-1 was on par and was higher than that of ONK-1.
- At Faizabad, NDR-8501 recorded higher values of yield attributes compared to other varieties under study. The highest yield was recorded when crop was sown on 25th Oct. Higher yield was recorded with NDR-8501 variety, which was significant over the yield of Varuna and Bio-902.

- Crop weather relationship mustard was studied using field experimental data of *rabi* seasons of years 2017-18 to 2022-23 at Anand.Maximum temperature, minimum temperature and morning relative humidity prevailed during early growth stages (up to flowering initiation) of mustard have strong positive association with seed yield.

Horticultural Crops

Mango

- A weather base statistical model for forecasting of meteorological week for emergence of vegetative flush in mango cv. Alphonso by using step down multiple regression equations was developed by Dapoli centre using observations of 22 years (1997-98 to 2020-21). Evaluation of the developed model indicated that the error percent in predicting meteorological week of vegetative flush in mango cv. Alphonso, three and four weeks before vegetative flush at different locations in Konkan region, was in the range of 1.15 to 9.52 per cent in both the years of validation with RMSE value of 1.07 to 3.09 per cent.

Guava

- Correlation of fruit yield and quality parameters of guava varietyHisar-Safeda with weather parameter under Hisar condition (pooled data analysis, 2013-14 to 2022-23) indicated that average fruit yield/plant showed significant positive correlation with minimum temperature, saturated vapor pressure and rainfall. The relative humidity had significant positive correction with fruit quality i.e. higher TSS (higher value of relative humidity favours the sweetness) and lower acidity.

Ginger

- June 1st planted crop reportedly had higher rhizhome yield while July 15th planted crop had the lowest yield at Thrissur. Early planting yielded higher yields than late planting, which had lower yields. The treatment with paddy straw mulch showed significantly higher yields over the other mulches viz. green leaves mulch and dry coconut leaves mulch.

Turmeric

- Fresh yield and dry yield of the crop was higher in both June1st and June 15th dates of plantings at Thrissur. Plots mulched with paddy straw produced more yield compared to other two mulching treatments. Detrimental effect was found between yield and rainfall during third phenophase of turmeric

CROP GROWTH MODELLING

- Sensitivity analysis of DSSAT-CROPGRO-Soybean model to temperature and CO_2 was studied by Akola centre. The increase in maximum and minimum temperatures gradually decreased the yield by -19.4 to -23.1% for crop sown during 26 SMW. The magnitude of yield reduction was to a greater degree with delayed sowing with 29 SMW sowing recording 11.8 to 38.0% reduction with upscaling of temperatures from 1 °C to 5 °C.
- Wheat yield prediction models for the three sowing environmentswere developed by Chatha centre using field experiment data during rabi 2015-16 to 2022-23.The regression equation for first growing environment (D_1) indicates that the average maximum temperature along at tillering stage, jointing and head emergence is positively related to wheat yield while a negative relation was observed with minimum temperature at emergence, sunshine hours at tillering and jointing stage, relative humidity and rainfall at head emergence, anthesis and hard dough stage.
- The calibratedand validated DSSAT CERES-wheat model was used to simulate yield and biomass for the consideredsowing window of Wheat in Punjab *i.e.*mid-October to late November which helped in deciding theoptimumdates forwheatsowing. The simulated sowing window on the basis of the calibrated and validated model was20th Octoberto 9th December.
- The impact of late transplanting on rice yield was studied using DSSAT-CERES-Rice model by Mohanpur centre. 1st July transplanted Satabdi and Swarna performed better than the 15th July transplanted kharif rice.With a delay of 15 days in transplanting, rice yield will be reduced by 18% and 10% in Satabdi and Swarna, respectively

WEATHER EFFECTS ON PESTS AND DISEASES

- Correlations between *S. litura* population and weather parameters during the current week of incidence, 1, 2, 3- and 4-weeks lag periods) showed a significant negative correlation of *S. litura* at Akola. Lower maximum and mean temperatures and higher humidity conditions are congenial for *S. litura* population on soybean crop.
- Mustard yield restricted to <1500 kg ha^{-1} when aphid population crosses aphid index value of 1.7 at Anand.
- Powdery mildew incidence was positively correlated with average relative humidity and wind velocity (0.01 and 0.16, respectively) and significantly positive with sunshine hours

(0.48*) and significantly negative relationship with minimum temperature (-0.65**), maximum temperature (-0.33) and rainfall (-0.34) at Bangalore.

- Hoppers population during the mango growing period was positively correlated with maximum temperature and wind speed (0.16 and 0.12, respectively) and significantly with sunshine hours (0.59**) and a significantly negative relationship with minimum temperature (-0.45**), relative humidity (-0.46*) and rainfall (-0.46*) with powdery mildew incidence at Bangalore.
- The peak aphid population occurs when the maximum, minimum, and mean temperature ranged between 29.0 to 34.4 °C, 11.4 to 20.6 °C, and 20.2 to 26.5 °C, respectively coupled with morning and evening relative humidity ranged from 83 to 96 and 41 to 57 %, respectively at Chatha.
- At Jorhat, the correlation matrix indicated a significant negative correlation for maximum, minimum and mean temperature with all three varieties of 21 June, 1 July sowing (r = -0.45*, -0.43*, -0.43*, -0.43*, -0.42*, -0.37*, -0.36*, -0.35*,-0.35*, -0.41and -0.41*) with maize stem borer infestation. The incidence of *C. partellus* has a non-significant positive correlation with rainfall, and sunshine hours at 21 June and 1 July sowing.

