AICRPAM

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ICAR

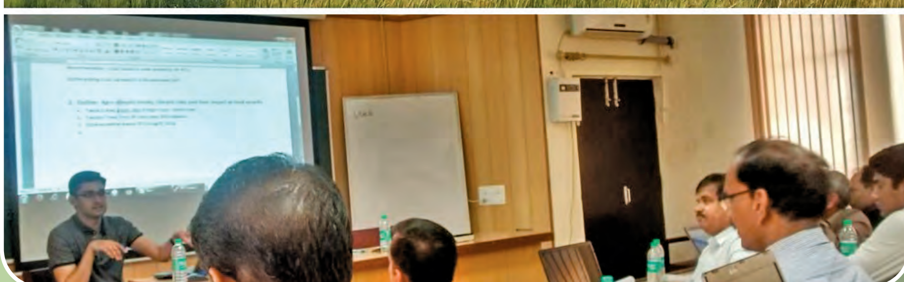
Annual Report 2016-17

All India Coordinated Research Project on Agrometeorology

ICAR- CRIDA, Santoshnagar, Hyderabad – 500059 TS


Organized by
School of Climate Change and Agricultural Meteorology
Punjab Agricultural University, Ludhiana


कृषि मौसम विज्ञान विभाग
इंदिरा गांधी कृषि विश्वविद्यालय, रायपुर (छ.ग.)
एक दिवसीय किसान जागरूकता एवं प्रशिक्षण कार्यक्रम
विषय : जलवायु परिवर्तन के संदर्भ में कृषि को लाभदायी बनायें
(AICRPAM)



All India Coordinated Research Project
on
Agrometeorology

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ICAR-Central Research Institute for Dryland Agriculture
Santoshnagar, Hyderabad – 500 059

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4. Dr H.S.Shivaramu, Bangalore
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Dr. K. SAMMI REDDY
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FOREWORD

Though production and productivity of agricultural crops in India witnessed tremendous increase due to technological advances, still agriculture in India is sensitive to weather conditions. Country's diverse climatic regions made agriculture location specific and weather/climate dependent. Availability of irrigation water for more than 50% cultivated area of the country may not be possible in near future. Conversely, climate change and related developments are altering the onset and spread of south west monsoon and the distribution of rainfall over the country during kharif crop season. However, improved weather forecasting by IMD as well as developments of research in agricultural meteorology are helping in providing better agromet extension services for developing strategies to save the crops from weather aberrations and reducing input cost and enhancing production, ultimately leading to reach the goal of doubling farmer's income.

In this endeavor, All India Coordinated Research Project on Agrometeorology (AICRPAM) with its network of 25 coordinated centers located in different agroclimatic zones of the country is playing a significant role in identifying regions vulnerable to climate change, development of adaptation strategies and dissemination of micro-level Agromet advisories. Besides these activities, AICRPAM is also involved in the development and dissemination of the Agromet advisories at block level. It is also undertaking research on impacts of change in temperature and rainfall patterns on crops through modeling, designing contingency crop plans for different rainfall situations, development of weather insurance products, decision support systems for crop management and forewarning of pests and diseases through its Network Centers located at different agroclimatic zones of the country.

The efforts of the Co-operating Centers of AICRPAM in pursuing the assigned research programs are highly appreciable. Their cooperation in providing information to develop user friendly products and integrated approaches to assess meteorological hazards and impacts of extreme events on agriculture is commendable. The linkage of AICRPAM with IMD in preparing National Agromet Advisory Services (NAAS) bulletin based on extended range weather forecasting is an achievement worth appreciating. The Annual Progress report of2016-17 contains results of research carried out during *Kharif 2016* and *Rabi* 2016-17 across 25 centers in the country. I take this opportunity to congratulate the efforts made by the Agrometeorologists of all the centers and the Project Coordinator, Dr. P. Vijaya Kumar and his team of scientists at the Coordinating Unit in compilation of this valuable report. I believe that the results presented in the report will be useful for researchers and policy makers for implementation of strategies to minimize the effect of weather aberrations.

K. SAMMI REDDY

ICAR-CRIDA, Hyderabad
Date: November 18, 2017

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I thank all the agrometeorologists and staff of all 25 cooperating centres for successfully conducting the research programs for the year 2016-17 and also contributing the research results for the annual progress report.

