

All India Coordinated Research Project on Agrometeorology



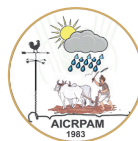
Annual Report 2023-24



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

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

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Coordinating Cell

Scientific

Dr. Santanu Kumar Bal, Project Coordinator (AICRPAM)

Dr. A.V.M. Subba Rao, Principal Scientist (Agrometeorology)

Dr. Sarath Chandran, M.A., Senior Scientist (Agrometeorology)

Dr. Timmanna, Scientist (Agricultural Entomology)

Supporting

Mr. A. Mallesh Yadav, SSS

Edited by

Santanu Kumar Bal, A.V.M. Subba Rao, Sarath Chandran M.A., Timmanna

Printed at :

PRINTOGRAPHY,

5-4-114 TO 116, Ranigunj, M G Road, Secunderabad – 500003, Telangana, INDIA

Mobile: +91 98489 24254

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	Sh 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 Kuldeep Medhi	-
12	Kanpur	Dr S.N. Pandey	-
13	Kovilpatti	Dr A. Solaimalai	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 S.V. Khadtare	Dr Vikas Londhe
23	Thrissur	Dr B. Ajithkumar	-
24	Udaipur	Dr Jagdish Choudhary	-
25	Vijayapura	Dr K.G. Sumesh	-
26	Barapani	Dr Debasish Chakraborty	-
27	Jhansi	Dr Yogeshwar Singh	-
28	Shimoga	Dr S. Sridhara	-
29	Srinagar	Dr Sameera Qayoom	Dr Latief Ahmad

फोन/Phone: कार्यालय/Off: +91-040-24530177

फैक्स/Fax: 24531802, 24535336

ई-मेल/e-mail: director.crida@icar.gov.in

वेब/Web: www.crida.in



भाकृअनुप - केंद्रीय बारानी कृषि अनुसंधान संस्थान

ICAR-Central Research Institute for Dryland Agriculture

संतोषनगर/Santoshnagar, हैदराबाद/Hyderabad-500 059, भारत/INDIA



वी. के. सिंह

निदेशक

V. K. Singh

Director

Foreword



Climate change and variability pose significant challenges to Indian agriculture, which is highly sensitive to weather extremes and seasonal shifts. Increasing temperatures, erratic rainfall patterns, and rising frequency of droughts and floods directly impact crop yields, soil health, and water availability. Smallholder farmers, who form the majority of India's agricultural sector, are particularly vulnerable due to limited resources for adapting to these changes. Addressing these challenges requires a combination of climate-resilient crop varieties, improved water management practices, and the adoption of sustainable farming techniques to safeguard food security and livelihoods in India.

Coordinated research projects in agrometeorology play a crucial role in addressing climate change challenges in agriculture by fostering collaboration among scientists, policymakers, and practitioners. This collaborative approach is essential for generating innovative solutions, optimizing resource use, and ensuring sustainable food production amid changing climate conditions. 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 30 AICRPAM centres, which are dispersed throughout the nation's various agroclimatic zones, are conducting research under five pertinent and distinct themes 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 30 AICRPAM centres during Kharif and Rabi seasons of 2023–24 are included in the AICRPAM Annual Progress Report of 2023–24. I would like to take this opportunity to thank the personnel of all 30 coordinating centres, 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 deeply thank the Indian Council of Agricultural Research for its constant and generous support during 2023-24. The encouragement and guidance from Hon'ble Secretary, DARE & Director General, Dr. Himanshu Pathak, and Deputy Director General (NRM), Dr. Suresh Kumar Chaudhari is gratefully acknowledged. The constant support Dr. Rajbir Singh, Assistant Director General (AAF&CC) extended 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 sincere efforts of the Agrometeorologists and other staff of all 25 regular and 04 voluntary centres are sincerely acknowledged for carrying out the research experiments as per the technical program and bringing out valuable information that made it possible to compile a comprehensive report.

The help rendered by Dr A.V.M. Subba Rao, Dr M.A. Sarath Chandran, and Dr Timmanna for the compilation of this report is greatly acknowledged. I appreciate Dr Deepti Verma, Mr A. Mallesh Yadav, and Mr. Harish, for contributing to this report.



Santanu Kumar Bal

Project Coordinator (AICRPAM)

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1. Introduction

The All India Coordinated Research Project on Agrometeorology (AICRPAM) was initiated by ICAR in May 1983 with the establishment of Coordinating Cell at the Central Research Institute for Dryland Agriculture, Hyderabad and 12 Cooperating Centres at various State Agricultural Universities. After a detailed review and evaluation on the progress made by the project and realizing the importance of agrometeorological research support for enhancing food production, ICAR had extended the Cooperating Centres to additional 13 Agricultural Universities of the country w.e.f. April 1995. The 25 Cooperating Centres of the AICRPAM network are: 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). In 2023, five new voluntary centres viz., Barapani, Bikaner, Jhansi, Shimoga, and Srinagar were included in the existing network. The Quinquennial Review Team has reviewed the research progress of the project in 1992, 1998-99, 2006, 2011 and 2017. In the last QRT Report performance of the AICRPAM was adjudged as **Very Good**.

1.1 Objectives

- To study the agricultural climate in relation to crop planning and assessment of crop production potentials in different agroclimatic regions
- To establish crop-weather relationships for all the major rainfed and irrigated crops in different agroclimatic regions
- To study the influence of weather on the incidence and spread of pests and diseases crops
- To evaluate adaptation strategies in crops against weather aberrations
- To provide research support for the agromet advisory services in India

1.2 Technical Program for 2023-25

The Technical Program for the years 2023-25 for different centres of the project and a common core program decided for all the centres with emphasis on location-specific research needs is given below.

1) Agroclimatic Characterization (All centres)

- Database (Block/Tehsil/Mandal level) on climate and crop statistics (district level)

Agroclimatic Analysis

- Rainfall probability analysis

- Dry and wet spells
- Characterization of the onset of crop season for crop planning
- Climatic and agricultural drought analysis
- Length of growing season and its variability
- Preparation of crop-weather calendars
- Development of Agroclimatic Atlases
- Preparation of crop-wise manuals for weather-based decisions in crop management.
- Documentation of extreme weather events and their impacts on agriculture

2) Crop Weather Relationships

- Development of weather-based crop yield prediction models
- Pooled analysis of 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), Moisture Use Efficiency (MUE) and Radiation Use Efficiency (RUE) for various crops
- Interaction effect of the growing environment with crops/varieties
- Crop weather relationship studies in horticultural crops

3) Crop Growth Modeling

- 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 Effects on Pests and Diseases

The technical program finalized in the workshop is presented in Table 1.1.

5) Agromet Advisory Services (All Centres)

- Monitoring of crop and weather situation, twice a week and its updation on the website
- Development of crop contingency plans for the aberrant weather situation
- Monitoring of extreme weather events and their impacts on farming systems on a near real- time basis
- Value-addition to agromet information
- Economic impact assessment



Fig. 1.1 Location map of 25 Cooperating centers, five voluntary centres and Project Coordinating Unit of AICRPAM

Table 1.1 Zone-wise technical program of AICRPAM centers for three different themes during 2023-25

S. No	Zones	Centre	Crop Weather Relationship Studies			Crop Growth Modeling	Weather Effects on Pests & Diseases
			<i>Kharif</i> Varieties	<i>Rabi</i> Varieties	Horticultural Crop		
1.	Arid and Semi Arid - Black soil	Akola	<i>Soybean</i> : JS 335, AMS MB 5-18, AMS 100-39 <i>Green gram</i> : PKV Green gold, PKV AKM-4, PKV 8802, AKM-140, Utkarsha	<i>Chickpea</i> : JG-14, IAKI 9218, Akash	Mandarin Orange	<i>Soybean</i>	<i>Soybean</i> : Spodoptera, Semilooper, Stem fly
		Vijayapura	<i>Soybean</i> : JS 335, DSB23-2, DSB-21	<i>Chickpea</i> : JG-14, JG-11, BG-11-05	Acid Lime	<i>Chickpea</i>	<i>Chickpea</i> : pod borer, rust <i>Rabi Sorghum</i> : FAW, Aphids
		Parbhani	<i>Soybean</i> : JS-335, MAUS-158, MAUS-162 <i>Pigeonpea</i> : Godavari, BDN 711, BDN 716	Fallow	Citrus	Cotton	Cotton: Mealybug, Sucking pest
		Solapur	<i>Pearl millet</i> : Dhanshakti, ICTP-8203, Mahyco hybrid <i>Sunflower</i> : MSFH-17, Bhanu, Phule Bhaskar	<i>Sorghum</i> : M-35-1, Phule Yeshoda, Phule Revati <i>Chickpea</i> : Vijay, Digvijay, Virat	Pomegranate	<i>Rabi Sorghum</i>	<i>Rabi Sorghum</i> : FAW, Stem borer <i>Pomegranate</i> : Aphids, Bacterial blight
		Kovilpatti	Fallow	<i>Sorghum</i> : CSV-20, K-12, K-13, CO-32 <i>Chilli</i> : K1, K2, KKMI, CoHI	Papaya Banana Sapota	<i>Rabi Maize</i>	Cotton: Wilt Chilli: Anthracnose

S. No	Zones	Centre	Crop Weather Relationship Studies			Crop Growth Modeling	Weather Effects on Pests & Diseases
			Kharif Varieties	Rabi Varieties	Horticultural Crop		
2.	Arid and Semi Arid -Redsoil	Anantapur	Pigeon pea: PRG 176, LRG 41, LRG 52 Groundnut: K6, Kadriharithandhra Kadiri Lepakshi 1812, TCGS-1694	Chickpea: JG 11, NBEG-47, NBEG-3	Mango: Benesan	Groundnut	Pigeon pea: Spotted Pod Borer Groundnut: Leaf miner
		Bangalore	Pigeon pea: PRG-176, BRG-1 BRG-5, Groundnut: Kadri-Lepakshi, KCG-6, K-6 Finger millet: MR-6, KMR-630, KMR-316	Fallow	Mango: Mallika	Pigeon pea	Groundnut: Tikka Disease, Pigeonpea: Spotted borer, Wilt, Mango: Powdery mildew, fruit fly
		Anand	Pearl millet: GHB 744, GHB 538, GHB 732, Pearl millet: GHB 732, Pearl millet: HSB-67 (improved), HHB-299	Mustard: Bio 902, GM-3, GDM-4 Barley: BH 393, BH 902 BH 946, BH 885 Potato: Kufri Lima Kufri Bahar, Kufri Pushkar	Mango	Pearl millet	Mustard: Aphid
3.	Western Arid and Semi Arid: loamy soil	Hisar	Pearl millet: GHB 732, HSB-67 (improved), HHB-299	Barley: BH 393, BH 902 BH 946, BH 885 Potato: Kufri Lima Kufri Bahar, Kufri Pushkar	Guava: Hisar Safeda	Pearl millet	Mustard: Aphid, Cotton: Leaf curl virus Guava: Fruit fly
		Udaipur	Maize: Pratap Maize 4, Pratap Maize 6, PHEM 2	Wheat: HI8498, HI863, HI8637	Guava	Maize	Mustard: Aphid Guava: Fruit fly
		Faizabad	Maize: Azad hybrid-1, -Azad hybrid-2, DKC-7074	Mustard: NDR-8501 Bio-902, Jyoti	Bael	Rice	Mustard: Aphid
4.	Sub Humid: alluvium -IGP	Kanpur	Maize: DKC-7074, Mallika, VNR 4226	Wheat: HD-2967, K307, K-9107	Guava	Wheat	Maize: Stem borer Guava: Fruit fly
		Ludhiana	Maize: PMH 14 19014 (c), PMH-13	Wheat: PBW 343 Unnat, PBW 550 Unnat, PBW 869	Kimow	Wheat	Cotton: Jassids Citrus: psylla
		Samastipur	Maize: Bio-9637, Shaktiman-4, Shaktiman-5	Rabi Maize: Bio-9637, Shaktiman-4, Shaktiman-5	Litchi	Maize	Maize: Stem borer, FAW Litchi: mite, borer

S. No	Zones	Centre	Crop Weather Relationship Studies			Crop Growth Modeling	Weather Effects on Pests & Diseases
			Kharif Varieties	Rabi Varieties	Horticultural Crop		
5.	Central India - Sub Humid (Dry): Black and red soils	Jabalpur	Rice: MTU 1010, Kranti, Sahbhagi,	Chickpea: JG-14, JGG-1 JGK-1	Mango	Rice	Chickpea: Pod borer Mango: Hopper
		Raipur	Rice: MTU-1010, Mahamaya, Vikram TCR	Chickpea: JG-14, Indira Chana-1, Vaibhav, CG Chana-2	Mango	Rice	Rice: Green Leaf Hopper, BPH Chickpea: Pod borer
		Ranchi	Rice: MTU 1010, Naveen, Sahbhagi	Chickpea: Sirsa Chana 3, GNG-1581, JG 14	Guava Okra	Rice	Okra: Aphids, Jassids Guava: Fruit fly Livestock: Goat
6.	East and NE- Hot Sub Humid (Moist): Deep loamy to clayey alluvium	Bhubaneswar	Rice: Swarna (MTU7029) Hasant, Mandakini, Bina-11 CR Dhan 801, Swarna Sub1	Pigeon pea: TDRG 59 GRG-152, GT-104 PANT-A-7	Cashew	Rice	Rice: Blast, Sheath blight, Stem borer
		Jorhat	Rice: Swarna Sub1, Rajit Sub1, TTB-404, Mahsuri, MTU 1010 Green gram: SGC-16, SGC-20	Potato: Kufri Pokhraj, Kufri Jyoti, Kufri Khayti Mustard	Okra Banana	Rice	Rice: Stem borer Okra: Jassids, shoot borer
		Mohanpur	Rice: Swarna, Satabdi, Nayanmani	Green gram: Samrat Neha, Sikha	Mango	Rice	Rice: Stem borer Mango: Hopper
7.	Sub Himalayan- Warm Sub Humid: Deep loam forest soils	Chatha/Jammu	Rice: Basmati- 370, Pusa basmati-1121, Jammu Basmati 123	Wheat: Raj-3077, RSP – 561, HD2967, Mustard: RH749	Kimow	Wheat	Rice: brown spot Mustard: Aphid
		Palampur	Rice: Basmati- 370, Pusa-1121, Kasturi Basmati	Wheat: HPW 368, HPW 373, HS 562 Mustard: ONK-1, GSL-1 Him Palam gobhi sarson 1	Citrus	Wheat	Rice: Blast Mustard: Aphid
		Ranichauri	Finger Millet: PRM – 2, VL Mandua 352, VL Mandua 379	Wheat: HD 2967 VL Gehun 892, UP 2572	Apple	Wheat	Wheat: Yellow Rust Finger millet: Blast Apple: Scab

S. No	Zones	Centre	Crop Weather Relationship Studies			Crop Growth Modeling	Weather Effects on Pests & Diseases
			Kharif Varieties	Rabi Varieties	Horticultural Crop		
8.	Coastal (western ghat) – Hot humid to per humid: Laterite and coastal alluvium	Dapoli	-	-	Black pepper Mango Cashew	Rice	Rice: Stem borer, BPH, Mango: thrips, fruit fly
		Thrissur	Rice: Jyothi, Uma, Maniratna	-	Black Pepper Mango Turmeric Ginger	Rice	Rice: Stem borer, BPH Black Pepper: Pollu Beetle, Pollu disease Mango: Thrips
		Shimoga	Maize: NK 6514, Pioneer 3305	-	Areca nut Tomato	Rice	Maize: FAW Arecanut: koleroğa
		Srinagar	Maize (Sweet corn): VLFCH-1 Almora, Mithas, Sugar-75	Oat: Shalimar Oat 2 Shalimar Oat 3 Shalimar Oat 7	Apple Almond Tomato Marigold	Maize	Apple: red mites
		Barapani	Maize: Megha maize-1, Megha maize-2	-	Tomato: Rocky, Megha Tomato-3 Citrus	Maize	Tomato: fruit borer Maize: FAW
		Jhansi	Groundnut: TG-37A, Harita, Ginnar-4 Maize: DMH-117, DHM-121	Chickpea: BG-3062, RVG-204, Pusa Manav Wheat: DBW-187, HI-1544	Sweet Orange Guava: L-49	-	Groundnut: Tikka disease Maize: FAW Chickpea: Fusarium Wilt Sweet Orange and Guava: fruit fly

2. Weather during 2023

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 2023 for the country as a whole and annual rainfall of 29 centres of AICRPAM are presented hereunder:

Onset of southwest monsoon

The Southwest monsoon set in over Kerala on 08 June 2023, seven days behind the normal date for onset (01 June) and covered the entire country by 2 July against the normal date of 8 July.

Rainfall distribution during the monsoon season

The seasonal rainfall (Jun-Sep) over the country as a whole was 94% of its Long Period Average, i.e. 820 mm rainfall against the LPA (868.6 mm). The 2023 season rainfall over two of the four geographical regions of the country (except Northwest India and Central India) was also less than the respective LPAs. The highest rainfall (101% of LPA) was received by Northwest India and the lowest rainfall (82% of LPA) was received by East & Northeast India. Central India and East & South India received seasonal rainfall of 100% of LPA and 91% of LPA, respectively.

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 the total 36 meteorological subdivisions, 3 subdivisions constituting 9% of the total area of the country received excess, 26 subdivisions received normal rainfall (73% of the total area) and 7 subdivisions (18% of the total area) received deficient season rainfall.

Withdrawal of southwest monsoon

Monsoon withdrawal commenced from west Rajasthan on 25 September 2023 (with a delay of 8 days) and covered the entire country on 15 October 2023.

Table 2.1 Rainfall in 36 meteorological sub-divisions during the 2023 southwest monsoon season

S.No.	Region	Subdivision	Actual	Normal	Deviation (%)
1	East & Northeast India	Arunachal Pradesh	1462	1641	-12
2		Assam & Meghalaya	1422	1729	-19
3		Nag-Man-Miz-Tri	940	1273	-27
4		Sub Him WB & Sikkim	1989	1847	7
5		Gangetic West Bengal	875	1138	-22
6		Jharkhand	732	1000	-26
7		Bihar	754	969	-23
8	Northwest India	East Uttar Pradesh	569	788	-29
9		West Uttar Pradesh	694	668	3
10		Uttarakhand	1210	1155	4
11		Haryana-Chd- Delhi	425	429	-1
12		Punjab	418	436	-5
13		Himachal Pradesh	877	730	19
14		Jammu & Kashmir	574	545	5
15		West Rajasthan	399	282	42
16		East Rajasthan	619	623	-1
17	Central India	Odisha	1095	1131	-3
18		West Madhya Pradesh	903	869	3
19		East Madhya Pradesh	992	1033	-4
20		Gujarat Region	897	917	-2
21		Saurashtra & Kutch	792	529	47
22		Konkan & Goa	3087	2833	11
23		Madhya Maharashtra	612	727	-12
24		Marathwada	535	628	-11
25		Vidarbha	903	927	-2
26		Chhattisgarh	1037	1117	-6

S.No.	Region	Subdivision	Actual	Normal	Deviation (%)
27	South Peninsula	A & N Island	2336	1573	55
28		Coastal Andhra Pradesh	561	580	-3
29		Telangana	829	717	15
30		Rayalaseema	334	389	-13
31		Tamil Nadu & Puduchery	339	309	8
32		Coastal Karnataka	2600	3060	-12
33		Karnataka (N Interior)	413	459	-10
34		Karnataka (S Interior)	481	655	-28
35		Kerala	1233	1986	-34
36		Lakshadweep	826	1010	-15
East & Northeast India			1115	1367	-18
Northwest India			593	588	1
Central India			982	978	0
South Peninsula			659	716	-8
The country as a whole			820	869	-6

Northeast monsoon

The northeast monsoon rains commenced on 16 October 2023, coinciding with the withdrawal date of the southwest monsoon from the entire country. Out of the five meteorological sub-divisions benefitted from the NEM, three subdivisions - Tamil Nadu (including Puducherry & Karaikal) (TN), Coastal Andhra Pradesh (CAP) & Kerala (KER) received normal to excess rainfall and the other two subdivisions - Rayalaseema (RYS), and South Interior Karnataka (SIK)] received deficient rainfall during the NEM season (October-December) 2023. Four cyclones affected the Indian seas during the season – Extremely Severe Cyclonic Storm (ESCS) TEJ over the Arabian Sea (AS) Very Severe Cyclonic Storm (VSCS) HAMOON, Cyclonic Storm (CS) MIDHILI and Severe Cyclonic Storm (SCS) MICHAUNG over the Bay of Bengal (BOB). The SCS MICHAUNG over the BOB during 01 -06 December crossed the south Andhra Pradesh coast, south of Bapatla on the 05 December afternoon as SCS with a maximum sustained surface wind speed of 90-100 kmph gusting to 110 kmph. With the gradual decrease in rainfall activity, the cessation of NEM 2023 rainfall over southern peninsular India was declared on 14 January 2024.

Rainfall at cooperating centers

During the year 2023, one centre of AICRPAM, Kovilpatti (65%) received large excess rainfall, while 4 centres received excess rainfall (+20 to +59% more than normal rainfall). Normal rainfall (-19 to +19%) was received in 15 coordinating centres while deficient rainfall (-20 to -59%) condition was experienced at five centres. The yearly rainfall of 25 AICRPAM centres during the year 2023 is furnished in Table 2.2.

Table 2.2 Annual rainfall received at AICRPAM centers during 2023

S. No.	AICRPAM Centre	Actual (mm)	Normal (mm)	Departure (%)
1	Akola	767	799	-4
2	Anand	969	853	14
3	Anantapuramu	571	590	-3
4	Bengaluru	829	916	-10
5	Bhubaneswar	1632	1502	9
6	Chatha	1545	1161	33
7	Dapoli	4045	3529	15
8	Faizabad	884	1002	-12
9	Hisar	266	508	-48
10	Jabalpur	1476	1253	18
11	Jorhat	1532	1924	-20
12	Kanpur	935	869	8
13	Kovilpatti	1176	714	65
14	Ludhiana	665	733	-9
15	Mohanpur	1168	1539	-24
16	Palampur	2950	2332	27
17	Parbhani	767	881	-13
18	Raipur	1721	1145	50
19	Ranchi	1389	1398	-1
20	Ranichauri	1323	1270	4
21	Samastipur	1309	1235	6
22	Solapur	745	721	3
23	Thrissur	2117	2757	-23
24	Udaipur	767	601	28
25	Vijayapura	327	594	-45
26	Barapani	2070	2406	-14
27	Jhansi	1022	884	16
28	Shimoga	629	1087	-42
29	Srinagar	961	820	17

3. Agroclimatic Characterization

Crop planning requires the characterization of crop-growing environments. It is a pre-requisite to evolve strategies for overcoming climate /weather-induced changes in the meso/microclimate. Anomalies in climatic variables need to be properly understood to make the agricultural sector resilient. Agroclimatic analysis is used to study the climatic characteristics and crop performance in a particular region and also to know the climatic variability/climate change and its impact on agriculture. Thus, historical data on climatic variables have to be analyzed using appropriate statistical tools enabling the development of location-specific technologies/adaptive strategies. The analysis carried out by different centres on agroclimatic characterization is reported hereunder:

Anand

Trend analysis of long dry spells in monsoon over Gujarat state

The dry spell affects the productivity of kharif crops in arid and semi-arid areas. The total and longest consecutive dry days during monsoon periods of the recent past time series (1991-2022) were considered for trend analysis. The gridded data (IMD) of Gujarat state (231 grids) for 1961-2022 was used for the study. Datasets were prepared for the reference period (1961-1990) and the recent period (1991-2022). The rainfall amount of 2.5 mm was used as a threshold to identify dry days. The daily rainfall amounts lower than 2.5 mm were counted in the normal monsoon period (15 June – 30 September). Longest consecutive dry days were determined as the longest spell of continuous dry days i.e. longest dry spell of the monsoon season. Linear trends of the reference 30 years and the recent 32 years for dry days were computed using simple linear regression. Trend values were tested for significance levels at 1% and 5%. The findings reveal that, while dry days and the longest dry spells showed increasing trends statewide during the reference period (1961-1990), they decreased in the recent period (1991-2022), indicating a shift toward wetter monsoon conditions, particularly across most of Gujarat except for parts of South Gujarat (regions of the Dangs, Tapi, and Valsad districts) (Fig. 3.1). Despite isolated areas showing longer dry spells, suggesting intra-seasonal variability and potential drought conditions, the general trend pattern of decreasing dry spells across the state (Fig. 3.2) aligns with the spatial trend pattern (Fig. 3.3), showing a reduction in long dry spells across Saurashtra and Kutch.

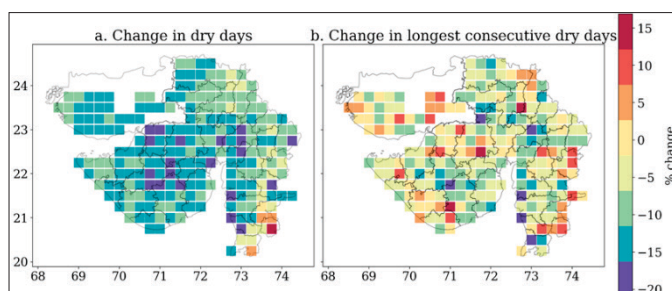


Fig. 3.1 Percent change in total dry days and longest consecutive dry days in monsoon over Gujarat state

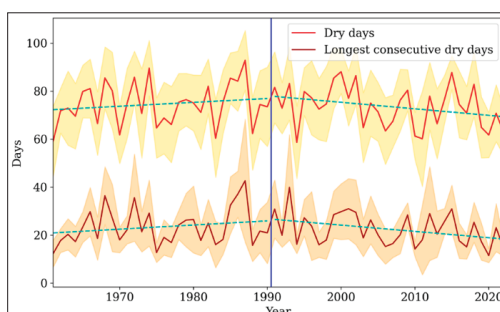


Fig. 3.2 Total dry days and longest consecutive dry days recorded in Gujarat state. The reference period (1961-90) and recent past (1991-2022) are separated by a vertical line.

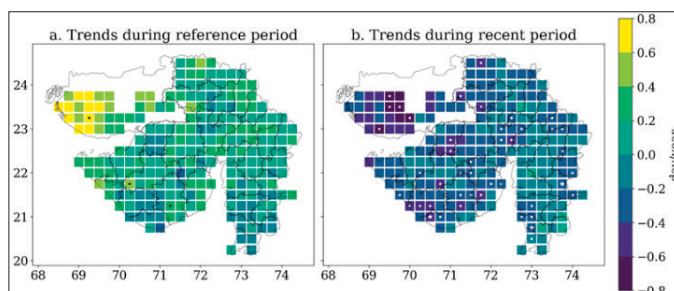


Fig. 3.3 Trends of longest dry spells in monsoon over Gujarat state during (a) reference period (1961-1990) and (b) recent past (years 1991-2022). Dot and star are significant at 5% and 1% levels, respectively.

Barapani

Long-term climatic trends in Barapani, Meghalaya

The long-term climate data for Barapani (Uiam), Meghalaya over 39 years from 1985 to 2023 presents noTable insights into the seasonal and annual climatic variations in the region. The data showcases distinct patterns in rainfall, maximum temperature (Tmax), and minimum temperature (Tmin) across different seasons. Monsoon is the dominant season in terms of rainfall, recording the highest average of 1538.7 mm (64% of total

rainfall), indicating the crucial role of the monsoons in the region's hydrological cycle and agriculture. It is closely followed by the pre-monsoon and post-monsoon contributing about 20% and 14% of the total annual rainfall, respectively. Conversely, Winter experiences the lowest rainfall levels at 36.8 mm (only 1.53% of total rainfall), underscoring the season's arid conditions and implications for water resources. The CV is lowest during the monsoon season followed by pre-monsoon, post-monsoon, and highest during the winter. The Monsoon season exhibits the highest Tmax values at 27.6 °C which is closely followed by the pre-monsoon (26.6 °C). The Tmin values reveal that the Monsoon season registers the highest average at 20.0 °C. Though it is followed by pre-monsoon (15.5 °C), there is quite a large difference. The Tmin during post-monsoon and winter seasons is quite lower indicating the season's propensity for chilly nights and cooler overall temperatures While Tmax and Tmin exhibit lower but still significant variability, with CV values ranging from 2.7 to 15.1, emphasizing the need to consider seasonal fluctuations in temperature when assessing climate impacts. The CV is comparatively lower for Tmax than Tmin, indicating that the variation in Tmin is quite higher, especially during the post-monsoon and winter seasons.

The application of the non-parametric Mann-Kendall test (MKT-Z) and Sen Slope analysis to the long-term climate data for Umiam, Meghalaya offers valuable insights into the trends and changes in rainfall, Tmax, and Tmin over the study period (Table 3.1).

Table 3.1 The results of the non-parametric Mann-Kendall test (MKT-Z) and Sen's Slope of climate data of Barapani, Meghalaya.

	Rainfall (mm)		Tmax (°C)		Tmin (°C)	
	MKT-Z	Sen Slope (mm/ decade)	MKT-Z	Sen Slope (°C/ decade)	MKT-Z	Sen Slope (°C/ decade)
Winter	-1.32	-5.56	4.50***	0.91	-0.4	-0.06
Pre-Monsoon	0.82	15.43	3.20***	0.52	-2.36***	-0.33
Monsoon	-0.60	-24.03	4.45***	0.48	-1.37	-0.11
Post-Monsoon	-0.97	-14.75	5.35***	0.67	-0.63	-0.11
Annual	-0.58	-29.76	5.21***	0.62	-1.70*	-0.18

The comprehensive analysis of the Mann-Kendall test and Sen Slope results provides a general understanding of the evolving climate dynamics in Umiam, Meghalaya, shedding light on the changing precipitation patterns and temperature trends across seasons, and over the long term.

Bhubaneswar

Agroclimatic onset of crop growing season over Odisha state

The agroclimatic onset was determined by defining the onset date as the first wet day of the three-day wet spell receiving at least 20 mm of rainfall without a 10-day dry spell (2.5 mm) starting from 1st June. Year-wise onset was calculated over time series (1991-2023) for 314 blocks (Fig. 3.4). The majority of Kharif crops are suitable for sowing at a given time and location, provided that the rainy season begins with enough precipitation to support the crop's early growth. The commencement of the rainy season can be more accurately determined using an agroclimatic technique, which is important information for agricultural purposes.

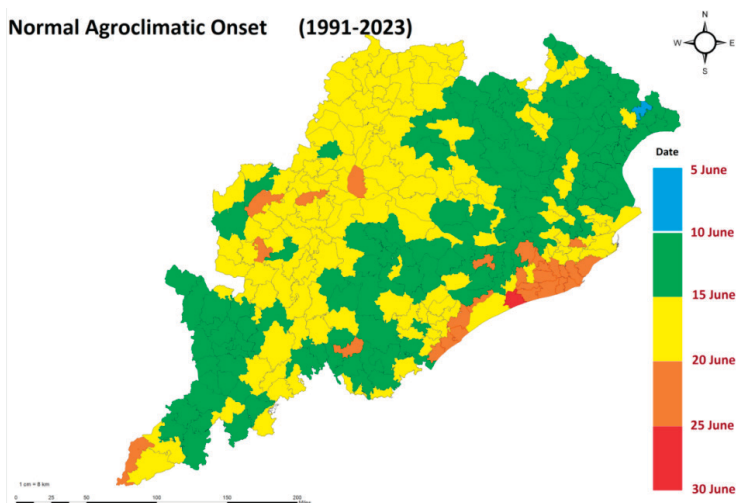


Fig. 3.4 Normal onset time (date) of the rainy season in the blocks of Odisha through an agroclimatic approach.

The agroclimatic onset of the kharif season progresses from the Northern Plateau to the Coastal plains of the state. After analyzing the onset data, it was found that the Rasgovindapur block of Mayurbhanj had early onset on 9 June and it covers the entire state with its latest onset in Brahmagiri block of Puri district on 27 June.

The effective first rainfall time for Kharif crop sowing varies greatly across all blocks. The state results indicated that 12 June is the mean onset date for the state. Agroclimatic onset follows the same pattern as the meteorological onset of the monsoon but with some lag

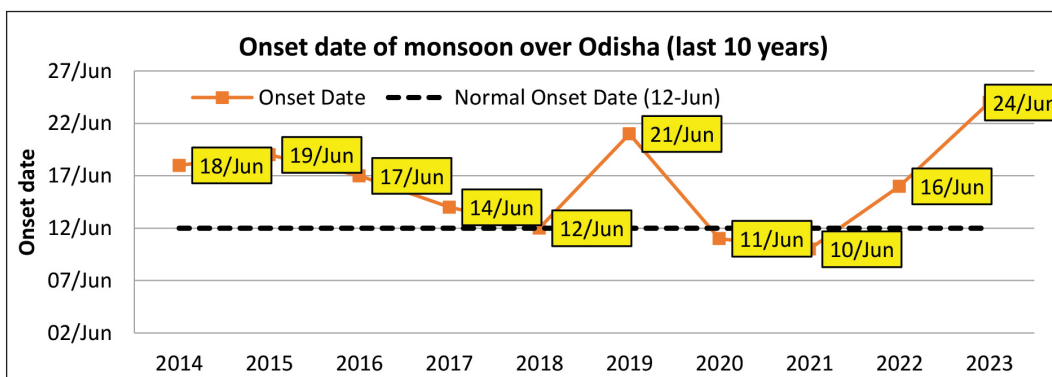


Fig. 3.5 Variation in agroclimatic onset during the year 2014-2023 in Odisha.

period. Finally, it is advised that Agroclimatic onset can be considered for the starting of the kharif season. The variation in the date of onset of Odisha state during the last 10 years is given in Fig. 3.5.

Bangalore

Trend and shifting pattern analysis of rainfall

Two non-parametric tests *viz.*, Man Kendal (MK test) and Modified Mann Kendall (MMK test) were employed to assess the trends in annual rainfall over the districts of the South interior Karnataka. All districts of SIK showed increasing trends except Chamarajanagar, where there was an observed 5.03 mm decrease per annum. The quantum of increase was higher in Chikkaballapur, Bangalore urban and Kolar (depicted as Sen's slope 9.96, 9.52 and 9.15, respectively). MK test and MMK test are undertaken to compare the ability of the two tests to identify trends in serially correlated datasets like time series rainfall. The MMK test was able to identify increasing trends in rainfall of Mandya and Uttara Kannada, and decreasing trends over Shimoga district which was not detected in the MK test. Further, shifting pattern analysis was conducted to analyze the shifting changes taking place in mean annual rainfall over the district of southern Karnataka, which revealed a decrease in mean annual rainfall in Chikkamagaluru and Udupi districts with 402.95 and 718.25 mm in 1984 and 2013, respectively. Except for these two districts, all other districts of the study area showed a positive shift (Table 3.2), with a maximum shift in Uttara Kannada of coastal region (1409.18 mm from 2018), Kodagu district in Malnad region (1708.19 mm from 2013) and Kolar district in SIK region (977.22 mm from 2020).

Table 3.2 Shifting pattern in mean rainfall over the southern districts of Karnataka as given by *likelihood ratio test*

District	Shifting year	Average rainfall (mm)		Change in rainfall (mm)	Nature of shift	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
Mysuru	2004	701.95	866.25	164.30	↑	770.07
Davanagere	2003	593.38	770.13	176.75	↑	670.98
Tumkuru	2020	656.30	1109.00	452.7	↑	667.30
Ramanagara	2016	833.32	1032.26	198.94	↑	857.60
Malnad						
Shimoga	2004	1592.41	2190.83	598.42	↑	1840.00
Hassan	2018	797.85	1975.10	1177.25	↑	883.99
Chikmagalur	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

Rainfall variability in the Agro-Climatic Zones of Karnataka

Zone-wise monthly rainfall and rain days (1981-2021) were analyzed for southern districts of Karnataka and the data reveals that the highest annual rainfall and rain days were observed in the Coastal Zone with 3901 mm and 147, respectively, and lower annual rainfall and rain days were observed in central dry zone with 654 mm and 65, respectively. Among different months, July month received higher rainfall and rainy days in the coastal zone with 1158 mm and 30, respectively (Fig. 3.6).

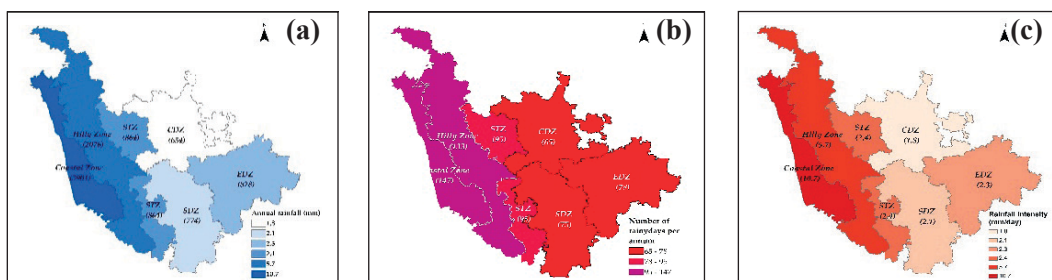


Fig 3.6 (a) Annual rainfall (mm), (b) number of rainy days and (c) rainfall intensity (mm/day) in different agro-climatic zones of south Karnataka.

Jorhat

Drought climatology assessment using SPEI for Assam

The seasonal trend and drought frequency under different drought categories during pre-monsoon (SPEI-3) and monsoon (SPEI-4) seasons (Fig. 3.7). The results of SPEI-3 for May showed- 6 drought events (1990, 1997, 2007, 2011, 2013 and 2006) in Chirang, 5 drought events (2001, 2006, 2018, 2011 and 2009) in Dhemaji, 4 drought events (2006, 2008, 2019 and 2020) in Hailakandi, 6 drought events (1992, 1995, 2000, 2014 and 2020) in Karbi Anglong, 5 drought events (2006, 2009, 2011, 2012 and 2014) in Nagaon, 5 drought events (2006, 2007, 2009, 2014 and 2018) in Nalbari, and 6 drought events (2001, 2006, 2007, 2009, 2011 and 2020) in Tinsukia districts of Assam during the period under study (1990-2020). The trend of SPEI-3 also depicts a decreasing tendency of SPEI over Dhemaji, Hailakandi, Nagaon, Nalbari, and Tinsukia with more possibilities of such drought events in the near future; whereas, a positive trend of SPEI was observed in Chirang and Karbi Anglong depicting possibility for more wet spells, especially during the pre-monsoon season in near future.