AGROMET ADVIORY SERVICES

- AICRPAM with the help of its cooperating centers across the country is involved in issuing AAS bulletins twice a week, both in English and vernacular languages.
- The Dynamic Crop Weather Calendar (DCWC), a decision support system developed by AICRPAM has been validated for 75 districts in the country for major crops grown in the respective districts.

9. Activities Organized by PC Unit

The coordinating unit of AICRP on Agrometeorology has conducted several programs during 2022-23 for the cause of strengthening research and capacity building in the field of agrometeorology. This section includes a brief description of the various programs organized.

1. Brainstorming meeting on 'Agroclimatic Atlas of India: A revisit'

A brainstorming meeting on 'Agroclimatic atlas of India: A revisit' was organized on 03 June 2022 in hybrid mode at ICAR-CRIDA, Hyderabad. The meeting was attended by around 50 participants physically and 30 participants virtually. Dr. V.K. Singh, Director, ICAR-CRIDA was the guest of honor and Dr. B.V. Ramana Rao, former PC (AICRPAM) acted as the chairman and Dr. Y.S. Ramakrishna, former Director, ICAR-CRIDA and Dr. V.U.M. Rao, former PC (AICRPAM) served as the co-chairmen. Serving and retired scientists from ICAR, SAUs, IMD, IIT, ISRO participated in the deliberation. The major points discussed were the source of climate and soil data to be used, agroclimatic indices to be included etc. The major suggestions were to develop a printed atlas with emphasis on regional/ sub-regional planning, explore possible collaboration with ICAR-NBSS&LUP for soil related information, inclusion of crop suitability zones, drought indices, crop weather calendars and extreme weather events in the proposed atlas, information on efficient cropping zones, all aspects related to weather hazards, areas prone to climate variability and change etc.


2. XVI Biennial Workshop of AICRPAM

The XVI biennial workshop of the AICRP on Agrometeorology was held at University of Agricultural Sciences,Bangalore during 12-14 November, 2022 to evaluate the research progress made during 2018-2022 and finalization of the technical program for the year 2023-2025.Dr S.K. Chaudhari, DDG (NRM), ICAR was the chief guest during the inaugural session. The workshop was conducted in seven technical sessions and a thorough review of the work done by 25 cooperating centres was made by the three experts namely Dr Y.S. Ramakrishna, Dr V.U.M. Rao and Dr P. Vijaya Kumar. The technical program for 2023-25 was also finalized during the workshop. It was decided to include at least one horticultural crop for all the centres.

3. Capacity building program (CBP) for AICRPAM scientists

Improving and upgrading the analytical skills of the scientists are an important mandate of AICRPAM. In this regard, AICRPAM organized the VII Capacity building program on “Agromet techniques for improving resource use in agriculture” at UAS Bangalore during 15-21 Nov 2022. Dr Santanu Kumar Bal was the Program Director, Dr A.V.M. Subba Rao and Dr M.A. Sarath Chandran served as Program Coordinators and Dr M.N. Thimmegowda served as Program Organizer. The program was attended by the agrometeorologists and junior agronomists of 25 AICRPAM centres. During the 7-days program, hands on training were imparted by external experts on temperature response functions, analysis of radiation data and optimizing irrigation water requirement were imparted. The CBP aims to enhance the research and analytical skills of AICRPAM scientists, to add value to the field experiment data generated by the project and development of new products, publications etc. The detail is as follows;

1. Temperature response functions for improving phenology prediction of field crops Resource person: Dr Rajkumar Dhakar, Scientist (Agril. Physics), IARI, New Delhi
2. Analysis of radiation data in relation to crop production
   Resource person: Dr M.K. Nanda, Head, Dept. of Agril. Meteorology & Physics, BCKV, WB
3. Optimizing irrigation water requirement using CROPWAT 8.0
   Resource person: Dr Saon Banerjee, Professor (Agril. Meteorology), BCKV, West Bengal

4.Training program on 'Agrometeorological Data Collection, Analysis and Management' for technical staff

Training program on 'Agrometeorological Data Collection, Analysis and Management' was organized during 18-27 January 2023 at ICAR-CRIDA for technical staff of ICAR institutes / SAUs / CAUs / ICAR funded KVKs. The program was attended by 15 participants from seven states, representing various ICAR institutes, SAUs etc. During the training period, the participants were exposed to lectures on various topics related to basic and applied aspects of agricultural meteorology, agromet data collection, practical sessions on data organization & analysis and field visits. The exposure visits included ICRISAT, India Meteorological Department, Hyderabad and NICRA research complex at Hayathnagar Research Farm, ICAR-CRIDA.