I highly appreciate the efforts made by my colleagues Dr S.K. Bal, Mr M.A. Sarath Chandran, Mr A.V.M. Subba Rao and Mr Rajkumar Dhakar for compilation of this report. I sincerely thank Mr. I.R. Khandgonda for providing technical support and Ms. Harini for type setting of the manuscript. The support provided by Mr A. Mallesh Yadav is acknowledged with thanks. I also thank Mr V.M. Sandeep, Mr V.P. Pramod, Ms O. Bhavani for their contribution to the report.

P. Vijaya Kumar

Project Coordinator (Ag. Met.)

1. Introduction

The All India Coordinated Research Project on Agrometeorology (AICRPAM) was initiated by Indian Council of Agricultural Research (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 of the progress made by the project and realizing the importance of agrometeorological research support for enhancing food production, ICAR had extended the Cooperating Centres to the remaining 13 Agricultural Universities of the country w.e.f. April 1995. The 25 Cooperating Centres of the AICRPAM network are: Akola, Anantapur, Anand, Bangalore, Bhubaneswar, Bijapur, Dapoli, Faizabad, Hisar, Jabalpur, Jorhat, Kanpur, Kovilpatti, Ludhiana, Mohanpur, Palampur, Parbhani, Raipur, Chatha/Jammu, Ranchi, Ranichauri, Samastipur, Solapur, Thrissur and Udaipur. The Quinquennial Review Team (QRT) has reviewed the research progress of the project in 1992, 1998-99, 2006 and 2011. In the last QRT Report, performance of the AICRPAM was adjudged as **Very Good.**

1.1 Objectives

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

1.2 Technical Program for 2016-18

The Technical Program for the years 2016-18 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

- Development of database (Block, Tehsil or Mandal level) on climate and crop statistics (district level)
- Rainfall probability analysis
- Dry and wet spells
- Effective rainfall, water balance studies (FAO-CROPWAT) and harvestable rainwater for every week

- Characterization of onset of monsoon for crop planning
- Climatic and agricultural drought analysis
- Length of growing season and its variability
- Preparation of crop-weather calendars
- Consolidation of agroclimatic analysis in the form of Technical Reports and Agroclimatic Atlases
- Preparation of crop-wise manuals for weather-based decisions in crop management.
- Documentation of extreme weather events and their impacts on agriculture including livestock, poultry and fish (During the reporting year).

2) Crop Weather Relationships

3) Crop Growth Modeling

4) Weather Effects on Pests and Diseases

} Technical program as finalized in the workshop for above themes is given in Table 1.

5) Agromet Advisory Services

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

Table 1: Zone-wise technical program of AICRPAM centers on three important research themes during 2016-18