Likewise, the results of SPEI-4 for September showed- 5 drought events (1990, 1992, 1994, 2001 and 2013) in Chirang, 4 drought events (2009, 2011, 2012 and 2013) in Dhemaji, 5 drought events (2002, 2006, 2013, 2015 and 2018) in Hailakandi, 7 drought events (1996, 2005, 2006, 2009, 2012, 2013 and 2015) in Karbi Anglong, 7 drought events (1996, 1998, 2001, 2005, 2006, 2011 and 2012) in Nagaon, 6 drought events (1996, 2001, 2006, 2013, 2016 and 2018) in Nalbari and 4 drought events (1992, 2012, 2013 and 2018) in Tinsukia districts of Assam. Excluding Chirang district, the remaining six districts showed a decreasing tendency in SPEI-4 corresponding to September month (Table 3.3). Thus, more possibilities for intensified drought-like situations during monsoon season.

Table 3.3 Frequency of drought under different categories during Pre-Monsoon and Monsoon season over different districts of Assam and Sen's estimator of slope of SPEI-3 and SPEI-4

Representative districts of Assam	Trend of SPEI				Frequency under different drought categories					
	Pre-Monsoon (SPEI-3)		Monsoon (SPEI-4)		Moderate drought (-1.00 to -1.49)		Severe drought (-1.50 to -1.99)		Extreme drought (≤ 2.0)	
	Z-value	Slope (Q)	Z-value	Slope (Q)	Pre-M	M	Pre-M	M	Pre-M	M
Chirang	1.28	0.03	2.53	0.05*	4	4	2	-	-	1
Dhemaji	-0.64	-0.01	-1.03	-0.03	3	3	1	-	1	1
Hailakandi	-0.71	-0.01	-2.28	-0.05*	2	3	1	2	1	-
K. Anglong	0.04	0.001	-2.36	-0.04	5	5	-	2	1	-
Nagaon	-1.28	-0.03	-1.32	-0.02	3	5	2	2	-	-
Nalbari	-1.32	-0.03	-2.5	-0.06*	3	4	2	2	-	-
Tinsukia	-0.89	-0.02	-1.86	-0.03	4	2	2	2	-	-

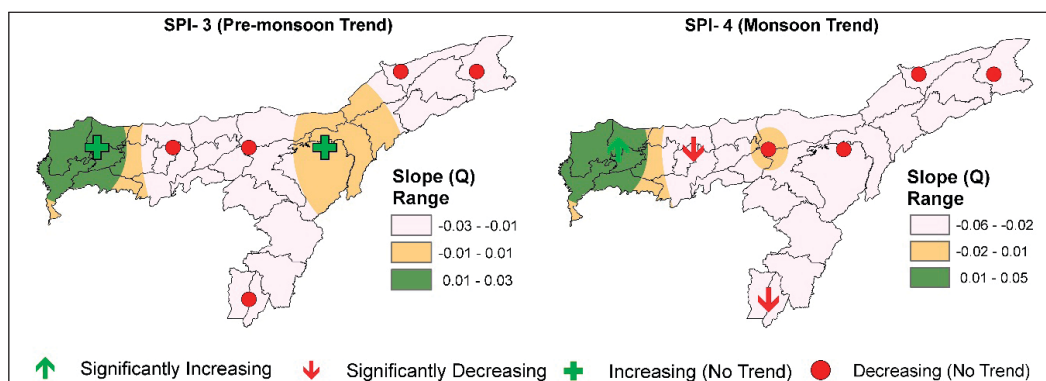


Fig. 3.7 Spatial distribution of Pre-Monsoon (SPEI-3) and Monsoon (SPEI-4) season trend

Kovilpatti

Impact of Rainfall on Coastal Zone of Tamil Nadu

The rainfall data from 1980 to 2023 was used for assessing the change point and trend detection in the total annual and NEM seasonal rainfall at Thiruvallur, Chennai, Chengalpattu, Villupuram, Cuddalore, Mayildathurai, Nagapattinam, Tiruvarur, Thanjavur, Pudukottai, Ramanathapuram, Thoothukudi, Tirunelveli and Kanyakumari which represents the coastal zone of Tamil Nadu (Fig. 3.8). The annual rainfall at different coastal districts has changed from an average of 425 mm to 2430 mm indicating the positive trend with excessive rainfall during the recent years with increase in single day heavy rainfall events substantially.

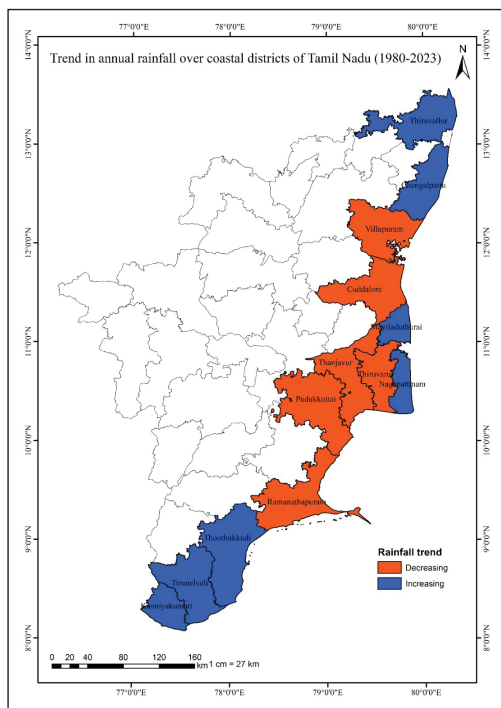


Fig. 3.8 Trend of annual rainfall pattern in coastal region of Tamil Nadu

Non-parametric test such as Man Kendal (MK test) was employed to assess the trends in annual and northeast monsoon rainfall over the coastal districts of the state. All the coastal districts showed increasing trends of annual rainfall. The quantum of increase was higher in Chengalpattu, Mayiladuthurai, and Kanyakumari districts (depicted as Sen's slope 21.21, 15.71, and 11.86 respectively). About northeast monsoon rainfall, Chengalpattu, Cuddalore, Kanyakumari, Mayiladuthurai, Pudukkottai, Ramanathapuram districts recorded an increasing trend while Nagapatinam, Tiruvarur and Thanjavur districts were observed with decreasing trend. The quantum of increase was higher in the Mayiladuthurai district (depicted as Sen's slope 12.02).

Ludhiana

Weather-based thumb rule models for predicting the high yield of wheat

The comparison of the average (2007-08 to 2021-22) monthly meteorological parameters with those observed during the respective high-yield crop years for wheat crops was done. Then the "Monthly Thumb Rules Models" were developed (Figs 3.9, 3.10, and 3.11) to predict the yield of wheat crops for three different locations in Punjab. The sowing to maturity period of wheat extends from October to April months. The above-given ranges of meteorological parameters are conducive to high productivity of wheat crops and these can be used to develop the monthly term sheets for weather-based crop insurance in Punjab state.

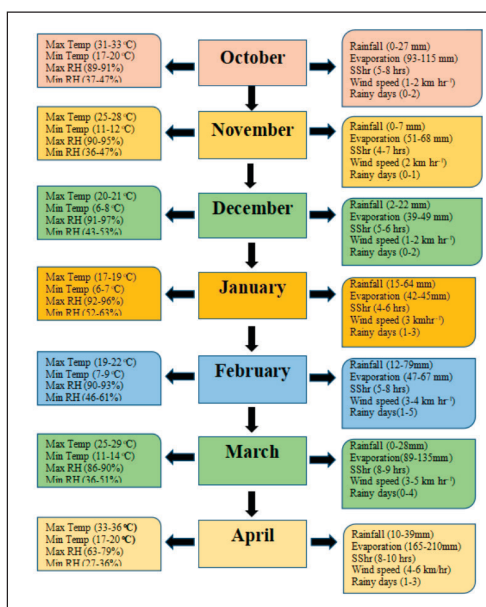


Fig. 3.9 Weather-based monthly “Thumb Rules” for prediction of the higher wheat yield at Ludhiana (2007-08 to 2021-22)

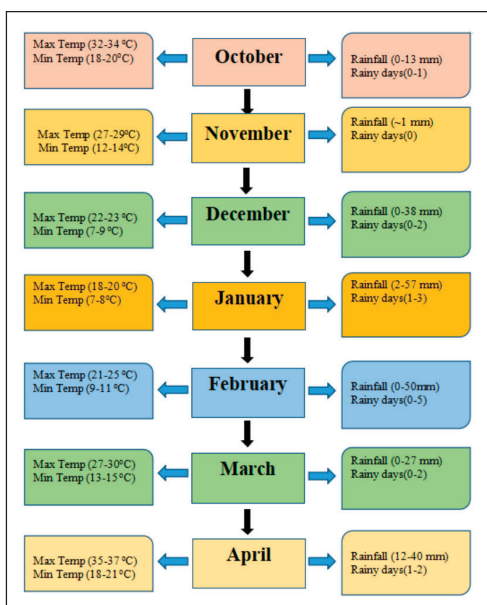


Fig. 3.10 Weather-based monthly “Thumb Rules” for prediction of the higher wheat yield at Patiala (2007-08 to 2021-22)

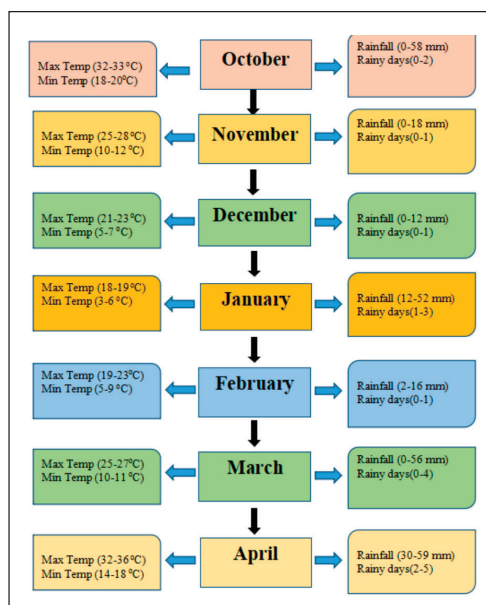


Fig. 3.11 Weather-based monthly “Thumb Rules” for prediction of the higher wheat yield at Amritsar (2007-08 to 2021-22)

Mohanpur

Temporal and spatial trends of Rainfall

Parametric and non-parametric trend estimation techniques such as the Mann-Kendell trend and Sen slope were deployed to identify the temporal trend of any region. Trend values when analysed spatially can provide an insight into the spatial distribution of rainfall change over time. The parametric trend estimated with the Mann-Kendell technique and the non-parametric trend estimated with the Sen slope of 23 districts of West Bengal has been presented in Table 3.4.

In the case of annual rainfall Alipurduar ($-4.16 \text{ mm year}^{-1}$), Dakshin Dinajpur ($-4.98 \text{ mm year}^{-1}$), Murshidabad ($-1.29 \text{ mm year}^{-1}$), Nadia ($-1.64 \text{ mm year}^{-1}$) indicated a significant decline in rainfall over the past 100 years, whereas, Darjeeling (4 mm year^{-1}), Jhargram ($2.46 \text{ mm year}^{-1}$), Kalimpong ($10.27 \text{ mm year}^{-1}$), Kolkata ($1.91 \text{ mm year}^{-1}$), North ($2.75 \text{ mm year}^{-1}$) and South 24 Parganas ($1.91 \text{ mm year}^{-1}$) indicated a significant increase in annual rainfall. All the trend directions of the Sen slope were verified by the Mann-Kendell trend estimation technique. Interestingly, locations of the Hill region indicated a significant increase in mean annual rainfall, however, a significant decline in annual rainfall can be observed from the Terai region (Alipurduar, Dakshin Dinajpur) to the locations close to Tropic of Cancer (Murshidabad and Nadia). Locations below the Tropic of Cancer like Jhargram, Howrah, North and South 24 Parganas showed significant increases in mean annual rainfall.

In case of monsoon rainfall trend, Darjeeling ($2.28 \text{ mm year}^{-1}$), Jhargram ($1.49 \text{ mm year}^{-1}$), Kalimpong (8 mm year^{-1}) and North 24 Parganas ($2.13 \text{ mm year}^{-1}$) showed significant increase, whereas, Alipurduar ($-3.84 \text{ mm year}^{-1}$), Dakshin Dinajpur ($-3.9 \text{ mm year}^{-1}$) and Murshidabad ($-1.1 \text{ mm year}^{-1}$) showed significant decrease. Intriguingly, Post-monsoon rainfall showed a significant increase in mean rainfall in the areas of Darjeeling (0.4 mm year^{-1}), Hooghly ($0.45 \text{ mm year}^{-1}$), Kalimpong ($0.68 \text{ mm year}^{-1}$) and North 24 Parganas ($0.46 \text{ mm year}^{-1}$), whereas winter rainfall showed a significant decrease in the mean rainfall in the districts of Alipurduar ($-0.11 \text{ mm year}^{-1}$), Dakshin Dinajpur ($-0.104 \text{ mm year}^{-1}$), Kalimpong ($-0.11 \text{ mm year}^{-1}$) and Malda ($-0.08 \text{ mm year}^{-1}$). Pre-monsoon rainfall indicating thunderstorm activity were found to be decreasing in the districts of Bankura ($-0.29 \text{ mm year}^{-1}$), Dakshin Dinajpur ($-0.47 \text{ mm year}^{-1}$), Nadia ($-0.732 \text{ mm year}^{-1}$) and Purba Bardhaman ($-0.29 \text{ mm year}^{-1}$), whereas, Kalimpong ($1.15 \text{ mm year}^{-1}$) and Jhargram ($0.61 \text{ mm year}^{-1}$) indicated increased rainfall.

Table 3.4 Trend (1901-2023) of annual and seasonal rainfall of the region

Locations	Annual			Monsoon			Post-Monsoon			Winter		Pre-Monsoon	
	Sen slope	Z value		Sen slope	Z value		Sen slope	Z value		Sen slope	Z value	Sen slope	Z value
Alipurduar	-4.166*	-2.282		-3.843*	-2.462		-0.284	-0.979		-0.113	-1.784	-0.239	-0.402
Bankura	-0.941	-1.364		-0.715	-1.141		0.015	0.092		0.020	0.363	-0.292	-1.688
Birbhum	0.633	0.835		0.507	0.673		0.116	0.555		0.027	0.446	0.002	0.004
CoochBehar	2.116	1.386		1.450	1.102		-0.047	-0.162		-0.070	-1.327	0.694	1.373
Dinajpur (s)	-4.986***	-4.634		-3.908***	-4.293		-0.297	-1.570		-0.104*	-2.363	-0.476*	-2.020
Darjeeling	4.033***	3.384		2.286*	2.357		0.409	1.863		-0.050	-0.547	0.476	1.325
Hooghly	1.036	1.434		0.947	1.539		0.458*	1.996		0.025	0.334	-0.289	-1.395
Howrah	1.911	1.911		1.130	1.425		0.440	1.626		-0.062	-0.857	-0.044	-0.179
Jalpaiguri	0.300	0.197		-0.156	-0.149		0.051	0.188		-0.028	-0.623	0.119	0.275
Jhargram	2.465***	3.410		1.498*	2.352		0.340	1.591		-0.014	-0.260	0.614**	2.855
Kalimpong	10.276***	7.044		8.068***	6.899		0.689**	3.043		-0.114	-1.779	1.150***	3.782
Kolkata	1.911	1.911		1.130	1.425		0.440	1.626		-0.062	-0.857	-0.044	-0.179
Malda	-1.079	-1.071		-1.015	-1.338		-0.123	-0.647		-0.080	-1.799	0.316	1.355
Murshidabad	-1.294	-1.828		-1.198	-1.863		0.061	0.293		0.056	1.008	-0.275	-1.202
Nadia	-1.649*	-2.033		-0.902	-1.395		-0.028	-0.157		-0.007	-0.096	-0.732**	-3.030
N. 24 Parganas	2.758***	3.336		2.137***	3.437		0.465*	2.129		0.017	0.269	0.013	0.057
Bardhaman (W)	0.902	1.342		0.413	0.800		0.109	0.669		-0.025	-0.512	0.256	1.561
Medinipur (W)	0.845	1.150		0.709	1.049		0.171	0.796		-0.004	-0.048	0.054	0.175
Bardhaman (E)	-0.941	-1.364		-0.715	-1.141		0.015	0.092		0.020	0.363	-0.292	-1.688
Purba Medinipur	1.208	1.390		0.927	1.456		0.376	1.421		-0.030	-0.396	-0.255	-0.931
Purulia	0.114	0.162		-0.081	-0.149		0.177	0.903		-0.055	-0.796	0.218	1.535
S. 24 Parganas	1.911	1.911		1.130	1.425		0.440	1.626		-0.062	-0.857	-0.044	-0.179
Uttar Dinajpur	-0.026	-0.044		0.002	0.004		-0.149	-0.809		-0.036	-0.925	0.299	1.277

p<0.1, * p<0.05, **p<0.01, ***p<0.001

Parbhani

Trend and shifting pattern of rainfall in the Marathwada region

Two non-parametric tests viz., Man Kendal (MK test) and Modified Man Kendal (MMK test) were employed to assess the trends in annual and south-west monsoon seasonal rainfall (1993-2023) in all districts in the Marathwada region. Annual rainfall of all districts of Marathwada showed increasing trends except Parbhani and Latur, where there was an observed 11.82 mm & 3.53 mm decrease per annum respectively. The quantum of increase was higher in Nanded, Chh. Sambhajinagar and Hingoli (depicted as Sen's slope 7.99, 5.63, and 5.45, respectively). A comparison of the MK test and MMK test was done to compare the ability of the two tests to identify trends in serially correlated datasets like time series rainfall (Table 3.5).

The southwest monsoon seasonal rainfall of four districts of Marathwada showed increasing trends i.e. Chh. Sambhajinagar, Hingoli, Jalna & Nanded, whereas Parbhani, Beed, Dharashiv & Latur observed a 10.0 mm, 0.80 mm, 0.85 mm & 2.83 mm decrease per season respectively. The quantum of increase was higher in Hingoli & Nanded (depicted as Sen's slope 6.16 and 5.24, respectively).

Table 3.5 Kendal's tau, significance (p) trends, and Sen's slope for annual & seasonal rainfall in the districts of Marathwada as given by MK test and MMK test

Annual	M-Ktest			MM-Ktest			Sen's slope
	Tau	p	Trend	Tau	p	Trend	
Annual							
Parbhani	-0.243	0.085	↓	-0.243	0.000	↓	-11.82
Beed	0.098	0.494	↑	0.098	1.382	↑	2.98
Chh. Sambhajinagar	0.113	0.427	↑	0.113	0.072	↑	5.63
Dharashiv	0.076	0.596	↑	0.076	0.160	↑	2.28
Hingoli	0.120	0.402	↑	0.120	0.014	↑	5.45
Jalna	0.64	0.659	↑	0.64	0.436	↑	2.72
Latur	-0.089	0.536	↓	-0.089	0.068	↓	-3.53
Nanded	0.138	0.331	↑	0.138	0.008	↑	7.99
South West Monsoon							
Parbhani	-0.212	0.133	↓	-0.212	0.000	↓	-10.00
Beed	-0.033	0.550	↓	-0.033	0.825	↓	-0.80
Chh. Sambhajinagar	0.953	0.508	↑	0.953	0.118	↑	2.03
Dharashiv	-0.040	0.791	↓	-0.040	0.413	↓	-0.85
Hingoli	0.107	0.453	↑	0.107	0.031	↑	6.16
Jalna	0.027	0.859	↑	0.027	0.701	↑	0.66
Latur	-0.095	0.508	↓	-0.095	0.019	↓	-2.83
Nanded	0.150	0.289	↑	0.150	0.002	↑	5.24

Samastipur

Change in the length of the growing period (LGP)

The length of growing periods (LGP) based on moisture adequacy index for different districts of Bihar in coarse, medium, and fine-textured soils for two periods viz. 1984-2003 and 2004-2023 have been worked out using the climatic water balance model to evaluate the change in moisture regimes in different districts. The growing period was considered from the week when I_{ma} equals to or becomes greater than 0.75 for upland *kharif* and *rabi* crops and when I_{ma} dropped below 0.33 for 3 consecutive weeks, it was considered as the termination of the growing period. Thus, the onset of sowing was considered when $I_{ma} \geq 0.75$ at the beginning of the growing season subject to the availability of the required thermal regime for the crop grown. Thus, given the above, the LGP was determined as follows:

$$\text{Length of growing period (LGP): } 0.33 \leq I_{ma} \leq 0.75$$

By employing the aforesaid procedure, LGP for each week and individual years was calculated for all the districts. The lengths of the growing period for coarse, medium and fine-textured soils for each district of the state were worked out. Barring some districts of south Bihar, almost all districts registered a decrease in LGP. The districts of Zone I (North-West plains) of the state, recorded the highest decrease, ranging from 14 to 36 days. Change in LGP during 2004-2023 against the LGP calculated for the period 1984-2003 is graphically presented in Fig. 3.12.

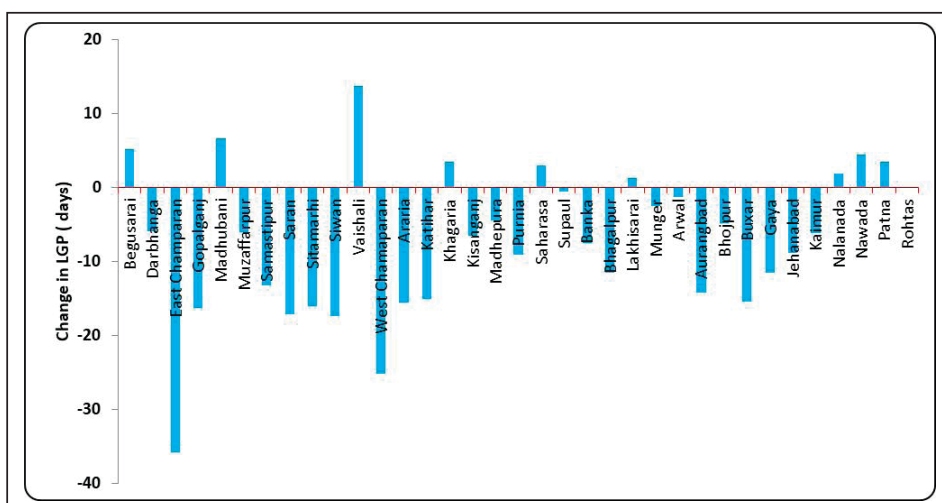


Fig. 3.12 Change in LGP during 2004-2023 in comparison to LGP calculated for the period 1984-2003.

Shimoga

Rainfall trend and change point analysis for Shimoga

The annual and seasonal shifts in the rainfall pattern have been studied for the Shimoga district from 1965 to 2023 daily rainfall data. The mean increased change in the rainfall pattern can be noticed from 2000 onwards for the annual, southwest, and summer seasons. The rainfall shift was shown for the northeast season in the year 1990 (Fig. 3.13).

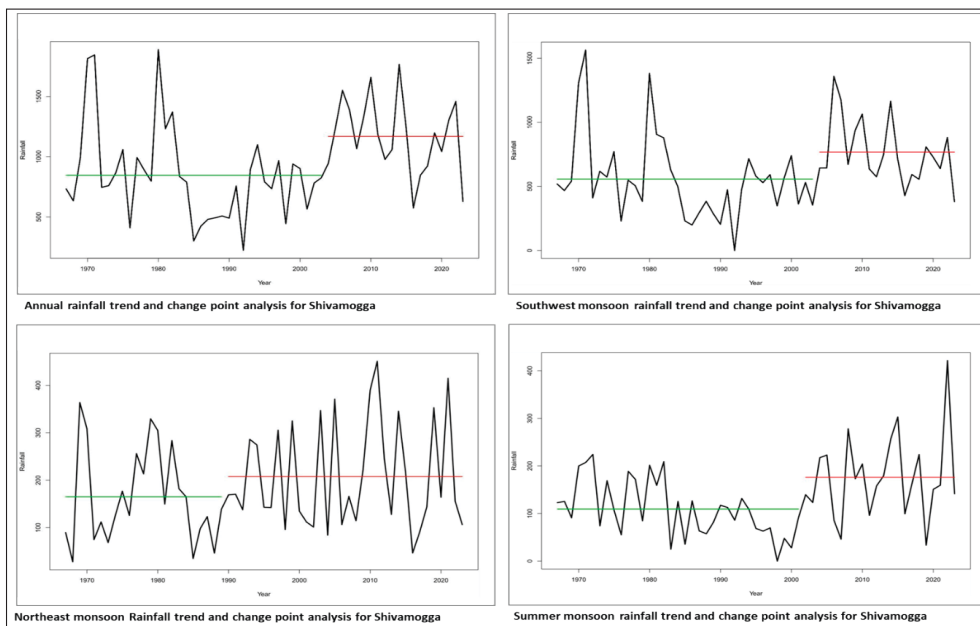


Fig. 3.13 Trend in annual and seasonal rainfall over Shimoga (1965-2023)

Udaipur

Shift in rainfall over Rajasthan

Long-term district-wise rainfall data (1991-2023) was used to analyze the shifts in rainfall of different districts over Rajasthan (Table 3.6). From the analysis, it was observed that the state mean rainfall increased from 575.3 mm during the period 1961-1990 to 626.52 mm during the period 1991-2023 which was 51.22 mm more. Similarly, rainy days were also increased from 27.9 days during 1961-1990 to 30.47 days during 1991-2023. Among the 33 districts, an increase in rainfall was observed in 28 districts and a decrease in rainfall was observed in 05 districts in the latest epoch. Pratapgarh district recorded 220 mm more rainfall over the previous duration (1961-1990). Whereas Baran district negative departure was observed in rainfall (-83.48 mm) followed by Sirohi (-25.9 mm).

Table 3.6 Shift of rainfall and rainy days in Rajasthan

Districts	Rainfall (mm)			Rainy days		
	1961-1990	1991-2023	Departure	1961-1990	1991-2023	Departure
Ajmer	555	588	33	29	33	4
Alwar	652	689	36	37	37	0
Banswara	1077	1066	-11	42	40	-2
Baran	914	830	-83	34	37	4
Barmer	249	338	89	14	18	4
Bharatpur	599	692	94	30	36	5
Bhilwara	674	682	8	33	31	-2
Bikaner	242	308	66	16	19	3
Bundi	721	736	15	32	37	5
Chittorgarh	796	843	47	36	38	2
Churu	360	443	83	22	27	5
Dausa	652	666	14	33	34	1
Dholpur	614	741	128	31	38	7
Dungarpur	757	784	26	34	33	-1
Sri Ganganagar	262	314	52	16	19	2
Hanumangarh	230	273	44	14	18	4
Jaipur	607	604	-4	33	33	0
Jaisalmer	172	252	80	10	14	4
Jalore	400	574	174	19	24	4
Jhalawar	920	960	40	38	40	3
Jhunjunu	396	453	57	23	28	5
Jodhpur	372	386	14	20	22	2
Karouli	746	748	2	34	37	3
Kota	699	728	29	33	33	0
Nagaur	393	397	4	21	23	2
Pali	401	484	83	20	22	2
Pratapgarh	901	1121	220	42	41	-1
Rajsamand	521	618	97	28	32	5
Sikar	515	511	-3	26	29	3
Sirohi	639	613	-26	25	27	1
Swaimadhopur	724	905	182	35	40	5
Tonk	601	646	45	31	33	2
Udaipur	626	681	55	34	35	2
Average	575	627	51	28	30	2

4. Crop Weather Relationship Studies

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

Kharif 2023

Rice

Chatha

A field experiment was conducted with three rice basmati cultivars viz., Pusa 1121, Jammu Basmati-123, and Basmati 370, transplanted under three different dates viz., 01, 15 and 30 July during kharif 2023. The Radiation use efficiency (RUE) of basmati rice crop under different transplanting environments and cultivars was computed and data is presented in Fig. 4.1.

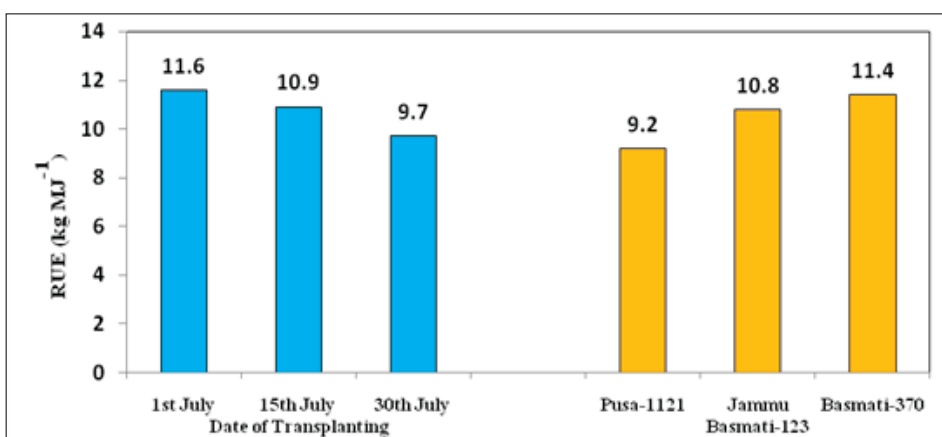


Fig 4.1 The Radiation use efficiency (RUE) of basmati rice crop under different transplanting environments and cultivars at Chatha during Kharif 2023

Radiation use efficiency (RUE) of transplanted Basmati rice crops showed an increase with the advancement of crop growth and was found highest at physiological maturity. The maximum RUE (11.6 kg MJ⁻¹) was recorded in the crop transplanted on 01 July followed by 15 July (10.9 kg MJ⁻¹) and minimum (9.7 kg MJ⁻¹) in the 30th July transplanted crop at physiological maturity. The variability in RUE can be attributed to the differential dry matter accumulation among different transplanting environments and the interception of varying amounts of radiation at different growth periods. The variation in canopy structure and architecture influenced the canopy, which influenced interception of the radiation, photosynthetic efficiency of the leaves in utilizing the intercepted radiation in the production of dry matter, and loss of various energy under physiological processes like respiration, evapotranspiration, metabolic activity, etc. Among different cultivars, the RUE of Basmati 370 cultivar was the highest (11.4 kg MJ⁻¹), followed by Jammu Basmati-123 (10.8 kg MJ⁻¹) and Pusa 1121 (9.2 kg MJ⁻¹) at physiological maturity.

Mohanpur

Crop-weather relationship studies in rice were undertaken with a field experiment consisting of three transplanting dates (20 June, 05 July, and 20 July) and three cultivars (Nayanmani, IET-4786, and IET-5656).

Long-term weather data and yield data of Kharif rice were gathered to establish a crop-weather relationship. The phenology of the rice crop was divided into three phases: P1 (Transplanting to Panicle Initiation), P2 (Panicle Initiation to 50% Flowering), and P3 (50% Flowering to Harvesting). In addition, the entire cropping period as P4 was also considered. Weather data and yield data for the years 2003, 2006, 2009, 2010, 2011, 2012, 2013, 2014, 2018, 2019, 2020, 2021, 2022, and 2023 were collected and curated for this purpose. The yield data was found to be normally distributed (Shapiro test: $W = 0.98$, $p\text{-value} > 0.5$), allowing for the development of a linear relationship. Stepwise both-way multiple linear regression was performed based on p-values using the “olsrr” package in R. A multiple linear regression equation was developed with weather parameters for yield prediction and the results are presented in Table 4.1

Table 4.1 Multiple linear regression with rice yield and weather variables developed by Mohanpur centre

Model performance					
R ²	0.72	Adj. R ²	0.68	RMSE	730.398
Anova Results					
	Sum of square	DF	MS	F	Sig
Regression	61421254.936	6	10236875.8	19.18	***
Residual	23473186.541	44	533481.5		
Total	84894441.477	50			
Parameters estimates					
Model	Beta	Std. Error	Std. Beta	t	Sig
Intercept	-68228.3	7813.402		-8.732	0
Tmin P4	790	217.635	0.409	3.63	0.001
Tmax P2	1060.172	164.175	0.65	6.458	0
Rain P2	5.359	1.256	0.39	4.265	0
Tmin P1	663.465	274.045	0.256	2.421	0.02
BSS P2	-303.916	142.538	-0.222	-2.132	0.039
Rain P1	1.285	0.73	0.148	1.759	0.085

P1: Transplanting to Panicle Initiation, P2: Panicle Initiation to 50% Flowering, P3: 50% Flowering to Harvesting, P4: Transplanting to Harvesting

The results indicated that the minimum temperature during transplanting to panicle initiation significantly affected the rice yield. Maximum temperature, Rainfall, and BSSH of PI to flowering stage affected rice yield. Only the BSSH of this stage was found to negatively affect the rice yield. The linear relationship was found significant with adj. R² value of 0.68 and RMSE of 730.3. However, higher rainfall at an early stage indicated higher yield though the coefficients are relatively small compared to temperature parameters. The optimal weather conditions for Kharif rice production were identified using a decision tree (Fig. 4.2).

The range of the weather variables is presented in Table 4.2. A minimum temperature (Tmin) greater than 25 °C is crucial for achieving higher yields. During the study period, Tmin values ranged from 23.2 °C to 26.7 °C, impacting crop productivity differently. If Tmin remains below 25 °C throughout the cropping period, it can reduce yield by 39% (Fig. 4.2). Rainfall during the Panicle Initiation to 50% Flowering stage also played a pivotal role in yield. Rainfall above 212 mm during this stage could produce yields of 5318 kg ha⁻¹, whereas rainfall below 212 mm could reduce yield by 22%. Maximum temperature

(Tmax) during the same stage is also critical. For optimum growth and yield, Tmax should be above 32 °C. The Tmax during this stage ranged from 30.9 °C to 34.3 °C. When Tmax remained below 32 °C, yield could decrease by 25%. Additionally, bright sunshine hours (BSS) negatively affected crop yield, with a 19% reduction observed when BSS exceeded 5.4 hours during the Panicle Initiation to 50% Flowering stage

Table 4.2 Optimum weather parameters for higher rice yield

Range of Data			
	Maximum	Minimum	Mean
Tmin P4	26.7	23.2	25.9
Tmax P2	34.3	30.9	32.8
Rain P2	614.5	31.4	174.5
Tmin P1	27.1	24.9	26.3
BSS_P2	6.9	2.9	5.0
Rain -P1	809.1	125	332

P1: Transplanting to Panicle Initiation,

P2: Panicle Initiation to 50% Flowering,

P3: 50% Flowering to Harvesting,

P4: Transplanting to Harvesting

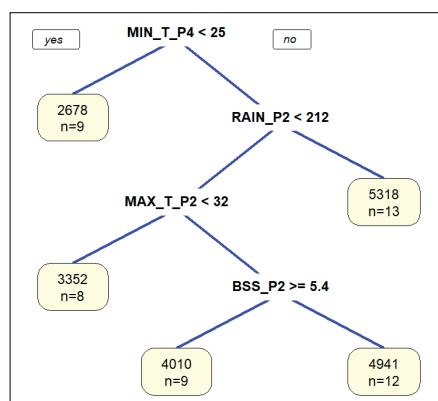


Fig. 4.2 Decision tree for optimum weather condition identification in kharif rice at Mohanpur

Raipur

Three rice cultivars (MTU-1010, Rajeshwari and CG Sugandhit Bhog) were cultivated under three growing environments (transplanted on 01 Jun, 15 Jun, and 30 Jun). The effects of treatments on yield attributes are presented in Table 4.3. The highest plant height was found when the crop was sown on D₁ (115.03 cm) and lowest under D₃ (103.96 cm). Significantly highest plant height was noticed at the maturity stage with Mahamaya (113.10 cm) followed by MTU-1010 (108.34 cm). The highest test weight was obtained with Mahamaya (31.78 gm/ thousand grains) and it was significantly higher than the Vikram TCR and MTU-1010. The most panicles per square meter were found under D₂ (253). There was a significant difference in grain yield among different growing environments. The highest yield was recorded with late growing environment D₃ (4198 kg ha⁻¹) followed by D₂ (3733 kg ha⁻¹) while the lowest grain yield was produced under the first growing environment (D₁). Significantly higher grain yield was recorded with Vikram TCR (4130 kg ha⁻¹) followed by Mahamaya (4009 kg ha⁻¹) when compared to that of MTU-1010 (2562 kg ha⁻¹).

Table 4.3 Yield and yield attributes of rice varieties as influenced by different growing environments (*Kharif* 2023) at Raipur

Dates of sowing	Plant height at maturity (cm)	Test weight (gm)	No. of panicles per m ²	Harvest index (%)	Number of filled grains panicle ⁻¹	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)
D ₁ (01 June)	115.03	26.27	249	23.78	100	2770	8710
D ₂ (15 June)	107	25.99	253	40.44	129	3733	5652
D ₃ (30 June)	103.96	28.40	250	69.89	132	4198	3688
SEm ±	1.2	0.3	4.9	4.8	8.1	11	140
CD (p≤0.05)	S	S	NS	S	S	S	S
Varieties							
V ₁ : MTU1010 (ZC)	108.34	27.13	248	38.22	92	2562	6100
V ₂ : Mahamaya	113.10	31.78	255	48.56	124	4009	6003
V ₃ : Vikram TCR	104.54	21.74	249	47.33	146	4130	5947
SEm ±	1.2	0.3	4.9	4.8	8.1	110	140
CD (p≤0.05)	3.6	1.0	14.7	14.5	24.2	330	420
SEm ± (DxV)	2.1	0.6	8.5	8.4	14		
CD(p≤0.05)	NS	NS	NS	NS	NS		

ZC- Zonal Check, V₁: MTU1010 (ZC), V₂: Mahamaya, V₃: Vikram TCR. D₁-01/06/2023, D₂-15/06/2023, D₃-30/06/2023

Ranchi

A field experiment with three growing environments (sown on 05, 15, and 25 June 2023) and three rice cultivars (Sahbhagidhan, Naveen, and MTU-1010) was undertaken to explore crop-weather relationship studies during kharif 2023. There was significant yield variation under different dates of sowing. The yield of the 25th June sown crop (1425 kg ha⁻¹) was higher than the 5th and 15th sown crop (Table 4.4). Among the varieties, Naveen performed best producing significantly higher grain yields of 1381 kg ha⁻¹. During kharif 2023, the overall performance of rice under different sowing dates was poor due to the late onset of monsoon and deficit rainfall during June, July and August with prolonged dry spells. It resulted in the production of a lesser number of effective tillers and more chaffy grains in all sowing dates and varieties of rice.