Training on
Agrometeorological Data Collection
Analysis and Management
AICRP on Agrometeorology
ICAR - Central Research Institute for Dryland Agriculture

10. Research Publications 2022-23

PC Unit, Hyderabad

Paper in Peer Reviewed Journals

Subba Rao, A.V.M., Sarath Chandran, M.A., Santanu Kumar Bal*, Pramod, V.P., Sandeep, V.M., Manikandan, N., Raju, B.M.K., Prabhakar, M., Adlul Islam, Naresh Kumar, S., Singh V.K. (2022). Evaluating area-specific adaptation strategies for rainfed maize under future climates of India. *Science of the Total Environment*, 836:155511.**(IF: 10.75)**

Santanu Kumar Bal, N. Manikandan*, V.M. Sandeep, P. Vijayakumar, M.M. Lunagaria, A.V.M. Subba Rao, V.P. Pramod and V.K. Singh (2022). Criteria based decisions for determining agroclimatic onset of the crop growing season. *Agricultural and Forest Meteorology*, 317, 108903. https://doi.org/10.1016/j.agrformet.2022.108903. **(IF: 6.24)**

Book Chapter

P. Vijaya Kumar, S. Muthu Pandiyan, Santanu Kumar Bal, M.A. Sarath Chandran, Rajkumar Dhakar and A.V.M. Subba Rao (2022) Weather and environment for crop production. In: Sunil Kumar, A.K. Tripathi, D.R. Palsaniya, P.K. Ghosh (Eds.) A textbook on recent advances in Agronomy, Kalyani Publishers, India. Chapter-1, pp.1.1-1.28.

Santanu Kumar Bal and M.A. Sarath Chandran (2022) Insurance based climatic risk management in rainfed crops. In: K. Nagasree et al. (Eds). Strategies for climate risk management and resilient farming. Collaborative online training programme, 20-24th September, 2021. ICAR- Central Research Institute for Dryland Agriculture, Hyderabad, India.

Popular articles

Santanu Kumar Bal, Manikandan, N., Subba Rao, A.V.M., Sarath Chandran, M.A., and Singh, V.K. (2022). Agroclimatic approach for sowing decisions. Indian Farming, November 72 (08): 05-07.

Subba Rao, A.V.M., Sarath Chandran, M.A., (2022). Crop Weather Calendars and their Prospects for Managing the Impacts of Climate Change. Agriculture and food e-newsletter, 4(4): 658-659.

Sarath Chandran M.A. (2022). Quantification of Climate Change Impact on Cropping Systems. Agriculture and food e-newsletter, October 4(10): 343-344.

Sarath Chandran M.A. (2022). Cloud Burst: The Science Behind and Management. Agriculture and food e-newsletter, August 4 (8): 360-361.

AICRPAM Centres Publications

Akola

Paper in Peer Reviewed Journals

Tupe, A.R., Thawal, D.W., Kharbade, S.B., Ganvir, M.M. and Morey, S.T. (2023). Effect of sowing date on thermal time requirement, heat use efficiency and radiation interception of soybean. The Pharma Innovation Journal. 12(1): 1866-1870.

Chorey, A.B., Gabhane, V.V., Patode, R.S., Ganvir, M.M, Tupe, A.R. and Mali, R.S. (2022). Overview of Dryland Agriculture Research and Development. *Indian Journal of Dryland Agricultural Research and Development*. Vol.37 (2):139-148.

Abstract/Papers Presented in Symposia/Seminar/Conference

Tupe, A.R. (2022). Quantification of impact of in-situ and water conservation technique on water balance in dryland agriculture, in "National Seminar on "Harnessing the Potential of Panchabhutas (tatvas) for sustainable climate resilient rainfed agriculture", during 28-29 September, 2022 at CRIDA Hyderabad.

Tupe, A.R. (2022). PASM induced yield variability in soybean crop at Akola conditions. in International Conference on "Reimagining Rainfed Agro-ecosystems: Challenges and Opportunities" during 22-24, December, 2022 at CRIDA Hyderabad.

Anand

Lunagaria, M.M., Vijayakumar, P., Chaudhari, N. J. and Bal, S. K. (2022) Onset, cessation and seasonality of rainfall during monsoon in Gujarat state of India. *Environment and Geoinformatics*, 9 (3), 65-72. DOI: 10.30897/ijegeo.995825

Ratiya, P. B. Lunagaria, M. M. and Sur, K. (2022). Determination of crop water stress index for *kharif* pearl millet in semi-arid environment. *Journals Krishi Vigyan*, 10 (2): 61-67. DOI:10.5958/2349-4433.2022.00011.3

Tak, V., Lunagaria, M.M., Virani, V.B. and Parmar, P.K. (2022). Thermal requirement, heat and radiation use efficiency of *kharif* soybean in middle Gujarat region as influenced by cultivars and plant geometry. *International Journal of Environment and Climate Change*, 13(1): 136-142. DOI: 10.9734/ ijecc/2023/v13i11644 n

Anantapur

Research article

Abhishek Kumar, Dillip Kumar swain, Dey Shiladitya, Ajay Singh, Kuttupurath Jayanarayan, Chander Girish and Ashok Kumar, K. (2022). Nutrient management may reduce global warming potential of rice cultivation. *Sub-tropical India*. 4:100169.

Ashok Kumar, K., Sudheer. K.V.S., Chaithanya, B.H., Uma devi, G.D., Pavani, K., and Sahadeva, B. Reddy. (2022). Crop-weather-disease relationship studies on rust severity in chickpea. (*Cicer arietinum* L.). *Scientist.* 1(3): 3458-3464

Ashok Kumar, K., Umadevi, G.D., Sudheer, K.V.S., Pavani, P. and Sahadeva, B. Reddy. (2023). Verification of medium range weather forecast for Anantapuramu district of Andhra Pradesh. *Scientist*. 3(3):74-81

Sahadeva, B. Reddy., Ashok Kumar, K; Sudheer. K.V.S., Anuhya, P., Radhika, P., Pavan Kumar Reddy and Maruthi Sankar, G.R. (2023). Efficient grouping of mandals for sustaining groundnut pod yield through crop seasonal rainfall and length of growing period and cultivated area under alfisols of Sri Sathya Sai district in south India. *Scientist*. 3(3): 82:107

Sahadeva Reddy, B., Ashok Kumar, K., Sudheer, K.V.S., Anuhya, P., Radhika, P., Pavan Kumar Reddy and Maruthi Sankar, G.R. (2023). Sustainability of pod yields of groundnut trough crop seasonal rainfall, length of growing period and cultivated area under alfisols of Anantapur in South India. *Asian Journal of Applied Science & Technology*. 7(1):80-104.