S. No	Zones	Centre	Crop Weather Relationship Studies		Crop Growth Modeling	Weather Effects on Pests & Diseases
			Kharif (Crops and Varieties)	*Rabi* (Crops and Varieties)		
1.	Arid and Semi Arid - Black soil	Akola	Soybean: JS 335, JS 9305, TAMS 9821	Chickpea: Vijay, JAKI 9218, Akash	Soybean	Soybean: Spodoptera / Semilooper
		Bijapur	Soybean: JS-335, DSB-23-2, DSB-21	Chickpea: Vijay, JG-11, BG-11-05	-	Grapes/Pomegranate: Powdery mildew, Downy mildew, Anthracnose, BLB
		Parbhani	Soybean: JS-335, MAUS-158, MAUS-71	Fallow	Cotton (DSSAT, INFOCROP)	Cotton: Mealy bug, Sucking pest
		Solapur	Pearl millet: Dhanshakti, ICTP-8203, Mahyco hybrid Sunflower: MSFH-17, Bhanu, Phule Bhaskar	Sorghum: M-35-1, Phule Yeshoda, Phule Revati Chick pea: Vijay, Digvijay, Virat	Sorghum	Sunflower: Thrips, Bud necrosis
		Kovilpatti	Fallow	Maize : S-6850, NK-6240, RMH-3033 COH-(M) 6 Sorghum: CSV-20, K-8, K-12	Maize	Maize: Aphid, Leaf hopper Blackgram: Powdery mildew
2.	Arid and Semi Arid –Redsoil	Anantapur	Pigeon pea: PRG 176, LRG 41, LRG 52 Groundnut: K6, Kadiri Harithandhra, Dharani & Anantha	Chickpea: JG 11, NBEG-47, NBEG-3	Groundnut	Groundnut : Leaf miner (DSS) Pigeon pea: Spotted pod borer
		Bangalore	Pigeon pea: PRG-176, TTB-7, BRG-1 Groundnut: Chintamani-2, JL-24, K-6	Mango: Mallika	-	Groundnut : Leaf miner, Tikka disease, Pod borer, Spotted pod borer Pigeon pea: Spotted boll worm
3.	Western Arid and Semi Arid loamy soil	Anand	Pearl millet: GHB 558, GHB 744, GHB 538	Mustard: Bio 902, GM-3, GDM-4	Pearl millet	Mustard: Aphid
		Hisar	Pearl millet: GHB 558, HSB-67, HHB-272, Guava: Hisar Safeda	Barley: BH 393, BH 902, BH 946, BH 885 Potato: Kufri Surya, Kufri Bahar, Kufri Pushkar	Pearl millet	Mustard: Aphid Wheat: Yellow rust
		Udaipur	Soybean: JS-335, Pratap Soya, RKS-45	Mustard: Bio-902, Giriraj, Swarna Jyoti	Mustard	Mustard: Aphid
4.	Sub –Humid alluvium-IGP	Faizabad	Maize: PMH 4, Naveen, UMC-1, Gaurav	Mustard: NDR-8501, NDRS-2001-1, Narendra Ageti Rai-4	Rice	Chickpea: Pod borer
		Kanpur	Maize: PMH 4, Azad Hybrid-2, Malviya-2, DKC-7044	Wheat: HD-2967, HD-2733, K-307, K-9107	Wheat, Rice	Maize: Stem borer Wheat: Blight
		Ludhiana	Maize: PMH 4, PMH 1 and PMH 2	Wheat : HD 2967, PBW 725, PBW 677	Wheat	Cotton: Sucking pests
		Samastipur	Maize: Bio-9637, Shaktiman-4, Shaktiman-5	*Rabi* Maize: Bio-9637, Shaktiman-4, Shaktiman-5	Maize	Maize: Stem borer

S. No	Zones	Centre	Crop Weather Relationship Studies		Crop Growth Modeling	Weather Effects on Pests & Diseases
			Kharif (Crops and Varieties)	*Rabi* (Crops and Varieties)		
5.	Central India-Sub Humid (Dry) : Black and redsoils	Jabalpur	Rice: MTU 1010, Kranti, Sahbhagi	Chickpea: JG-14, JG-1 & JJGH-1	Rice , Soybean	Chickpea: *Heliothis*
		Raipur	Rice: MTU-1010, Chhattisgarh Sugandhit Dhan, IGKV R-1	Chickpea: JG-14, Indira Channa-1, Vaibhav	Rice	Rice: Yellow Stem Borer, Leaf folder, Brown Plant Hopper Chickpea: *Heliothis*
		Ranchi	Rice: MTU 1010, Naveen, Sahbhagi	Chickpea: JG 14, Birsa Channa 3, GNG 1581	Rice	Rice: BLB, Brown spot
6.	East and NE-Hot Sub Humid (Moist) : Deep loamy to clayey alluvium	Bhubaneswar	Rice : Swarna, Satabdi, Bina-11	Greengram: Samrat, TARM-1, PDM-54	Rice	Rice: Sheath Blight Blast
		Jorhat	Rice: Swarna, TTB-404, Mahsuri	Green gram: Samrat, Pratap, SGC-16	Rice	Rice: Stem borer
		Mohanpur	Rice: Swarna, Satabdi, Nayanmoni,	Green gram: Samrat, Pant Moong-5, Meha (IPM-99-125)	Rice	Rice: Stem borer
7.	Sub Himalayan-Warm Sub Humid :Deep loam forest soils	Chatha/ Jammu	Rice: Basmati- 370, Pusa-1121, R.S. Pura local	Wheat: HD-2967, Raj-3077, RSP - 561 Mustard: ONK-1, GSL-1, DGS-1	Wheat	Wheat: Yellow Rust Mustard: Aphid
		Palampur	Rice: Basmati- 370, Pusa-1121, Kasturi Basmati	Wheat: HD-2967, HS-490, VL-907 Mustard: ONK-1, GSL-1, HPN-1	Wheat	Rice: Blast Wheat: Yellow Rust
		Ranichauri	Finger Millet: PRM-2, VL Mandua 149, VL Mandua 324	Wheat: HD 2967, VL Gehun 892, UP 2572	Wheat	Wheat: Yellow Rust Finger millet: Blast
8.	Coastal (western ghat) – Hot humid to per humid : Laterite and coastal alluvium	Dapoli	Rice: Jaya, Karjat-5, Palghar-1, Swarna, Karjat-2	Spice Pepper: Panniyur-1, Shakti, Thevam	Rice	Rice: Stem borer, Blue Beetle, BPH,
		Thrissur	Rice: Jyothi, Kanchana and Jaya	Spice: Pepper: Panniyur 1 to Panniyur 8 (8 varieties)	Rice	Rice: Stem borer, Leaf roller Pepper: Pollu Beetle