Table 4.4 Yield and yield attributes of rice varieties under different growing environments at Ranchi during Kharif 2023

Treatments	Effective tillers/m ²	Fertile grain/ear	Chaffy grain/ear	1000 grain wt (g)	TDM (kg ha ⁻¹)	Yield (kg ha ⁻¹)	HI (%)
Date of Sowing							
Early	146	108	25	23	2528	1191	47
Normal	159	92	31	23.7	2464	1114	45
Late	154	101	19	24.2	2861	1425	50
S Em	3.3	3.7	1.6	0.14	119	55.7	2
CD (p≤0.05)	NS	11	4.9	0.4	NS	167	NS
Variety							
Sahbhagi	135	99	21	22.9	2234	1079	49
Naveen	165	107	38	21.3	2730	1381	50
MTU1010	159	94	15	26.6	2889	1269	44
S Em	3.3	3.7	1.6	0.14	119	55.7	2
CD (p≤0.05)	9.9	NS	4.9	0.4	359	167	NS
Interaction							
S Em	5.7	6.4	2.8	0.25	207	96	3.6
CD (p≤0.05)	NS	NS	8.5	0.76	NS	NS	NS
CV%	6.5	11.1	19	1.8	13.7	13.4	13

Thrissur

Phenophase-wise optimum weather requirement for achieving higher rice yield was identified using field experiment data and daily weather data during 2013-2022.

Table 4.5 Phenophase-wise optimum weather requirement for achieving higher yield for Jyothi at Thrissur centre

Phenophase	Tmax (°C)	Tmin (°C)	BSS (hrs)	Rainfall (mm)
Emergence	29 - 32	24-25	2.0-3.0	60-180
Transplanting	29-31	23-24	2.0-3.0	337-800
Active Tillering	29-31	22-24	2.0-4.0	250-725
Panicle Initiation	29-31	22-24	1.0-5.0	100-295
Booting	30-31	22-24	2.0-6.0	135-425
Heading	30-32	22-24	2.0-6.0	50-140
50% flowering	29-32	22-24	2.0-7.0	32-79
Physiological maturity	31-32	22-24	4.0-6.0	170-485

The dataset included 50 dates of planting for each year five dates of planting from June 5 to August 5 at fortnight intervals and the data was arranged in descending order to get the optimum yield. The optimum yield and the optimum weather data for each phenophase were calculated by statistical analysis as well as scatter plot technique (Table 4.5).

Jorhat

Crop-weather relationship studies in *sali* rice were undertaken with a field experiment consisting of three dates of transplanting (2nd fortnight of June, 1st fortnight of July, and 2nd fortnight of August) and four cultivars (Mahsuri, Swarna Sub-1, TTB-404 and Ranjit Sub-1) during 2018-2023. Among the varieties, mean yield varied from 3286 to 3782 kg ha⁻¹, 3611 to 5400 kg ha⁻¹, 3732 to 5158 kg ha⁻¹, and 4000 to 5300 kg ha⁻¹ in Mahsuri, Swarna Sub-1, TTB-404, and Ranjit sub-1, respectively irrespective of their growing environments (Table 4.6).

Table 4.6 Effect of growing environment on grain yield (kg ha⁻¹) of *Sali* rice in Jorhat during 2018-2023

Treatment details	2018	2019	2020	2021	2022	2023	Pooled
<i>Varieties</i>							
Mahsuri	3651.5	3782	3592.7	3566.6	3286	3455.7	3315.5
Swarna Sub-1	3611.3	3912	5321.1	5400	4108.9	4998.5	4354.5
TTB-404	3732.5	3866	5002.5	5158.3	3960.4	4005.4	3923.3
Ranjit Sub-1	-	-	-	5300	4000.8	4774.4	4176.3
Mean	3665	3853	4639	4856	3839	4308	3942
CD (p≤0.05)	NS	7.6	309	1097	332.6	313.5	240.4
<i>Microclimatic regimes</i>							
D ₁	3971.6	4023	4170.2	4818.7	3808.5	4578.5	3986.6
D ₂	3632.9	3910	5060.7	5137.5	4069	4639.1	4245.4
D ₃	3390.9	3627	4685.5	4612.5	3639.5	3707.9	3595.2
Mean	3665	3853	4639	4856	3839	4308	3942
CD (p≤0.05)	335.9	17.3	798	NS	199.3	217.2	126.2
Interaction	NS	10.0	443	NS	NS	NS	NS

The pooled analysis revealed that- among the four varieties, Swarna Sub-1 and Ranjit Sub-1 recorded maximum yield (>4000 kg ha⁻¹); whereas Mahsuri and TTB-404 recorded a mean yield of 3315 kg ha⁻¹ and 3923 kg ha⁻¹, respectively irrespective of their growing environment. Likewise, the mean grain yield of *Sali* rice varied from 3808 to 4817 kg

ha⁻¹, 3632 to 5137 kg ha⁻¹, and 3391 to 4685 kg ha⁻¹, when transplanted within the second fortnight of June, the first fortnight of July, and the second fortnight of July, respectively irrespective of the varieties. Overall yield was found to decline when transplanted beyond the first fortnight of July which may be attributed to a decrease in effective tillers per square meter.

To support the findings, cluster analysis using Ward's linkage method was applied to find the variability among independent weather variables within different levels of yield clusters and presented in Fig. 4.3. The results of cluster analysis depicted that- a mean maximum and minimum temperature of 32-33 °C and 24-26 °C; 31-34 °C and 22-25 °C, and 28-32 °C and 22-24 °C, respectively during the vegetative, reproductive and ripening phase of *Sali* rice were found to be in the optimal range for better yield. On the other hand, uniformly distributed rainfall throughout the growing period (Table 4.7) was found favorable for supporting the optimum level of yield in *Sali* rice.

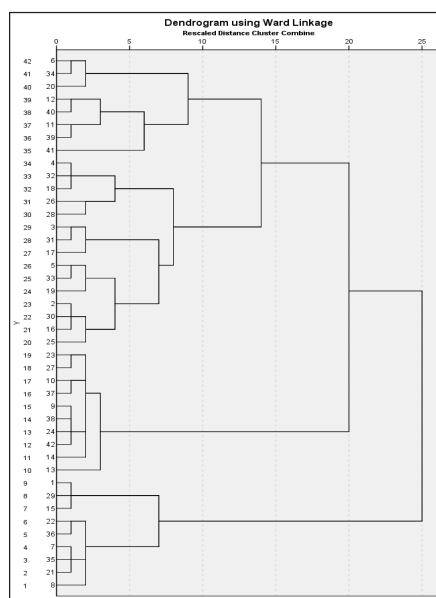


Fig. 4.3 Dendrogram depicting variability in grain yield of *Sali* rice during 2018-2023

Table 4.7 Weather threshold for optimum yield of *Sali* rice under the agroclimatic condition of Jorhat (as per field data of 2018-2023)

Yield level	Phenophases	Mean Weather threshold
4000 kg ha ⁻¹ (STDEVA= 27; N=3)	Vegetative and reproductive	Tmax: 32.0-33.0 °C Tmin: 25.0-26.0 °C RF (Vegetative): 800-850mm RF (Reproductive): 300-350mm RH: >80%
	Maturity	Tmax: 28.0-32.0 °C Tmin: 22.0-24.0 °C RF: 200-250mm RH: >80%

Based on the long-term field experimentation, an attempt has been made to develop a predictive model using the Principal Component Analysis (PCA) regression method using the crop-weather relationship data of the past 7 years (2017-2023). The stepwise PCA regression model was developed with 7 significant transformed weather parameters. The scree plot diagrams are presented in Fig. 4.4a and b. Overall, the performance of the model was quite acceptable with higher R^2 (0.61) and Adjusted R^2 (0.56) values, and can be used for grain yield prediction.

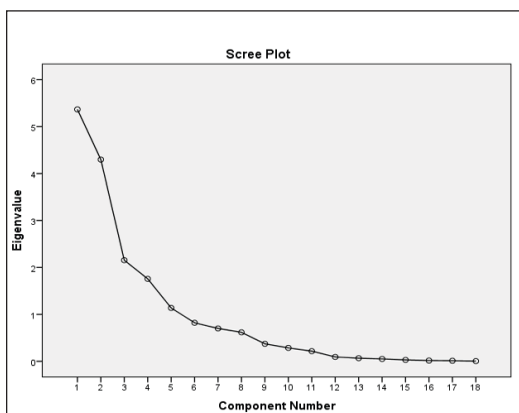


Fig. 4.4 (a): Scree plot diagram depicting variable selection with eigenvalue >1.0

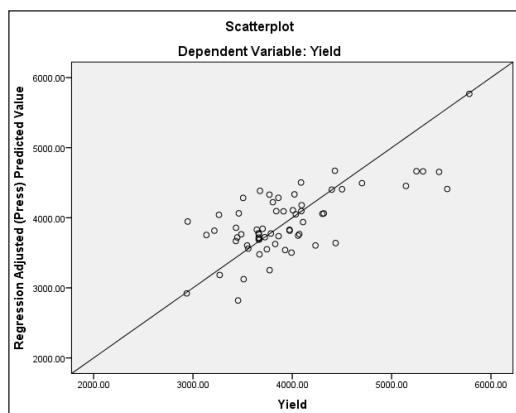


Fig. 4.4 (b): Scatter plot diagram for observed and predicted grain yield of Sali rice using PCA regression model

The yield prediction model developed is as follows:

$$\text{Yield} = 3949.0 - 250.5 \cdot \text{PC1} + 237.1 \cdot \text{PC2} - 192.2 \cdot \text{PC3} - 152.6 \cdot \text{PC4} - 130.5 \cdot \text{PC5} - 126.6 \cdot \text{PC6} + 112.4 \cdot \text{PC7} \quad (R^2 = 0.61; \text{Adj. } R^2 = 0.56)$$

(Where, PC1: Mean maximum temperature during ripening; PC2: accumulated rainfall during ripening; PC3: Mean relative humidity during vegetative; PC4: Mean maximum temperature during reproductive; PC5: Accumulated pan evaporation during reproductive; PC6: Accumulated pan evaporation during ripening and PC7: mean bright sunshine hour during ripening)

Kharif Maize

Faizabad

The crop weather relationship study in *kharif* maize was undertaken with three growing environments (05, 15, and 25 July 2023) and three varieties/hybrids (Kanchan, Azad hybrid-1, and Azad hybrid-2). The weight of grains per cob, cob, test weight, and yields varied significantly due to the crop growing environment. Genotypes also significantly influenced all the yield attributes and yield of maize. Sowing on 5 July recorded significantly

higher values followed by July 15 and July 25 growing environment (Table 4.8). Among the varieties, Kanchan was superior to the rest of the varieties in yield attributes and yield of maize.

Table 4.8 Yield and yield attributes of maize as affected by crop growing environment and varieties at Faizabad

Treatments	Weight of grains per cob(g)	Weight of cob (g)	Test weight (g)	Grain Yield (kg ha ⁻¹)	Stover Yield (kg ha ⁻¹)
Crop Growing Environment					
July, 05	99.4	159.1	226.2	3310	6130
July, 15	88.5	152.2	220.3	2820	5510
July, 25	76.6	144.4	213.4	1940	5020
SEm±	2.15	3.53	5.62	111	120
CD (p≤0.05)	7.34	12.32	19.33	393	420
Varieties					
Kanchan	97.1	158.2	224.1	3110	6010
Azad hybrid-1	90.2	152.5	220.2	2620	5620
Azad hybrid-2	76.3	145.4	215.3	2440	5140
SEm±	2.14	3.52	5.64	1012	120
CD (p≤0.05)	7.32	12.33	19.32	392	410

Kanpur

The crop weather relationship study in *kharif* maize was undertaken with three growing environments (05, 15, and 25 July 2023) and three varieties/hybrids (DKC-7074, Azad hybrid-1, and Azad hybrid-2). Using the pooled data during 2017-2023, optimum temperature and rainfall thresholds for attaining three categories of maize yield were identified. The three categories of yields considered were above normal (mean + SD), average and below average (mean – SD). For these yield categories, the corresponding maximum temperature, minimum temperature and average soil temperature at 5.0 cm for the three cultivars were calculated and the results are presented in Table 4.9. The highest above-average yields (6653 kg ha⁻¹) were obtained when higher maximum temperatures were recorded during emergence (36.1 °C), knee high (33.9 °C), 50% silking (33.5 °C), milk (33.5 °C) and dough (33.3 °C) and higher minimum temperature during knee high (26.7 °C), 50% tasselling (25.9 °C), dough (25.2 °C) and maturity (24.2 °C)

Table 4.9 Temperatures, heat unit, and rainfall during different phonological stages of three maize cultivars for obtaining three different categories of yield at Kanpur

Yield category	Emer.	Knee-high	50% tasselling	50% silking	Milking	Dough	Maturity	Yield (kg ha ⁻¹)
Maximum temperature (°C)								
Above avg.	36.1	33.9	33.1	33.5	33.5	33.3	33.0	6653
Average	35.6	33.8	33.0	33.4	33.3	33.2	32.8	5690
Below avg.	34.5	33.0	33.1	33.4	33.3	32.1	33.1	4678
Minimum temperature (°C)								
Above avg.	26.7	26.7	25.9	25.8	25.6	25.2	24.2	6653
Average	27.0	26.5	25.9	25.8	25.7	25.2	23.6	5690
Below avg.	26.8	26.0	25.7	25.9	25.6	24.4	22.7	4678
Soil temperature (°C)								
Above avg.	34.6	31.6	29.7	30.0	30.0	30.1	29.7	6653
Average	33.5	31.3	29.7	29.9	30.2	30.0	29.4	5690
Below avg.	31.8	30.4	29.7	30.4	30.4	29.2	29.3	4678
Heat unit (°days)								
Above avg.	137.0	645.2	365.3	129.7	205.2	237.1	198.4	6653
Average	134.9	584.7	356.5	112.1	226.1	220.5	183.1	5690
Below avg.	126.1	517.7	349.1	106.9	219.7	199.0	160.8	4678
Rainfall (mm)								
Above avg.	33.3	284.8	177.5	31.5	61.0	82.1	28.0	6653
Average	41.3	283.5	183.9	33.8	75.3	50.7	47.5	5690
Below avg.	54.0	266.9	166.3	25.2	56.4	62.8	28.3	4678
Duration (Days)								
Above avg.	7	38	57	63	74	86	97	6653
Average	6	35	54	59	71	82	93	5690
Below avg.	6	33	51	56	67	78	87	4678

Ludhiana

Crop-weather relationship in kharif maize was studied by undertaking a field experiment with three genotypes PMH13, PMH14, and JH-19014 grown under three growing environments (sown on 01, 15 and 30 June 2023). The effect of treatments on leaf chlorophyll concentration was studied. The concentration of chlorophyll increased from knee knee-high stage (~30 DAS) to the tasselling stage (~60 DAS) and then decreased

up to physiological maturity (~90 DAS). Amongst dates of sowing, on average the earlier sown crop had higher chlorophyll concentration as compared to other later dates of sowing (Fig. 4.5). Among varieties, JH 19014 had a higher chlorophyll concentration.

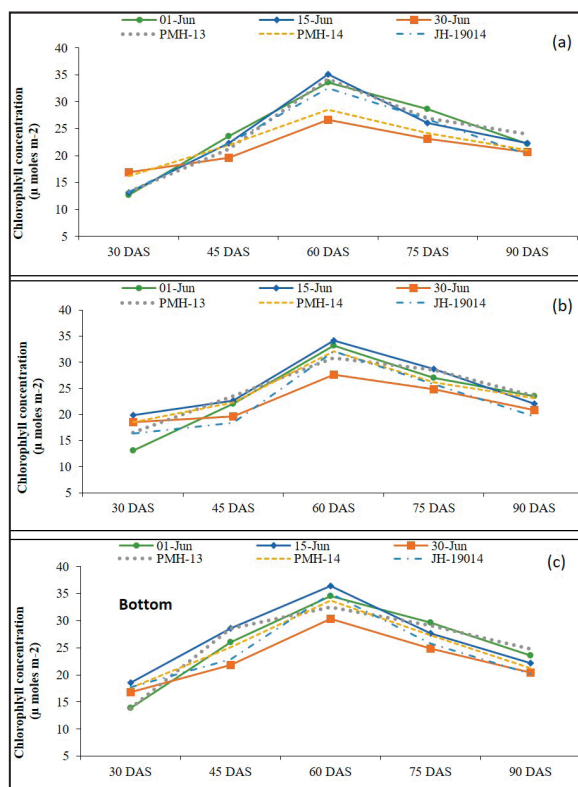


Fig. 4.5 Periodic variation in chlorophyll concentration (μ moles m^{-2}) of (a) top (b) middle and (c) bottom leaf of Maize varieties sown under different dates of sowing, Kharif 2023 at Ludhiana

The yield and yield attributes were greatly influenced by the different dates of sowing and cultivars. The yield attributes like Grain yield, No. of grains, Weight of grains, Cob length, 100 grain weight (g), and cob perimeter, were found to be higher in JH 19014 as compared to other varieties (Table 4.10). Among the dates of sowing higher values of these parameters were noticed in D_1 (01 June) as compared to other dates of sowing. Averaged over cultivars biomass and grain yield was maximum in D_1 date of sowing (01 June) as compared to other two dates of sowing. Averaged over dates of sowing, the biomass and grain yield of JH-19014 was higher as compared to the rest of the cultivars. It is clear from the Table that the sowing on 01 June of JH 19014 resulted to highest yield and it got decreased by late sowing of the maize crop.

Table 4.10 Yield and yield attributes of Maize as affected by genotypes grown under three growing environments in Ludhiana during kharif 2023

Treatment	Grain yield (kg ha ⁻¹)	No. of grains / cob	Weight of grains per cob (g)	Cob length (cm)	100 grain weight (g)	Cob perimeter (cm)	Biomass yield (kg ha ⁻¹)	Harvest Index %
Dates of sowing								
01-Jun	6571	341.4	100.2	18.28	25.8	14.56	20757	31.70
15-Jun	5971	328.3	92.8	17.21	25.4	14.34	18660	32.05
30-Jun	5720	313.9	87.7	16.07	24.3	13.76	17935	32.05
CD (p≤0.05)	338	21.6	5.8	0.76	1.2	0.25	1163	NS
Varieties								
PMH-13	5895	311.0	87.3	16.48	24.8	14.02	18315	32.30
PMH-14	6043	326.1	94.0	17.29	25.2	14.28	18990	31.90
JH-19014	6324	346.6	99.3	17.79	25.6	14.36	20048	31.60
CD (p≤0.05)	338	21.6	5.8	0.76	NS	0.25	1163	NS

Samastipur

The field experiment consisted of three maize genotypes (V_1 : Bio 9637, V_2 : Shaktiman 4, and V_3 : Shaktiman 5) and four growing environments (D_1 : 1 November, D_2 : 10 November, D_3 : 20 November and D_4 : 30 November).

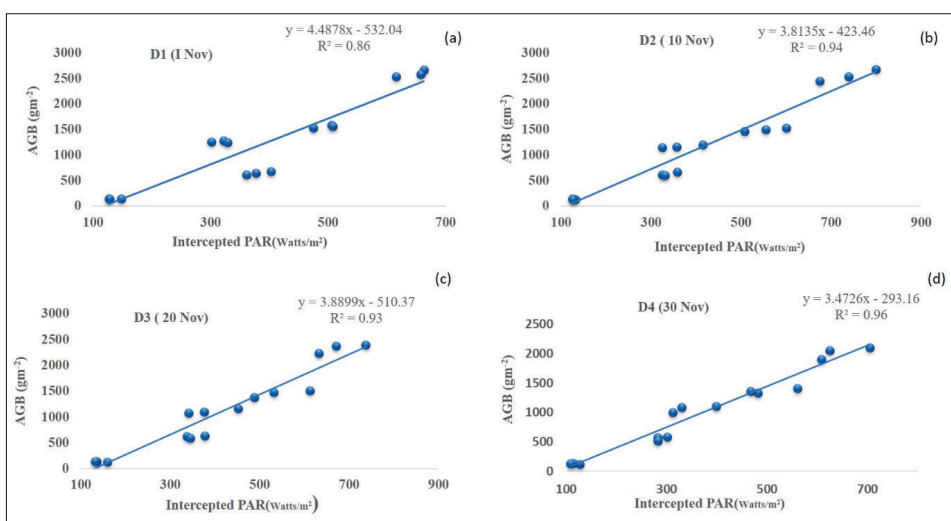


Fig. 4.6 Relationships between accumulated intercepted PAR (Watts m⁻²) and above-ground biomass (AGB, g m⁻²) for different growing environments in kharif maize at Samastipur during 2023

Further, the relationship between accumulated intercepted PAR and above-ground biomass at various growth stages was explored and the result is presented in Fig. 4.6. Accumulated intercepted PAR and above-ground biomass were recorded for different dates of sowing at different phenological stages. Linear models for predicting biomass based on intercepted PAR were developed. Among all dates of sowing, the highest slope of 4.488 was obtained for the relation between biomass and intercepted PAR for the crop sown on D_1 followed by D_2 (3.813).

Pearl millet

Anand

Field experiments consisting 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) were conducted in Anand during *Kharif* season of 2017-2023. The crop weather relationship in *Kharif* pearl millet was studied using experimental data for 2017 to 2023 under rainfed conditions. Phase-wise heat unit requirement of pearl millet cultivars is given in Table 4.11 The crop requires more growing degree days for emergence to booting phase (>683 °C day) followed by grain filling to physiological maturity (>285 °C day). While GDD requirement for 50 % flowering to 100% flowering period is the least (86-94 °C day). Cultivar GHB 558 and GHB 744 require nearly similar heat units (1365 °C day, and 1381 °C day, respectively) while GHB 538 has a comparatively low requirement (1337 °C day) to complete its life cycle. The photothermal quotient (corrected with vapour pressure deficit) of the crop during different phenophases ranged between 0.57 to 0.81 MJ m⁻² day⁻¹ °C⁻¹ with a seasonal average 0.7 MJ m⁻² day⁻¹ °C⁻¹.

Table 4.11 Phase-wise thermal time requirement (°C day) and Photothermal quotient (MJ m⁻² day⁻¹ °C⁻¹) for pearl millet (2017-2023) at Anand

Phase	GHB - 538		GHB - 558		GHB - 744		PTQ _{vpd}
	GDD	SD	GDD	SD	GDD	SD	
Emergence- Booting	683	59	686	62	737	66	0.57
Booting -50% Flowering	144	35	161	31	151	30	0.66
50% Flowering-100% flowering	94	25	94	29	86	26	0.73
100% flowering –Grain filling	122	40	118	41	123	52	0.71
Grain filling – Physiological maturity	293	148	309	167	285	141	0.81
Complete life cycle	1337	99	1365	92	1381	87	0.70

The grain yield was significantly influenced by different dates of sowing under individual years as well as on a pooled basis. Among the individual years, D₁ sowing produced significantly higher grain yield in the years 2017 to 2020 and the pooled analysis, which was statistically at par with D₂ sowing in the year 2017 and the pooled analysis. In the years 2021 and 2023, the highest grain yield was reported in D₂ sowing, which was statistically similar to D₁ sowing (Table 4.12).

During the year 2022, it was recorded in D₃ sowing which was statistically at par with D₂ sowing. On a pooled basis, there were nearly 5 % and 14 % grain yield reductions under D₂ and D₃ sowing when compared to D₁ sowing, respectively. GHB 744 recorded significantly high grain yield as compared to other cultivars in every individual year of experimentation as well as in pooled analysis, which was statistically at par with GHB 558 in all individual years, but not in year 2023 and pooled analysis.

Table 4.12 Grain yield of pearl millet influenced by growing environments and genotypes in Anand (2017-2023)

	Grain Yield (kg ha ⁻¹)						
	2017	2018	2020	2021	2022	2023	Pooled
Date of sowing							
D ₁ (Onset of monsoon)	3776	3268	2578	2577	2310	2475	2831
D ₂ (Ten days after D ₁)	3526	2834	2222	2612	2339	2564	2683
D ₃ (Ten days after D ₂)	2699	2690	2106	2234	2531	2299	2427
S.Em.±	179	114	69	85	53	50	99
CD (p≤0.05)	621	395	240	294	183	175	313
CV (%)	18.62	13.48	10.42	11.87	7.65	7.14	13.35
Variety							
V ₁ : GHB-338	3085	2773	2138	2310	2272	2343	2487
V ₂ : GHB-558	3275	2923	2320	2495	2367	2385	2628
V ₃ : GHB-744	3640	3096	2449	2617	2541	2609	2825
S.Em.±	138	66	55	74	65	64	34
CD (p≤0.05)	410	197	162	221	192	190	94
CV (%)	14.36	7.85	8.19	10.42	9.36	9.07	1072
Significance of interaction effect	NS	DxV	NS	NS	NS	NS	YxD, YxDxV

Solapur

The field experiments were conducted using three sowing windows (2nd fortnight of June, July, and August) and three varieties/hybrid (ICTP-8203, Mahyco hybrid, and Dhanshakti) during 2016-2023. The crop sown in the second fortnight of July (S_2) produced significantly higher grain yield (1573 kg ha⁻¹) (Table 4.13), biomass yield (2569 kg ha⁻¹), and total monetary returns (Rs. 36714 ha⁻¹) (Data not included in the Table). among the genotypes Dhanshakti produced significantly higher grain yield (1512 kg ha⁻¹), biomass yield (2531 kg ha⁻¹) and total monetary returns (Rs.35026 ha⁻¹). This indicates the sustainability of the Dhanshakti variety over other varieties. The Sustainable Yield Index (SYI) was used as an approach to evaluate the minimum yield likely to be achieved in relation to changes in sowing windows. SYI of late sown bajra is higher (0.61) as compared to early (June & July) sown crop (i.e. 0.51 & 0.45, respectively). Though the yield of S_3 sown crop is 17% less than the mean. In response to a change in crop growing environment S_3 i.e. August sown pearl millet was found better for SYI (0.61). Further, based on SYI it can be included as a contingent crop for its sustainable yield of 1108.4 Kg ha⁻¹.

Table 4.13 Grain yield (kg ha⁻¹) of *kharif* pearl millet as influenced by various sowing dates and varieties (2016 to 2023) at Solapur

Treatment	2016	2017	2018	2019	2020	2021	2022	2023	Mean	SYI
Main= Sowing dates										
S_1 = SMW 26	1719.8	888.1	1146.7	867.2	1147.9	1570.18	1211.6	990.6	1348.6	0.51
S_2 = SMW 30	2185.3	1099.8	1503.8	1253.5	1551.9	885.80	1410.4	1137.5	1572.9	0.45
S_3 = SMW 35	1328.7	710.7	812.6	744.2	1044.9	1185.64	975.3	931.7	1108.4	0.61
Mean	1744.6	899.5	1154.4	954.9	1248.2	1213.87	1199.1	1020.0	1343.3	0.56
Sub=Three varieties										
V_1 = ICTP-8203	1598.5	769.1	1025.4	823.8	1127.3	1135.29	1081.4	942.8	1211.6	0.55
V_2 = Mahyco hybrid	1628.7	852.6	1155.9	936.3	1227.3	1174.20	1159.5	1027.7	1306.3	0.60
V_3 = Dhanshakti	1952.6	1076.9	1281.8	1104.9	1390.0	1332.13	1356.4	1089.4	1512.0	0.56
Mean	1744.6	899.5	1154.4	954.9	1248.2	1213.87	1199.1	1020.0	1343.3	0.57
S.E. $\pm$ (Sowing dates)	74.5	70.3	60.81	67.1	69.1	44.3	85.6	24.2	76.0	
CD ($p \leq 0.05$)	292.5	275.9	238.77	263.6	221.4	174.1	264.2	94.9	230.4	
S.E. $\pm$ (Varieties)	52.0	48.1	63.67	62.5	63.8	36.5	15.9	36.4	15.2	
CD ($p \leq 0.05$)	160.3	148.1	196.19	192.7	196.7	112.3	45.5	112.0	43.3	
S.E. $\pm$ (SD x V)	90.1	83.2	110.28	108.3	110.6	63.1	27.5	63.0	26.3	
CD ($p \leq 0.05$)	NS	NS	NS	NS	NS	NS	NS	NS	NS	

S_1 - 2nd fortnight of June, S_2 - 2nd fortnight of July, S_3 - 2nd fortnight of August.

Hisar

A field experiment consisting of three growing environments (D_1 : 30 June 2023, D_2 : 13 July 2023, and D_3 : 27 July 2023) and three varieties (V_1 : GHB 558, V_2 : HHB 67 and V_3 : HHB 299) was conducted in Hisar during *kharif* season of 2023. The crop sown on 30 June was superior in terms of yield attributes and yield as compared to the sowing on 13 and 27 July. Maximum grain and biological yield were obtained when the crop was sown on 30 June (3588 and 14919 kg ha⁻¹) followed by 13 July (2763 and 11756 kg ha⁻¹) and 27 July (1443 and 6414 kg ha⁻¹) (Table 4.14). Among pearl millet varieties, higher grain and biological yield (2824 and 11765 kg ha⁻¹) were recorded by GHB-558 as compared to HHB 299 (2616 and 11100 kg ha⁻¹) and HHB 67 improved (2354 and 10224 kg ha⁻¹).

Table 4.14 Yield attributes and yield at maturity in different cultivars of rainfed pearl millet under different growing environments at Hisar during Kharif 2023

Treatments	Total no. of tillers/ plant	No. of effective tillers/ plant	1000-grain weight (g)	Grain yield Kg ha ⁻¹	Stover yield Kg ha ⁻¹	Biological yield Kg ha ⁻¹	Harvest index (%)
Factor A (Sowing dates)							
D_1 (30 June)	4.45	2.98	9.14	3588.0	11331.0	14919.0	24.4
D_2 (13 July)	3.89	2.65	8.84	2763.3	8993.1	11756.4	23.5
D_3 (27 July)	3.36	2.26	7.98	1443.1	4971.1	6414.2	22.5
SE (m)	0.22	0.12	0.15	52.1	192.4	241.5	0.1
CD ($p \leq 0.05$)	0.79	0.43	0.52	183.8	678.7	852.1	0.5
Factor B (Varieties)							
V_1 (GHB 558)	4.65	2.92	8.66	2824.1	8941.0	11765.0	23.8
V_2 (HHB 67 Imp)	3.29	2.41	8.49	2354.0	7870.4	10224.4	22.7
V_3 (HHB 299)	3.75	2.56	8.80	2616.3	8483.8	11100.1	23.5
SE (m)	0.18	0.08	0.15	39.6	123.8	154.4	0.2
CD ($p \leq 0.05$)	0.54	0.25	NS	118.6	370.6	462.3	0.6

Finger millet

Bangalore

Crop weather relationship studies in finger millet were undertaken using a field experiment with three growing environments (28 SMW, 30 SMW, and 32 SMW) and three genotypes (MR-6, KMR-316, and KMR-630) during *Kharif* 2023. During the growth period of the early sown crop, higher rainfall was received during the early stages of the crop leading

to grand vegetative growth and it went down during reproductive growth, creating milder moisture stress, which is essential in finger millet for better grain formation and grain filling. On the second sowing date, there was an observed high rainfall during 90 to harvest stages, leading to the occurrence of pests and diseases, lodging of the crop resulting in lower grain and straw yield (4504 and 7468 kg ha⁻¹, respectively) similarly in late sown crop (2875 and 6527 kg ha⁻¹, respectively) (Table 4.15).

Table 4.15 Effect of varieties and growing environments on grain and straw yield of finger millet during *Kharif* 2023 at Bangalore

Treatment	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)
Variety (V)		
V ₁ (MR-6)	3779	8995
V ₂ (KMR-316)	4835	7786
V ₃ (KMR-630)	3982	5382
S.Em.±	136	268
CD (p≤0.05)	406	802
Date of Sowing (D)		
D ₁ (July SFN: 11-07-23)	5216	8168
D ₂ (August FFN: 24-07-23)	4504	7468
D ₃ (August SFN: 07-08-23)	2875	6528
S.Em.±	136	268
CD (p≤0.05)	406	802
Interaction (V X D)		
V ₁ D ₁	5267	10000
V ₁ D ₂	5573	8588
V ₁ D ₃	4809	5916
V ₂ D ₁	4389	9237
V ₂ D ₂	5229	7710
V ₂ D ₃	3893	5458
V ₃ D ₁	1679	7748
V ₃ D ₂	3702	7061
V ₃ D ₃	3244	4771
S.Em.±	235	464
CD (p≤0.05)	704	NS

KMR-316, the identified potential variety for July sowing conditions in the region, recorded significantly higher grain yield (4835 kg ha⁻¹) followed by KMR-630 (3982 kg ha⁻¹) significantly lower yield was observed in MR-6 variety (3779 kg ha⁻¹). The difference among the varieties was majorly due to differential growing conditions requirement of the varieties, their interaction with existing weather factors, etc. The interaction of sowing dates and varieties was significant for grain yield, higher yield was observed in KMR-316 variety sown on the second sowing date (5573 kg ha⁻¹) as the result of better interaction of the variety with the environment.

Ranichauri

The field experiment consisted of three growing environments (10 June, 20 June, and 30 June 2023) and three varieties (VLM-352, VLM-379, PRM-2). The sowing of crops on 30.06.2023 accumulated more GDD as compared to other sowing dates. Among the cultivars, PRM-2 recorded higher GDD compared to the other two varieties. The yield and yield attributes of finger millet cultivars grown under different growing environments are presented in Table 4.16.

Table 4.16 Yield and yield attributes of Finger millet as influenced by sowing dates and varieties during *Kharif* 2023

Treatments	Tillers per plant	1000 seed weight (g)	Seed yield (kg ha ⁻¹)	Biological Yield (kg ha ⁻¹)	GDD Flowering
Sowing Windows					
D ₁ (10.06.2023)	1.9	2.29	1314	3264	821
D ₂ (20.06.2023)	1.5	2.63	2108	3924	693
D ₃ (30.06.2023)	1.9	2.32	1269	3571	672
SeM ±	0.2	0.08	86	230	12
CD (p<0.05)	NS	0.26	NS	NS	NS
Varieties (V)					
V ₁ (VLM-352)	1.5	2.54	1475	3747	753
V ₂ (VLM-379)	1.8	2.47	1548	3731	735
V ₃ (PRM-2)	2.0	2.23	1669	3281	698
SeM ±	0.2	0.08	86	230	12
CD (p<0.05)	NS	NS	NS	NS	36
Interaction (D×V)	S	NS	S	NS	NS

The influence of sowing windows was found to be non-significant in all these parameters except the weight of 1000 seeds where a significant difference was observed. Sowing of finger millet on 20 June 2023 (D_2) resulted in a maximum weight of 1000 seeds and remained significantly superior over the other two growing environments. The influence of varieties on all these parameters was found to be non-significant, except, for growing degree days (GDD) at the flowering stage of finger millet, where the difference was significant. VLM-352 (V_1) took maximum GDD for flowering and remained significantly superior overall V_3 (PRM-2) and at par with V_2 (VLM-379).

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 pigeonpea cultivars (LRG 41, PRG 176, LRG 52 and BRG 2) was taken up during *kharif* 2023. The crop grown under protective irrigation gave a significantly higher seed yield (654 kg ha⁻¹) than rainfed crops (367 kg ha⁻¹) (Table 4.17).

Table 4.17 Seed yield of pigeonpea varieties as influenced by time of sowing under rainfed and protective irrigation during 2023-24

Seed Yield (kg ha ⁻¹)					
	27.06.2023	06.07.2023	22.07.2023	10.08.2023	Mean
RF	303	446	483	236	367
PR	734	751	755	378	654
Mean	518	598	619	307	
	LRG-41	PRG-176	LRG-52	BRG-2	Mean
RF	321	581	395	169	367
PR	588	909	758	364	654
Mean	454	745	576	267	
	LRG-41	PRG-176	LRG-52	BRG-2	Mean
27.06.23	468	769	595	242	518
06.07.23	511	930	648	303	598
22.07.23	517	950	721	288	619
10.08.23	322	330	342	233	307
Mean	454	745	576	267	
	I	D	V	IxD	
CD (p<0.05)	58.6	23.8	20.9	33.7	
	IxV	VxD	IxDxV		
CD	29.6	41.8	59.2		

The crop sown during the 2nd FN of July has given a significantly higher seed yield (619 kg ha⁻¹), than the crop sown during the 1st FN of July (598 kg ha⁻¹), 2nd FN of June (518 kg ha⁻¹) and 1st FN of August (307 kg ha⁻¹) sown crop. Among the four varieties (LRG 41, PRG 176, LRG 52, and BRG 2) evaluated, irrespective of dates of sowing, PRG 176 and LRG 52 recorded higher seed yield than LRG 41 and BRG 2.

Bangalore

A field experiment with three growing environments (21 SMW, 25 SMW, and 30 SMW) and three varieties (BRG-1, BRG-5, PRG-176) was taken up at Bangalore centre during *Kharif* 2023.

Table 4.18 Effect of varieties and date of sowing on grain and stalk yield of pigeonpea.

Treatment	Grain yield (kg ha ⁻¹)	Stalk yield (kg ha ⁻¹)
Variety (V)		
V ₁ (BRG-1)	1479	6369
V ₂ (BRG-5)	1249	7739
V ₃ (PRG-176)	1520	6447
S.Em.±	28.50	832.2
CD (p≤0.05)	85.45	NS
Date of Sowing (D)		
D ₁ (22-05-2023)	2068	7279
D ₂ (21-06-2023)	1201	6801
D ₃ (25-07-2023)	979	6474
S.Em.±	28.50	832.2
CD (p≤0.05)	85.45	NS
Interaction (V x D)		
V ₁ D ₁	1777	6570
V ₁ D ₂	1468	8587
V ₁ D ₃	1194	6680
V ₂ D ₁	1999	6070
V ₂ D ₂	1011	7304
V ₂ D ₃	737	7030
V ₃ D ₁	2428	6467
V ₃ D ₂	1124	7325
V ₃ D ₃	1008	5631
V ₁ D ₁	1777	1441.4
CD (p≤0.05)	148.01	NS

There was an observed difference in varietal response to environmental factors among the three varieties sown. Pigeonpea being highly physiologically elastic to biotic and abiotic stresses of the surrounding environment, respond by sooner changes in temperature and moisture availability. Such response was observed in PRG-176 for a relatively higher degree compared to BRG-1 and BRG-5 varieties under the study. PRG-176 can switch to reproductive and vegetative phases under resource-scarce and abundance, because of this characteristic it produced a significantly higher grain yield (1520 kg ha^{-1}) which was on par with BRG-1 (1479 kg ha^{-1}) and a significantly lower yield was observed in BRG-5 (1201 kg ha^{-1}) which are relatively determinate in their phenophasic development (Table 4.18). The interactive effect of sowing date and variety was also significant, higher yield (2428 kg ha^{-1}) was observed in the PRG-176 variety sown during the early season due to better utilization of resources by the variety. However, the lowest interaction effect of variety and environment was observed in late sown BRG-5 variety leading to poor yield (737 kg ha^{-1}).