Popular articles

Ashok Kumar, K., Sudheer, K.V.S., Pavan Naik., L. and Sahadeva Reddy, B. (2022). agrometeorological observatory – establishment and general maintenance. chronicle of bio-resource management. *An international magazine*, September, 2022.

Bangalore

Paper in Peer Reviewed Journals

Thimmegowda, M.N., Manjunatha, M.H., Huggi, L., Shivaramu, H.S., Soumya, D.V., Nagesha, L., and Padmashri, H.S. (2023). Weather-Based Statistical and Neural Network Tools for Forecasting Rice Yields in Major Growing Districts of Karnataka. *Agronomy*, 13(3), 704-724.

Shivaramu, H.S., Manjunatha, M.H., Lingaraj Huggi, Santanu K. Bal, Vijaya Kumar, P., Padmashri, H.S., Soumya, D.V., Nagesha, L. and Mohanty, M. (2022). Soil moisture induced yield variability in major crops of Karnataka. *Indian Journal of Agricultural Sciences*, 92 (7): 836-41.

Mudalagiriyappa, M.N., Thimmegowda, K.M., Puneetha, B.G., Vasanthi, H.S., Latha, K., Devaraja, M. and Madan Kumar. (2022). National Innovation in Climate Resilient Agriculture–A case study at Bangalore rural district of Karnataka. *International Journal of Environment and Climate Change*, 8(12): 34-42.

Krupashree, R., Shivaramu, H.S., Thimmegowda, M.N., Manjunath, B.L., Mallikarjuna Gowda, A.P., Murali, K. and Lingaraj Huggi, (2022). Studies on crop water balance and yield of mango (cv. *Mallika*) as influenced by the weather parameters. *Mysore Journal of Agricultural Sciences*, 56 (3): 152-160.

Abstract/Papers Presented in Symposia/Seminar/Conference

Manjunatha, M.H., Shivaramu, H.S., Soumya, D.V., Lingaraj Huggi, Nagesha, L., Krupashree, R, (2022). Development and Validation of statistical yield forecast models for rice using Agrometeorological indices for major rice growing districts of Southern Karnataka in national conference on “Managing weather and climate risks in Agriculture (adapting crops to climate variability and uncertainty)”, during March 24-26, 2022, at SKUAST-Kashmir, Shalimar, Srinagar.

Shivaramu, H.S., Manjunatha, M.H., Lingraj Huggi, Nagesha, L., Soumya, D.V. and Krupashree, R. (2022). Socio economic upliftment of dry farming farmers of eastern dry zone of Karnataka through Agromet advisories and farmers awareness programmes in national conference on “Managing weather and climate risks in agriculture (adapting crops to climate variability and uncertainty)”, during March 24-26, 2022, at SKUAST-Kashmir, Shalimar, Srinagar.

Thimmegowda, M.N., Manjunatha, M.H., Lingaraj Huggi, Nagesh, L. and Soumya, D.V, (2022). Agrometeorological interventions for enhancing farmers income in the drylands of south interior Karnataka in International conference on “Reimagining rainfed agro ecosystems: Challenges and opportunities”, during 22-24, December, 2022 at CRIDA Hyderabad.

Popular articles (Kannada/ English)

Nagesha, L., Lingaraj Huggi, Soumya, D.V., Thimmegowda, M.N., Manjunatha, M.H. and Rajegowda, M.B. (2022). Role of agricultural extension units in imparting agro-climatic utility to the farmers group. *Krishi Kayaka* (Newsletter), October-December 2022.

Thimmegowda, M.N., Manjunatha, M.H., Lingraj Huggi, Nagesha, L. and Soumya. D.V. (2022). *Angaiyalli havamana mahithi* (Kannada).

Faizabad

Paper in Peer Reviewed Journals

Gupta, S., Mishra, S.R., Singh, A.K and Mishra, A.N. (2022). Studies on thermal unit and heat use efficiency requirement of mustard crop (*Brassica juncea* L.) under different ambient temperature and cultivar. *International Journal of Environment and Climate Change*, 12(3):51-57.

Agrahari, R.K., Mishra, A.N., Mishra, S.R. and Singh, A.K. (2022). Heat unit and heat use efficiency under different growing environment of mustard crop (*Brassica juncea* L.). *International Journal of Environment and Climate Change*, 12(10):1205-1209.

Lavkush, Singh, A.K, Singh, Shraddha, Tiwari, D, Singh, Piyusha, Zaidi, S.T., Yadav, R.K., Mishra, S.R. and Singh, A.K. (2022). Evaluation of wheat varieties for terminal heat stress under varying environments. *International Journal of Environment and Climate Change*. 12(10):546-554.