2. Weather During 2016

A brief account of onset, progress, withdrawal and rainfall distribution details of southwest monsoon and post monsoon seasons of the year 2016 for the country as a whole and rainfall of 25 centres of AICRPAM are presented hereunder:

2.1 Onset of Southwest Monsoon

The southwest monsoon set in over Kerala on 8 June 2016, which was 7 days later than its normal date (1 June). On the same day, it advanced into south Arabian Sea, Maldives-Comorin area, most parts of Kerala & Tamil Nadu, some parts of south interior Karnataka, remaining parts of south Bay of Bengal and some more parts of central Bay of Bengal.

In the subsequent two days, a hiatus occurred on western part due to weakening of the Arabian Sea branch of the monsoon. A comparatively stronger Bay of Bengal branch led to advance of monsoon into Northeast India by 14 June. In the third week of June, as the active phase of the Madden Julian Oscillation (MJO) moved eastwards over the Indian Seas, the Bay of Bengal became more convectively active. Triggered by this, further advance of monsoon was rapid and it covered most parts of peninsular India & western Himalayan region, entire central & east India and some parts of north Arabian Sea and northwest India by 22 June. After a brief hiatus during the last week of June, monsoon advanced further very rapidly to cover most parts of the country, outside some areas of Kutch and West Rajasthan by 5 July. The monsoon covered the entire country on 13 July.

2.2 Rainfall distribution during monsoon season

The seasonal (June to September) rainfall received at 36 meteorological sub-divisions of the country during the 2016 SW monsoon season are given in the Table 2.1 along with respective long period average (LPA) values and deviations from normal.

The rainfall during southwest monsoon season from 1 June to 30 September 2016 was normal in 23 sub-divisions (72% of the total area of the country) and excess in 4 sub-divisions (13% of the total area of the country). However, the seasonal rainfall was deficient in 9 sub-divisions constituting 15% of the total area of the country. Out of the 9 deficient sub-divisions, 4 sub-divisions were from Southern Peninsula (Coastal Karnataka, South Interior Karnataka, Kerala and Lakshadweep), 3 from Northwest India (Haryana, Chandigarh & Delhi, Punjab and Himachal Pradesh), and 1 each from Northeast India (Assam & Meghalaya) and Central India (Gujarat region). Similarly, out of the 4 excess sub-divisions, 2 each were from northwest India (West and East Rajasthan) and Central India (Konkan & Goa and Marathwada). Rest of the 23 sub-divisions received normal rainfall.

Table 2.1: Rainfall at 36 meteorological sub-divisions during monsoon season (June - September, 2016)