Groundnut

Anantapur

A field experiment was taken up with two main plot treatments (rainfed and protective irrigated), four sowing environments (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). Among the main plot treatments, protective irrigated crops recorded a higher yield (mean yield of 1408 kg ha^{-1}) compared to rainfed (645 kg ha^{-1}) under all sowing windows (Table 4.19). Among the cultivars, K 1812 recorded the highest yield under both rainfed as well as protective irrigated conditions.

Table 4.19 Pod yield of groundnut as influenced by sowing environments and cultivars at Anantapur during *Kharif* 2023-24

	D ₁ (27.06.23)	D ₂ (07.07.23)	D ₃ (22.07.23)	D ₄ (10.08.23)	Mean
RF	869	1008	525	178	645
PR	1197	1453	1652	1331	1408
Mean	1033	1231	1089	754	
	K6	KH	K 1812	TCGS 1694	Mean
RF	581	637	713	649	645
PR	1203	1398	1700	1332	1408
Mean	892	1018	1206	990	

	K6	KH	K 1812	TCGS 1694	Mean
D ₁	856	1041	1282	952	1033
D ₂	1013	1292	1403	1213	1231
D ₃	966	1032	1289	1068	1089
D ₄	735	705	851	727	754
Mean	892	1018	1206	990	
	I	D	V	I×D	
CD (p≤0.05)	40.2	46.3	40.1	65.5	
	I×V	V×D	I×D×V		
CD (p≤0.05)	56.8	80.3	113.5		

Bangalore

Three varieties of Groundnut (KCG-6, Kadri Lepakshi, and K-6) were sown on two different dates of sowing (26-06-2023 and 11-7-2023).

Table 4.20 Effect of varieties and date of sowing on pod and haulm yield of groundnut at Bangalore during kharif 2023

Treatment	Pod yield (kg ha ⁻¹)	Haulm yield (kg ha ⁻¹)
Date of sowing (D)		
D ₁ (July SFN: 26.6.23)	2124.7	11217.9
D ₂ (August FFN: 11.7.23)	2589.8	5986.0
S.Em.±	70.9	248.6
CD (p≤0.05)	210.6	749.4
Varieties (V)		
V ₁ (KCG-6)	1854.7	7942.1
V ₂ (Kadri Lepakshi)	3454.2	12066.4
V ₃ (K-6)	1762.8	5797.5
S.Em.±	86.8	304.5
CD (p≤0.05)	257.9	917.8
Interaction (D×V)		
D ₁ V ₁	1706.3	10181.0
D ₁ V ₂	3107.8	16119.9
D ₁ V ₃	1560.1	7352.9
D ₂ V ₁	2003.2	5703.2
D ₂ V ₂	3800.6	8012.8
D ₂ V ₃	1965.5	4242.1
S.Em.±	122.8	430.6
CD (p≤0.05)	NS	1297.9

*FFN - First Fortnight, SFN - Second Fortnight

Among the three varieties tested, Kadri Lepakshi recorded significantly higher pod and haulm yield (3454.2 and 12066.4 kg ha⁻¹, respectively) compared to KCG-6 (1854.7 and 7942.1 kg ha⁻¹ pod and haulm yield, respectively) and K-6 (1762.8 and 5797.5 kg ha⁻¹ pod and haulm yield, respectively). The variability among the varieties was attributable to the genetic makeup of the variety and its interaction with the environmental factors. Numerically higher pod yield was observed in the late sown Kadri Lepakshi variety (3800.6 kg ha⁻¹) and lower pod yield was observed in the early sown KCG-6 variety (1560.1 kg ha⁻¹). However, significant variability in haulm yield was captured by the interaction, the early sown Kadri Lepakshi variety recorded a higher haulm yield (16119.9 kg ha⁻¹) (Table 4.20).

Soybean

Akola

Crop-weather relationship studies in soybean at Akola were taken up using four growing environments (sown on 26, 27, 28, and 29 SMW) and three genotypes [JS-335, AMS-MB-5-18, and AMS-100-39 (AMBA)]. Crop sown during 26 SMW (D₁ - 28 June) recorded significantly higher seed and biomass yield. It was followed by 27 SMW (D₂ - 05 July) sowing both concerning seed yield and biomass yield (Table 4.21).

Table 4.21 Seed and biomass production as influenced by growing environments and genotypes in soybean at Akola during *Kharif* 2023

Treatment	Seed yield (kg ha ⁻¹)	Total biomass yield (kg ha ⁻¹)
Sowing time		
D ₁ - 26 MW (28 June)	1730	4040
D ₂ - 27 MW (05 July)	1621	3748
D ₃ - 28 MW (11 July)	1325	3027
D ₄ - 29 MW (18 July)	852	1949
SE (m) ±	43	100
CD (p≤0.05)	122	288
Variety		
V ₁ - JS-335	1429	3306
V ₂ - AMS-MB 5-18	1311	3020
V ₃ - AMS-100-39	1406	3247
SE m ±	37	87
CD (p≤0.05)	NS	NS
Interaction		
SE m ±	74	173
CD (p≤0.05)	NS	NS
CV%	11	11

Crop sown on 18 July (29 SMW) recorded the lowest seed and biomass yields. The higher yield level achieved by 26 SMW (June 28) sowing was due to adequate rainfall (moisture) across vegetative and reproductive periods, and comparatively favourable thermal regimes and photoperiod across the vegetative and reproductive phase of the crop compared to remaining sowings. Further delayed sowings exposed the crop to lower soil moisture during vegetative growth this year, and comparatively lower photoperiod phenophase, particularly across critical phases of pod formation and seed development. Among the varieties seed yield was found non-significant. Similar results were also recorded with respect to biomass yield.

Parbhani

Field experiments consisted of four growing environments (25 SMW, 26 SMW, 27 SMW, and 28 SMW), and three soybean varieties (MAUS-158, MAUS-162, and JS-335) were conducted at Parbhani from 2013 onwards.

The relationship between the percent available soil moisture (PASM) and the yield of soybean at different phenophase and growing environments was also studied using long-term field experiment data (2013-2022). The developed relationships were used to estimate the yield of a crop under a particular level of PASM, aiding in the amendment of regulations of drought declaration. PASM < 25% (severe drought), 25-50% (moderate drought, 50-75% (mild drought), and >75 % (No drought) as shown in Fig. 4.7. The outcomes revealed that in soybeans, the crop yield recorded at 25 PASM was only 200-405 kg ha⁻¹ & PASM >75% to 1800-2100 kg ha⁻¹ of soybean yield. Therefore, based on the research outcomes, existing PASM ranges for drought declaration were amended which will support the assessment and

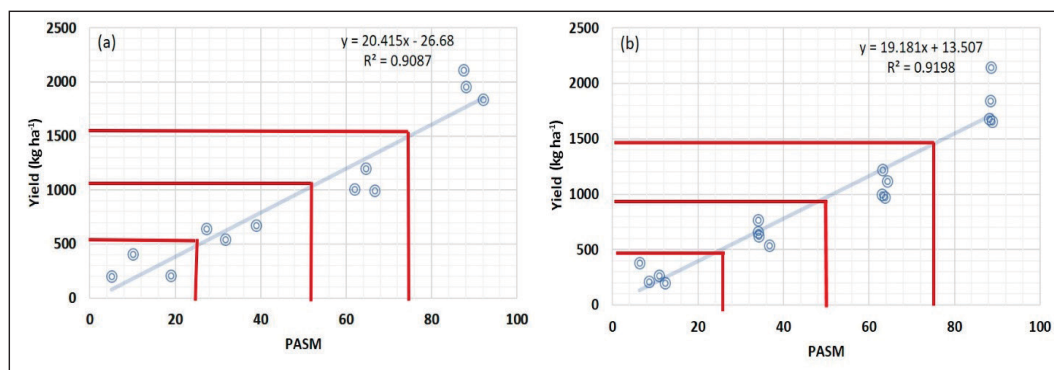


Fig. 4.7 Relationship between soybean yield and plant available soil moisture across (a) at different phenological stages and (b) different sowing environments in Parbhani

declaration of drought along with other mandatory triggers like Standardized Precipitation Index (SPI) and rainfall deficit.

Udaipur

The experiment on soybean crop was laid out at Udaipur to evaluate the performance of soybean varieties under different growing environments. This experiment was continuously sown since *kharif* 2017 to assess the growth characters and yield and correlate to weather parameters. The experiment consisted of 9 treatment combinations *i.e.*, 3 soybean varieties (JS 335, RKS 45, RKS 18) and 3 sowing environments (July 1, 10, 20).

Table 4.22 Effect of growing environment and soybean varieties on yield (Pooled 2017-2023) at Udaipur

Treatments	Yield (kg ha ⁻¹)			Harvest index (%)	Economics		
	Seed	Haulm	Biological		Gross return (Rs ha ⁻¹)	Net return (Rs ha ⁻¹)	B:C ratio
Sowing Environment							
01 July	1781	2935	4716	3766	80276	53014	1.95
10 July	1733	3030	4763	3685	78593	51332	1.88
20 July	1721	2584	4305	4066	77032	49770	1.83
SEm±	14	42	47	43	587.67	587.67	0.02
CD (p≤0.05)	41	120	134	122	1677.22	1677.22	0.06
Varieties							
JS 335	1959	3077	5036	3941	87984	60722	2.23
RKS 45	1854	2982	4836	3877	83397	56135	2.07
RKS 18	1423	2490	3912	3699	64520	37259	1.36
SEm±	07	24	21	29	307.98	307.98	0.01
CD (p≤0.05)	20	69	58	80	861.95	861.95	0.03

Early sowing environment (1 July) resulted in maximum seed yield (1781 kg ha⁻¹) which was significantly superior over the rest of the sowing environments *i.e.*, 10 and 20 July (Table 4.22). However, the maximum biological yield (4763 kg ha⁻¹) and haulm yield (3030 kg ha⁻¹) were recorded by the second sowing environment (10 July) which was at par with the early sowing environment (1 July) but significantly superior over the delayed sowing environment (20 July). With respect to the varieties based on pooled data (Table 4.30) the highest seed yield (1959 kg ha⁻¹), haulm yield (3077 kg ha⁻¹), and biological yield (5036

kg ha⁻¹) was recorded by variety JS-335 which was significantly superior over the other varieties sown. However, the highest harvest index (39.41 %) was recorded under variety JS-335 which was at par with RKS-45. The pooled analysis revealed that the highest gross return (80,276 Rs. ha⁻¹), net return (53,014 Rs ha⁻¹), and B:C ratio (1.95) were observed with the early sowing environment (1 July) which were significantly superior over the further sowing environments (Table 4.31). However, the JS-335 variety was found to be superior over the other varieties with the highest gross return (87,984 Rs ha⁻¹), net return (60,722 Rs ha⁻¹), and B:C ratio (2.23).

Cotton

Akola

Crop-weather relationship studies in soybean at Akola were taken up during 2018-2023 using a split-split-plot design. The main plot treatments included monsoon sowing (D₁) and late sowing (D₂); Sub-plot included planting densities (P₁: 60 cm x 10 cm; P₂: 75 cm x 10 cm) and Sub-sub-plot included three cotton genotypes [AKH-081 (*G. hirsutum*), AKA-7 (*G. arboreum*) and Balwan NCS 8899 BG-II (Bt Cotton)]. The seed cotton yield (kg ha⁻¹) under different sowing times during 2018-2022 is shown in Table 4.23. Crop sown during D₁-Monsoon sowing recorded significantly higher seed cotton yield (1272 kg ha⁻¹) which decreased with successive later sowings. Crop sown during D₂- Late sowing recorded the lowest seed yield (972 kg ha⁻¹). Similarly, the crop sown under high population density P₁- 60 x 20 cm (83,333 plants/ha) recorded significantly higher seed cotton yield (1178 kg ha⁻¹) which decreased with successive less population density P₂-75 x 20 cm (66,666 plants/ha) by (1066 kg ha⁻¹). Among the cultivars, the higher seed cotton yield was recorded in Balwan (1281 kg ha⁻¹) followed by AKH 081 (1072 kg ha⁻¹) and AKA 7 (1014 kg ha⁻¹).

The percent yield reduction in the late sown crop compared to that of timely sown (monsoon sown – D₁) was estimated and presented in Table 4.24. The crop sown in D₂- Late sowing (-24%) recorded an average highest seed cotton yield reduction percentage. As of the different population densities, the highest seed cotton yield reduction percentage (-10%) was recorded in P₂-75 x 20 cm (66,666 plants ha⁻¹) higher population density. Among the cultivars, the highest seed yield reduction percentage was recorded in V2-AKA-7 (-21%) followed by V1-AKH-081 (-16%).

Table 4.23 Seed cotton yield (kg ha⁻¹) of cotton genotype, plant density under different weather variability (2018-2023) at Akola

Treatment	2018	2019	2020	2021	2022	2023	Average
Weather variability							
D ₁ - Monsoon sowing	1122	1741	1530	1019	1187	1034	1272
D ₂ - Late sowing	765	1368	1224	746	901	828	972
SE	7.4	8.8	5.5	25.0	25.0	26.6	16.4
CD (p≤0.05)	25.5	30.3	19.2	86.7	86.6	92.1	56.7
Population density							
P ₁ - 60 x 20 cm	990	1630	1419	931	1106	995	1178
P ₂ - 75 x 20 cm	897	1480	1336	834	982	868	1066
SE	7.4	8.8	5.5	25.0	25.0	26.6	16.4
CD (p≤0.05)	25.5	30.3	19.2	86.6	86.7	92.1	56.7
Genotype							
V ₁ - AKH 081	825	1518	1315	860	1022	889	1072
V ₂ - AKA 7	930	1415	1262	767	932	776	1014
V ₃ - Balwan	1074	1732	1556	1020	1178	1128	1281
SE	9.6	19.1	13.0	37.5	37.6	38.6	25.9
CD (p≤0.05)	29.0	57.6	39.2	112.6	112.7	115.7	77.8

Table 4.24 Yield reduction percentage of seed cotton genotype, plant density under late sown conditions compared to normal sown (2018-2023) at Akola

Treatment	2018	2019	2020	2021	2022	2023	Mean
Weather variability							
D ₁ - Monsoon sowing	0	0	0	0	0	0	0
D ₂ - Late sowing	-32	-21	-20	-27	-24	-20	-24
Population Density							
P ₁ - 60 x10 cm	0	0	0	0	0	0	0
P ₁ - 75 x10 cm	-9	-9	-6	-10	-11	-13	-10
Variety							
V ₁ - AKH-081	-23	-12	-15	-16	-13	-21	-16
V ₂ - AKA-7	-13	-18	-19	-25	-21	-31	-21
V ₃ - Balwan	0	0	0	0	0	0	0

Rabi 2023-24**Rice****Bhubaneswar**

A field experiment was conducted with four growing environments with the crop transplanted on 15 January, 31 January, 15 February, and 28 February 2023 and four genotypes (Mandakini, Bina Dhan -11, MTU 1001, Sahbhagi Dhan, and Naveen). The effect of date of transplanting and genotype on grain yield and yield attributes was studied and the results are presented in Table 4.25.

Table 4.25 Effect of date of transplanting and genotype on grain yield (kg ha⁻¹) and yield attributes at Bhubaneswar during rabi 2023-24

Treatments	Number of panicles/m ²	Number of fertile grains per panicle	Test weight (g)	Harvest index	Grain yield (kg ha ⁻¹)
Transplanting dates					
15.01.2023	340	73	22	46	3080
31.01.2023	304	72	23	40	2366
15.02.2023	285	71	22	40	2056
28.02.2023	282	66	21	36	1823
CD (p≤0.05)	35.2	6.77	1.1	2.9	209.6
Rice genotypes					
Mandakini	324	77	22	45	2527
Bina Dhan -11	311	72	24	41	2447
MTU1001	298	70	22	36	2261
Sahbhagi Dhan	293	67	23	41	2337
Naveen	288	66	19	40	2084
CD (p≤0.05)	39.4	7.4	1.2	3.2	234.3
CV%	15.8	12.9	7.0	9.6	12.2

Changes in transplanting date significantly influenced the number of panicles per m² at harvest. The number of panicles per m² decreased as transplanting was delayed from 15 January to 28 February (340 to 282). Among the 5 varieties, Mandakini (324) recorded the highest number of panicles per m² followed by Bina dhan-11 (311). The three transplanting dates i.e. 15 January (73), 31 January (72), and 15 February (71) were on par in the number of fertile grains per panicle. There was a significant decrease in the number of fertile grains per panicle for late DAT i.e. 28 February (66). Mandakini also recorded highest in the number of fertile grains per panicle (77) and Naveen recorded the lowest (66). The paddy transplanted on 31 January recorded the highest test weight (23g), while the crop transplanted on 28 February recorded the lowest (21g). Among the cultivars,

Binda Dhan-11 recorded the highest test weight (24g) and Naveen recorded the lowest (19g). Bina Dhan-11 transplanted on 15 January recorded the maximum yield (3815 kg ha⁻¹) followed by MTU 1001 (3428 kg ha⁻¹). However, the cultivar Bina Dhan-11 when transplanted on 28 February recorded a minimum yield of 1593 kg ha⁻¹ as compared to other cultivars.

Wheat

Chatha

A field experiment was conducted at the research farm of Agrometeorology section, SKUAST-J, Chatha, Jammu during rabi 2023-24 with the three wheat varieties (HD 2967, Raj 3077 and RSP 561) under three growing environments. A higher Radiation Use Efficiency (RUE) was observed in variety HD-2967 for all dates of sowing. The RUE at 120 days after sowing was 1.03, 0.79, and 0.87 g MJ⁻¹ for HD-2967(V₁), RAJ-3077 (V₂) and RSP-561 (V₃), respectively. The percentage reduction of the peak value of radiation use efficiency was 15.53 and 23.30% for RSP-561 (V₃) and RAJ-3077 (V₂) as compared to HD-2967(V₁). Due to higher RUE, more total above-ground dry matter was produced by the variety HD-2967 which was responsible for its higher yield than the remaining two wheat varieties (Table 4.26).

Table 4.26 Influence of different growing environments and varieties on periodic Radiation use efficiency (g MJ⁻¹) of the wheat crop during *rabi* 2023-24 at Chatha

Treatments	Days after sowing							
	30	45	60	75	90	105	120	135
Date of Sowing								
D ₁ - 05 Nov, 23	0.39	0.43	0.44	0.48	0.70	0.92	1.05	0.96
D ₂ - 20 Nov, 23	0.26	0.39	0.41	0.45	0.65	0.82	0.91	0.84
D ₃ - 05 Dec, 23	0.24	0.33	0.35	0.43	0.47	0.71	0.80	0.78
Varieties								
V ₁ - HD-2967	0.29	0.40	0.44	0.52	0.66	0.87	1.03	0.95
V ₂ - Raj 3077	0.28	0.35	0.34	0.38	0.50	0.73	0.79	0.74
V ₃ - RSP 561	0.28	0.38	0.39	0.42	0.60	0.79	0.87	0.83

The long-term field experimental results (rabi 2017-18 to 2023-24) were used to identify, optimal weather variables for different growth stages of the crop were determined for achieving higher wheat yield; the results are presented in Table 4.27.

Table 4.27 Optimum weather conditions required for different phenophases of the wheat for high productivity (*rabi* 2017-18 to 2023-24) at Chatha

Sowing environment	Tmax (°C)	Tmin (°C)	RF (mm)	BSS (hr)	GDD	Tmax (°C)	Tmin (°C)	RF (mm)	BSS (hr)	GDD	Tmax (°C)	Tmin (°C)	RF (mm)	BSS (hr)	GDD
D ₁ : 1 st FN of November															
D ₂ : 2 nd FN of November															
D ₃ : 1 st FN of December															
Sowing-emergence	25.4	10.7	11.0	5.2	98.2	22.2	7.8	2.0	5.0	88.3	20.9	7.4	23.4	4.2	90.6
Emergence-CRI	24.4	9.1	8.8	5.4	177.3	21.3	6.6	17.2	5.0	177.6	18.3	4.9	5.8	4.5	120.1
CRI - Tillering	23.7	8.4	4.6	5.6	71.7	18.0	4.8	16.8	4.4	45.0	17.3	4.6	24.4	3.8	62.5
Tillering -Jointing	19.6	5.8	50.6	4.5	283.0	17.2	5.5	64.9	3.8	226.8	17.4	5.9	63.9	4.0	219.0
Jointing – Flag leaf	16.9	5.8	60.1	3.7	190.2	21.6	7.3	39.3	5.4	218.3	23.8	8.4	38.5	5.8	212.0
Flag leaf- Head Emergence	19.8	6.8	32.5	5.0	122.2	23.4	9.4	24.6	5.2	158.6	24.4	10.2	16.2	5.7	165.7
Head Emergence - Anthesis	22.3	8.3	13.2	5.4	143.9	25.9	10.7	12.3	6.1	159.6	27.0	11.3	14.1	6.2	158.3
Anthesis - Milking	24.9	10.0	15.8	6.0	190.9	27.7	12.7	15.1	5.9	189.4	28.5	13.6	17.5	5.9	184.2
Milking – Hard Dough	27.1	12.1	17.3	5.7	208.4	30.0	13.9	26.2	6.6	196.7	31.4	14.5	18.3	6.8	208.7
Hard Dough- Phy. Maturity	30.6	14.3	31.6	6.6	301.6	33.9	16.1	15.0	7.0	259.0	33.8	17.1	16.0	6.7	237.1
Mean	23.5	9.1	245.5	5.3	1787.4	24.1	9.5	233.4	5.4	1719.3	24.3	9.8	238.1	5.4	1658.2
Grain yield (kg ha ⁻¹)															
HD-2967			3960					3670					3150		
Raj-3077			3330					3000					2780		
RSP-561			3640					3140					3000		
Mean			3640					3270					2970		

Kanpur

Crop weather relationship studies in wheat were undertaken with three genotypes viz. K-307, K-9107, and HD-2967 were sown on three dates viz., 30 Nov., 15 Dec., and 30 Dec. during *Rabi* 2023-24. The yield and yield attributes of wheat as influenced by growing environments and genotypes are presented in Table 4.28. The early sown crop received lower maximum temperature during Jointing, PI, anthesis, milking, dough, and maturity stages i.e. 18.0, 22.6, 25.6, 28.4, 33.1, and 37.0 °C, respectively was congenial and favorable for growth and development of the crop. Among the varieties, HD-2967 produced a higher grain yield (4500 kg ha⁻¹) followed by K-307 (4160 kg ha⁻¹) and K-9107 (3610 kg ha⁻¹) respectively. This might be due to the better performance of yield attributes viz., Number of grain/ears, grain weight, and 1000 grain weight performed by the variety HD-2967. The interaction effects between the date of sowing and varieties were observed as non-significant concerning grain yield. The significant straw yield was recorded when the crop was sown on 30 November (70.2 q ha⁻¹) followed by 15 Dec. (6990 kg ha⁻¹) and 30 December (6220 kg ha⁻¹) sown crop. Among the varieties, K-9107 produced a higher straw yield (7670 kg ha⁻¹) due to higher plant height followed by HD-2967 (6390 kg ha⁻¹) and K-307 (6170 kg ha⁻¹) respectively. The interaction effects between the date of sowing and varieties were observed as non-significant for straw yield.

Table 4.28 Influence of sowing date and varieties and its interaction on yield and yield attributing characters of wheat, during 2023-24

Treatments	Yield (kg ha ⁻¹)			Harvest index (%)	No. of spike-lets/ear	Length of ear (cm)	No. of grains / ear	Grain wt./ear (g)	1000 grain wt.(g)
	Grain	Straw	Biomass						
Date of Sowing									
D ₁	4810	7020	11830	40.7	19.4	9.8	54.6	2.20	39.5
D ₂	4030	6990	11030	36.7	18.9	9.5	50.5	2.08	38.7
D ₃	3420	6220	9630	35.6	18.3	9.4	48.8	1.88	37.3
SE ±(D)	56	139	181	0.34	0.01	0.11	0.39	0.01	0.20
CD (p≤0.05)	1.59	3.97	5.16	0.96	0.23	0.30	1.13	0.04	0.58
Genotypes									
V ₁	4160	6170	10330	40.0	18.3	9.1	49.4	2.04	38.4
V ₂	3610	7670	11270	31.9	19.0	9.9	50.7	1.99	37.8
V ₃	4500	6390	10890	41.1	19.4	9.8	53.8	2.13	39.3
SE ±(V)	81	145	179	0.56	0.01	0.11	0.29	0.02	0.14
CD (p≤0.05)	1.78	3.18	3.94	1.23	0.18	0.23	0.63	0.04	0.32

Ludhiana

The daily weather data i.e. maximum and minimum temperature, maximum and minimum relative humidity, rainfall for six locations (Ludhiana, Ballawal Saunkhari, Amritsar, Patiala, Bathinda, and Faridkot) for 23 years, i.e. from 1999-2000 to 2021-22 were collected to compute the weekly and crop stage wise normals. The data for the phenology of wheat have been collected from field experiments conducted under “All India Coordinated Research Project on Agrometeorology” in the Department of Climate Change and Agricultural Meteorology, Punjab Agricultural University, Ludhiana. The historical data on the productivity of wheat for 23 years and six locations were obtained from Statistical Abstracts, Punjab. These 23 years were then categorized into high, medium, and low-yield years. Mean weekly values of weather parameters for higher wheat productivity in Punjab have been identified and presented in Table 4.29.

Table 4.29 Values of weekly parameters for higher productivity of wheat in Punjab (1999-2000 to 2021-22)

Crop Stage	Temperature (°C)		Rainfall (mm)	Relative Humidity (%)	
	Maximum	Minimum		Maximum	Minimum
Vegetative	16 - 22	3 - 11	26	82 - 98	36 - 77
Flowering	15 - 22	4 - 9	47	85 - 99	40 - 76
Grain development	21 - 28	7 - 13	27	80 - 92	32 - 65

Palampur

A field experiment was conducted with four growing environments with the crop sown on 05 November, 20 November, 05 December, and 20 December and three varieties (HPW-368, HPW-373, and HS-562). The data on the effect of wheat varieties sown at different dates of sowing on the grain yield, straw yield, and biological yield was analyzed along with the interaction effect between varieties and date of sowing. Significantly higher grain yield and biological yield was recorded in HPW 373 though this variety was at par with HPW 368 while significantly lower grain and biological yield was recorded from HS 562. The straw yield also followed a similar trend. Among dates of sowing, a significantly higher grain yield was recorded from the crop sown on 05 November though it was at par with 20 November sowing while a significantly lower grain yield was observed from 20 December sowing though this date was also at par with 05 December sowing.

Table 4.30 Interaction effect of varieties and date of sowing on grain yield of wheat at Palampur during rabi 2023-24

Date of Sowing/Variety	HPW-368	HPW-373	HS-562	Mean
05 November	2663	4392	1716	2924
20 November	2427	2467	1564	2152
05 December	1932	1435	1225	1530
20 December	2273	1332	1087	1564
Mean	2323	2406	1398	
LSD ($p \leq 0.05$)	D	V	D×V (1)	D×V (2)
	86.0	89.8	179.5	169.6

The interaction between varieties and dates of sowing (Table 4.30) revealed that the yield of all the varieties was at par between the first two dates (05 November and 20 November) while the yield significantly declined on 3rd and 4th sowing dates (05 December and 20 December).

Rabi Maize

Samastipur

An experiment with four growing environments [D_1 : 1 November, D_2 : 10 November, D_3 : 20 November, and D_4 : 30 November] and three rabi maize varieties [V_1 : Bio 9637, V_2 : Shaktiman 4, and V_3 : Shaktiman 4] was taken up during rabi 2023-24. Accumulated

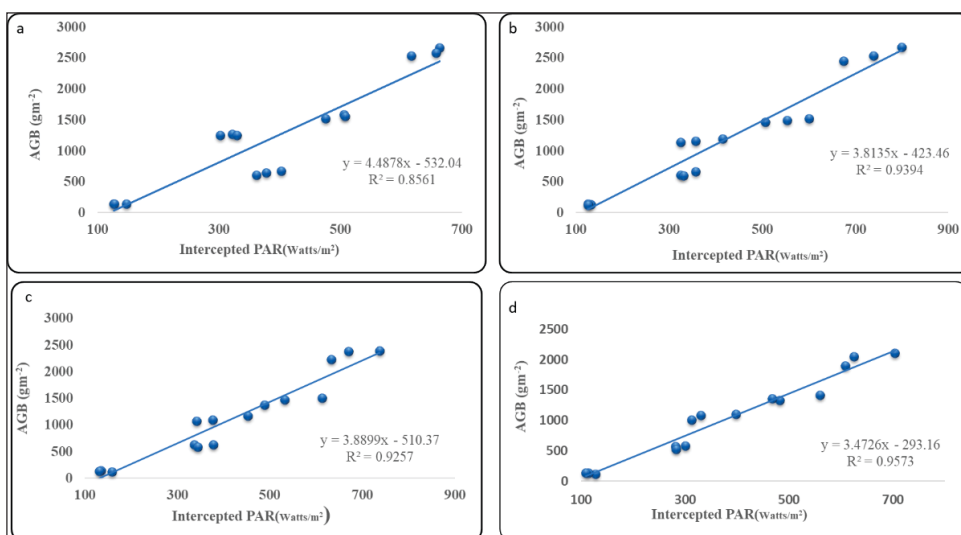


Fig. 4.8 Relationships between accumulated intercepted PAR (Watts m⁻²) and above-ground biomass (AGB, g m⁻²) for (a) D_1 , (b) D_2 , (c) D_3 and (d) D_4 dates of sowing in rabi maize at Samastipur during 2023-24

intercepted PAR and above-ground biomass were recorded for different dates of sowing at different phenological stages. Different sowing environments led to differential interception of photosynthetic active radiation at different stages along with different above-ground biomass. It was observed that crops grown on the D_1 date of sowing achieved maximum above-ground biomass followed by D_2 and D_3 .

Relationships between accumulated intercepted PAR (Watts m^{-2}) and above-ground biomass (g m^{-2}) under different dates of sowing are graphically presented in Fig. 4.8. Linear models for predicting biomass based on intercepted PAR were developed. Among all dates of sowing, the highest slope of 4.488 was obtained for the relation between biomass and intercepted PAR for the crop sown on D_1 followed by D_2 (3.813).

Barley

Hisar

The field experiment on barley is being conducted at Hisar with four growing environments (D_1 : 1st fortnight of Nov, D_2 : 2nd fortnight of Nov, D_3 : 1st fortnight of Dec, and D_4 : 2nd fortnight of Dec) and four varieties (V_1 : BH 393, V_2 : BH 902, V_3 : BH 946 and V_4 : BH 885) since Kharif 2016. Correlation studies between pooled data of weather parameters and the yield of barley were undertaken using data from 2016 to 2023. The grain yield showed a negative significant correlation with minimum temperature, wind speed, and BSH, whereas, the straw yield showed a negative significant correlation with morning relative humidity (Table 4.31).

Table 4.31 Correlation of weather parameters and yield of barley (2016-17 to 2023-24)

Weather parameters	Grain yield	Straw yield
Tmax	-0.25	-0.04
Tmin	-0.64*	-0.35
RH-I	-0.31	-0.55*
RH-II	-0.21	-0.29
WS	-0.43*	-0.30
BSH	-0.44*	-0.40
Rain	-0.24	-0.15

*Values are significant at 0.05 probability level ($N=32$)

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 (CSV-20, K-13, K-12, and CO-32) during *rabi* 2023-2024. The effect of sowing windows on yield and yield attributes of sorghum varieties under rainfed conditions during 2023-2024 is presented in Table 4.32. Among the varieties tested, sorghum variety CSV 20 recorded significantly higher plant height (263.9 cm), DMP (11015 kg ha⁻¹), number of seeds per panicle (942 no./panicle), 1000 seed weight (15.7 g), grain yield (1470 kg ha⁻¹) and stalk yield (9300 kg ha⁻¹) due to lesser quantity of rainfall during flowering stages leads to better pollination and fertilization thereby grain yield. The crop sown during the 39 SMW recorded a higher grain yield of 1845 kg ha⁻¹ which was 42 and 163% higher than the 41st and 43rd standard meteorological week sown crop (699 kg ha⁻¹), respectively. The varieties CSV 20 and CO 32 produced 27 and 23% increased yields than the newly released pipeline variety, respectively.

Table 4.32 Effect of growing environments and varieties on growth, yield, and yield attributes of Sorghum at Kovilpatti during *rabi* 2023-24

Treatments	Plant height (cm)	DMP (kg ha ⁻¹)	No. of seeds panicle ⁻¹	100 seed weight (g)	Grain yield (kg ha ⁻¹)	Stover yield (kg ha ⁻¹)
Date of sowing						
D ₁ : 39 SMW	265.9	13631	1063.0	16.4	1845	11537
D ₂ : 41 SMW	256.8	10487	919.8	14.9	1295	8954
D ₃ : 43 SMW	224.9	6247	672.8	14.5	699	5319
SEd	14.1	596	51	0.8	72	511
CD (p≤0.05)	NS	1653	142	NS	199	1418
Sorghum varieties						
V ₁ : CSV 20	263.9	11015	942	15.7	1470	9300
V ₂ : K 13	237.3	9884	840	15.1	1160	8489
V ₃ : K 12	232.4	9041	824	14.6	1063	7748
V ₄ : CO 32	263.2	10546	934	15.6	1425	8877
SEd	12.9	594	48	0.8	79	503
CD (p≤0.05)	27.0	1249	101	NS	167	1058
M at S SEd	23.9	1072	89	1.5	139	912
M at S CD (p≤0.05)	NS	NS	NS	NS	NS	NS
S at M SEd	22.3	1029	84	1.4	137	872
S at M CD (p≤0.05)	NS	NS	NS	NS	NS	NS

Chickpea

Akola

Chickpea varieties Jaki -9218, Akash, and Vijay were grown under three growing environments (44, 45, and 46 SMW) to study the crop weather relationships during rabi 2023-24.

Field experiment data from 2018-23 was used to study the correlation between phenophase-wise weather parameters and the seed yield of chickpea. The data indicate a significant association of yield with weather parameters mainly in Sowing-Anthesis (S-ANTH) flowering and Anthesis-First Pod (ANTH-FP) pod development stages. The role of maximum temperature from S-ANTH and First Seed-Physiological Maturity (FS-PM) was negative. In the S-ANTH stage minimum temperature, afternoon relative humidity, rainfall, growing degree days and photothermal units were significantly positive at $p < 0.01$ and morning relative humidity at $P < 0.05$, while the role of maximum temperature and daily sunshine duration was negative (Table 4.33). In the Anthesis-First Pod (ANTH-FP) flowering stage, the role of maximum and minimum temperature, both the relative humidity, rainfall, growing degree days, and photothermal unit was significantly positive at $P < 0.05$. In the pod development stage, the yield was positively influenced by maximum and minimum temperature, bright sunshine hours, and heliothermal unit but negatively with both the relative humidity and rainfall at $p < 0.05$.

Table 4.33 Correlation coefficient between weather parameters in different phenophase and seed yield of chickpea pooled (2018-2023) for three cultivars at Akola

Parameters	Phenophases			
	Sowing -Anthesis (S-ANTH)	Anthesis -First Pod (ANTH-FP)	First Pod- First Seed (FP-FS)	First Seed-Physiological Maturity (FS-PM)
Tmax (°C)	-0.11	0.44*	0.57*	-0.53*
Tmin (°C)	0.66**	0.51*	0.31*	0.51*
RHm (%)	0.56*	0.36*	-0.30*	0.61**
RHe (%)	0.60**	0.37*	-0.53*	0.60**
Rain (mm)	0.69**	0.38*	-0.56*	0.56*
BSS (hrs)	-0.04	0.12	0.36*	-0.04
GDD	0.77**	0.38*	0.16	0.91**
HTU	0.09	0.21	0.43*	-0.03
PTU	0.79**	0.44*	0.17	0.90**

** Correlation is significant at $p \leq 0.01$, * Correlation is significant at $p \leq 0.05$

Anantapur

The field experiment consisted of three growing environments (The second fortnight of October, the first fortnight of November, and the second fortnight of November 2023) and three chickpea varieties (JG-11, NBeG-3, and NBeG-49). During 2022-23, the mean seed yield with the 2nd FN of October was higher (1005 kg ha⁻¹) as compared to the 1st FN of November (931 kg ha⁻¹) and the 2nd FN of November (939 kg ha⁻¹) (Table 4.34). Among the varieties, the mean seed yield with all three varieties (JG-11, NBeG 3, and NBeG 49) evaluated NBeG 49 has recorded the highest seed yield (1112 kg ha⁻¹) followed by JG-11 (907 kg ha⁻¹).

Table 4.34 Yield and yield attributes of chickpeas as influenced by sowing environment and varieties during *rabi* 2023-24 at Anantapur

	Days to 50% flowering	Plant height (cm)	No. of Branches/plant	Days to Maturity	No. of Pods per/m ²	100 seed wt (g)	Grain yield (kg ha ⁻¹)
Date of Sowing							
D ₁	40	40.1	15.0	90	762	25.7	1869
D ₂	40	40.1	14.2	89	786	23.8	1543
D ₃	40	40.1	12.3	89	829	23.8	1405
CD	-	NS	NS	-	NS	0.93	NS
Varieties							
JG11	38	38.2	14.7	88	852	21.9	1627
NBeG 3	40	40.7	15.2	90	791	25.3	1647
NBeG 49	40	41.4	11.7	91	733	26.1	1543
CD	-	2.27	2.04	-	NS	1.4	NS

Jabalpur

A field experiment with three growing environments (D₁: November 28, D₂: December 12, D₃: December 27) and three chickpea genotypes [V₁: JG-14 (Desi type), V₂: JGK-1 (Kabuli type) and V₃: JGG-1 (Gulabi type)] during *rabi* 2023-24. The impact of treatments on yield and yield attributes is presented in Table 4.35.

Among the sowing dates, D₁ observed 37.3 filled pods while 4.2 unfilled pods per plant. Similarly, D₂ observed an average of 28.9 and 3.7 and D₃ with 30.5 and 5.3 number of filled and unfilled pods per plant. Among the varieties, V₃ observed an average of 35.4 and 6.7 filled and unfilled pods per plant. Similarly, V₁ observed 32.6 and 3.1 and V₂ by 28.7 and 3.3 numbers of filled and unfilled pods per plant. The seed yield exhibited among the sown

dates as $D_1 > D_3 > D_2$. Among the varieties, V_2 observed more seed yield than V_1 and V_3 varieties. The total biological yield among the sown dates is maximum in D_3 followed by D_2 and D_1 sown dates ($D_3 > D_2 > D_1$). Among the varieties, all the varieties exhibited similar total biological yield in a range of 2807-3383 kg ha⁻¹. There are no significant differences between sowing dates and also between varieties in terms of seed weight. Among the sowing dates, it ranges in a range of 0.23-0.24 whereas 0.16-0.29 among the varieties. As gulabi type is small in size as compared to the Kabuli type, which is big in size compares the difference in seed weight among the varieties.