Abstract/Papers Presented in Symposia/Seminar/Conference

Anushka Pandey, Singh A.K, Mishra A.N. and Mishra S.R. (2023). Study on crop weather calendar of wheat crop of eastern plain zone of UP, in proceeding of National Conference AGMET-2022 “Advances in Agro meteorological Interventions for Climate Resilient Agriculture”, during 15-17 Feb. 2023 at TNAU, Coimbatore.

Anurag Tripathi, Mishra S.R. Mishra A.N. and Singh A.K. (2023). Climate change and its effect on agriculture production, in proceeding of national conference AGMET-2022 “Advances in Agro meteorological Interventions for Climate Resilient Agriculture”, during 15-17 Feb. 2023 at TNAU, Coimbatore.

Shubham Pandey, Mishra S.R. Mishra A.N. and Singh A.K. (2023). Role of ITC and ITK in weather forecasting and weather based agro-advisory services in proceeding of national conference AGMET-2022 “Advances in Agro meteorological Interventions for Climate Resilient Agriculture”, during 15-17 Feb. 2023 at TNAU, Coimbatore.

Hisar

Paper in Peer Reviewed Journals

Renu, Kumar, A., Dagar, C.S. and Singh, R. (2023). Study the relationship of barley with growth-yield, weather and agrometeorological condition under different growing environments. *The Pharma Innovation Journal*, 12(4): 1764-1769.

Yadav, P., Dagar, C.S., Kumar, A. and Dahiya, P. (2022). Effect of soil moisture on growth and yield of pearl millet (*Pennisetum glaucum* L.) under different dates of sowing. *Environment and Ecology*, 40 (3B): 1489-1496.

Harshana, Kumar, A., Shekhar, C., Singh, R., Kumar, M., Tomar, D., Khichar, M.L., Thakral, S.K. and Mamta (2022). Assessment of agrometeorological observations on pearl millet (*Pennisetum

glacum L.) genotypes grown under different growing environments. *Forage Research*, 48(2):185-190

Abstract/Papers Presented in Symposia/Seminar/Conference

Kumar, A., Dagar, C.S. Anurag and Khichar, M.L. (2023). Climatic based futuristic scenario of climatic study: A review in International Conference on "Climate Resilient Agriculture for Food Security and Sustainability", during 17-19 February, 2023 at CCS HAU Hisar.

Harshana, Kumar, A., Shekhar, C., Rahul and Ankit (2023). Impact of growing environments on growth and yield of pearl millet genotypes under semi-arid regions of Haryana, in International Conference on "Climate Resilient Agriculture for Food Security and Sustainability", during 17-19 February, 2023 at CCS HAU Hisar.

Khichar, M.L., Niwas, R., Kumar, A., Anurag, Kumar, N. and Dagar, C.S. (2023). Web enabled agromet information system emausamhau for farming community of Haryana, in International Conference on "Climate Resilient Agriculture for Food Security and Sustainability", during 17-19 February, 2023 at CCS HAU Hisar.

Kumar, A., Dagar, C.S., Anurag, Khichar, M.L. and Bal, S.K. (2023). Long term analysis of western disturbance, characteristics and its statistical frequencies in Haryana in International Conference on Natural farming for Revitalizing Environment and Resilient Agriculture (NF-RERA, 2023) at CAU, Imphal Manipur.

Book Chapter

Dagar, C.S., Anil Kumar, Khichar, M.L., Surender Singh, Bal, S.K., Anurag and Bhan, S.C. (2022). Advancement in the weather based seasonal Agromet Advisories services for agricultural sectors to farmers of Haryana State. In: Research Trends in Agricultural Extension, AkiNik Publications, pp: 1-22. New Delhi (ISBN 978-93-5570-400-9).

Jabalpur

Paper in Peer Reviewed Journals

Lanjhewar, A., Agrawal, K.K. and Manish Bhan. (2022). Phenology and heat unit requirement of wheat varieties under different thermal environments and IW: CPE ratio-based irrigation scheduling. *International Journal of Plant and Soil Science*, 34(23):1522-1531.

Lanjhewar, A., Agrawal, K.K. and Manish Bhan. (2022). Influence of thermal regimes and irrigation schedules on growth, yield attributes and yield of wheat (*Triticum aestivum* L.) varieties. *International Journal of Environment and Climate Change*. 123:484-490.

Chatha

Paper in Peer Reviewed Journals

Bhagat Rakshit, Singh, Mahender and Sharma, B.C. (2023). Growth and productivity of gobhi sarson (*Brassica napus*) cultivars under diverse sowing environments. *Indian Journal of Agricultural Sciences*, 92(10): 1202-1207.

Bhagat Rakshit, Singh, Mahender, Sharma, B.C. and Gurinder Singh. (2023). Influence of sowing date on growth and productivity of rapeseed-mustard: a review. *Journal of Oilseed Brassica*, 14 (1): 1-10.

Abstract/Papers Presented in Symposia/Seminar/Conference

Mahender Singh, Monika Banotra, Charu S., Sharma, B.C. and Rohit Sharma. (2022). "Yield forecasting of wheat crop using statistical model in five districts of Jammu Region in union territory of Jammu and Kashmir" in 10th National Conference on "Agriculture and More: Beyond 4.0", during May 26-28, 2022, at SKUAST-K, Kashmir, (J & K).