S. No.	Meteorological Sub-division	Actual (mm)	Normal (mm)	Excess or deficit (mm)	Deviation (%)
1	Andaman & Nicobar Islands	1563	1682.5	-120	-7
2	Arunachal Pradesh	1699	1768.0	-69	-4
3	Assam & Meghalaya	1249	1792.8	-544	-30
4	Nagaland, Manipur, Mizoram & Tripura (NMMT)	1244	1496.9	-253	-17
5	Sub-Himalayan West Bengal & Sikkim	1996	2006.2	-10	0
6	Gangetic West Bengal	1163	1167.9	-5	0
7	Orissa	1031	1149.9	-119	-10
8	Jharkhand	1097	1091.9	+5	0
9	Bihar	994	1027.6	-33	-3
10	East Uttar Pradesh	790	897.6	-107	-12
11	West Uttar Pradesh	640	769.4	-129	-17
12	Uttarakhand	1104	1229.1	-125	-10
13	Haryana, Chandigarh & Delhi	338	466.3	-128	-27
14	Punjab	352	491.9	-140	-28
15	Himachal Pradesh	625	825.3	-201	-24
16	Jammu & Kashmir	482	534.6	-53	-10
17	West Rajasthan	316	263.2	53	20
18	East Rajasthan	813	615.8	197	32
19	West Madhya Pradesh	1040	876.1	164	19
20	East Madhya Pradesh	1249	1051.2	198	19
21	Gujarat Region	695	914.7	-220	-24
22	Saurashtra, Kutch & Diu	417	477.5	-61	-13
23	Konkan & Goa	3550	2914.7	635	22
24	Madhya Maharashtra	819	729.3	90	12
25	Marathwada	825	682.9	142	21
26	Vidarbha	1045	954.6	90	9
27	Chhattisgarh	1176	1153.3	23	2
28	Coastal Andhra Pradesh	663	581.1	82	14
29	Telangana	900	755.2	145	19
30	Rayalaseema	392	398.3	-6	-2
31	Tamil Nadu & Pondicherry	258	317.2	-59	-19
32	Coastal Karnataka	2429	3083.8	-655	-21
33	North Interior Karnataka	526	506.0	20	4
34	South Interior Karnataka	525	660.0	-136	-21
35	Kerala	1352	2039.6	-687	-34
36	Lakshadweep	746	998.5	-253	-25

Monthly distribution of rainfall: In June, two sub-divisions (Gujarat and Saurashtra & Kutch) received scanty rainfall, 10 sub-divisions deficient and six sub-divisions received excess and 18 sub-divisions normal rainfall. Out of the 10 deficient sub-divisions, 5 were from Northeast India, 3 from Central India, and 2 from Northwest India. All the 6 excess sub-divisions were from Southern Peninsula. In July, 16 sub-divisions received normal rainfall and 10 sub-divisions each received excess and deficient rainfall. Out of the 10 deficient sub-divisions, 5 sub-divisions (Gujarat, Saurashtra & Kutch, West Rajasthan, Punjab and Himachal Pradesh) were from western and northwestern most part of the country, 4 sub-divisions (Andaman & Nicobar Island, Coastal Andhra Pradesh, Coastal Karnataka and Kerala) were from Southern Peninsula and 1 sub-division (NMMT) was from Northeast. Out of 10 excess sub-divisions, 5 were from Central India (both sub-divisions of Madhya Pradesh and 3 of the 4 sub-divisions of Maharashtra), 3 were from Southern Peninsula and 2 were from Northwest India. In August, 2 sub-divisions were scanty, 17 sub-divisions were deficient and 8 sub-divisions each were normal and excess. Most noticeable feature of rainfall distribution during the August was that all the 10 sub-divisions from Southern Peninsula were deficient or scanty resulting in large rainfall deficiency (-40% of LPA) over the region. Similarly, out of the 7 sub-divisions from Northeast India, 2 each received deficient and scanty rainfall. Out of the 8 excess sub-divisions, 4 were from Central India and 2 each were from Northeast India and Northwest India. In September, 20 sub-divisions were deficient or scantly (4 sub-divisions), 10 were excess and 6 were normal. The most noticeable feature of the rainfall distribution during September was that all the 9 sub-divisions from Northwest India were deficient or scanty resulting in large rainfall deficiency (-52% of LPA) over the region. In addition, 4 sub-divisions from Central India, 5 sub-divisions from Southern Peninsula and one sub-division from Northeast were deficient or scanty. However, Northeast India was the main beneficiary as 6 out of 7 sub-divisions were normal or excess, with the region as a whole receiving 115% of LPA rainfall during the month.

2.3 Withdrawal of Southwest Monsoon

Withdrawal of southwest monsoon from the northwestern parts of Rajasthan remained subdued since 5 September. Due to change in the lower tropospheric circulation pattern over the region from cyclonic to anti-cyclonic on 15 September, the southwest monsoon withdrawal commenced from West Rajasthan. Subsequent to this, moisture incursion due to the low level south easterlies caused isolated rainfall over most parts of northwest India. The monsoon further withdrew from some more parts of the northwest India on 28 September. Thereafter, with the southward shift of the Sub-tropical westerly Jet stream over to the northern most Indian Latitudes from 5 October, the southwest monsoon further withdrew from remaining parts of Jammu & Kashmir and Punjab, most parts of Himachal Pradesh and some more parts of Haryana & Chandigarh and West Rajasthan on 5 October. Thereafter, it has further withdrawn from remaining parts of Himachal Pradesh, Haryana, Chandigarh & Delhi, most parts of Uttarakhand, some parts of West Uttar Pradesh & East Rajasthan and some more parts of West Rajasthan on 8 October. The withdrawal line passes through Dharchula, Aligarh, Jaipur and Barmer as on 10 October.