Table 4.35 Post-harvest observations of chickpea types at different sown dates and varieties

Varieties	D_1	D_2	D_3	Mean
No. of filled Pod/plant				
V_1 - JG - 14	37.9	29.5	30.5	32.6
V_2 - JGK -1	34.4	26.7	24.9	28.7
V_3 - JGG-1	39.7	30.5	36.2	35.4
Mean	37.3	28.9	30.5	
No. of Unfilled Pod/plant				
V_1 - JG - 14	3.4	2.9	3.1	3.1
V_2 - JGK -1	3.7	3.4	2.7	3.3
V_3 - JGG-1	5.4	4.8	10.0	6.7
Mean	4.2	3.7	5.3	
Seed Yield (kg ha ⁻¹)				
V_1 - JG - 14	1285	1026	1186	1165
V_2 - JGK -1	1467	1586	1595	1549
V_3 - JGG-1	1168	1134	1156	1152
Mean	1306	1248	1312	
Total Biological Yield (kg ha ⁻¹)				
V_1 - JG - 14	2867	2700	2856	2807
V_2 - JGK -1	2917	3569	3664	3383
V_3 - JGG-1	3069	3317	3353	3246
Mean	2951	3195	3291	
100 Seeds weight (g) Seed index				
V_1 - JG - 14	0.23	0.27	0.25	0.25
V_2 - JGK -1	0.30	0.28	0.28	0.29
V_3 - JGG-1	0.17	0.16	0.14	0.16
Mean	0.23	0.24	0.23	

Raipur

Chickpea crop was sown during *rabi* 2023-2024 with three varieties V_1 - Vaibhav, V_2 - JG-14 (ZC), and V_3 - CG Chana 2. There were three growing environments D_1 -10/11/2023, D_2 -25/11/2023, D_3 - 10/12/2023.

Significantly higher grain yield was recorded when sown on D_2 (1439 kg ha⁻¹) while the lowest grain yield was produced under normal sowing (D_3), the ultimate reason being thermal stress. Generally late sowing results in thermal stress conditions and there is a challenge of making the fields ready by farmers for sowing by 20-25 Nov. Different varieties influenced the grain yield. The highest grain yield was recorded by zonal check JG-14 variety (1323 Kg ha⁻¹) followed by Vaibhav (1315 Kg ha⁻¹) (Table 4.36). The better performance of the JG-14 variety is due to better HUE and RUE. There is no significant difference among the varieties in terms of grain yield. The data on the test weight (100 seed weight) of chickpea indicates that the highest test weight was noticed under the D_1 growing environment (25.51 g) followed by D_2 (23.54 g each). Growing environments did influence the test weight significantly and in early growing environments, this attribute was favoured. Test weight as influenced by different varieties recorded no difference.

Table 4.36 Yield and yield attributes of chickpea varieties as influenced by different growing environments (*Rabi* 2023-24)

Dates of sowing	Plant height at maturity (cm)	Dry matter production at maturity (g)	Test weight (gm)	Stover yield (kg ha ⁻¹)	Grain yield (kg ha ⁻¹)	Harvest index (%)
D_1 (10 Nov.)	48.0	61.1	25.51	1510.9	1297.4	46.5
D_2 (25 Nov.)	36.9	55.6	23.54	1249.8	1439.0	54.8
D_3 (10 Dec.)	36.9	40.5	22.74	1302.0	1151.4	43.4
SEm $\pm$	0.8	2.2	0.3	107.6	72.2	2.4
CD ($p \leq 0.05$)	S	S	S	NS	S	S
Varities						
V_1 : Vaibhav	42.4	46.3	24.0	1534.7	1315.2	46.6
V_2 : JG-14 (ZC)	39.0	48.1	24.0	1329.4	1323.3	47.9
V_3 : CG Chana-2	40.6	62.8	24.0	1198.6	1249.3	50.3
SEm $\pm$	0.8	2.2	0.3	107.6	72.2	2.4
CD ($p \leq 0.05$)	2.5	6.6	1.0	322.7	216.4	7.2
SEm $\pm$ (DxV)	1.4	3.8	0.6	186.4	125.0	4.2
CD ($p \leq 0.05$)	NS	NS	NS	NS	NS	NS

Ranchi

An experiment was conducted at Ranchi centre with three varieties of chickpea viz., JG14, GNG 1581, and Birsa Chana 3 which were sown on 10 Nov (Early), 25 Nov (Normal), and 10 Dec (Late) to find out the response of chickpea to varied weather conditions. Yield and yield-defining characters were significantly influenced by varied thermal regimes as well as varietal differences.

Table 4.37 Effect of dates of sowing and cultivars on yield and yield attributes of chickpea at Ranchi during rabi 2023-24

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	34	1.6	19.8	4119	1564	38
Normal	29	1.6	19.8	3907	1540	39
Late	22	1.7	19.5	2993	1277	43
S Em	1.18	0.07	0.11	142	77	1
CD (p≤0.05)	3.5	NS	NS	426	231	NS
Variety						
JG 14	24	1.2	27.1	3483	1303	39
GNG 1581	29	1.9	16.7	3744	1693	45
Birsa Chana 3	31	1.6	15.3	3792	1385	37
S Em	1.18	0.07	0.11	142	77	1
CD (p≤0.05)	3.5	0.23	0.34	NS	231	NS
Interaction						
S Em	2	0.13	0.2	246	134	2.5
CD (p≤0.05)	6.1	NS	NS	738	NS	NS

The average performance of chickpea sown on 10 Nov (Early) was significantly higher (1564 kg ha⁻¹) than crop sown on 10 Dec. (1277 kg ha⁻¹) during 2023-24 (Table 4.37). Yield of normal sown crops is at par with early sown chickpea crops. Among the varieties, a significantly higher yield was recorded by GNG 1581 (1693 kg ha⁻¹) with a 45 % harvest index followed by Birsa Chana 3 (1385 kg ha⁻¹) and JG 14 (1303 kg ha⁻¹).

Solapur

A field experiment with four dates of sowing (38, 40, 42, and 44 SMWs) and three chickpea genotypes (Vijay, Digvijay, and Virat) was undertaken during rabi 2023-24. A significantly higher biological yield of 2785 kg was obtained from early sowing (S_1) with HI of 38.7 percent (Table 4.38). The rainfall of about 78.8 mm received in SMW 48 was found useful for seed filling and overall growth of chickpeas and ultimately resulted in significantly superior seed and biological yield. Numerically higher total returns of Rs. 79531 ha⁻¹ were anticipated from the earlier sown chickpea. cv. Vijay produced significantly higher seed yield (848 kg ha⁻¹) than other varieties under investigation. Other varieties viz. Digvijay and Virat are found better under protective irrigation, but their performance under stress conditions is influenced inversely.

Table 4.38 Seed yield and total monetary returns of *rabi* chickpea as influenced by various sowing dates and varieties. (2023-24)

Treatment	Seed yield (kg ha ⁻¹)	Biological yield (kg ha ⁻¹)	HI (%)	Total returns (Rs ha ⁻¹)	B: C ratio
Main plot treatment: Sowing Environments (4)					
S_1 - SMW 38 (Sept 17-23)	1075	2785	38.7	79533	2.27
S_2 - SMW 40 (Oct. 01-07)	909	2656	34.3	67261	1.91
S_3 - SMW 42 (Oct. 15-21)	648	2085	31.5	47979	1.36
S_4 - SMW 44 (Oct. 29- Nov.04)	402	1198	34.3	29764	0.84
Subplot treatments: Varieties (3)					
V_1 - Vijay	848	2248	37.46	62772	1.78
V_2 - Digvijay	754	2201	33.42	55848	1.58
V_3 - Virat	673	2094	33.35	49783	1.41
Mean	758	2181	34.7	56132	1.59
S.E. $\pm$ (SD)	46.4	58.6	2.66		
CD ($p \leq 0.05$)	133	171	NS		
S.E. $\pm$ (V)	36.4	69.3	2.31		
CD ($p \leq 0.05$)	113	206	NS		
S.E. $\pm$ (SD X V)	NS	NS	NS		
CD ($p \leq 0.05$)	17.3	20.9	17.6		

Green gram

Jorhat

A field experiment with four micro-climatic regimes (crop sown on 07, 14, 21, and 28 September 2023) and two genotypes (SGC-16 and SGC-20) was taken up during rabi 2023-24. The results of field experiments from 2018-19 to 2023-24 were pooled, and treatments' effect on pod yield was estimated. Among the varieties, the mean yield varied from 491.2 to 895.2 kg ha⁻¹, 470.6 to 848.1 kg ha⁻¹ and 432.5 to 859.7 kg ha⁻¹ in SGC-16, SGC-20, and IPM-02-3, respectively irrespective of their growing environments (Table 4.39). The pooled analysis revealed that- among the three varieties of green gram, SGC-16 records the maximum yield (676.1 kg ha⁻¹); whereas SGC-20 and IPM-02-3 record a mean yield of 648.4 kg ha⁻¹ and 646.1 kg ha⁻¹, respectively irrespective of their growing environment.

Overall yield was found to be declining when sown beyond mid-September which may be attributed to a decrease in minimum air temperature below 14 °C for consecutive days causing low-temperature stress in flower bud formation and pod development. To support the above findings, cluster analysis was performed using Ward's linkage method for delineating variability among independent weather variables within different levels of yield clusters and presented in Fig. 4.9.

Table 4.39 Effect of growing environment on yield of green gram during 2018-2023

Treatments	2018	2019	2020	2021	2022	2023	Pooled
<i>Variety</i>							
SGC-16	774.4	607.42	895.2	865.2	491.2	641.9	676.1
SGC-20	746.7	621.25	848.1	805.7	470.6	626.6	648.4
IPM-02-3	718.8	600.15	859.7	821.3	432.5	-	646.1
Mean	746.7	609.6	867.6	830.7	464.7	634.2	656.8
CD (p≤0.05)	10.7	6.3	19.2	13.1	20.9	NS	22.7
<i>Microclimatic regimes</i>							
MR-I	787.25	638.00	753.8	889.7	513.1	627.7	629.0
MR-II	654.50	605.23	839.5	811.3	476.5	762.1	678.9
MR-III	537.08	585.58	1009.6	791.1	404.7	513	662.7
Mean	746.7	609.6	867.6	830.7	464.7	634.2	656.8
CD (p≤0.05)	13.5	16.4	60.7	24.5	21.7	140.4	30.1
Interaction	14.8	9.1	32.1	32.1	NS	NS	53.7

The results of cluster analysis (Fig. 4.9) depicted- a mean maximum and minimum temperature of 31-33 °C and 23-25 °C during the sowing to the budding stage; 28-30 °C and 18-20 °C during the budding to podding stage, and 28-29 °C and 16-19 °C, respectively during podding to maturity phase of *Kharif* green gram were found to be in optimal range for better seed yield. On the other hand, rainfall amounts of 200-300mm and 49-100 mm corresponding to sowing to budding and budding to the pod stage are found favorable, when provided with a proper drainage channel to avoid water stagnation in the field. The rainfall during the pod development phase should be less for better pod filling and partitioning. A mean bright sunshine period of 3-5 hours during sowing to budding and 5-8 hours during budding to podding and podding to maturity are found suitable for better seed yield in green gram.

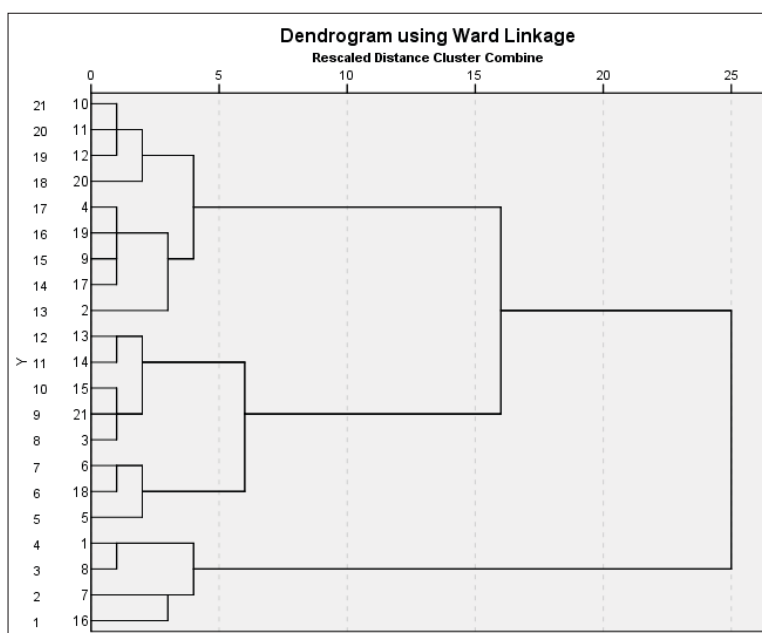


Fig. 4.9 Dendrogram depicting variability in seed yield of green gram amongst the different clusters at Jorhat during 2018-2023

Further, the optimum range of weather parameters to obtain higher pod yield was also identified and presented in Table 4.40.

Table 4.40 Weather threshold for optimum yield of *Kharif* Green gram at Jorhat

Yield level	Phenophase	Mean weather threshold
600 kg ha ⁻¹ (STDEV= 97; N=4)	Sowing to flower bud	Tmax = 31.0-33.0 °C, Tmin = 23.0-25.0 °C RF = 200-300mm, RH = 80-86% BSSH = 3-5 hrs.
	Flower bud to Pod development	Tmax = 28.0-30.0 °C, Tmin = 18.0-20.0 °C RF = 49-100mm, RH = 80-84% BSSH = 5-7 hrs.
	Podding to maturity	Tmax = 28.0-29.0 °C, Tmin = 16.0-19.0 °C RF = <30 mm, RH = 78-83% BSSH = 5-8 hrs.

Mohanpur

A field experiment with four dates of sowing (27 Feb, 12 Mar, 26 Mar and 09 Apr 2024) and three green gram genotypes (Samrat, Sikha, and Meha) was undertaken during rabi 2023-24. The pod yield of green gram as affected by the treatments is presented in Table 4.41.

Table 4.41 Variation of green gram yield (kg ha⁻¹) at Mohanpur

Treatments	Samrat	Sikha	Meha	Average yield
D ₁	1263	1596	1582	1480
D ₂	1211	1421	1214	1282
D ₃	1350	1453	1420	1408
D ₄	203	174	135	171
Average yield	1006	1161	1088	
Factors		SE(m)	CD (p≤0.05)	
Date of Sowing		13.467	47.508	
Variety		56.898	N/A	
Variety at same level of DOS		23.326	N/A	
DOS at same level of Variety		93.886	N/A	

Irrespective of different varieties, there was a significant statistical variation in yield among the different dates of sowing (Table 4.41). D₁ sown green gram crop produced the highest yield of 1480.2 kg ha⁻¹ followed by D₃ (1407.8 kg ha⁻¹) and D₂ (1282 kg ha⁻¹). The lowest yield was observed under late sown D₄ treatment (170.6 kg ha⁻¹). This is the classic example of weather's effect on crop growth and yield. The D₄ accumulated relatively very high biomass due to high rainfall received at different growth stages. This in return

affected the reproductive growth of the plant, hence very low yield was recorded. The rainfall, maximum and minimum temperatures were found to significantly and negatively affect the yield. The effect of rainfall showed a strong significantly negative correlation, which describes the reason behind the very low yield in this treatment. Up to 88% of yield reduction was recorded under late sown (April sown) D_4 green gram plants compared to the earliest date of sowing, i.e., D_1 (February sown). Higher vegetative growth during the peak reproductive phase resulted in low pod formation or formation of seedless vegetative pods, resulting in lower economic yield. Using the experimental data of 2017-2021, yield prediction equations were developed using multiple linear regression (Table 4.42).

Table 4.42 Regression equation of green gram and weather variables

Model performance					
R^2	0.9	Adj. R^2	0.89	RMSE	132.9
Anova Results					
	Sum of square	DF	MS	F	Significance
Regression	11375703.8	3	3791901.9	214.5	***
Residual	1255120.8	71	17677.7		
Total	12630824.7	74			
Parameters estimates					
Model	Beta	Std. Error	Std. Beta	t	Significance
Intercept	3360.6	553.5		6.1	***
DVT	346.5	16.4	1.4	21.0	***
PR	-2.8	0.2	-0.7	-15.6	***
Tmax	-193.8	22.4	-0.5	-8.6	***

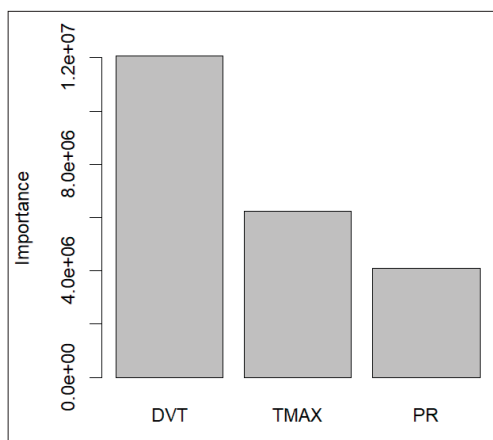


Fig. 4.10 Importance of weather variables for yield of green gram at Mohanpur

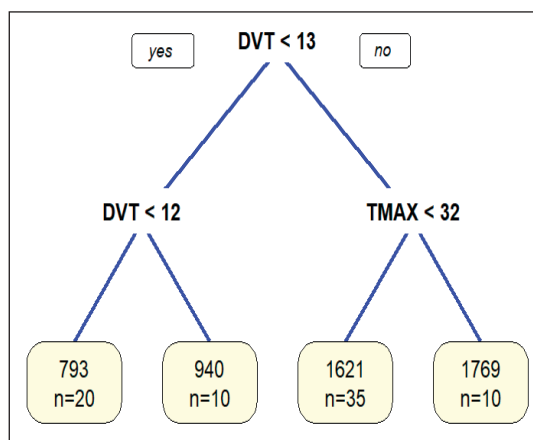


Fig. 4.11 Decision tree for optimum weather condition identification in green gram

From the linear relationship, it was found that diurnal temperature variation was the most important weather parameter in green gram performance followed by maximum and minimum temperature (Fig. 4.10). The threshold value of 13 °C and 12 °C for DVT and 32 °C for maximum temperature was obtained from the decision tree. The minimum temperature has a relatively smaller effect on yield (Fig. 4.11).

Mustard

Anand

Crop weather relationship mustard was studied using field experimental data of *rabi* seasons of years 2017-18 to 2023-24. The pooled results of grain yield (2017-18 to 2023-24) are given in Table 4.43.

Table 4.43 Grain yield of mustard influenced by different treatments at Anand (2017-24)

Treatment	Grain yield (kg ha ⁻¹)							
	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	Pooled
Date of sowing								
D ₁ - 10 Oct.	2526	2213	2183	2025	1601	1677	1131	1908
D ₂ - 20 Oct.	2092	1936	2073	1951	1439	1616	1089	1742
D ₃ - 30 Oct.	1751	1439	2014	1628	1396	1450	1064	1534
D ₄ - 10 Nov.	1402	1244	1691	1380	1375	1203	993	1327
S.Em.±	84	68	79	46	47	40	29	65
CD (p≤0.05)	268	217	252	147	150	129	93	192
CV %	14.96	13.79	13.71	9.12	11.20	9.39	9.46	12.63
Variety								
V ₁ - Bio 902	1856	1673	2002	1760	1438	1484	1063	1611
V ₂ - GM 3	2080	1930	2090	1830	1527	1544	1115	1731
V ₃ - GDM 4	1892	1521	1878	1647	1395	1431	1030	1542
S.Em.±	50	48	46	43	33	27	21	23
CD (p≤0.05)	147	139	134	126	97	79	60	72
CV %	10.35	11.14	9.21	9.91	9.13	7.29	7.72	9.75
Sig.int. effect	NS	NS	D x V	NS	NS	NS	NS	YxD, YxV, YxDxV

Results showed that grain yield was significantly influenced by different dates of sowing under individual years as well as on a pooled basis. During experimental years and in pooled, D₁ sowing produced significantly higher grain yield, which was statistically similar

to D₂ sowing during year 2019-20, year 2020-21, year 2022-23, and in pooled. During the year 2019-20 and 2023-24, it was also at par with D₃ sowing. In pooled there were nearly 8 %, 20 %, and 31 % grain yield reduction under D₂, D₃, and D₄ sowings, respectively than D₁ sowing. In varieties, GM 3 recorded significantly high grain yield as compared to other cultivars in individual years as well as in pooled analysis, which is statistically at par with variety Bio 902 during years 2019-20, 2020-21, 2021-22, 2022-23 and 2023-24. In pooled, there were 7 % and 11 % yield reductions under bio 902 and GDM 4 than GM 3. There exist significant interaction effects of D x V (2019-20) and Y x D, Y x V, Y x D x V (pooled).

Udaipur

The experiment consisted of two factors viz., sowing environment (October 1, 16, November 1, 16) and 5 varieties (Bio 902, Giriraj, RH 0749, NRCHB-101, and NRCDR-2) to study the crop weather relationships in mustard.

Table 4.44 Effect of sowing environment and mustard varieties on yield and harvest index (Pooled 2017-18 to 2022-23) at Udaipur

Treatment	Yield (kg ha ⁻¹)			Harvest index (%)
	Seed	Straw	Biological	
Sowing Environment				
1 Oct	1597	5524	7122	22.55
16 Oct	1599	5502	7101	22.87
1 Nov	1171	5019	6190	18.90
16 Nov	936	4313	5249	18.03
SEm±	13	48	53	0.19
CD ((p≤0.05)	37	137	151	0.55
Varieties				
Bio-902	1368	4971	6339	21.41
Giriraj	1282	5265	6547	19.55
RH 0749	1382	5234	6616	20.60
NRCHB-101	1398	4847	6244	22.35
NRCDR-2	1198	5133	6331	19.04
SEm±	09	41	43	0.18
CD ((p≤0.05)	25	115	121	0.49

The highest quantity of seed yield (1599 kg ha^{-1}) and harvest index (22.87%) was obtained under the 2nd sowing environment (16 October) which was statistically equivalent to the 1st date of sowing (01 October), but significantly superior over the rest date of sowing environments. However, the maximum amount of biological (7122 kg ha^{-1}) and straw yield (5524 kg ha^{-1}) were recorded under crop sown on 1st October which was statistically at par with the 2nd sowing environment (16 October) although significantly higher over remaining dates of sowing (Table 4.44).

With respect to varieties, the utmost quantity of seed yield (1398 kg ha^{-1}) was recorded with variety NRCHB-101 which was statistically analogous to RH-0749 (1382 kg ha^{-1}) but significantly superior over the other varieties. Variety NRCHB-101 also leads to the maximum harvest index value (22.35%) which was statistically superior over the others. The loftiest amount of biological yield (6616 kg ha^{-1}) was recorded under RH-0749 and it was statistically at par with the variety Giriraj (65.47 kg ha^{-1}) however, was significantly higher over all the other varieties. The maximum straw yield of 5265 kg ha^{-1} was recorded with variety Giriraj and followed by RH-0749 (5234 kg ha^{-1}).

Horticulture Crops

Mango

Bangalore

Correlation studies were carried out to analyze the relation between growth, yield parameters, and accumulated weather parameters based on the observations recorded during the reproductive cycles (Oct-June) from 2018 to 2021 in the Mallika variety of Mango. The yield of mango had a significant positive correlation with vegetative factors like tree height, tree girth, tree volume (0.50^{**} , 0.69^{**} , 0.58^{**}) and reproductive factors like the number of panicles per tree, number of hermaphrodite flowers per panicle, fruit retention (%) at maturity (0.86^{**} , 0.61^{**} , 0.28^{**}) and there was a significant negative correlation between yield and number of male flowers, sex ratio (male to hermaphrodite flowers ratio), number of fruits at lemon stage/ panicle (-0.55^{**} , -0.56^{**} , -0.25^{**} , -0.28^{**}) indicating differential relation between growth and yield attributing factors on the performance of mango (Table 4.45).

Table 4.45 Correlation between yield vs growth and yield attributes in mango at Bangalore

Parameter	2018-2021
Average fruit weight (g)	0.47**
Tree height (m)	0.50**
Girth of tree (m)	0.69**
Volume of the tree (cm ³)	0.58**
Number of panicles	0.86**
Number of hermaphrodite flowers per panicle	0.61**
Number of male flowers	-0.55**
Sex ratio (male to hermaphrodite flowers)	-0.56**
Number of fruits at Pea stage/panicle	0.02
Number of fruits at Marble stage/panicle	-0.07
Number of fruits at Lemon stage/ panicle	-0.25**
Number of fruits at Maturity/panicle	-0.01
Fruit drop (%) at maturity	-0.28**
Fruit retention (%) at maturity	0.28**

Dapoli

Weather-based statistical models were developed for forecasting 50 percent flowering in mango cv. Alphonso was developed using a step-down multiple regression equation (1997-98 to 2019-20 - 22 Years) along with validation.

Standard Meteorological week (3 weeks before) for 50 percent flowering in mango cv. Alphonso

$$= 90.275 - 1.319 \cdot T_{\min} - 0.784 \cdot E_{\text{pan}} - 0.884 \cdot T_{\text{dev}} \quad R^2 = 0.65^{**}$$

Where, $T_{\min}$ = Minimum temperature, E_{pan} = Pan evaporation, T_{dev} = Daily temperature deviation

Table 4.46 presents the trigger values of weather parameters that influence 50 percent of flowering in mango cv. Alphonso.

The data regarding prediction model validation for the meteorological week of 50 percent flowering in mango cv. Alphonso, three weeks before 50 percent flowering are presented in Table 4.47. The data revealed that the error percent in predicting a meteorological week of 50 percent flowering in mango cv. Alphonso, three weeks before 50 percent flowering at different locations in the Konkan region was in the range of 1.14 to 10.20 percent in both the years of validation with an RMSE value of 0.98 to 2.97 percent.

Table 4.46 Trigger values of weather parameters influencing 50% flowering

Sr. No.	Weather parameters	Range	Average	Significance level
1.	Minimum temperature (°C)	11.7 – 21.7	16.4	1%
2.	Temperature deviation (°C)	9.8 – 20.2	15.9	
3.	Evaporation (mm/day)	2.4 – 6.4	4.0	

Table 4.47 Error % of predication model for forecasting the meteorological week of 50 per cent flowering

Location	2022-23			2023-24		
	Error (%)	S.D.	RMSE (%)	Error (%)	S.D.	RMSE (%)
Dapoli	4.99	1.95	2.18	4.47	1.84	2.11
Wakawali	6.74	2.37	2.60	6.24	1.25	2.50
Rameshwar	5.57	2.97	2.36	1.14	1.17	1.07
Mulde	9.90	1.42	3.15	8.69	0.98	2.95
Vengurla	10.20	1.18	2.24	5.02	1.18	2.24

Mohanpur

The yield data of the Bombai variety of mango from 2014 to 2023 were collected along with phenological observation on 50% flowering and 100% flowering. In 2016 and 2022, the yield was considerably low due to off-year and other crop management factors. Hence, those two years are not considered for analysis.

Table 4.48 Year-wise variation of yield and different meteorological parameters

Year	Yield (t/ha)	GDD (50% FI)	GDD (100% FI)	BSS (100% FI)	RF (50% FL)	RF (50 to 100% FI)
2014	1.71	163.1	262	7.5	16.2	12.3
2015	4.18	212.6	322.4	6.7	13.6	0.0
2017	4.4	176.0	257.0	6.1	0.0	0.0
2018	5.84	173.3	285.2	6.6	0.0	0.0
2019	3.42	139.6	241.7	7.8	0.6	0.0
2020	1.73	113.1	184.7	7.5	0.2	0.0
2021	2.59	229.5	314.9	6.6	1.1	0.0
2023	5.61	155.3	249.1	6.3	0.0	0.0
Corr. Coeff		0.17	0.30	-0.67	-0.35	-0.49

(GDD (50% FI) = Growing Degree Days values for bud initiation to 50% flowering in °C-day; GDD (100% FI) = Growing Degree Days values for bud initiation to 100% flowering in °C-day; BSS = average of Bright Sunshine in hours during bud initiation to 100% flowering; RF (50% FL) = Total rainfall in mm during bud initiation to 100% flowering; RF (50 to 100% FI) = Total rainfall in mm during 50 to 100% flowering)

It is observed that the rainfall and BSS (for the period of bud initiation to 100% flowering) are negatively correlated with yield (Table 4.48). The Growing Degree Days values for bud initiation to 50% flowering and 100% flowering are also worked out, which are positively correlated with yield.

Guava

Udaipur

An experiment was conducted at MPUAT, Udaipur (Rajasthan) to study the effect of weather parameters on the performance of different guava varieties. The results revealed that the pruning process is essential for inducing the flowering in guava and was done on 10 April, 2023. In the guava crop after the pruning process, at least 40-55 days is required as stress/ dormant period and the field is open up for excellent flowering. In commercial crops, flowering is started from June *i.e.*, MirgBahar and its fruits are available from November to March. In the *dormant period* if the crop receives more moisture resulted break down crop dormant period, such conditions induce vegetative growth which causes less flowering. In this study continuous moisture received (rainfall 263.9 mm) throughout the dormant or stress period (April to June) in the form of the pre-monsoon showers which adversely affected the flowering process *i.e.*, MirgBahar (except Arka Rashmi) (Fig. 4.12).

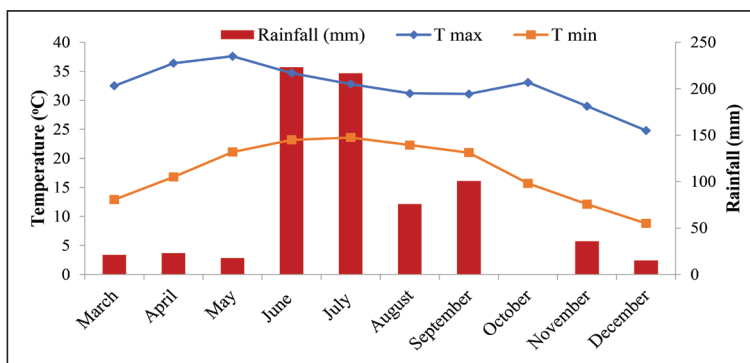


Fig. 4.12 Rainfall and temperature during the crop period of guava at Udaipur

In this experiment a good amount of rainfall *i.e.*, 22.4 mm was received just 18 days after the pruning process, followed by 15.2 mm, and in June continuous rain was received due to the cyclone Biparjoy. The data indicates that the maximum fruit yield (4.21 tonne ha⁻¹) was obtained in Arka Rashmi out of five tested guava varieties (Table 4.49). The variety is more resistant to excess rain compared to CISH-GS14, Lalit, Arka Poorna, and Allahabad Safeda.

Table 4.49 Plant height and fruit yield characters of new hybrids of guava at Udaipur

Varieties	Plant height (m)	Fruits/tree	Fruit weight (g)	Fruit yield (tree kg ⁻¹)	Fruit yield (t ha ⁻¹)
Arka Rashmi	2.85	22.50	168.25	3.79	4.21
CISH-GS14	2.70	17.75	157.75	2.80	3.11
Lalit	2.35	14.25	152.00	2.17	2.41
Arka Poorna	2.47	15.50	175.50	2.72	3.02
All Safeda	2.78	18.75	186.25	3.49	3.88
SEm±	0.11	0.84	7.08	0.12	0.13
CD (p≤0.05)	0.34	2.59	21.82	0.36	0.40
CV (%)	8.72	9.48	8.43	7.76	7.90

Turmeric

Thrissur

The turmeric variety *kanthi* was cultivated at four dates of planting under three different mulch conditions (green leaf mulching, paddy straw mulching and coconut mulching).

Influence of different mulches on yield

Among the mulching types paddy straw mulch produced the highest yield (16,263 kg ha⁻¹), followed by green leaf mulch (13,096 kg ha⁻¹) and coconut leaf mulch (10,248 kg ha⁻¹) (Fig. 4.13). The afternoon soil temperature at a 5 cm depth was found to influence yield reductions. Compared to other mulches the paddy straw mulch had lower afternoon soil temperature and temperature variation. This may be the reason for the increased yield in paddy straw mulch.

Black pepper

The influence of weather on phenophases explained a strong significant positive correlation (Table 4.50) between rainfall and duration of spike enlargement at the same time minimum temperature during this period had a significant negative correlation (Fig. 4.14 & 4.15). The results also concluded with a significant negative correlation between maximum temperature and duration to maturity and harvest (Fig. 4.16).

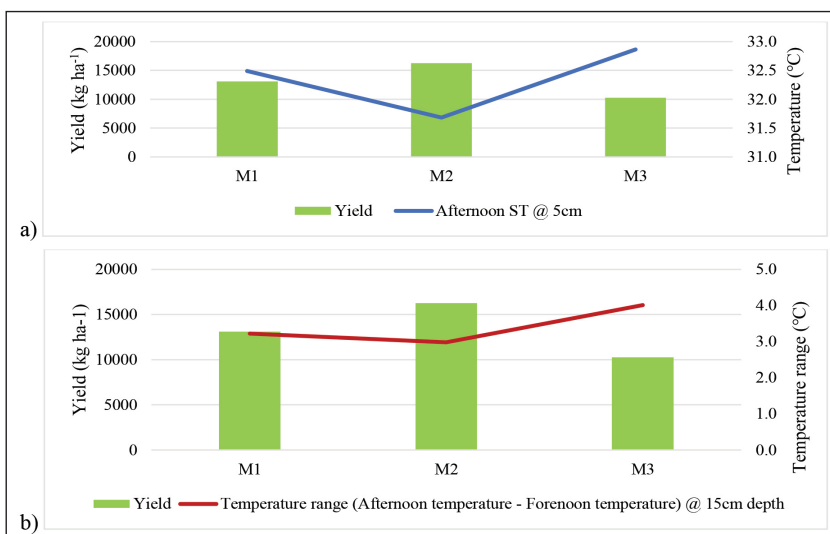


Fig. 4.13. Effect of mulching on yield at 5 cm and 15 cm depth

Table 4.50 Correlation Table between phenophase and weather variables

	Tmax	Tmin	WS	RF	RH I	RH II
Spike Initiation (Mar-Apr)	-0.28	0.12	-0.58	0.70	0.32	0.45
Spike Emergence (May-Jun)	-0.34	0.09	0.19	0.68	0.20	0.27
Spike Enlargement (July- Sep)	0.06	-.91*	-0.53	0.84*	0.00	0.34
Berry Development (Oct- Nov)	0.50	-0.70	0.74	-0.56	-0.71	-0.58
Maturity & Harvest (Dec- Feb)	-.92**	0.04	0.61	0.29	0.20	0.72

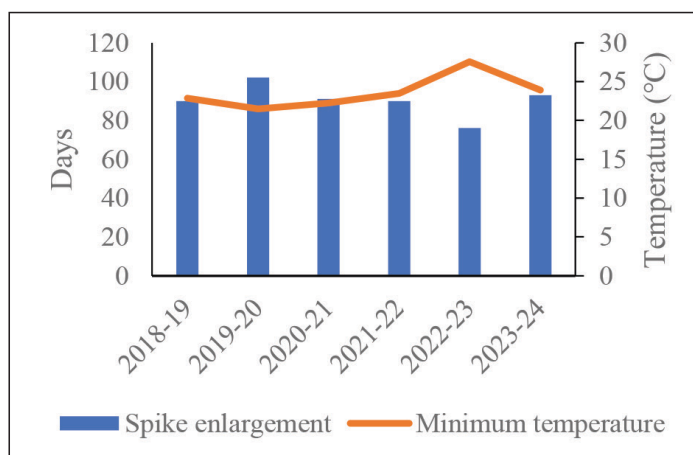


Fig. 4.14 Impact of maximum temperature on duration of maturity and harvest

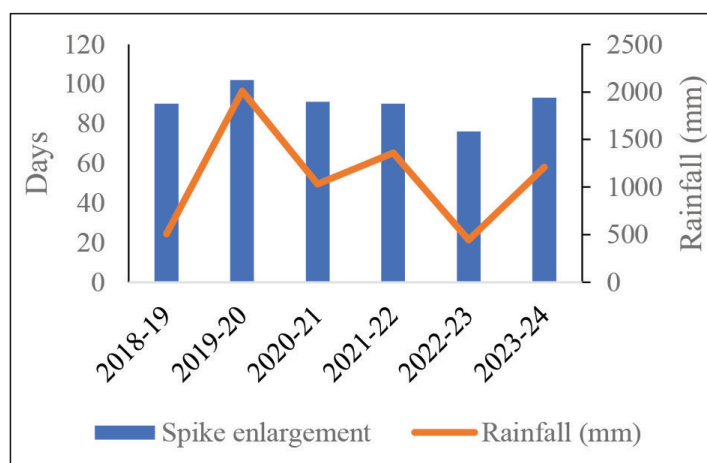


Fig. 4.15 Impact of minimum temperature on duration of spike enlargement

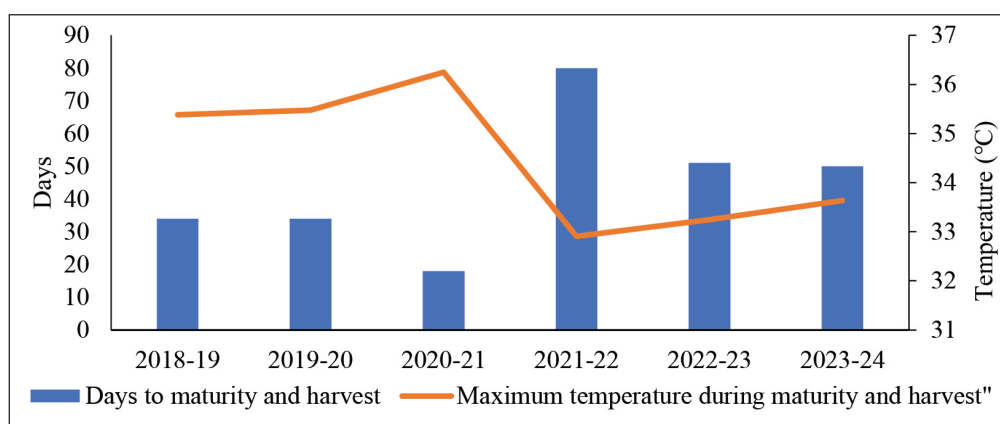


Fig. 4.16 Impact of rainfall on duration of spike enlargement

5. Crop Growth Modeling

Crop simulation models are powerful tools for assessing the impacts of climate change on agriculture and for planning adaptation strategies. These models simulate crop growth, development, and yield under varying environmental conditions, enabling researchers to evaluate how factors like temperature, precipitation, and CO₂ levels affect productivity. By integrating climate projections with crop models, scientists can estimate future crop performance, identify potential yield losses, and explore effective adaptation measures, such as changes in planting dates, crop varieties, or management practices. Crop simulation models thus provide valuable insights for policymakers and farmers, supporting evidence-based decisions to ensure food security and resilience in the face of climate change. The applicability of exogenous and Indian crop growth models for Indian conditions has been studied at various locations and the results of those studies are reported hereunder:

Anand

Potential impact of climate change on pearl millet in Gujarat state

Pearl millet is considered one of the promising crops under changing climatic conditions due to its hardy and drought-thriving nature. Many studies suggest the crop is likely to be less impacted in the future compared to other crops. Climate change impact assessment was conducted using a calibrated CERES-Millet model for cultivar GHB 744. The bias-corrected climate projection data of the climate projection model BCC-CSM2-MR were used to simulate the crop performance under the baseline period (1975-2014) and future period (2024-2100). The projection scenarios SSP245 and SSP585 were considered for 239 grid locations across the state. Crop relationships clearly show that the high rainfall is negatively associated with pearl millet productivity. So, the projected precipitation change was explored. Except in the near future (2022-2040), most periods in the future under both scenarios show an increase in rainfall. The spatial change in the rainfall receipt is also likely to influence the crop suitability of many parts of the state. Dry farming regions of Saurashtra, Kutch, and North Gujarat regions are projected to receive more rainfall in the future (Fig. 5.1).