Rohit Sharma, Vikas Sharma, Rajesh Kumar, Mahender Singh, Vishal Sharma, Ashu Sharma and Monika Banotra. (2022). Verification of medium range weather forecast for Rajouri District of J & K in 10th National Conference on "Agriculture and More: Beyond 4.0", during May 26-28, 2022, at SKUAST-K, Kashmir, (J & K).

Veena Sharma and Mahender Singh (2022). Usability of biweekly Rainfall Forecast for issuing Agro-Advisory, in 10th National Conference on "Agriculture and More: Beyond 4.0", during May 26-28, 2022, at SKUAST-K, Kashmir, (J & K).

Kanpur

Abstract/Papers Presented in Symposia/Seminar/Conference

Ajay Kumar, Pandey, S.N., Singh, C.B., Naushad Khan, Karam Husain and Shivam Mishra. (2022). Climate change and its effects on horticulture and agriculture crops in Uttar Pradesh, in National Conference on Climate Resilient and Sustainable Development of Horticulture during 28-31 May, 2022 at CSAUA&T, Kanpur.

Naushad Khan, Karam Husain, Pandey, S.N., Singh, C.B., Ajay Kumar and Shivam Mishra. (2022). Climate change and adaptation strategies in horticultural crops, in National Conference on Climate Resilient and Sustainable Development of Horticulture during 28-31 May, 2022 at CSAUA&T, Kanpur.

Ajay Kumar, Pandey, S.N., Singh, C.B., Naushad Khan, Karam Husain and Shivam Mishra. (2022). Effect of temperature rise on crop growth and productivity in Central plain zone in Uttar Pradesh in National Conference on Climate Resilient and Sustainable Development of Horticulture during 28-31 May, 2022 at CSAUA&T, Kanpur.

Kovilpatti

Research article

Thenmozhi, S., Thiyagarajan, G., Manikandan, M., and Bhuvaneswari, J. (2022). Studies on growth yield and water use efficiency of maize as influenced by irrigation methods and fertilizer application. *The Pharma Innovation Journal*; 11(2): 1151-1154.

Thenmozhi.S, Thiyagarajan, G., Manikandan, M., and Bhuvaneswari, J. (2022). Study on the impact of various irrigation methods on soil properties in maize. *International Journal of Farm Sciences*, 12(2):105-110.

Sankar T., Ramanathan, S.P., Kokilavani, S., Chandrakumar, K., Kalarani, M.K. (2023). Assessment of Aquacrop model for simulating Baby corn (*Zea Mays* L.) growth and productivity under different sowing windows and crop geometrics. *Journal of Agrometeorology*, 25(2): 280-286.

Abstract/Papers Presented in Symposia/Seminar/Conference

Bhuvaneswari, J., Kokilavani, S., Arthirani, B. and Baskar, K. (2023) Rainfall analysis for Kovilpatti, Thoothukudi District. in National Conference, AGMET 2022, during Feb15-17th, 2023 at ACRC, TNAU, Coimbatore.

Book

Bhuvaneswari, J., Akshaya, S. and Balasree, R. (2023). Wind Profile in crop canopies. Book - Crop Weather Relationship. Published by ACRC, DCM, TNAU, Coimbatore. ISBN:978-959652-9-8. P.No.67.

Popular Article

Baskar, K., Bhuvaneswari, J., Kokilavani, S. and Manikandan, M. (2022). Training programme on advances in pulses production technology in *TNAU News*, P:8 on December 2022.

Bhuvaneswari, J., Kokilavani, S., Arthirani, B. and Baskar, K. (2022). Rainfall analysis for Kovilpatti, Thoothukudi District. Abstract No.IPF02 on 15.02.2023.

Baskar, K., Arthirani, B., Kokilavani, S., Ananthi and Bhuvaneswari, J. (2023). ARS Kovilpatti dual mela. *Dinamani (Tamil)* P:4 .

Baskar, K., Arthirani, B., Kokilavani, S., Ananthi and Bhuvaneswari, J. (2023). ARS Kovilpatti - Awareness Programme. *Dinathanthi (Tamil)*. P:2.

Ludhiana

Paper in Peer Reviewed Journals

Shivani Kothiyal, Prabhjyot-Kaur and Jatinder Kaur. (2023). A critical analysis of effect of projected temperature and rainfall for differential sowing of maize cultivars under RCP 4.5 and RCP 6.0 scenarios for Punjab. *Theoretical and Applied Climatology*, 151:329-354.

Sarabjot Kaur Sandhu and Prabhjyot-Kaur. (2023). A case study on the changing pattern of monsoon rainfall duration and its amount during the recent five decades in different agroclimatic zones of Punjab state of India. *Mausam* 74(3):651–662,

Garima and Sandhu, S.S. (2023). Phenology, growth and productivity of rice (*Oryza sativa* L.) under reduced sunlight intensity and foliar nitrogen application. *Journal of Agrometeorology*, 25(1): 98-104.

Jatinder Kaur, Prabhjyot Kaur and Shivani Kothiyal. (2022). Futuristic changes in monthly meteorological parameters as simulated by four GCMs under four emission-based scenarios at Ludhiana, Punjab. *Arabian Journal of Geosciences*, 15: 906

Jatinder Kaur and Prabhjyot-Kaur. (2022). A critical assessment of changes in climate predicted by four GCMs under different RCP scenarios in Punjab (India). *Mausam* 73(4): 749-762.

Kuldeep Kaur and Prabhjyot-Kaur. (2022). Evaluating the impact of intra-seasonal change in temperature and solar radiation on phenology and yield of rice using CERES-rice model in Punjab. *Mausam*, 73(2): 423-432.

Sukhjeet Kaur, Prabhjyot-Kaur and Harleen Kaur. (2022). The role of meteorological parameters in determining yield of rice cultivated under flooded transplanted conditions in Ludhiana district - A case study. *Journal of Agrometeorology*, 24 (3): 299-304.

Sandeep Singh, Prabhjyot-Kaur and Sandhu, S.S. (2022). Crop-weather calendars for optimizing maize yield. Punjab. *Agricultural Research Journal*, 59 (1): 146-151.

Kuldeep Kaur and Prabhjyot-Kaur. 2022. Simulation of yield of rice cultivars under variable agronomic management options using CERES-Rice and INFOCROP-Rice models in irrigated plains of Punjab. *Agricultural Research Journal*, 59 (3): 438-446.

Shivani Kothiyal, Prabhjyot-Kaur and Jatinder Kaur. (2022). Simulation and analysis of maize (*Zea mays* L.) yield trend under different emission scenarios in Ludhiana district of Punjab. *Agricultural Research Journal*, 59 (4): 639-652.

Rajveer Kaur, Seema Bedi and Prabhjyot-Kaur. (2022). Evaluation of growth and yield in wheat (*Triticum aestivum* L.) under heat stress conditions. *Agricultural Research Journal*, 59 (4): 609-615.

Navneet Kaur and Prabhjyot-Kaur. (2022). Calibration and validation of CERES- Maize model under different environments for Ludhiana, Punjab. *Journal of Agricultural Physics*, 22(1): 99-106.

Prabhjyot-Kaur, Sandhu, S.S., Shivani Kothiyal and Jatinder Kaur. (2022). Determination of sowing window for wheat in Punjab, India using sensitized, calibrated and validated CERES-Wheat model. *Journal of Agricultural Physics*, 22(2):215-227

Sandhu S.S., Prabhjyot-Kaur and Gill K.K. (2022). Weather parameters for higher rice productivity in Central Punjab. *Journal of Agricultural Physics,* 22 (2) 241-249.

Abstract/Papers Presented in Symposia/Seminar/Conference

Prabhjyot-Kaur, Sandhu, S.S. and Dhir, A. (2022). Role of Agromet advisory in strategizing the agronomic practices for managing climate risks in Punjab - A case study, in proceedings of “Managing Weather and Climate Risks in Agriculture-Adapting Crops to Climate Variability and Uncertainty”, during 24-26 March 2023, at SKUAST-K, J & K.

Sandhu, S.S., Prabhjyot-Kaur, Gill, K.K., Singh, J., Dhir, A. and Kaur, J. (2022). Susceptibility of rice (*Oryza sativa* L.) to low sunshine intensity and its management options, in proceedings of “Managing Weather and Climate Risks in Agriculture-Adapting Crops to Climate Variability and Uncertainty”, during 24-26 March 2023, at SKUAST-K, J & K.

Jaspreet Kaur and Sandhu, S.S. (2022). Response of field grown wheat to artificial periodic heat stresses, in National Seminar on “Agrophysics for Smart Agriculture”, during 22-23 February 2022, NASC Complex, New Delhi.

Technical bulletin

Prabhjyot-Kaur, Sandhu, S.S., Shivani Kotiyal, Anupama Aryal, Jatinder Kaur, Jashandeep Singh, Jagjeet Kaur and Gurpreet Singh. (2023) Productivity and management of cereals under projected climate change in Punjab. Dept of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana. 120 p.

Popular article:

Prabhjyot Kaur and Gosal S.S. (2022). Acclimatization the key to Agri sustainability. *The Tribune,* December 26, 2022.

Mohanpur

Paper in Peer Reviewed Journals

Banerjee S., Singal, G., Saha, S., Mittal, H., Srivastava, M., Mukherjee, A., Mahato, S., Saikia, B., Thakur, S., Samanta, S., Kushwaha, R., and Garg, D. (2022). Machine Learning approach to predict net radiation over crop surfaces from global solar radiation and canopy temperature data. *International Journal of Biometeorology*. DOI: 10.1007/s00484-022-02364-5

Saha, S., Banerjee, S., Mondal, S., Mukherjee, A., Nath, R. and Chowdhury, S. (2022). Evaluating radiation interception pattern and RUE of green gram grown in lower Gangetic plains and assessing future yield based on RUE. *Journal of Agrometeorology*, 24 (1): 3-9.

Banerjee, S., Biswas, R., Mukherjee, A., Sattar, A. (2022). Simulating the impact of elevated thermal condition on wet-season rice grown in Eastern India by different crop growth models. *Italian Journal of Agrometeorology*, (2): 63-71. doi: 10.36253/ijam-758.

Palampur

Paper in Peer Reviewed Journals

Tigangam P. Gangmei, Navneet Kaur, Alisha Thakur, Sidharth Baghla, Kishor Kumar Sahu, Anil Kumar and Sandeep Manuja. (2022). Studies on irrigation scheduling and nutrient management on wheat growth and productivity. *Himachal Journal of Agricultural Research*, 48 (1): 48 – 55

Shabnam Kumari, Sandeep Manuja, Suresh Kumar, Sharma, R.P., Ankit and Anil Kumar. (2022). Growth analysis of rice hybrids as influenced by dates of transplanting under lowland conditions. *Himachal Journal of Agricultural Research*, 48 (1): 107 – 111

Ankit Saini, Sandeep Manuja, Anil Kumar and Gurudev Singh. 2022. Tillage methods and varieties influence on phenology and productivity of rice-wheat cropping system under rainfed conditions. *Scientist*,1(3):4734-4740, https://doi.org/10.5281 /zenodo.7457535.