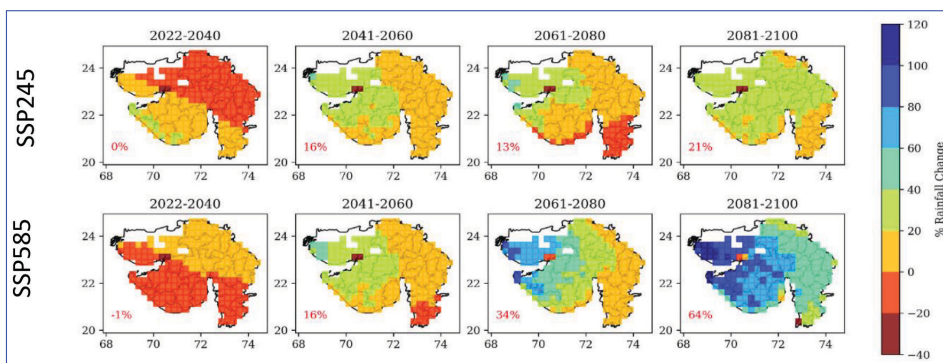


Fig. 5.1 Potential impact of climate change on rainfall pattern in Gujarat

The simulated yields under SSP245 and SSP585 under different future periods are compared with the baseline period. The model simulated a relatively high yield compared measured in the field experiments. The yield simulations under SSP245 and SSP585 are close to the mean yield observed in experiments (Fig. 5.2). However, under both scenarios yield losses are significant compared to the baseline period. In the near future (years 2024-2040), under SSP585 model predicts a relatively higher yield compared to SSP245, which might be due to better suitability of over large areas by change in rainfall pattern. The spatial distribution of the pearl millet productivity depicted in Fig. 5.3 shows most of the state will have yield loss while some parts of North Gujarat and Kutch region will be more productive. This agrees with the projected change in rainfall pattern. The high rainfall zone of South Gujarat is likely to be unsuitable for pearl millet production in future.

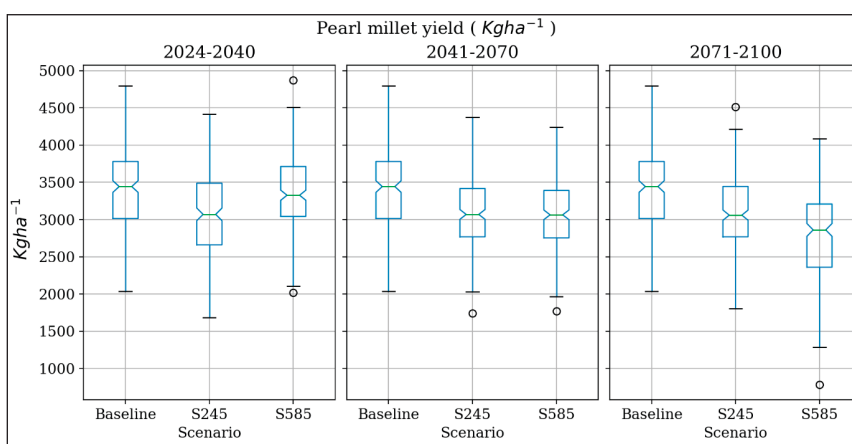


Fig. 5.2 Projected pearl millet productivity for future periods in comparison to baseline period (1975-2014)

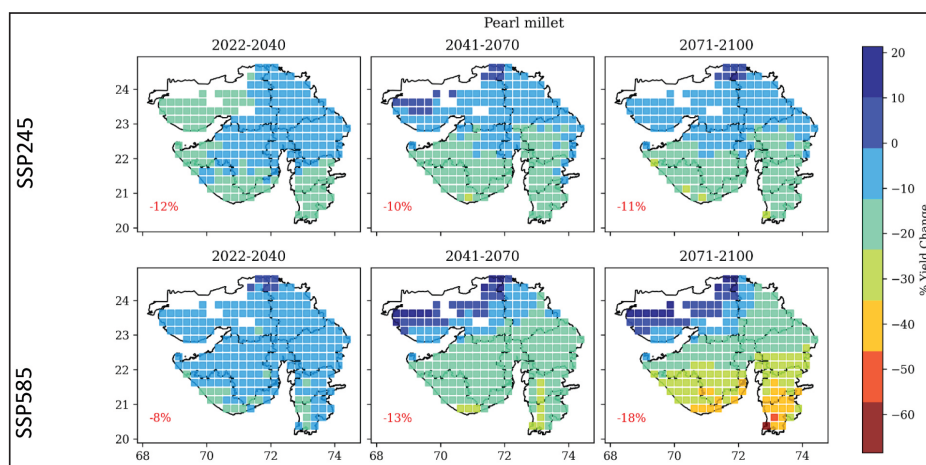


Fig. 5.3 Potential impact of projected climate change on pearl millet yield in Gujarat

Production performances of pearl millet crop under different agronomic adaptation options (listed below) in cultivation were simulated under the SSP245 scenario. The distribution of pearl millet yield (kg ha^{-1}) across twelve different adaptation options is depicted in Fig. 5.4. Each box plot represents a specific cultivation method, incorporating changes in standard practices such as cultivar type, sowing time, nitrogen application, and irrigations.

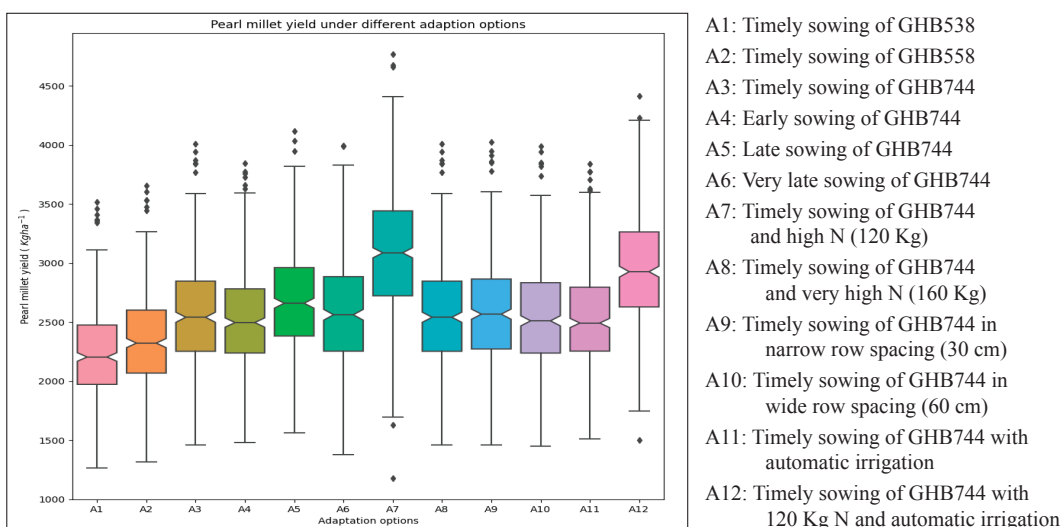


Fig. 5.4 Productivity of pearl millet under SSP245 with different agronomic adaptations in Gujarat

The box plots reveal significant variability in yield across different adaptation options. The median yield represented by the horizontal line within each box) varies considerably among the adaptation options. This indicates that certain cultivation practices have a more pronounced impact on overall yield than others. These outliers represent exceptionally high or low yields, which could be attributed to factors such as extreme weather conditions with soil heterogeneity.

Comparing options A1, A2, and A3 (timely sowing of different cultivars) with standard practices suggests that cultivar selection influences yield, and cultivar GHB 744 (A3) performs better than others. Options A3, A4, A5, and A6 demonstrate the effect of sowing time on yield. Timely sowing (A3; onset of monsoon) appears to result in higher yields compared to early (A4) or late sowings (A5, A6). Options A7 and A8 indicate increasing nitrogen levels from the recommended 80 kg ha⁻¹ to 120 kg ha⁻¹ (A7) and 160 kg ha⁻¹ (A8). An additional 40 kg ha⁻¹ N enhances the production significantly, but further increase does not lead to higher yields. On the contrary, the model simulates a negative impact on yield. The impact of row spacings (A9 (narrow), A10 (wide)) and automatic irrigations (A11, A12) at critical depletion do not influence yield significantly. The addition of irrigations to the highest performing option (A7), was also simulated to lower the yield. Thus, to lessen the detrimental effects of climate change on pearl millet yield, rainfed cultivation with sowing of cultivar GHB744 at the onset of monsoon and high N (120 kg) is a potential choice.

Bangalore

Seasonal analysis of pigeon pea yield variability under three sowing windows using the calibrated DSSAT model

The model was calibrated using the genetic coefficients. The key model performance indicators such as R², Normalized Root Mean Squared Error (NRMSE), Modeling Efficiency (ME), etc. were utilized, first, the performance of the model for simulating the yield by the two varieties was evaluated (Fig. 5.5). Outcomes revealed a better agreement between observed and simulated yield by the model for the two varieties, with an R² of 0.70. Therefore, the model explains a substantial portion of the variability in the data. The intercept of 152.2 suggested that when the simulated value is zero, the expected observed value is approximately 152.2, and the slope of 0.66 indicates that for every one-unit increase in the simulated value, the observed value is expected to increase by

approximately 0.66 units, all these together contributing to a modeling efficiency of -0.63. such modest performance of the model is attributed to limited data points on observed and simulated yield.

Therefore, to assess the long-term performance of the model under different growing environments, treatments with three sowing dates (Early i.e. May 2nd FN, Normal i.e. June, and Late i.e. July 1st FN onwards) and two varieties were carried out using the ‘seasonal analysis’ module available in the model. Outcomes revealed the better performance of the model under early sowing windows ($R^2=0.60$) followed by normal ($R^2=0.64$) and late sown conditions ($R^2=0.45$). Even though, the normal sowing had a good agreement between

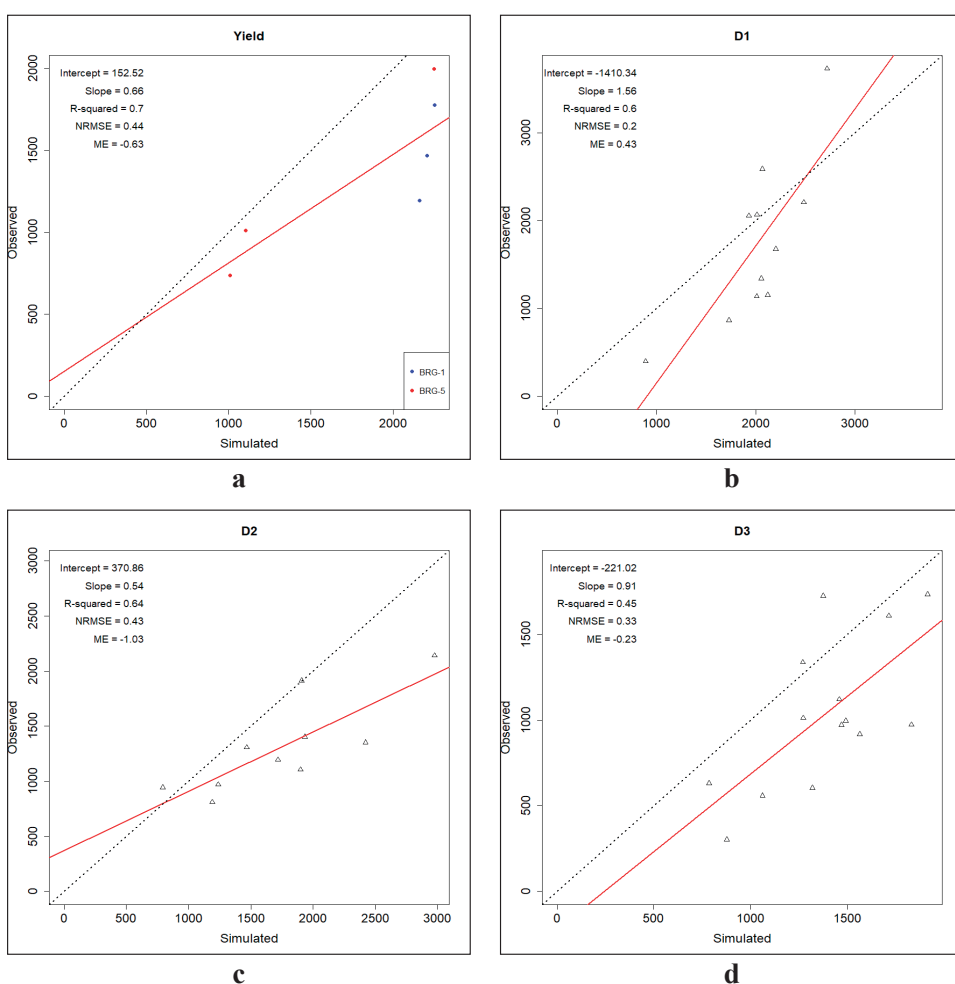


Fig. 5.5 Model performance indicators for varietal simulation(a) and yield under the three sowing windows (b: early i.e. May 2nd FN, c: normal i.e. June, d: late i.e. July 1st FN onwards).

observed and simulated yields, underestimation of the yield (depicted by the sign of ME; which is +0.43 for early, -1.03 for normal, and -0.23 for late sown conditions) by the model (Fig. 5.5 b, c, d) during this sowing period. The differential performance of the model under three sowing windows emphasizes the need for further calibration of the model for accurate simulation and studying the advanced techniques for rectifying observed datasets and their putting-in into the model while calibrating, etc.

Bhubaneswar

Future scenario of summer rice yield under projected seasonal climate change scenario

Field experiment was carried out at the Research farm of OUAT, College of Agriculture, Bhubaneswar, Odisha, during the summer season from December - April with one variety of rice namely Sahabhagi Dhan (115 Days) in four different dates of transplanting (15 January, 31 January, 15 February and 28 February). Projected Climate Change scenarios (RCP 2.6, 4.5, 6.0, and 8.5) for temperature, and CO₂ concentration for the years 2040, 2060, and 2080 were extracted for the Khordha district falling under the East and South East Coastal Plain Zone of Odisha for assessing the impact of climate change on rice crop (Sahabhagi Dhan) using the CERES-Rice model.

Assessing the Climate Change Impact on Summer Rice Yield

The predicted yield of Sahabhagi Dhan in four different environments D₁, D₂, D₃, and D₄ under the projected scenarios RCP 2.6, 4.5, 6.0, and 8.5 for the years 2040, 2060, and 2080. It was observed that, for the year 2040, the rice yields showed a likely decrease of 10.77%, 8.56%, 6.31%, and 16.78% respectively under the D₁ environment. Whereas under D₂ Environment a likely decrease of 9.33%, 8.05%, 13.63%, and 15.50%, respectively was observed. In the D₃ environment, it was observed that the likely decline in the yields was 8.20%, 3.45%, 9.90%, and 15.10%, respectively. Finally, in the D₄ environment, the likely decline yields were 8.34%, 13.43%, 20.19%, and 21.43% under RCP 2.6, 4.5, 6.0, and 8.5 scenarios, respectively. The same pattern during the projected years 2060 and 2080 the decline in yields continued and the same is presented in Fig. 5.6.

In the present investigation, it has been found that the projected impact under RCP 4.5, RCP 6.0, and RCP 8.5 scenarios is more severe as compared to the RCP 2.6 scenario on the grain yield characteristic of rice resulting in a likely decrease of the yield in future for the years 2040, 2060 and 2080. The extent of the likely decrease in yield is mostly because of the fact there is a significant increase in projected mean maximum and minimum temperature by the

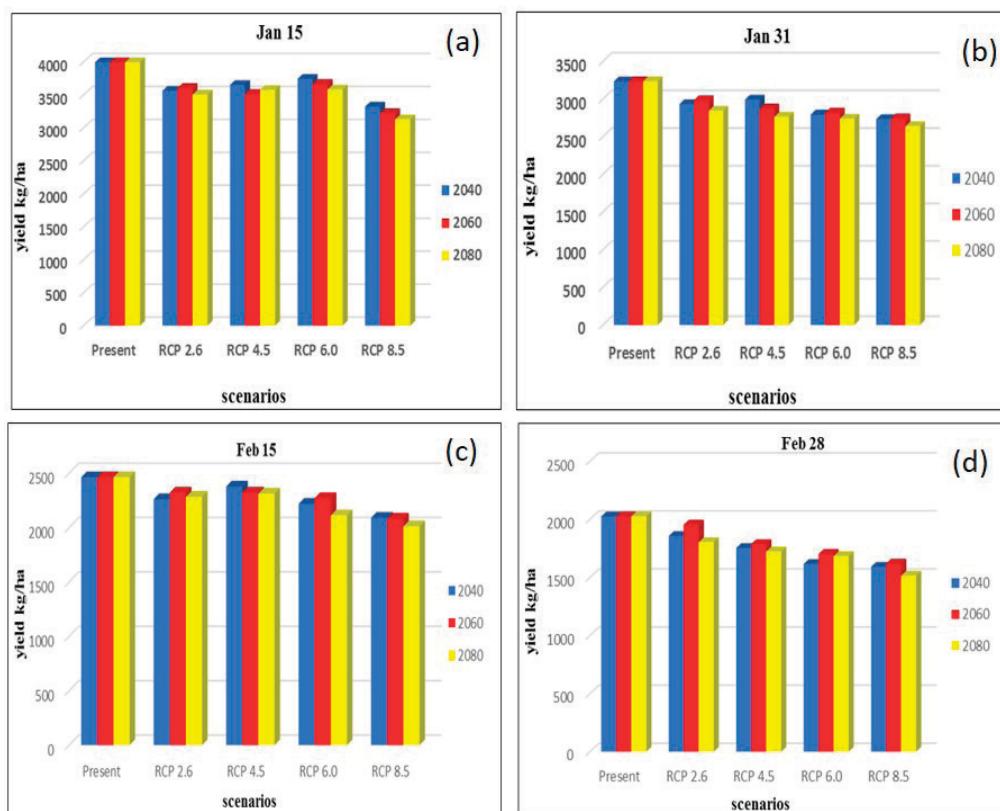


Fig. 5.6 The changes in the simulated yield of summer rice under future period when transplanted on (a) 15 Jan, (b) 31 Jan, (c) 15 Feb, and (d) 28 Feb at Bhubaneswar

years 2040, 2060, and 2080. In this study, the crop model was used to assess the impact of climate change on Rice yield in the Odisha region. There is seen an increase in temperature more than the optimum in the study area with an average of 30-35 °C in RCP 4.5 and RCP 8.5. An increase in 1 °C will reduce the yield by 6-11%, and due to an increase in minimum temperature over the years, the yield is affected as a higher minimum temperature would increase respiration rate and thus reduce yield.

There is a likely increase in temperature more than the optimum in the study area with an average of 30-35 °C in RCP 4.5 and RCP 8.5. As observed, an increase in 1 °C will reduce the rice yields by 6-11%. Due to the increase in minimum temperature over the years, the yield is affected as it affects the respiration rate and thus reduces yield.

Jorhat

Assessing the Impact of Climate change in *Sali* rice under RCP scenario in over Upper Brahmaputra Valley Zone of Assam

The impact of climate change on yield of *Sali* rice (*cv.* Mahsuri) was studied based upon the Representative Concentration Pathway (RCP) scenario (RCP 4.5 and 8.5) generated from the MakSim DSSAT weather file generator (<http://gismap.ciat.cgiar.org/MarkSimGCM/>) for the year 2025 and 2050 in future for five different districts (*viz.*, Golaghat, Jorhat, Sivasagar, Dibrugarh and Tinsukia) of Upper Brahmaputra Valley Zone (UBVZ) of Assam. The yield projections from the actual mean yield of Mahsuri cultivars transplanted under three different transplanting environments (early (D_1): 26 June; mid (D_2): 11 July and late (D_3): 26 July) during *khari*f season were studied and results were depicted in the following Table and figure.

The grain yield under early transplanting (D_1) date will increase subsequently from its mean observed yield during 2025 and 2050 in Jorhat (19-24%), Dibrugarh (40-43%) and Tinsukia (30-47%) districts; whereas it showed a decline in Sivasagar (-7 to -45%) under RCP 4.5 scenario. In Golaghat, a positive impact was observed on yield in 2025 (29%) whereas negative in 2050 (-17%). On the contrary, under mid (D_2) and late (D_3) transplanting conditions, grain yield was relatively declining in Golaghat and Jorhat districts; whereas the reverse effect is projected in Dibrugarh and Tinsukia districts during 2025 and 2050. Relatively an improvement in yield was noticed in Sivasagar under mid (D_2) transplanting condition; though did not persist during late (D_3) planting (Fig. 5.7). Similarly, under the RCP 8.5, grain yield under early planting (D_1) date will increase subsequently from its mean actual yield during 2025 in Golaghat (23%), Jorhat (25%), Dibrugarh (43%) and Tinsukia (48%) districts; whereas it showed a decline in Sivasagar (-40%) district of UBVZ of Assam during 2025 under RCP 8.5 scenario.

Likewise, an increase in grain yield was observed in Jorhat (18%), Dibrugarh (36%), and Tinsukia (39%) districts; whereas the reverse scenario was observed in Golaghat (-11%) and Sivasagar (-40%) districts. In contrary, under mid (D_2) and late (D_3) transplanting condition, grain yield was relatively declining in Golaghat and Jorhat district, almost similar with RCP 4.5; whereas the reverse effect was projected in Dibrugarh district during 2025 and 2050. On the other hand, in Sivasagar and Tinsukia districts, it showed a discrete effect i.e., a rise in yield when planted within the first fortnight of July (D_2), whereas a decline in yield was observed in 2050 when planted in the second fortnight (D_3) of July in both the districts under the RCP 8.5 (Fig. 5.8).

Overall, the yield potential of Mahsuri in Golaghat, Jorhat, Dibrugarh and Tinsukia district were found to be less vulnerable under RCP 4.5 during the early and mid-part of the century when transplanted early (Second fortnight of June). Overall, the yield potential of Mahsuri in the Dibrugarh and Tinsukia districts was found to be less vulnerable under RCP 8.5 when transplanted within the first fortnight of July.

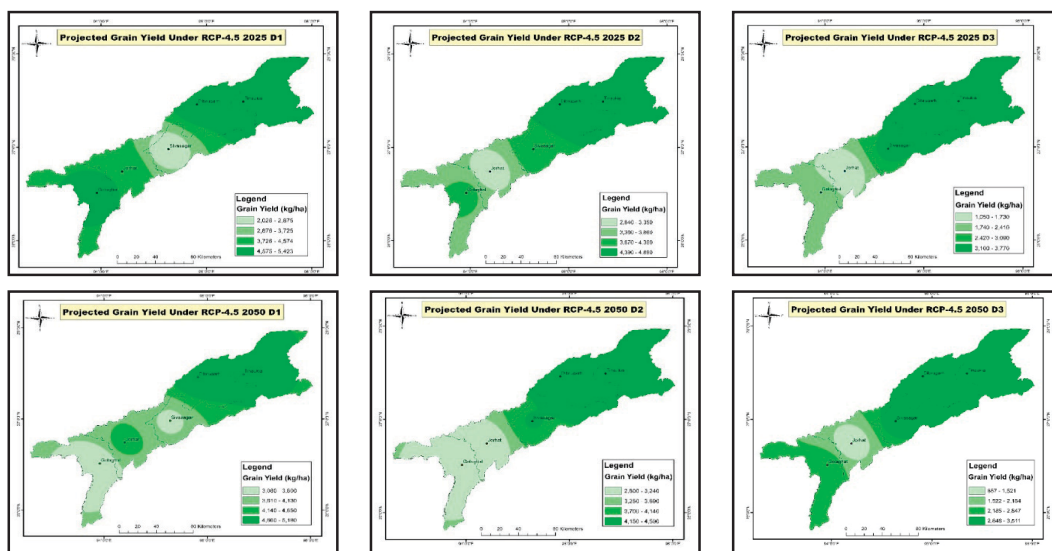


Fig. 5.7 Projected variability in grain yield (%) of Mahsuri under RCP 4.5 scenarios over the Upper Brahmaputra Valley Zone of Assam during 2025 and 2050

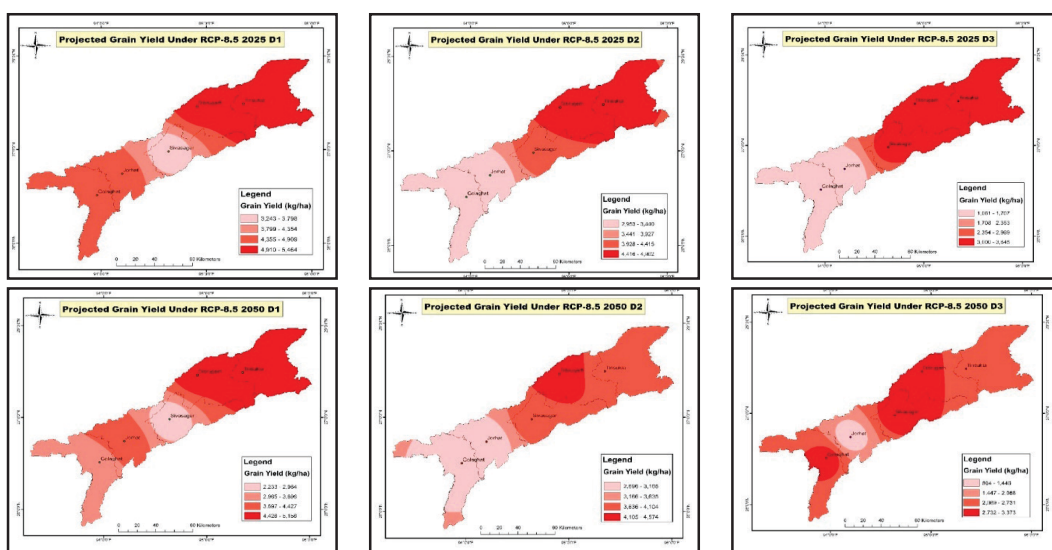


Fig. 5.8 Projected variability in grain yield of Mahsuri under RCP 8.5 scenarios over Upper Brahmaputra Valley Zone of Assam during 2025 and 2050

Ludhiana

Optimizing transplanting window for higher productivity of rice cultivars in Punjab using CERES-Rice model

The validated CERES-Rice model available in DSSAT v4.7.5 was used for simulating the transplanting window applicable for rice in Punjab i.e., 1st June to 20th July. The transplant age was kept as 30 days under the transplant tab in a crop management file, for simulating the yield of both the cultivars in all the transplanting dates assumed in the simulation. The temperature at the time of transplantation was changed for each date of planting according to the prevalent weather during the year 2020. The moving average was worked out to determine the best period of 7 days for transplanting these cultivars. The highest value of the grain yield in the seven-day moving average was considered as best time for transplanting. The sensitivity analysis, calibration, and validation of the CERES-rice model confirmed a good agreement between observed and simulated values of days taken for anthesis and maturity, LAI, and grain yield of both rice cultivars. The calibrated and validated model was used to optimize the date of transplanting window for the rice cultivars. Generally, farmers of the Punjab region transplant 30-35 days old seedlings of Parmal varieties between mid-June and mid-July. So, the transplanting window was considered from 1st June up to 20th July for evaluation by taking a weekly average. The variability in grain yield and LAI for PR 126 and PR 127 within the transplanting window are presented in Fig. 5.9.

The results of the present study showed that the grain yield and LAI had a polynomial relationship with the transplantation date. The simulation results on a weekly average basis indicated 24 to 30 June for PR 126 and 20 to 26 June for PR 127 as the optimum transplanting window with grain yield and LAI for PR 126 ranging between 8425-8473 kg ha⁻¹ and 4.23-4.24, respectively and for PR 127 between 8298-8356 kg ha⁻¹ and 4.20-4.21, respectively. The minimum yield of both cultivars was observed on 07 June i.e. early transplanted rice with grain yield and LAI being 6703 kg ha⁻¹ and 3.8, respectively for PR 126 and 6865 kg ha⁻¹ and 3.9, respectively for PR 127. The coefficient of determination (R^2) of grain yield and LAI was 0.98 and 0.94, respectively for PR 126 and 0.89 and 0.84, respectively for PR 127, thereby indicating a very good agreement between observed and simulated values. The polynomial regression model was able to explain more than 80% variation in grain yield and LAI with the date of transplantation for both cultivars.

The deviation of grain yield and HI (Harvest index) from the mean, clearly depicted the reduction in HI as a result of a reduction in the grain yield of rice (Fig. 5.9). The deviation between the grain yield and HI of PR 126 varied between -14.2 to +8.2 % and -15.1 to

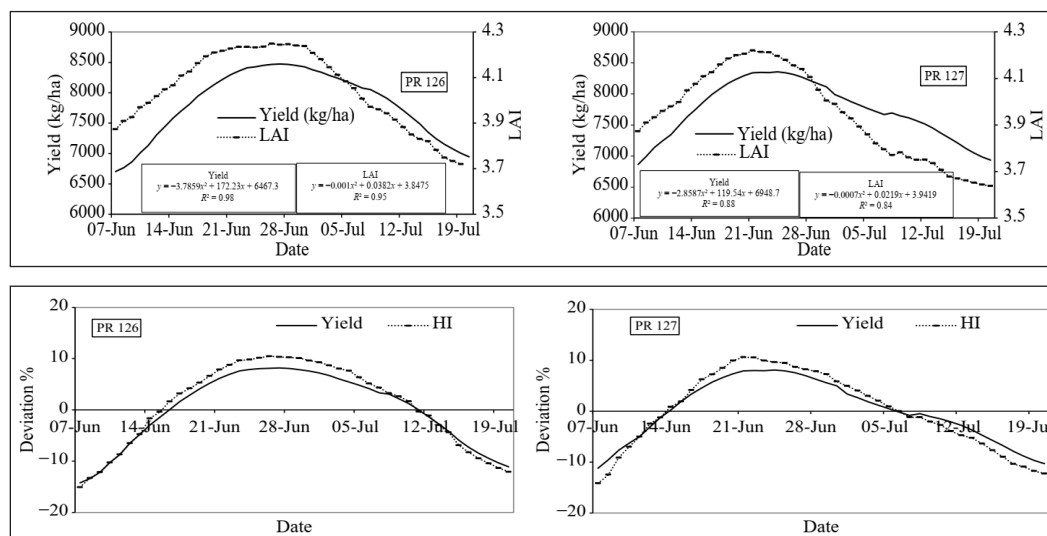


Fig. 5.9 Leaf area index (LAI), grain yield and harvest index (HI) relation with the sowing window for PR 126 and PR 127 at Ludhiana

+10.5 % respectively, while for PR 127 deviations varied between -11.2 to +8.1 % and -14.2 to +10.6 %, respectively. The negative deviation in the yield/ HI from the average in the case of late transplantation for PR 126 and PR 127 was observed after 11th July and 6th July, respectively. On the other hand, in the case of earlier transplantation, the model showed depreciation in yield and HI when transplanted before the 15 June for PR 126 and the 13 June for PR 127. The negative effect on yield and HI of both the cultivars which occurred in case of early and late transplantation could be due to unfavourable climatic conditions during the critical phenological stages of rice.

Mohanpur

Impact of CC on the growth and yield of *Kharif* rice

The maturity may be accelerated by 8-12 days during mid and end centuries in Old and New Alluvial Zones under moderate emission scenarios (Fig. 5.10). Under SSP5-8.5, an extreme projection scenario, 11-15 days and 9-10 days of advancements may be observed from Old and Alluvial Zones respectively to enter the maturity phase by *Kharif* rice. The Coastal Saline Zone, which is detected with the least changes in temperature, may experience less reduction in the growing period. The maturity phase may be shortened by 4-8 days in this location across different projection scenarios.

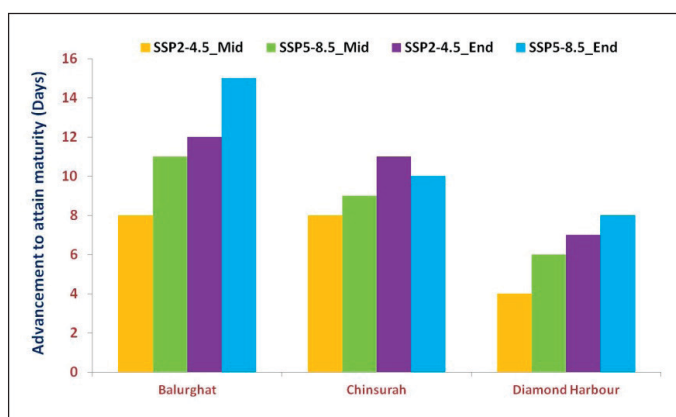


Fig. 5.10 Advancement to attain maturity of Kharif rice in the future (days)

Biomass of *Kharif* rice in the Old alluvial Zone under SSP2-4.5 may range between 5025 to 8823 kg ha⁻¹ and 4489 to 8628 kg ha⁻¹ during mid and end-centuries respectively with average values of 6676 kg ha⁻¹ and 6372 kg ha⁻¹ (Fig. 5.11). The biomass reduction is expected to be between 9 to 13% on average. The yield may vary between 3500 to 3530 kg ha⁻¹ in the future under this scenario. The minimum yield may be recorded as 2180 kg ha⁻¹ during the century. The average yield drop may be around 7% from the baseline condition. The biomass under the extreme emission scenario is observed as 8974 kg ha⁻¹ and 8907 kg ha⁻¹ during 2040-2069 and 2070-2099 respectively. The lowest biomass for the future may be around 4000-4200 kg ha⁻¹. The average value of biomass is likely to be 6613 kg ha⁻¹ and 6048 kg ha⁻¹ during mid-century and end-century respectively. The average yield noted for the mid and end century under SSP5-8.5 may be 3306 and 3125 kg ha⁻¹ respectively. The change of yield may range between -38 to +6% and -36 to +5% during 2040-2069 and 2070-2099. On average, a 12-17% yield reduction can be recorded from this location under extreme emission scenarios.

In the New Alluvial Zone, the biomass range under SSP2-4.5 is estimated to be 4980 to 7894 kg ha⁻¹ during the mid-century and 4819 to 8787 kg ha⁻¹ during the end-century. The biomass values averaged over the centuries may range between 6540 to 6658 kg ha⁻¹. The biomass may be reduced up to 33 to 35% in the future but some years are denoted with increments also. So, on average, the biomass maybe 10 to 12% less than baseline values. The values of yield during the 2040-2069 and 2070-2099 periods may be 2580 to 4739 kg ha⁻¹ and 2339 to 4020 kg ha⁻¹ respectively with average values of 3323 kg ha⁻¹ and 3263 kg ha⁻¹. The yield also is marked with a 10 to 11% decline. Likewise, 6387 to 6795 kg ha⁻¹

yield is expected to be recorded from NAZ under an extreme projection scenario. The end-century is observed to experience more biomass than the mid-century. The yield range may be 5918 to 8042 kg ha⁻¹ for that period. The deviation of biomass from baseline may be between 9 to 14% on average. The average yield for mid and centuries is simulated to be near about 3170 and 3116 kg ha⁻¹ respectively. The average decrease in yield for both periods is estimated to be 14 to 15%.

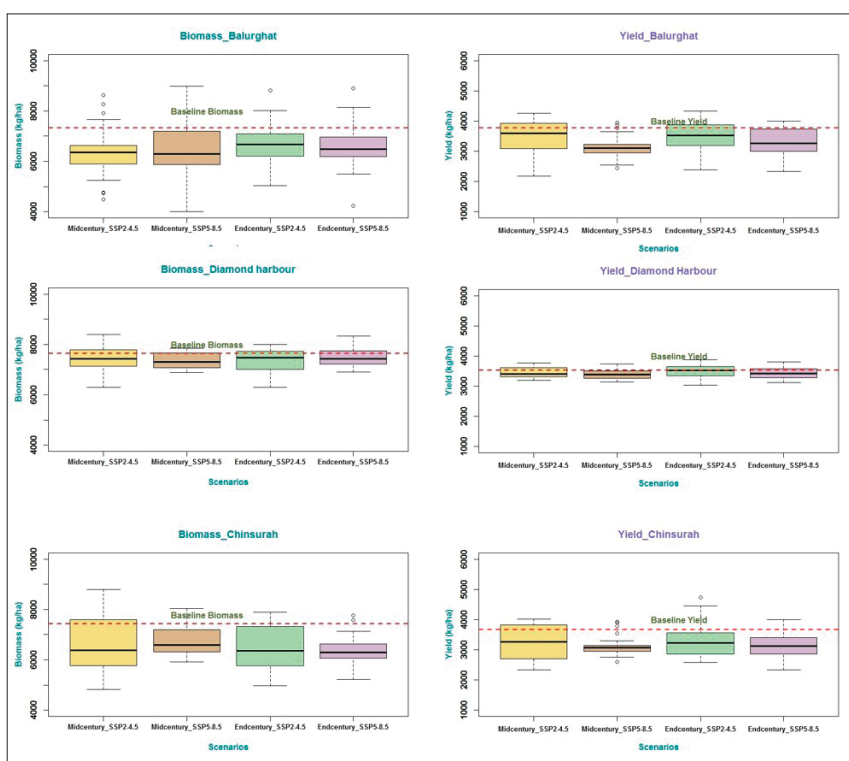


Fig. 5.11 Change in biomass and yield of Kharif rice in three locations of Southern West Bengal (Balurghat, Diamond Harbour and Chinsurah) during future periods simulated using DSSAT

The Coastal Saline Zone is noted with a biomass range of 6287 to 7989 kg ha⁻¹ and 6297 to 8389 kg ha⁻¹ during the mid and end centuries respectively. The average biomass values under SSp2-4.5 may be 7373 kg ha⁻¹ and 7410 kg ha⁻¹. The reduction of biomass from baseline values is lower than other two agro-climatic zones. The simulated biomass for the future maybe 3% lower than the baseline. 3082 to 3882 kg ha⁻¹ future yield can be expected under this projection scenario. The yield values averaged over mid and end centuries may be to the tune of 3493 and 3457 kg ha⁻¹ respectively. The maximum yield

drop may be around 10 to 14%. But several years are also detected with 7-10% increased yield. So, a marginal decrease of yield by 1-2% can be expected from this region. The highest future biomass under SSP5-8.5 in the said location may range between 7356 to 8325 kg ha⁻¹ with average values of 7464 kg ha⁻¹ and 7356 kg ha⁻¹ during the 2040-2069 and 2070-2099 periods respectively. The lower range of future biomass may be 6875 to 6905 kg ha⁻¹. The future biomass can deviate upto 10% more than baseline but the average reduction is noted in between 2-4%. The registered yield may be as high as 3813 kg ha⁻¹ and 3742 kg ha⁻¹ during the mid and end centuries respectively. The minimum yield values are found to be around 3118 to 3148 kg ha⁻¹. The average yield values are projected to be 3422 and 3394 kg ha⁻¹ for the mid and end centuries. Yield changes are predicted to be +8 to -12% for 2040-2069 and +6 to -11% for 2070-2099 periods. The average reduction may be recorded as 3 to 4%.