Book Chapters :

Shabnam Kumari, Rana, S.S., Sandeep Manuja, Bharat Bhushan Rana and Akashdeep Singh. (2023). Futuristic Agriculture with Robots: A Concept to Reality. In: Impact of Climate Change on Agriculture Scientific Publications, Agra. pp 141 – 157 (ISBN No. 978 – 9393483 – 140).

Raipur

Paper in Peer Reviewed Journals

Sahu, K.K., Chaudhary, J.L. and Puranik, H.V. (2021). Identification of weather parameters affecting the yield of chickpea under different growing environments. *Journal of Pharmacognosy and Phytochemistry*, 10 (IS), pp. 77-79.

Technical Bulletins

Chaudhary, J.L., Das, G.K., Sonboier, K.K., Unjan, D., Jain, S., Manikandan, N. and Bal, S.K. (2022). Agroclimatic onset, withdrawal and length of crop growing season over Chhattisgarh state. Technical Bulletin number DeAM/2022-23/AICRPAM/01. 15p.

Chaudhary, J.L., Das, G.K., Puranik, H.V., Khilendra Kumar Sonboier, Dilip Kumar Patle and Singh, K.K. (2020). Economic impact analysis of agro-advisories dissemination in Lakholi village of Raipur district-a pilot study under GKMS project. Technical bulletin number, DeAM/GKMS/2019-20/02, IGKV Raipur 24p.

Ranchi

Paper in Peer Reviewed Journals

Kumari Pragyan, Minz, S.P, Sahay, Swati and Das, S.S. (2022). Influence of weather variables on cattle diseases in Ranchi, Jharkhand. *Journal of Agrometeorology*, 24(4): 417-419.

Gupta, C.K, Wadood, A., Kumar R., Kumari Pragyan, Prasad, S.M. and Gupta D.K. (2022). Characteristics of meteorological and agricultural drought of Hazaribagh District, Jharkhand. *Journal of Agricultural Physics*, 22 (2): 284-290.

Samastipur

Paper in Peer Reviewed Journals

Sattar, A., Singh, G., Khan, S.A., Jha, R.K. and Kumar, K. (2022). Estimation of evaporation and soil moisture index-based length of growing period for enhanced agricultural production in Bihar. *Mausam*, (73):389-404, https://doi.org/10.54302/mausam.v73i2.5482

Book chapter

Sattar, A., Kumar, M., Jha, R.K., Singh S.K., Kumar, U., Nilanjaya, Bal, S.K. and Singh, G. (2023). Crop Weather Calendars for major crops of Bihar: Agroclimatic Tools for Climatic Risk Management, RPCAU, Pusa (Samastipur), 84p.

Sattar, A., Jha, R.K., Singh, G., Kumar, M., Brahmanand, P.S. and Bal, S.K. (2023) Evaluation of water balance components for different districts of Bihar, RPCAU, Pusa (Samastipur),108p.

Sattar, A., Kumar Ankit, Singh Gulab and Jha, R.K. (2022). Micrometeorological requirements of winter maize in Bihar for enhanced production, in M. Kumar (Eds.), Maize in Glorious Journey in Bihar, 25-34.

Solapur

Paper in Peer Reviewed Journals

Londhe, V.M., Jadhav, V.T., Jadhav, J.D., and Amrutsagar, V.M. (2022). Studies on shifting of sowing windows for sustainable production of chickpea (Cicer arietinum L.) under variable rainfall situation in scarcity zone of Maharashtra. *Journal of Agriculture Research and Technology*, 47(3) 247-251.

Jadhav, V.T., Londhe, V.M., Jadhav, J.D., and Amrutsagar, V.M. (2022). Effect of Changing Rainfall Situation on Yield of Pearl millet in Medium Deep Soil of Scarcity Zone of Maharashtra. *Journal of Agriculture Research and Technology*, 47(3)274-280

Londhe, V.M., Jadhav, V.T., Jadhav, J.D. and Amrutsagar, V.M. (2022). Studies on sowing windows for sustainable production of rabi sorghum (*Sorghum bicolour* L.) under changing climatic condition in scarcity zone of Maharashtra. *Journal of Agriculture Research and Technology*, 47 (3)316-321.

Jadhav, V.T., Londhe, V.M., Jadhav, J.D. and Amrutsagar, V.M. (2022). Yield prediction of sunflower using regression equation under changing rainfall situation in scarcity zone of Maharashtra, *Journal of Agriculture Research and Technology*, 47 (3) 322-330.

Udaipur

Paper in Peer Reviewed Journals

Kumar, R., Choudhary, J., Choudhary Roshan, Kaushik, M.K., Meena, R.H. and Swami. (2022). Effect of sowing environment and varieties on growth and quality of durum wheat (*Triticum durum* L.). *The Pharama Innovation*, SP-11 (8): 826-829.

Staff position at cooperating centers during 2022-23

(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	V	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	V	V
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**	**10**	**16**	**18**
Post Sanctioned	**25**	**12**	**25**	**25**

AICRPAM – Field activities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V1 : MTU 1010


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