Adaptation options evaluated through CGM

Optimum Sowing Window: The sowing of *Kharif* rice during the July 1st fortnight is seen to produce a higher yield than the other two sowing windows across all locations under every projection scenario (Figs 5.12 and 5.13). The yield may range between 3466 to 3635 kg ha⁻¹ during mid-century and 3476 to 3600 kg ha⁻¹ during the end-century under SSP2-4.5 when sowing is performed in the first fifteen days of July. The overall yield advantage with this sowing window may be around 4-6% and 6-7% over the D₁ (during June 2nd fortnight) and D₃ (July 2nd fortnight). Under the SSP5-8.5 scenario also, the yield from the July 1st fortnight sown crop may be recorded as 3521 kg ha⁻¹ and 3349 kg ha⁻¹ during the mid and end centuries respectively. Chinsurah may register the highest yield increment of about 9% during mid-century under this projection scenario. Sowing from 1-15 July may generate a 4-7% elevated yield in the future as per the extreme projection scenario. The monsoon period starts in the study region in June, though peak rainfall periods occur during July and August. So, sowing during the second half of June may produce the yield due to insufficient rainfall for proper growth of the crop. On the other hand, sowing during the latter half of July may induce more vegetative growth leading to poor reproductive growth. But sowing during the first half of July is observed to result in better crop stand, maximum tillering, and other yield parameters. That's why sowing during this period may be considered an effective adaptation measure for *Kharif* rice in the study region.

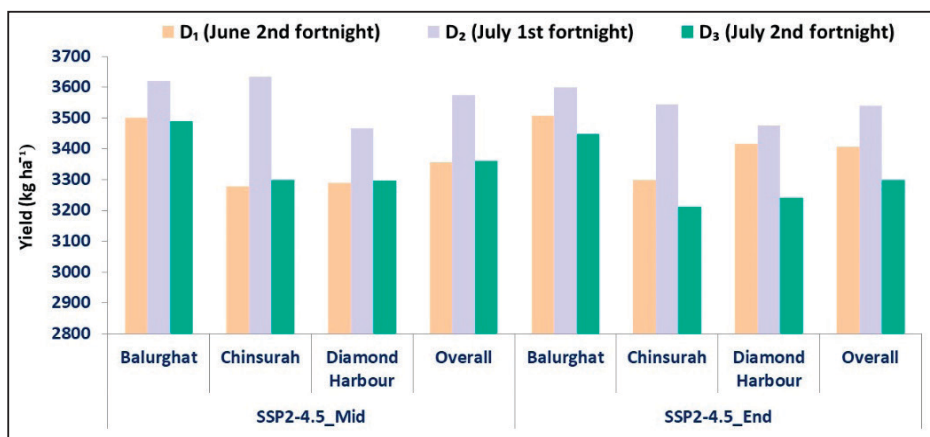


Fig. 5.12 Yield under different sowing windows during mid and end centuries for SSP2-4.5

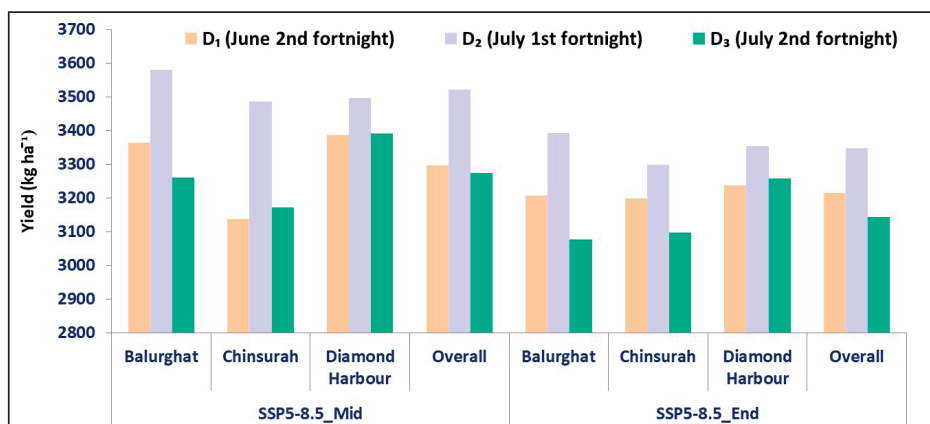


Fig. 5.13 Yield under different sowing windows during mid and end centuries for SSP5-8.5

Effect of different seedling ages for transplanting: It is observed that the highest yield is obtained from *Kharif* rice when 20 days of seedlings are transplanted to the main field from the nursery for both the projection scenarios (Figs 5.14 and 5.15). A transplanting age of 15 days also generates similar yield values. The yield difference between these two options is between 1-2 %. However, delayed transplanting can deteriorate the yield drastically. In the case of Balurghat, yield reduction during mid-century under SSP2-4.5 is found to be 8.42%. The overall reduction when transplanting is done at 30-35 DAS is around 3-4% during the end-of the century under the same projection scenario. The percentages of reduction in yield due to different seedling ages for transplanting are observed to be under

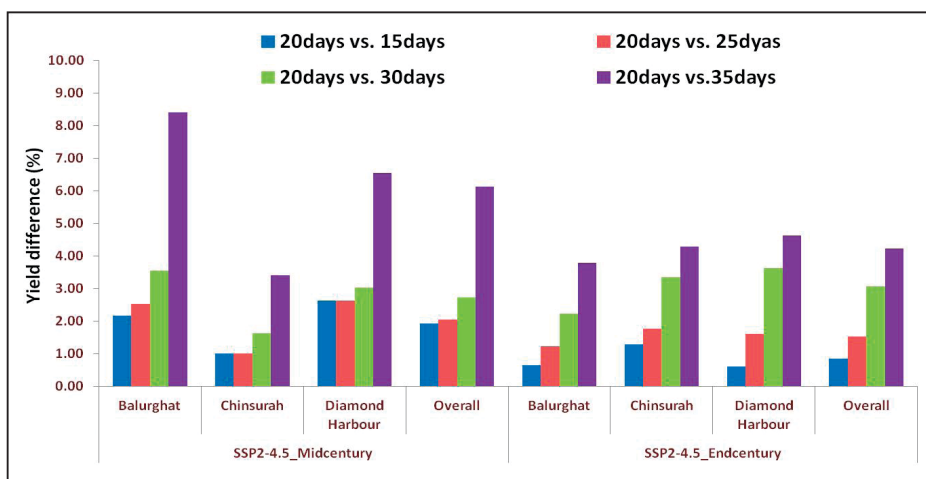


Fig. 5.14 Yield difference between different seedling ages for transplanting during mid and end centuries for SSP2-4.5

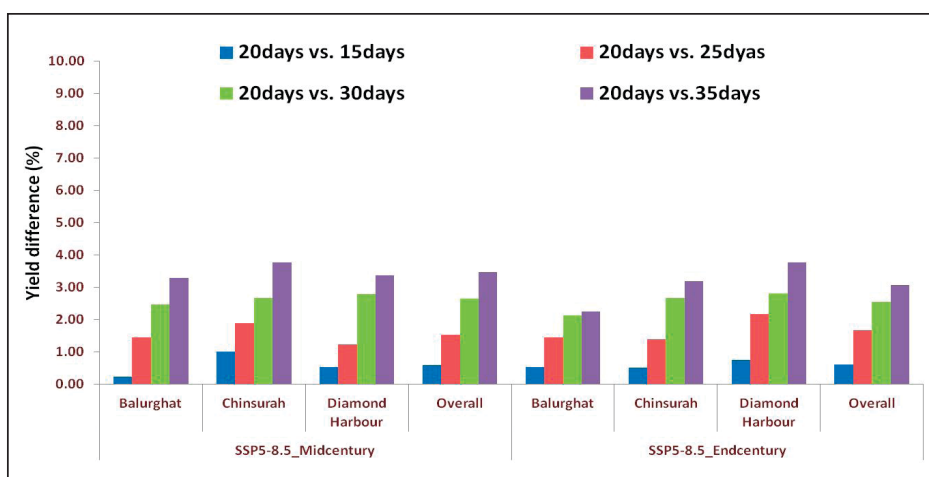


Fig. 5.15 Yield difference between different seedling ages for transplanting during mid and end centuries for SSP5-8.5

extreme projection scenarios indicating the diminishing effect of adaptation options in more variable climates. Transplanting older seedlings may decrease the yield by between 2-3% across locations.

The combination that will provide the best adaptation for Lower Gangetic West Bengal is a sowing window of 1st fortnight of July; Seedling age for transplanting: 15-20 days and a spacing of 15x20 cm, 20x20cm

6. Weather Effects on Pests and Diseases

Field crops

Anand

Time series modeling for forecasting mustard aphid

This study examined the population dynamics of mustard aphids during the Rabi seasons across two decades, from 2002 to 2022. The weekly aphid index values from 47 SMW to 8 SMW showed no prominent trend over time, it has seasonality, and residuals are well distributed with a few extremes. Hence the SARIMA time series modelling was employed, with 64 possible combinations of parameters. The AIC (Akaike Information Criterion) score was used as the benchmark for selecting the optimal model. The score indicates a balance between model complexity and goodness-of-fit. The analysis identified SARIMA (1, 1, 2) (1, 1, [1], 14) with a favorable AIC score (123.6) as the optimal model for the purpose. The Bayesian Information Criterion (BIC) was higher (145.1) than the AIC, but the difference is relatively small. The specific model configuration suggests that the aphid population can be influenced by factors from the previous season (AR(1)), the current season (MA(2)), and a seasonal pattern with a period of 14 (for the Rabi cycle). An integration order of 1 was used in the model to achieve stationarity.

Table 6.1 The estimated coefficients for the model terms and statistics

Model term	Coefficient	std err	z	P> z
AR.L1	0.613	0.062	9.942	0.001**
MA.L1	-0.8421	0.15	-5.597	0.001**
MA.L2	-0.1526	0.089	-1.714	0.087
AR.S.L14	0.0675	0.051	1.334	0.182
MA.S.L14	-0.9979	2.298	-0.434	0.664
Sigma2	0.0749	0.174	0.431	0.666

The term AR.L1 represents the coefficient for the autoregressive term of lag 1 (previous season's aphid population). The positive value (0.613) suggests a positive influence of the prior season's population on the current season's population. MA.L1 coefficient's negative value (-0.842) indicates a potential dampening effect of some random influence from the

previous season on the current aphid population. The coefficients AR.S.L14, and MA.S.L14 are shown for the seasonal AR and MA terms, likely capturing seasonal patterns in the aphid population data. The sigma2 (0.0749) represents the estimated variance of the error term in the model. A lower variance implies the errors are clustered closer to the mean, indicating a good fit (Table 6.1).

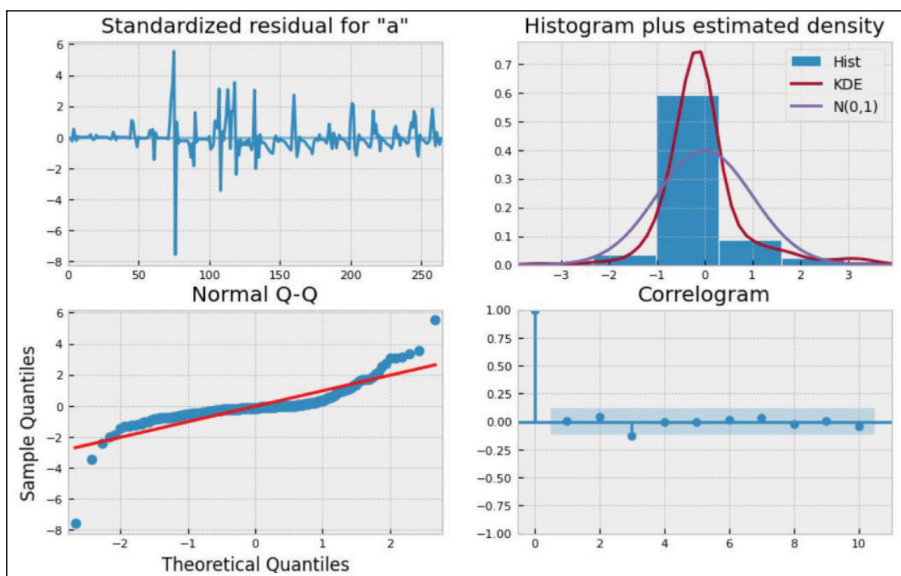


Fig. 6.1 Diagnostics plots of SARIMA(1, 1, 2) (1, 1, [1], 14) fitted to aphid index

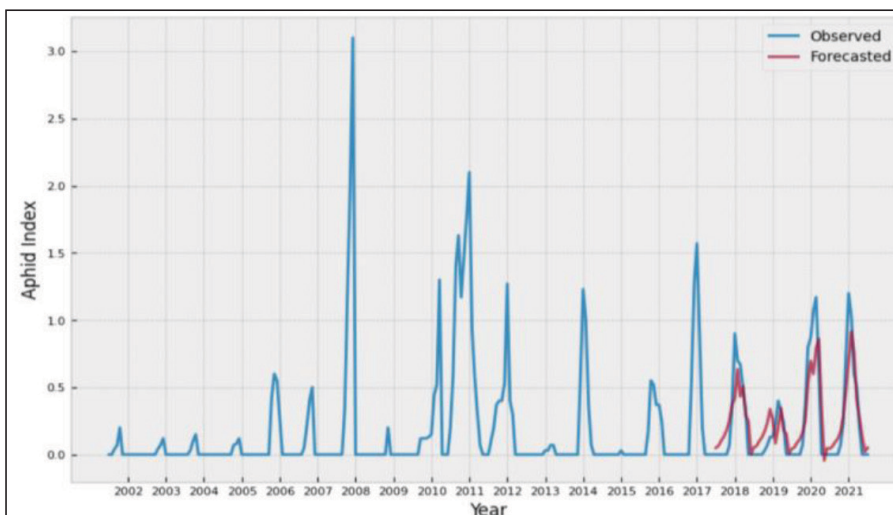


Fig. 6.2 Weekly aphid index observed (full series) and observed vs forecasted for years 2018 to 2021

The validation of the model for eight years was a positive indicator. This validation process likely involved comparing the model's one-step-ahead forecast with the actual observed data of the respective period. If the model's forecasts are closely aligned with the observations (Fig. 6.1 & 6.2). The Root Mean Squared Error (RMSE) of our forecasts for the year 2018-2021 is 0.18. It suggests the model has the potential to forecast one step ahead of aphid population trends with some accuracy.

Akola

Weather-based prediction model for *Semilooper* and *Spodoptera litura* on soybean

Five-year pest and weather data (2018 to 2023) used for developing prediction models. The step-wise multiple regression analysis was used to develop a prediction model to forecast the damage based on weather variables. Weekly data of *semilooper* and *S. litura* incidence in soybean crop. During the current week, the minimum temperature, relative humidity, sunshine hours, windspeed, and evaporation contributed to the increased incidence of the pest population, and its applicability was 17-18%, 27-28%, and 30-47% in the current week, at one lag week and two lag weeks, respectively.

The favorable weather conditions for semilooper minimum temperature in the range of 21.6 to 22.3 °C, sunshine hours ranging between 2.8 to 3.5 hours, morning relative humidity between 87 to 88%, evening relative humidity between 70 to 72%, evaporation range between 3.4 to 4.3 mm, wind speed 5.6 to 6.2 km hr⁻¹ were found to be congenial weather conditions for Semilooper population on soybean crop.

Anantapur

Relationship between weather and pod borer complex in redgram (Cv PRG 176)

The results of the two season's pest monitoring data (2022-23) revealed that the number of webs m⁻² recorded peaked during 49 SMW with the late sown crop. Under the rainfed situation, the number of live larvae/m² reached the peak stage during 49 and 50 SMW, whereas, in the irrigated situation, the peak incidence of the number of live larvae m⁻² was noticed during 50 SMW. Under rainfed conditions, D3 recorded the highest seed yield (271 kg/ha), followed by D2(256 kg/ha) and D1(231 kg/ha), as this was influenced by a similar trend in the level of damage caused by pod borer pests. Whereas in irrigated conditions, D3 recorded the highest seed yield (561 kg/ha), followed by D2(398 kg/ha) and D1(341kg/ha). Here also the pest followed a similar trend as rainfed conditions (Table 6.2).

Table 6.2 Effect of different growing environments on yield and yield attributes of redgram and pest incidence during *Kharif*, 2023

Sowing date	Treatments	Filled pods m ⁻²	Unfilled pods m ⁻²	No. of damaged pods m ⁻²	100 seed weight (g)	Seed yield (kg/ha)
	Rainfed					
D1	26-06-2023	684	105	13	8.1	231
D2	06-07-2023	628	86	10	7.7	256
D3	22-07-2023	640	126	6	7.8	271
D4	10-08-2023	513	129	10	7.7	190
	Protective Irrigation					
	26-06-2023	711	50	12	7.6	341
	06-07-2023	771	51	10	7.9	398
	22-07-2023	846	66	4	7.4	561
	10-08-2023	720	160	7	7.2	223

Samastipur

Poisson regression model for Fall Armyworm in Kharif maize

Kharif maize was grown for two years viz., 2022 and 2023 at Pusa on six dates starting from 17 July to 21 August at weekly intervals and data on the incidence of fall armyworm on the crop was collected. The infestation and number of larvae were used to develop the Poisson regression model (Table 6.3). The analysis revealed a significant relation of maximum temperature, rainfall, and afternoon relative humidity with pest infestation. The data shows that a 1 °C increase in maximum temperature contributed to the increase of 19.6 % increase in percent plant infestation, while rainfall decreased the infestation. Afternoon relative humidity had a significant positive influence on pest build-up.

Table 6.3 Poisson regression model for fall armyworm and weather parameters

	Percent plant infestation		Number of larvae	
	2022	2023	2022	2023
Intercept	0.00009	0.00015	0.00016	0.00044
T _{Max}	1.19*	1.31	1.14	1.76*
T _{Min}	0.96	0.91	1.26	0.79
RF	0.99*	0.99*	0.99*	0.99*
RHI	1.15	1.12	1.06	1.06
RH II	1.09*	1.07*	1.18	1.14*

Considering the relation of the larval population with weather variables in 2022-23 it was observed that afternoon relative humidity had a positive influence on larval development, while rainfall had a negative impact. In 2023, maximum temperature and afternoon relative humidity showed a significant positive impact on the pest population, while rainfall showed a negative influence.

Udaipur

Correlation study of aphid population in mustard

Based on the weekly observations of aphid population count, a pest-weather relationship has been established using long-term pest-weather data (2017-2023). A linear regression model was developed for the prediction of aphid population count. The model summary is listed under for both current and preceding week conditions:

Current week:

$$Y \text{ (aphid count)} = 3678.4 - 125.4 \cdot T_{\max} + 126.0 \cdot T_{\min} - 35.4 \cdot RH-I + 15.4 \cdot RH-II - 0.91 \cdot RF + 159.1 \cdot BSSH \quad (R^2 = 0.45; \text{Adj. } R^2 = 0.29)$$

Preceding one week:

$$Y \text{ (aphid count)} = 4284.6 - 149.5 \cdot T_{\max} + 168.0 \cdot T_{\min} - 47.5 \cdot RH-I + 22.2 \cdot RH-II - 0.63 \cdot RF + 224.1 \cdot BSSH \quad (R^2 = 0.56; \text{Adj. } R^2 = 0.43)$$

The model performance was found relatively better in the preceding week with a higher R^2 (0.56) than the current week (0.45). The above model can be considered for further testing so as to enhance its reliability in aphid count prediction.

Horticulture crops

Ludhiana

Impact of weather parameters on the population of citrus psylla in Mandarin

Field experiments were carried out to study the population dynamics of citrus psylla, *Diaphorina citri* K on Kinnow Mandarin for twelve years [2007-08 to 2019-20] with different weather parameters and develop a population prediction model.

To identify the weather parameter having a significant impact on psylla population, the coefficient of determination (R^2) was worked out. 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. The temperature-humidity index (THI) was calculated following:

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

where T = average daily temperature (°C), RH = average daily relative humidity (%)

Development of psylla population prediction model

Based on the statistically significant values of R^2 , maximum and minimum temperatures, duration of bright sunshine, morning relative humidity, and THI were selected for the development of the citrus psylla population prediction model. Log transformed {Log (x+10)} citrus psylla population data was used to develop a relationship between insect count and the selected meteorological variables. 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:

$$Y = 0.029 - 0.033 \times T_{\text{max}} + 0.008 \times T_{\text{min}} + 0.038 \times \text{SSH} - 0.003 \times \text{RHI} + 0.032 \times \text{THI}$$

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. The data from these years were not used in the development of the model. The results of the validation (Table 6.4) are as follows:

Table 6.4 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	32.9	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	6.43	11.38	59.50	

The coefficient of determination (R^2) was statistically highly significant during all four years as evidenced by high values of F and very low values of probability levels. The overall results of the validation suggested that the model was able to satisfy the requirements of various indices. The performance of the developed model ranged from excellent to satisfactory during different years. Thus, the developed model can be used for the prediction of the citrus psylla population by using seven days of weather data.

Bangalore

Results of correlation analysis of four-year (2018-2021) data of weather and mango pests in 20-year orchard (A1) and 26-year orchard (A2) revealed that a significant positive correlation was observed between hopper population and sunshine hours (0.42** and 0.43** in A1 and A2, respectively) and a negative correlation with other weather parameters (Table 6.5). Fruit fly population had a significant positive correlation with maximum temperature (0.36** and 0.69** in A1 and A2, respectively), and minimum temperature (0.50** and 0.45** in A1 and A2, respectively).

Table 6.5 Correlation between weather factors and mango pests

Parameters	Hopper		Fruit fly	
	A1	A2	A1	A2
Rainfall (mm)	-0.30	-0.31	0.19	0.06
Tmax (°C)	-0.09	-0.07	0.36**	0.69**
Tmin (°C)	-0.44	-0.44	0.50**	0.45**
RH I (%)	0.14	0.13	-0.33	-0.54
RH II (%)	-0.10	-0.12	-0.25	-0.61
Sunshine hours (hr)	0.42**	0.43**	-0.25	0.23*

A1 : 20-year orchard, A2 : 26-year orchard

* Correlation is significant at $p \leq 0.05$ ** Correlation is significant at $p = 0.01$,

Kovilpatti

Weather- Pests and Diseases Relationship in Chilli

A field trial was conducted to study the influence of weather variables on anthracnose disease in chili during 2022-23. The variety K1 was transplanted during 44 SMW and harvested during 18 SMW. The disease incidence was initiated during 7 SMW (fruit development) and peaked during 18 SMW (fruit maturity stage). Among the weather parameters, maximum temperature, minimum temperature, wind speed and sunshine positively correlated with anthracnose disease in chili while rainfall, morning, and evening RH negatively correlated.

The multiple regression analysis showed

$$Y = 2.86 - 0.47 T_{\max} + 1.45 T_{\min} - 0.065 RHI - 0.264 RHII + 3.94 WS - 0.286 SSH + 0.0063 RF \quad (R^2 = 0.92)$$

The mean maximum temperature was 34.0 °C and the minimum temperature was 23.4 °C prevailed during the crop growth period. The total amount of rainfall received was 634.1 mm and the mean sunshine hour was 6.59 hours. The disease initiation was observed during 7 SMW with the disease incidence of 3.31 and 2.07% and there was a higher to 25.32% during 18 SMW. The age of the crop especially fruit development to maturity was more susceptible to the disease incidence.

Ranchi

Interaction between weather and insect pests and diseases of okra

The multiple regression analysis revealed that all the weather parameters influenced the pest and diseases of okra, and 44% variability was explained with aphids, 60% with jassids, 48% with whiteflies, and 60% with fruit and shoot borer. Similarly, 63% variability was explained with okra yellow vein mosaic (OYVMV) disease and 74% with Cercospora disease (Table 6.6).

Table 6.6 Multiple regressions analysis of pests and diseases of okra and weather parameters

Pest and disease	Multiple Regression	R ²
Aphid	$Y = 98.7 - 0.04T_{\max} + 0.33T_{\min} - 0.17RHI - 1.19RHII - 0.53WS - 0.23BSS + 0.001RF$	0.44
Jassids	$Y = 90.5 - 0.90T_{\max} - 0.003T_{\min} + 0.17RHI - 1.06RHII + 0.27WS + 0.55BSS - 0.0002RF$	0.60
Whitefly	$Y = -73.49 - 0.21T_{\max} - 0.49T_{\min} + 0.26RHI + 1.01RHII + 2.81WS - 0.56BSS + 0.001RF$	0.48
Fruit & shoot borer	$Y = 34.4 - 0.17T_{\max} + 0.0003T_{\min} + 0.02RHI - 0.41RHII + 0.09WS + 0.02BSS + 0.001RF$	0.60
OYVMV	$Y = -59.23 + 1.50T_{\max} - 2.34T_{\min} - 1.69RHI + 3.07RHII + 9.08WS - 3.46BSS + 0.03RF$	0.63
Cercospora	$Y = 136.6 - 1.06T_{\max} - 1.35T_{\min} + 0.70RHI - 1.95RHII + 7.77WS - 0.50BSS + 0.03RF$	0.74

7. Agromet Advisory Services

Under Changing climate scenarios, crop planning, its surveillance, and yield sustainability have become ambiguous. Timely monitoring of weather and accurate weather forecasts is the need of the hour for better crop planning and management during crop season for the farmers. With the improved weather forecast mechanisms, advancement in communication technologies, and availability of better crop management options, farmers benefit from the Agromet advisories which enable them to plan farm-related operations/ decisions and also remedial measures to reduce the losses in farm produce due to aberrant weather conditions. *Kharif* crop season in general is influenced by the onset of southwest monsoon rains and their distribution, which governs the entire gambit of agriculture as well as the economy of India. Uncertain and extreme weather such as heavy rainfall, cyclones, floods, droughts, heat and cold waves, frost and hailstorms, etc. are the other factors affecting the production and productivity of field and horticultural crops. Based on the improved weather forecasts of different periods and the existing crop conditions during the season, an expert group of multidisciplinary scientists prepared the agromet advisories and issued them to the farming community in time. These advisories help the farmers save inputs (seeds, fertilizers, plant protection chemicals, etc.) as well as the crop at critical stages (especially at the maturity stage). This improves the crop performance and enhances the farmer's income. Agromet advisories issued through the Agromet Advisory Service (AAS) are a part of Extension Agrometeorology and are defined as "Agrometeorological and agro-climatological information that can be directly applied to improve and/or protect the livelihoods of Indian farmers".

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

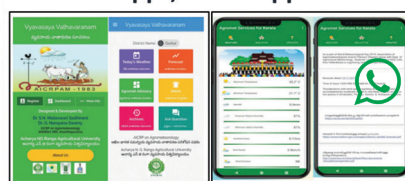


AICRPAM provided the weekly agromet advisories for major crops in advance with the forecast information received from IMD and by getting the information from AICRPAM centres across the country during *kharif* season and reported to officials of ICAR, Ministry of Agriculture and Farmers Welfare, and other stakeholders across the country. Apart from this, AICRPAM also provided weekly bulletins on the status of monsoon, *kharif* sowings progress, and Agromet advisories for excess/deficit rainfall districts.

AICRPAM is preparing and communicating the “Monthly Cabinet Report” on the agromet advisories to ICAR headquarters. AICRPAM has also published a technical bulletin on the heat wave of 2022, explaining the causes, impacts on agriculture and allied sectors, and adaptation strategies including the agromet advisories to be followed during the heat wave conditions. The Dynamic Crop Weather Calendar, a decision support system developed by AICRPAM has been validated for 92 districts in the country for major crops grown in the respective districts. A few centres have also developed Android Apps for disseminating the agromet advisories to the farmers in time. This is helping in saving the crops from damage as well as giving benefits to the farmers. AICRPAM centres are also conducting climate change awareness programs and explaining to the farmers that by following agromet advisories, farmers can increase resilience towards adverse weather /climate and save their crops from the adverse conditions influenced by climatic aberrations and extremes.



Android Apps, WhatsApp and SMS



8. Summary

Agroclimatic Characterization

Anand

- The dry days are decreasing during monsoon in most parts of the Gujrat state except part of South Gujarat (regions of the Dangs, Tapi and Valsad districts).
- Many isolated places in the state show a high mean length of dry spells, indicating mid-season and terminal drought conditions during recent past.
- It indicates that despite an extreme long dry spell recorded in recent years, the tendency of long dry spell is decreasing at most parts of the state.

Barapani

- The long-term climate data for Barapani (Umiyam), Meghalaya over a 39-year period from 1985 to 2023 presents noTable insights into the seasonal and annual climatic variations in the region.
- At Barapani, Monsoon is the dominant season in terms of rainfall, recording the highest average of 1538.7 mm (64% of total rainfall), indicating the crucial role of the monsoons in the region's hydrological cycle and agriculture. It is closely followed by the pre-monsoon and post-monsoon contributing about 20% and 14% of the total annual rainfall, respectively.
- Conversely, Winter experiences the lowest rainfall levels at 36.8 mm (only 1.53% of total rainfall), underscoring the season's arid conditions and implications for water resources.
- Trends in rainfall shows pre-monsoon showers are on the rise and annual rainfall shows a decline. These trends are non-significant.

Bhubaneswar

- Year wise onset was calculated over time series (1991-2023) for 314 blocks. After analysing the onset data, it was found that, Rasgovindapur block of Mayurbhanj has early onset on 09 June and it cover the entire state with its latest onset in Brahmagiri block of Puri district on 27 June.

- 12th June is the mean onset date for the state. Agroclimatic onset follows same pattern as meteorological onset of monsoon but with some lag period. Finally, it is advised that Agroclimatic onset can be considered for starting of kharif season.

Bangalore

- All districts of South Interior Karnataka (SIK) showed increasing trends except Chamarajanagar, where there was an observed 5.03 mm decrease per annum. The MMK test was able to identify increasing trends in rainfall of Mandya and Uttara Kannada, decreasing trends over Shivamogga district

Jorhat

- The drought analysis at different level of intensities revealed a statistically significant positive trend of SPEI-3 (0.05**) in Sivasagar district during pre-monsoon season; whereas substantial negative trend in SPEI-4 was observed in Tinsukia district during monsoon season. The results of SPEI-3 and SPEI-4 for the UBVZ as a whole depict a decreasing tendency in pre-monsoon and monsoon, though non-significant.
- A statistically significant increasing trend in annual rainfall was observed in Chirang (36.5 mm/year) and Hailakandi (19.6 mm/year), respectively; while a significant decreasing trend in Karbi Anglong (19.9 mm/year) and Nalbari (26.1 mm/year).
- Trend of maximum temperature showed a statistically significant trend in all the districts under consideration; while a non-significant increasing trend was observed for minimum temperature.

Kovilpatti

- All the coastal districts showed increasing trends of annual rainfall. The quantum of increase was higher in Chengalpattu, Mayiladuthurai, and Kanyakumari districts (depicted as Sen's slope 21.21, 15.71, and 11.86, respectively).
- Concerning northeast monsoon rainfall, Chengalpattu, Cuddalore, Kanyakumari, Mayiladuthurai, Pudukkottai, Ramanathapuram districts recorded an increasing trend while Nagapatinam, Tiruvarur and Thanjavur districts were observed with decreasing trend. The quantum of increase was higher in Mayiladuthurai district (depicted as Sen's slope 12.02)

Ludhiana

- Compared the long-term average (2007-08 to 2021-22) weekly meteorological parameters with the years of observed weather data during the harvest of higher yield of wheat crop and developed the crop stage-wise “Weekly Thumb Rules” for predicting the yield of wheat crop for three different locations of Punjab.
- The sowing to maturity period of wheat extends from October to April months. The developed ranges of meteorological parameters are conducive to high productivity of wheat crops and these can be used to develop the monthly term sheets for weather-based crop insurance in Punjab state.

Mohanpur

- significant increasing trend was observed in monsoon rainfall over Darjeeling (2.28 mm/year), Jhargram (1.49 mm/year), Kalimpong (8 mm/year) and North 24 Parganas (2.13 mm/year), whereas, Alipurduar (-3.84 mm/year), Dakshin Dinajpur (-3.9 mm/year) and Murshidabad (-1.1 mm/year) showed significant decreasing trend
- The end of June is best for rice transplanting in NAZ of WB if the onset of monsoon occurs in time (8th June) closely followed by the first fortnight of July.

Parbhani

- Increasing trend in the southwest monsoon seasonal rainfall in four districts of Marathwada viz. Chh. Sambhajinagar, Hingoli, Jalna & Nanded, whereas Parbhani, Beed, Dharashiv & Latur observed a 10.0 mm, 0.80 mm, 0.85 mm & 2.83 mm decrease per season, respectively.

Samastipur

- The length of the growing period (LGP) for coarse, medium, and fine-textured soils for each district of the state was worked out. Barring some districts of south Bihar, almost all districts registered a decrease in LGP. The districts of Zone I (North-West plains) of the Bihar state, recorded the highest decrease, ranging from 14 to 36 days.

Shimoga

- The annual and seasonal shifts in the rainfall pattern have been studied for the Shivamogga district from 1965 to 2023 daily rainfall data. The mean increased change in the rainfall pattern can be noticed from 2000 onwards for the annual, southwest, and

summer seasons. The rainfall shift was shown for the northeast season in the year 1990

Udaipur

- Long-term district-wise rainfall data (1991-2023) was used to analyze the shifts in rainfall of different districts over Rajasthan (Table 4.1). From the analysis, it was observed that the state mean rainfall increased from 575.3 mm during the period 1961-1990 to 626.52 mm during the period 1991-2023 which was 51.22 mm more.
- Rainy days were also increased from 27.9 days during 1961-1990 to 30.47 days during 1991-2023. Among the 33 districts, an increase in rainfall was observed in 28 districts and a decrease in rainfall was observed in 05 districts in the latest epoch. Pratapgarh district recorded 220 mm more rainfall over the previous duration (1961-1990). Whereas Baran district negative departure was observed in rainfall (-83.48 mm) followed by Sirohi (-25.9 mm).

Crop weather relationship studies

Kharif 2023

Rice

- Cluster analysis was performed using long-term field experiment data (2018-2023) for Sali rice at Jorhat to identify the optimum range of weather parameters for obtaining higher yield. A mean maximum and minimum temperature of 32-33 °C and 24-26 °C; 31-34 °C and 22-25 °C, and 28-32 °C and 22-24 °C, respectively during the vegetative, reproductive, and ripening phases of *Sali* rice were found to be in the optimal range for better yield.
- Phenophase-wise optimum weather requirement for achieving higher rice yield was identified for rice cultivar Jyothi using field experiment data and daily weather data during 2013-2022 at Thrissur.
- Among different cultivars, the RUE of Basmati 370 cultivar was the highest (11.4 kg MJ⁻¹), followed by Jammu Basmati-123 (10.8 kg MJ⁻¹) and Pusa 1121 (9.2 kg MJ⁻¹) at physiological maturity at Chatha during Kharif 2023.
- Mahamaya was transplanted on 15 June and recorded the highest RUE of 2.67 g/MJ, followed by MTU-1010, which was transplanted on 01 June 2023 at Raipur during Kharif 2023.

Maize

- At Kanpur, using the pooled data during 2017-2023, optimum temperature and rainfall thresholds for attaining three categories of maize yield were identified. The highest above-average yields (6653 kg ha⁻¹) were obtained when higher maximum temperatures were recorded during emergence (36.1 °C), knee high (33.9 °C), 50% silking (33.5 °C), milk (33.5 °C) and dough (33.3 °C) and higher minimum temperature during knee high (26.7 °C), 50% tasselling (25.9 °C), dough (25.2 °C) and maturity (24.2 °C)
- At Faizabad, crop sown on 5th July recorded a significantly higher yield (3310 kg ha⁻¹) followed by July 15th and then July 25th growing environment. Among the varieties, Kanchan was superior to the rest of the varieties in yield attributes and yield of maize.
- The yield attributes like grain yield, no. of grains, weight of grains, cob length, 100 grain weight (g), and cob perimeter, were found to be higher in maize cultivar JH 19014 as compared to other varieties (PMH-13 and PMH-14) in Ludhiana. Among the dates of sowing, higher values of these parameters were noticed in crop sown on 1st June as compared to other dates of sowing

Pearl millet

- At Anand, the pooled data analysis (2017-23) indicated that crops sown after the onset of monsoon produced significantly higher grain yield. GHB 744 recorded significantly high grain yield as compared to other cultivars in every individual year of experimentation as well as in pooled analysis, which was statistically at par with GHB 558 in all individual years, but not in year 2023 and pooled analysis.
- At Solapur, the Sustainable Yield Index (SYI) was used as an approach to evaluate the minimum yield likely to be achieved with changes in sowing windows. SYI of late sown bajra is higher (0.61) as compared to early (June & July) sown crop (i.e. 0.51 & 0.45 respectively).

Finger millet

- During Kharif 2023, crop sown during the second fortnight recorded the highest yield (5216 kg ha⁻¹) at Bangalore. Among different finger millet genotypes, KMR-316 recorded the highest yield (4835 kg ha⁻¹).

- At Ranichauri, the crop sown on 20 June 2023 recorded the highest yield (2108 kg ha⁻¹), and among the cultivars, PRM-2 (1669 kg ha⁻¹)

Pigeonpea

- The crop grown under protective irrigation gave a significantly higher seed yield (654 kg ha⁻¹) than rainfed crops (367 kg ha⁻¹) at Anantapur. The crop sown during the 2nd FN of July has given a significantly higher seed yield (619 kg/ha), than the crop sown during the 1st FN of July (598 kg ha⁻¹). Among the four varieties (LRG 41, PRG 176, LRG 52 and BRG 2) evaluated, irrespective of dates of sowing, PRG 176 and LRG 52 recorded higher seed yield than LRG 41 and BRG 2.
- At Bangalore, a higher yield (2428 kg ha⁻¹) was observed in the PRG-176 variety sown during the early season due to better utilization of resources by the variety

Groundnut

- At Anantapur, protective irrigated crop recorded a higher yield (mean yield of 1408 kg/ha) compared to rainfed (645 kg/ha) under all sowing windows. Among the cultivars, K 1812 recorded the highest yield under both rainfed as well as protective irrigated conditions.
- Among the three varieties tested, Kadri Lepakshi recorded significantly higher pod and haulm yield (3454.2 and 12066.4 kg ha⁻¹, respectively) compared to KCG-6 (1854.7 and 7942.1 kg ha⁻¹ pod and haulm yield, respectively) and K-6 (1762.8 and 5797.5 kg ha⁻¹ pod and haulm yield, respectively) at Bangalore. Interaction of variety and sowing date was non-significant concerning pod yield and was significant for haulm yield.

Soybean

- At Parbhani, the relationship between the percent available soil moisture (PASM) and yield in soybean at different phenophase & sowing of the environment was studied using experiment data from 2013-22. The crop yield recorded at 25 PASM was only 200-405 kg ha⁻¹ & PASM >75% to 1800-2100 kg ha⁻¹ of soybean yield.

Cotton

- At Akola, it is recommended that for a higher yield of rainfed cotton, the sowing should be done after the onset of monsoon with receipt of adequate rainfall (75 mm

to 100 mm) over the Vidarbha region. Sowing from 10 to 15 July, resulting in yield reduction to the extent of 24 %.

Rabi 2023-24

Wheat

- In Punjab, higher wheat productivity is expected if the maximum temperature remains within 15-22 °C and 21-28 °C and the minimum temperature remains within 4-11 and 7-13 °C during vegetative and grain development stages, respectively. The higher temperature during the vegetative stage results in poor tillering and early heading. The higher temperature during grain grain-filling stage leads to premature ripening and a reduction in grain weight.

Rabi maize

- Linear models for predicting biomass based on intercepted PAR were developed at Samastipur. Among all dates of sowing, the highest slope of 4.48 was obtained for the relation between biomass and intercepted PAR for the crop sown on 01 November, followed by the crop sown on 10 November (3.81)

Barley

- A pooled data analysis (2016 to 2023) at Hisar showed that the grain yield of barley had a negative significant correlation with minimum temperature, wind speed, and BSH, whereas, the straw yield showed a negative significant correlation with morning relative humidity.

Rabi sorghum

- Sorghum variety CSV 20 recorded significantly higher plant height (263.9 cm), dry matter production (11015 kg ha⁻¹), number of seeds per panicle (942 no./panicle), 1000 seed weight (15.7 g), grain yield (1470 kg ha⁻¹) and stalk yield (9300 kg ha⁻¹) due to lesser quantity of rainfall during flowering stages leads to better pollination and fertilization thereby grain yield at Kovilpatti. The crop sown during the 39 SMW recorded a higher grain yield of 1845 kg ha⁻¹.
- At Solapur, among the phenophases, flag leaf to 50% flowering recorded the highest RUE. Yashoda sown during 40 SMW recorded the highest RUE of 2.88 g MJ⁻¹ during flag leaf to 50% flowering

Chickpea

- Significantly higher grain yield was recorded when sown on 25 November (1439 kg ha⁻¹), while the lowest grain yield was produced under normal sowing (10 December), the ultimate reason being thermal stress at Raipur. The highest grain yield was recorded by zonal check JG-14 variety (1323 kg ha⁻¹) followed by Vaibhav (1315 kg ha⁻¹).
- At Solapur, a significantly higher biological yield of 2785 kg ha⁻¹ was obtained from early sowing.

Green gram

- The optimum range of weather parameters was identified for achieving higher pod yields using pooled experimental data from 2018-23.
- A pooled data analysis (2017-2021) at Mohanpur revealed that, diurnal temperature variation was the most important weather parameter in green gram performance followed by maximum and minimum temperature. The threshold value of 13 °C and 12 °C for diurnal variation of temperature and 32 °C for maximum temperature was obtained from the decision tree.

Mustard

- The phase-wise average weather parameters were correlated with the yield of mustard using seven years' rabi season (2017-18 to 2023-24) data at Anand. Maximum temperature and morning relative humidity prevailed during the early growth stages (up to flowering initiation) of mustard and had a strong positive association with productivity.
- At Faizabad, Maximum yield was recorded when the crop was sown on 25 Oct. which was significantly superior over 04 Nov. and 14 Nov. Higher yield was recorded with NDR-8501 variety which was significant over Jyoti while at par with variety Bio-902 of mustard variety.
- At Udaipur, the highest quantity of seed yield (1599 kg ha⁻¹) and harvest index (22.87 %) was obtained under the 2nd sowing environment *i.e.*, 16 October which was statistically equivalent to the 1st date of sowing (01 Oct.) but significantly superior over the rest date of sowing environments.

Horticultural crops

- A correlation study was conducted to study the relation between growth, yield parameters, and accumulated weather parameters during the reproductive cycles (Oct-June) from 2018 to 2021 in the Mallika variety of Mango at Bangalore centre. The yield of mango had a significant positive correlation with reproductive factors like the number of panicles per tree, number of hermaphrodite flowers per panicle, fruit retention (%) at maturity
- Weather-based statistical models were developed for forecasting 50 per cent flowering in mango cv. Alphonso using long-term data (1997-98 to 2019-20) and validated by Dapoli centre.
- Mango yield prediction equations were developed for Bombai variety at Mohanpur using meteorological data collected during 2014-2023.
- The correlation studies in pepper with meteorological parameters at Thrissur indicated a strong significant positive correlation between rainfall and duration of spike enlargement and a significant negative correlation between maximum temperature and duration between maturity and harvest.

Crop Growth Simulation Modeling

Anand

- The potential impact of climate change on pearl millet cultivar GHB 744 using a calibrated CERES-Millet model for Gujarat state was studied. The model simulates a relatively high yield compared to those observed in the field experiments. While the yield simulations under SSP245 and SSP585 are close to the mean yield observed in experiments
- Though, both scenario yield losses are significant compared to baseline period. In near future (years 2024-2040), under SSP585 model predicts relatively higher yield compared to SSP245, might be due to better suitability of over large area by change in rainfall pattern.
- Production performances of pearl millet crop under 12 different agronomic adaptation options in cultivation were simulated by incorporating change in standard practices such as cultivar type, sowing time, nitrogen application, and irrigations under SSP245 scenario.

Bangalore

- Seasonal analysis of pigeon pea yield variability under three sowing environments using the calibrated DSSAT model was studied.
- It was observed that, the better agreement between observed and simulated yield by the model for the two varieties with R^2 of 0.7. This modest performance of the model is attributed to limited datapoints on observed and simulated yield.

Bhubaneswar

- Future scenario of summer rice (cv. Sahabhazi Dhan) yield under projected seasonal climate change scenario was studied.
- Predicted yield of Sahabhazi Dhan under the projected scenarios RCP 2.6, 4.5, 6.0 and 8.5 for the years 2040, 2060 and 2080 showed that, for the year 2040, the rice yields showed a likely decrease of 10.77%, 8.56%, 6.31%, and 16.78% respectively under Jan 15 sown environment.
- The reason behind decrease of yields is likely increase in temperature beyond the optimum temperature in the study area with an average of 30-35 °C in RCP 4.5 and RCP 8.5 scenarios. As observed, increase in 1 °C will reduce the rice yields by 6-11%. Due to increase in minimum temperature over the years, the yield is affected as it effects the respiration rate and thus reduce yield.

Jorhat

- Impact of climate change on yield of Sali rice (cv. Mahsuri) was studied based upon the RCP scenario 4.5 and 8.5 for the years 2025 and 2050 for five different districts viz., Golaghat, Jorhat, Sivasagar, Dibrugarh and Tinsukia of Upper Brahmaputra Valley Zone (UBVZ) of Assam
- Yield potential of Mahsuri in Golaghat, Jorhat, Dibrugarh and Tinsukia district were found to be less vulnerable under RCP 4.5 during early and mid-part of the century when transplanted Second fortnight of June. Overall, yield potential of Mahsuri in Dibrugarh and Tinsukia district were found to be less vulnerable under RCP 8.5 when transplanted within first fortnight of July

Ludhiana

- Optimizing transplanting window for higher productivity of rice cultivars in Punjab was studied using CERES-Rice model

- The simulations revealed that 24th to 30th June for PR 126 and 20th to 26th June for PR 127 as the optimum transplanting window with grain yield for PR 126 ranging between 8425-8473 kg/ha and for PR 127 between 8298-8356 kg/ha.
- The minimum yield of both cultivars was observed on 7th June i.e. early transplanted rice with grain yield being 6703 kg/ha for PR 126 and 6865 kg/ha for PR 127.

Mohanpur

- Impact of climate change on Kharif rice was studied at Mohanpur using the DSSAT cropping systems simulation model. It was observed from the simulations that the physiological maturity may be accelerated by 8-12 days during mid and end centuries in Old and New Alluvial Zones under moderate emission scenario.
- Under SSP5-8.5, an extreme projection scenario, 11-15 days and 9-10 days of advancements may be observed from Old and Alluvial Zones respectively to enter maturity phase by *Kharif* rice.
- Coastal Saline Zone, which is detected with least changes in temperature, may be experience less reduction in growing period. The maturity phase may be shortened by 4-8 days in this location across different projection scenarios.

Weather Effects on Pests and Diseases

- Anand Centre developed a SARIMA time series model for forecasting mustard aphids. The model indicated the AR.L1 (previous season's aphid population) with a positive value (0.613) suggests a positive influence of the previous season population on the current season's population, The sigma² (0.0749) represents the estimated variance of the error term in the model. The Root Mean Squared Error (RMSE) of 2018-2021 is 0.18. It suggests the model has the potential to forecast one step ahead of aphid population trends with some accuracy.
- Weather-based prediction model for soybean crop lepidopteran pests developed using five-year pest and weather data (2018 to 2023) at Akola centre. The favourable weather conditions like T_{min} (21.6 to 22.3 °C), sunshine hours (2.8 to 3.5 hours), RHI (87 to 88%), and RHII (70 to 72%), were found to be congenial pest buildup.
- At Jorhat centre, the principal component analysis of weather and pest and disease in Sali rice revealed that a T_{max} (34.0 °C) and T_{min} (25.0 °C), with RHI (83%) were found favourable for the occurrence of brown spot disease, leaf folder, and stem borer.

In the case of Kharif green gram, Tmax (25.0-30.0 °C), Tmin(11.0-20.0 °C), and RHI (78-90%) and intermittent light rainfall was found favourable for Cercospora leaf spot disease and spread of aphid population.

- The Poisson regression model developed by Samastipur Centre for Fall armyworm in kharif maize, the model revealed a significant relationship between Tmax, rainfall, and RHII with pest infestation. The data shows that a 1 °C increase in maximum temperature contributed to the increase of 19.6 % increase in % infestation, while rainfall decreased the infestation. RHII had a significant positive influence on pest build-up. while rainfall showed a negative influence
- The pest-weather relationship has been established for mustard at Udaipur by using six-year weekly pest-weather data (2017-2023). A linear regression model revealed that the model performance was found relatively better in the preceding week ($R^2=0.56$) than in the current week ($R^2=0.45$).
- Long-term field experiments were carried out at Ludhiana centre to monitor the population of citrus psylla, *Diaphorina citri* K in Kinnow Mandarin for twelve years (2007-08 to 2019-20) and a weather-based prediction model was developed and validated. The model revealed that the mean temperature (both maximum and minimum), bright sunshine hours, RHI, and THI (temperature-humidity index) on psylla count were found to be statistically significant. The four-year (2016, 2017, 2018, 2019) validation results revealed that a different level of variability was explained between the psylla population and weather conditions (52%, 38%, 52%, and 85%, respectively).
- The correlation analysis of four-year (2018-2021) data of weather and mango pests at the Bangalore centre revealed that a significant positive correlation was observed between hopper population and sunshine hours (0.42** and 0.43** in A1 and A2, respectively) and a negative correlation with other weather parameters. Fruit fly population had a significant positive correlation with Tmax (0.36** and 0.69** in A1 and A2, respectively), and Tmin (0.50** and 0.45** in A1 and A2, respectively).
- The multiple regression analysis revealed that there was 44% variability explained with aphids, 60% with jassids, 48% with whiteflies, and 60% with fruit and shoot borer. Similarly, 63% variability was explained with okra yellow vein mosaic (OYVMV) disease and 74% with Cercospora disease.

9. Products and Technologies Developed

Thrissur

Crop-weather calendar for rice

Crop-weather calendar for rice was prepared for Jyothi and Manu Ratna cultivars (Figs 9.1). The climatic normal for rice was observed between the 20 - 36 SMW, covering the entire growth phases from sowing to harvesting shown in the upper portion of the crop weather calendar. The peak of normal weekly rainfall was 179.3 mm recorded in the 24 SMW. Meanwhile, the highest normal maximum temperature (33.2 °C) occurred in the 20 SMW, and the lowest minimum temperature (22.8°C) was noted during the 29 SMW. Forenoon relative humidity peaked at 95.0 % and afternoon relative humidity at 81.0 % in the 29 and 28 SMW, while the lowest mean relative humidity of 75.0 % was observed in the 20 SMW.

CROP WEATHER CALENDAR																		
Crop: Virippu Rice			Variety: Jyothi				Duration : Short Duration (110-115 days)						District: Thrissur			State: Kerala		
Climate Normals	Month	May		June				July					August			Septem		
	SMW	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	
	Tmax(°C)	33.2	33.1	32.2	30.9	30.0	30.0	29.8	29.9	29.4	29.3	29.6	29.7	29.4	29.8	30.2	30.2	
	Tmin(°C)	24.5	24.5	24.1	23.5	23.2	23.1	23.0	23.6	22.8	23.0	23.2	23.0	23.3	23.3	23.3	23.3	
	Tmean(°C)	28.9	28.8	28.2	27.2	26.6	26.6	26.4	26.5	26.5	26.0	26.3	26.5	26.2	26.6	26.7	26.8	
	RHI(%)	88	89	90	92	93	94	94	94	94	95	94	94	95	94	94	94	
	RHII(%)	63	63	69	73	77	77	77	78	81	78	76	76	76	74	72	72	
	Rhmean(%)	75	76	79	83	85	85	85	86	88	87	85	85	85	84	83	83	
	WS(kmph)	3.6	3.6	3.6	3.4	3.5	3.3	3.2	3.2	3.1	3.1	3.1	3.2	3.0	3.1	3.1	3.1	
	BSS(hrs)	6.0	6.1	5.3	3.8	3.0	3.2	3.2	3.3	2.6	2.5	3.0	3.3	3.2	3.9	4.8	4.7	
SRAD(MJ/m ²)	9.7	9.7	9.5	9.0	8.8	8.8	8.9	8.9	8.7	8.7	8.8	9.0	8.9	9.2	9.5	9.5		
RF(mm)	51.9	49.5	86.5	139.2	179.3	157.1	168.1	130.4	159.4	164.0	121.0	128.2	131.5	108.8	71.1	79.4		
Evp(mm)	28.9	27.4	25.5	21.2	19.4	20.3	19.7	20.2	19.4	17.9	20.3	20.0	19.6	20.9	22.3	22.9		
Phenophase																		
	Emergence	Transplanting	Active tillering				Panicle initiation		Booting		Heading		50%flowering	Physiological maturi				
Duration	5	12 to 13		26 to 27				8 to 10		21 to 23		9 to 11		4 to 6	28 to 33			
wise weather for better yield	Tmax(°C)	29-32		29-31		29-31		29-31		30-31		30-32		29-32		31-32		
	Tmin(°C)	24-25		23-24		22-24		22-24		22-24		22-24		22-24		22-24		
	BSS(hrs)	2.0-3.0		2.0-3.0		1.6 - 3.9		0.6 - 5.0		2.2 - 5.5		2.2 - 6.3		2.0 - 6.9		3.7 - 6.0		
	RF(mm)	60 - 180		337 - 800		250 - 725		100 - 295		135 - 425		50 - 140		32 - 79		170 - 485		
Congenial weather for pest /disease	Leaf Roller (Tmax :31-32 °C % and RHmean:88-92%)																	
	Stem borer (Tmax :30-31 °C % and RHmean:54-82%)																	
	Rice bug (Tmax :32-34 °C % and RHmean:70-72%)																	
	Bacterial Leaf Blight (Tmax :29-33 °C % and RHI:81-97%)																	
	Sheath Blight (Tmax :31-34 °C % and RHII:70-83%)																	
	Leaf Blast (Tmax :25-28 °C % and RHI:92-96%)																	

Fig. 9.1 Crop weather calendar developed for rice cultivar Jyothi by Thrissur centre

Mohanpur

DSS/ Software developed

A DSS platform has been devised to reduce the input cost of plant protection practices and promote proper operational forecasting of plant protection materials against yellow stem borer in kharif rice. Pheromone traps catch and prevalent weather was recorded in Kharif rice during 2016, 2017, 2018, 2019, 2021, and 2022. An Artificial neural network model was trained through the ‘nnet’ function in the caret package in Rv4.1.2. A singular hidden neuron model was first developed to identify the perfect decay for the input variables through ‘expand.grid’ function ranging from 0.001 to 1 by 0.001. Finally, a 4-68-1 ANN model was developed to establish the pest-weather relationship.

It was found that the ideal maximum and minimum temperature range for the rice stem borer outbreak was 28-30 °C and >17 °C, respectively and morning and afternoon relative humidity of 92-97% and 50-57%, respectively are favourable for rice stem borer outbreaks. With this informed decision, a DSS platform was developed to inform the end users. The real-time forecasted weather data of any area can be obtained through API directly from IMD so that scrapping of recent forecasts can be automated with the help of the “rvest” package in R. Otherwise one can copy the data from the IMD website and paste it in Excel file and then load it in R.

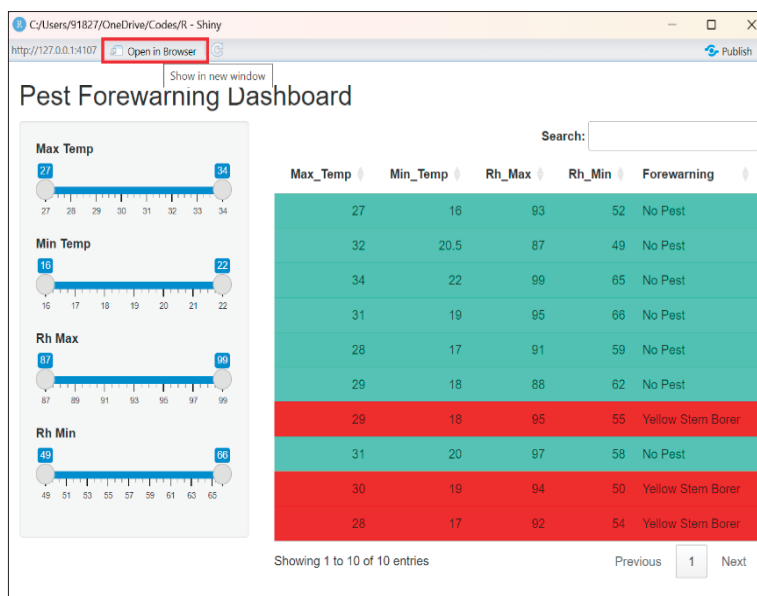


Fig. 9.3 The DSS for forewarning yellow stem borer in kharif rice developed by Mohanpur centre

10. Recommendations by AICRPAM Centres

(Included in the Package of Practices / Research Advisory
Meetings of SAUs during 2023-24)

Akola

Sowing time recommendation for Cotton for Vidarbha region, Maharashtra

Recommendation: For a higher yield of rainfed cotton, the sowing should be done after the onset of monsoon with receipt of adequate rainfall (75 mm to 100 mm) over the Vidarbha region. Sowing during 10 to 15 July, resulting in yield reduction to the extent of 24 %.

Source: Accepted in the Maharashtra Agricultural University 52nd Joint Agricultural Research and Development Committee – 2024

Ludhiana

Climatic requirements for higher wheat productivity in Punjab

Recommendation: In Punjab, higher wheat productivity can be expected if the maximum temperature remains within 15-22 and 21-28 °C and the minimum temperature remains within 4-11 and 7-13 °C during vegetative and grain development, respectively. The higher temperature during the vegetative stage results in poor tillering and early heading. The higher temperature during the grain grain-filling stage leads to premature ripening and a reduction in grain weight.

Source: Included in the package of practices, Punjab Agricultural University

Solapur

Prediction of occurrence of whitefly in Brinjal for Western Maharashtra

Recommendation: The regression equation based on weather parameters (one week prior) for forewarning whitefly occurrence in Brinjal for Western Maharashtra.

Brinjal Whitefly/leaf/plant = $-26.313 + (1.042 \times T_{\max}) - (0.871 \times WS) + (0.04 \times E_{\text{pan}}) + (0.348 \times BSS)$

Where, Whitefly = Av. Number of whitefly/leaf/plant (in equation); $T_{\max}$ = Maximum temperature (25.0-32.4 °C); WS = Wind velocity (0.8-4.0 Kmph); E_{pan} = Pan evaporation (4.1-5.4 mm); BSS = Bright sunshine hours (3.3-9.3 hrs)

Source: Included in the Maharashtra Agricultural Universities 52nd Joint Agreso Meet – 2024 held at Dr PDKV Akola during 07-09 June 2024.

Prediction of occurrence of Thrips in Chilli

Recommendation: The regression equation based on weather parameters (one week prior) for forewarning thrips occurrence on Chilli is recommended for Western Maharashtra.

Chilli thrips/leaf/plant = $-34.757 + (1.182 \times T_{\max}) - (1.255 \times T_{\min}) + (0.426 \times RH-I) + (0.012 \times RH-II) - (0.159 \times WS) - (0.707 \times BSS)$

Where, Thrips = Av. number of thrips/leaf/plant (in equation); $T_{\max}$ = Maximum temperature (27.6-32.4 °C); $T_{\min}$ = Minimum temperature (8.6-22.7 °C); RH-I = Relative humidity morning (56.0-81.6 %); RH-II = Relative humidity evening (28.0-62.4 %); WS = Wind speed (0.4-4.5 Kmph); BSS = Bright sunshine hours (3.5-9.5 hrs/day)

The linear regression model was found precise for the prediction of incidence and further spread of chilli thrips. Thus, this model can be utilized in Agro-Advisories for thrips prediction on chilli. However, the linear regression equation confirms the validity of the model in the prediction of thrips on chilli and estimating the per cent thrips index.

Source: Included in the Maharashtra Agricultural Universities 52nd Joint Agreso Meet – 2024 held at Dr PDKV Akola during 07-09 June 2024.

Parbhani

Crop Coefficient of Soybean (*Glycine max L. Merrill*) cv. MAUS-71 for Marathwada

Recommendation: Crop coefficient (Kc) values of 0.64, 1.31, and 0.66 for the initial stage (1-28 days), mid stage (29-84 days), and end stage (85-110 days) respectively are recommended for estimating the crop water requirement of soybean crops for Marathwada.

Source: Accepted in the Maharashtra Agricultural University 51st Joint Agricultural Research and Development Committee – 2023 held at MPKV, Rahuri

Crop Coefficient of Bt. Cotton hybrid (*Gossypium hirsutum L.*) for Marathwada

Recommendation: Crop coefficient (Kc) values 0.51, 1.24 & 0.95 for initial (1-30 days), mid stage (31-111 days) and end stage (112-164 days) respectively are recommended for estimation of crop water requirement of Bt. cotton crop for Maharashtra state

Source: Accepted in the Maharashtra Agricultural University 51nd Joint Agricultural Research and Development Committee – 2023 held at MPKV, Rahuri

Critical Growth Stages of Soybean for Water Stress-induced yield reduction in Maharashtra

Recommendation: If the soil moisture is reduced due to a dry spell in the following stage of the soybean crop, the yield of the soybean crop decreases as follows:

1. Vegetative stage: 39.1%
2. Flowering stage: 55.4%
3. Pod formation stage: 45.1%
4. Pod development stage: 23.0%
5. Vegetative stage to Flowering stage: 62.8%
6. Flowering stage to pod formation stage: 67.3%
7. Pod formation to pod development stage: 59.1%

Source: Included in the Maharashtra Agricultural Universities 52nd Joint Agresco Meeting – 2024 held at Dr PDKV Akola during 07-09 June 2024

Bhubaneswar

Rice transplanting date recommendation under temperature stress conditions

Recommendation: Cultivation of rice cultivars *Mandakini* and *Bina Dhan II* are suitable for late planting conditions on or beyond 31st January up to 28th February during summer in E&SE Coastal Plain Agro-climatic Zone of Odisha. Productivity of cv *Mandakini* was higher by 10%, 13.5%, and 15.4% respectively over cultivars viz. *Sahabhagi Dhan*, *Naveen* and *MTU 1001* under transplanting on or beyond 31st January up to 28th February

Source: State Level Research & Education Council (SLREC) Meeting 2024, OUAT

Transplanting of kharif rice in Bhubaneswar condition

Recommendation: Kharif rice can be transplanted up to 2nd week of August with no significant reduction in yield

Source: State Level Research & Education Council (SLREC) Meeting 2024, OUAT.

Dapoli

Weather based prediction model for vegetative flush in in Alphonso mango

Recommendation: It is recommended to use the following weather-based regression model to predict vegetative flush emergence in Alphonso mangoes before three or four weeks using seven days' average temperature from the second fortnight of September (38th Met week) and onwards in orchards managed using the recommended technology given by Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, under Konkan agro-climatic conditions.

Alphonso mango vegetative flush emergence (3 weeks before)

$$= 31.600 + 0.757 * T_{\max} - 0.551 * T_{\min} \quad (R^2 = 0.75^{**})$$

Alphonso mango vegetative flush emergence (4 weeks before)

$$= 26.848 + 1.110 * T_{\max} - 0.768 * T_{\min} \quad (R^2 = 0.64^{**})$$

Source: Accepted in the Maharashtra Agricultural University 51st Joint Agricultural Research and Development Committee – 2023

Sowing time of different rice varieties (early duration) for four districts of Maharashtra

District	Varieties			Transplanting date
	Early	Mid-late	Late	
Palghar	Karjat-7, Karjat-3, Ratnagiri-1 and Phondaghat-1			24-25 SMW (11-24 June)
Sindhudurg	Karjat-3 and Phondaghat-1	Palghar-1, Karjat-5 and Karjat-9	Karjat-2 and Ratnagiri-8	23 SMW (04-10 June)
Ratnagiri	Ratnagiri-1*	Karjat-5**	Ratnagiri-3 and Ratnagiri-8*	24 SMW (11-17 June)* 23 SMW (04-10 June)**
Raigad	Karjat-7, Karjat-3 and Phondaghat-1*	Ratnagiri-6, Ratnagiri-7, Karjat-5 and Karjat-9**	Ratnagiri-8*	24 SMW (11-17 June)* 23 SMW (04-10 June)**

*Corresponding transplanting time

Source: Accepted in the Maharashtra Agricultural University 51nd Joint Agricultural Research and Development Committee – 2023

11. Events Organized by PC Unit

The coordinating unit of AICRP on Agrometeorology has conducted several programs during 2023-24 for the cause of strengthening research and capacity building in the field of agrometeorology.

1. Hydromet and Early Warning Joint Learning Exercise

A delegation of 21 officials from the World Bank and the governments of Bangladesh and Sri Lanka visited ICAR-CRIDA on 02 May 2023. The exercise was to enhance the operational knowledge of participants through the workshop and visits to institutions and practice sites in India. ICAR-CRIDA was identified as one of the partner institutes for the theme ‘Agrometeorology’. Ms. Arti Belle, Senior disaster risk management specialist, at the World Bank detailed the inception of the joint learning exercise and the purpose of the study visit.



2. Brainstorming Workshop

ICAR-CRIDA Hyderabad and Association of Agrometeorologists (AAM), Anand organized a brainstorming workshop on ‘Reorienting Education and Research in Agricultural Meteorology for Efficient Agromet Advisory Services and Climate Resilient Agriculture’ at ICAR-CRIDA, Hyderabad during 28-29 September 2023. The workshop was attended by around 50 participants from various ICAR institutes, State Agricultural

Universities (SAUs), IMD and other institutes across the country. The workshop consisted of three technical sessions viz., Prioritizing Research Areas in Agrometeorology, Reorienting Postgraduate Teaching in Agrometeorology and Re-positioning the Role of Agrometeorology in Undergraduate Teaching.

The house discussed various aspects of future thrust areas in agromet research, and desirable changes in PG and UG teaching. On the second day, the rapporteurs of the first-day sessions presented the recommendations emanating from the first day's brainstorming followed by deliberations.



3. AICRPAM WGM at Palampur

The Working Group Meeting of AICRP on Agrometeorology (AICRPAM) was held at CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur (HP), from 20-21 Nov 2023 at CSK HPKV, Palampur to evaluate the research progress. Dr. S.K. Chaudhari, DDG (NRM) Dr. Rajbir Singh, ADG (AAF & CC), Dr. V.K. Singh, Director, ICAR-CRIDA, Dr. D.K. Vatsa, Hon'ble Vice Chancellor, CSK HPKV and Scientists of AICRPAM attended the working group meeting. The meeting consisted of seven technical sessions, including inaugural and plenary sessions, in which the cooperating centres made presentations of research achievements. The progress was evaluated by four experts namely, Dr. Y.S. Ramakrishna, Dr. V.U.M. Rao, Dr S.C. Bhan, and Dr G.G.S.N Rao.



4. ICAR Sponsored 21-Day Winter School on “Application of Weather Information for Climate Resilient Farming”

An ICAR-sponsored 21-day winter school training “Application of Weather Information for Climate Resilient Farming” was successfully organized at ICAR-CRIDA from 23 Jan to 12 Feb 2024. 24 participants of various disciplines from ICAR Institutes, SAUs, and KVK representing 11 states of the country attended the winter school. It consisted of 70



sessions of lectures, hands-on sessions, demonstrations, and visits. The winter school was organized by Dr Santanu Kumar Bal as Course Director, Dr AVM Subba Rao, Dr MA Sarath Chandran, and Dr Timmanna as Course Coordinators.

5. VIII Capacity Building Program of AICRP on Agrometeorology (AICRPAM)

The VIII capacity building program of AICRPAM on ‘Application of machine learning in agricultural meteorology’ was organized at ICAR-CRIDA from 24 Feb to 03 Mar 2024. Thirty-two participants from the cooperating centers of AICRPAM attended the program. Nine experts in agricultural statistics representing ICAR, SAUs, North Eastern Hill University, CWRDM, etc. imparted both theoretical and practical sessions of machine learning through the R program. The topics included statistical techniques for climate change studies, spatiotemporal time series modeling, ARCH family of models, factor analysis, canonical correlation, classification and regression trees, principal component analysis, analysis of multi-location experiment data, etc. The capacity-building program was organized by Dr Santanu Kumar Bal (Program Director) and Drs AVM Subba Rao, MA Sarath Chandran, and Timmanna (Program Coordinators) for the program.



12. MSc and PhD Work Supported by AICRPAM during 2023-24

Scientists from the PC unit and AICRPAM centres are associated with undergraduate and postgraduate teaching in State/Central Agricultural Universities and ICAR institutes. They are also guiding M.Sc. and Ph.D. students in the discipline of Agricultural Meteorology/Physics.

Table 12.1 List of M.Sc. and Ph.D. students' research work supported by AICRPAM and completed during 2023-24

S. No.	Centre	No. of MSc students	No. of PhD students
1	Akola	02	-
2	Anand	-	-
3	Anantapur	-	-
4	Bangalore	01	01
5	Bhubaneswar	02	-
6	Chatha	-	01
7	Dapoli	-	-
8	Faizabad	04	02
9	Hisar	02	01
10	Jabalpur	02	-
11	Jorhat	01	-
12	Kanpur	02	-
13	Kovilpatti	-	-
14	Ludhiana	02	01
15	Mohanpur	-	02
16	Palampur	02	-
17	Parbhani	01	-
18	Raipur	05	-
19	Ranchi	04	-
20	Ranichauri	01	-
21	Samastipur	01	-
22	Solapur	01	04
23	Thrissur	01	-
24	Udaipur	01	-
25	Vijayapura	-	-
26	Barapani	-	-
27	Jhansi	-	-
28	Shimoga	1	-
29	Srinagar	04	-
Total		40	12

13. Research Publications 2023-24

Summary of Publications

S. No.	Centre	Research Papers with NAAS rating		Book	Book chapter	Technical Bulletin/ Manual	Popular Article
		> 6.0	< 6.0				
1	PC Unit	4	-	-	1	1	1
2	Akola	1	1	-	-	-	4
3	Anand	2	2	-	-	-	-
4	Anantapur	2	4	-	-	1	1
5	Bangalore	1	5	-	-	-	4
6	Bhubaneswar	-	3	1	-	1	-
7	Chatha	1	3	-	-	-	-
8	Dapoli	-	1	-	-	-	-
9	Faizabad	-	5	1	-	-	-
10	Hisar	-	7	-	1	-	1
11	Jabalpur	-	6	-	-	-	-
12	Jorhat	2	3	-	1	-	-
13	Kanpur	-	3	-	-	-	1
14	Kovilpatti	2	7	-	2	1	5
15	Ludhiana	8	12	-	-	1	1
16	Mohanpur	4	4	-	1	-	3
17	Palampur	3	4	1	6	1-	9-
18	Parbhani	3	4	-	-	-	-
19	Raipur	1	4	-	-	-	-
20	Ranichauri	-	1	-	-	-	-
21	Samastipur	3	2	3	-	-	-
22	Solapur	-	6	-	-	-	-
23	Shimoga	4	2	-	-	-	-
24	Srinagar	2	4	2	2	1	1
25	Thrissur	1	12	-	-	1	-
26	Udaipur	-	3	-	-	-	-
Total		45	103	8	11	8	31

PC Unit, ICAR-CRIDA, Hyderabad

Paper in Peer-Reviewed Journals

Bal, S.K., Shivaramu, H.S., Vijaya Kumar, P., Lingaraj, H., Sandeep, V.M., Subba Rao, A.V.M., Sarath Chandran, M.A., Manikandan, N., Thimmegowda, M.N., Manjunatha, M.H., Malleswari, S.N., Tupe, A., Sudhakar, G., Dakhore, K.K., Subbulakshmi, S., Minhas, P.S., Singh, V.K., and Singh, R. (2023) Re-evaluating soil moisture-based drought criteria for rainfed crops in peninsular India. *Frontiers in Environmental Science*, (12) 1319912

Bal, S.K., Sattar, A., Nidhi, Chandran, M.A.S., Subba Rao, A.V.M., Manikandan, N., Banerjee, S., Choudhary, J.L., More, V.G., Singh, C.B., Sandhu, S.S. and Singh, V.K. (2023). Critical weather limits for paddy rice under diverse ecosystems of India. *Frontiers in Plant Science*. 14:1226064. doi: 10.3389/fpls.2023.1226064.

Bal, S.K., Pramod, V.P., Sandeep, V.M., Manikandan, N., Sarath Chandran, M.A., Subba Rao, A.V.M., Vijayakumar, P. and Singh, V.K. (2023). Identifying appropriate prediction models for estimating hourly temperature over diverse agro-ecological regions of India. *Scientific Reports*, 13:7789. <https://doi.org/10.1038/s41598-023-34194-9>

Bal, S.K., Sarath Chandran, M.A., Subba Rao, A.V.M., Manikandan, N., Ramana Rao, B.V. (2023). Coordinated research on agrometeorology: India perspective. *J of Agrometeorology*. 25(2): 215-223.

Book chapter

Bal, S.K., Banerjee, S., Saha, S., Chakraborty, D., Sarath Chandran, M.A. (2023). Climate. In: Ghosh, P.K., Das, A., Saxena, R., Banerjee, K., Kar, G., Vijay, D. (eds) *Trajectory of 75 years of Indian Agriculture after Independence*. Springer, Singapore. https://doi.org/10.1007/978-981-19-7997-2_20

Training Manuals

Bal, S.K., Subba Rao, A.V.M., Chandran, M.A.S. and Timmanna. 2024. Training manual - Application of Weather Information for Climate Resilient Farming. Central Research Institute for Dryland Agriculture, Hyderabad- 500 059. 287p.

Popular articles

Bal, S.K., Manikandan, N., Subba Rao, A.V.M., Sarath Chandran, M.A. and Singh, V.K. (2022). Agroclimatic approach for improving sowing decisions. *Indian Farming*, 72(11): 05-07.

Publications by AICRPAM Centres

Akola

Paper in Peer-Reviewed Journals

Gabhane, V.V., Pratik Ramteke, Ravindra Chary, G., Patode, R.S., Ganvir, M.M., Anita Chorey and Tupe, A. R. (2023). Effects of long-term nutrient management in semi-arid vertisols on soil quality and crop productivity in a cotton-greengram intercropping system. *Field Crops Research*, (303): 109115

Popular articles

Patode, R.S., Gabhane, V.V., Chorey, A.B., Ganvir, M.M., Tupe, A.R. and Mali, R.S. (2023). Farm pond: A sustainable source of income for farmers. *Agritech Today*, 01, pp. 115-119.

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Booklet

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14. Staff position at cooperating centers during 2023-24

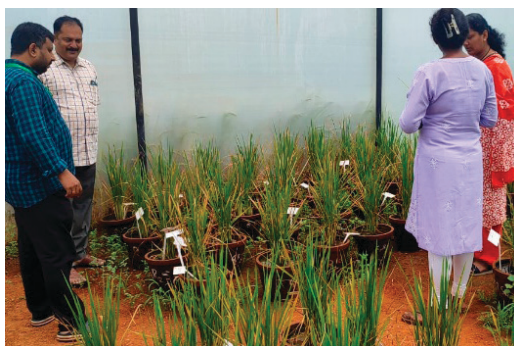
(AICRP on Agrometeorology)

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	V	F
Jabalpur	F	F	V	V
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	V	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	V
Post Filled	21	09	15	16
Post Sanctioned	25	12	25	25

AICRPAM – Field activities



AICRPAM – Field activities





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