2.4 Post-Monsoon (October - December) 2016

In the sub division-wise Post-Monsoon (October - December) season rainfall, it was noticed that rainfall was excess in 4 sub-divisions *viz*., Andaman & Nicobar Islands, West Rajasthan, Gujarat Region and Saurashtra, Kutch & Diu, normal in 6 sub-divisions *viz*., Nagaland, Manipur, Mizoram, Tripura, Sub-Himalayan West Bengal & Sikkim, East Rajasthan, Marathwada, Vidarbha and Chhattisgarh, deficient in 13 sub-divisions *viz*., Arunachal Pradesh, Assam & Meghalaya, Gangetic West Bengal, Bihar, Jharkhand, Odisha, East UP, West & East Madhya Pradesh, Konkan & Goa, Madhya Maharashtra, Telangana and Lakshadweep and scanty in remaining 13 sub-divisions.

2.5 Rainfall at cooperating centers

During the year 2016, 6 out of 25 centers of the AICRPAM, *viz*., Anantapur, Dapoli, Jabalpur, Jorhat, Parbhani and Udaipur received excess rainfall, 13 centers *viz*., Akola, Bijapur, Chatha (Jammu), Hisar, Kanpur, Ludhiana, Mohanpur, Palampur, Raipur, Ranchi, Ranichauri, Samastipur and Solapur received normal rainfall and remaining 6 centers Anand, Bangalore, Bhubaneswar, Faizabad, Kovilpatti and Thrissur received either deficit or scanty rainfall (Table 2.2).

Table 2.2: Annual rainfall received at AICRPAM centers during 2016

S. No.	Center	Actual (mm)	Normal (mm)	Departure (%)
1	Akola	853	813	5
2	Anand	587	853	-31
3	Anantapur	545	432	26
4	Bangalore	707	917	-23
5	Bhubaneswar	1015	1502	-32
6	Bijapur	498	594	-16
7	Chatha	1015	1124	-10
8	Dapoli	4504	3529	28
9	Faizabad	414	1001	-59
10	Hisar	511	452	13
11	Jabalpur	1750	1395	25
12	Jorhat	2207	1822	21
13	Kanpur	691	834	-17
14	Kovilpatti	200	714	-72
15	Ludhiana	592	733	-19
16	Mohanpur	1593	1607	-1
17	Palampur	2280	2320	-2
18	Parbhani	1160	963	20
19	Raipur	1265	1399	-10
20	Ranchi	1457	1270	15
21	Ranichauri	1064	1270	-16
22	Samastipur	1014	1235	-18
23	Solapur	805	721	12
24	Thrissur	1760	2782	-37
25	Udaipur	723	566	28

3. Agroclimatic Characterization

Crop growing environments are characterized for various purposes. Some of the predominant uses are prioritizing research on a broad scale, extrapolating technologies to farming community, interpreting multilocation network research, and identifying recommendation zones. Whatever the purpose, characterization in general is supposed to help increase the productivity of rainfed environments via a better understanding of their properties. In addition, anomalies in climatic variables need to be properly understood to make agricultural sector resilient to climate change. The analysis carried out by various centres on agroclimatic characterization is reported hereunder:

Anand

Rainfall seasonality was estimated based on temporal distribution of rainfall (during 23 to 39 SMW) received at 28 stations of Gujarat state through determining trend in individual years' seasonality. The estimation was done using seasonality index method developed by Walsh and Lawler (1981). The monsoon rainfall seasonality index ((SI)¯_mi) was calculated using long period mean weekly rainfall as well as individual year's weekly data during the monsoon period. The seasonality index classes for monsoon seasonality was related to rainfall regime estimated as sum of the absolute deviations of mean weekly rainfall from the overall weekly mean, divided by the mean weekly rainfall. The changes through time in seasonality was explored by trend analysis of monsoon seasonality index of individual years. The qualitative classification of degree of seasonality was categorized as very equable (<0.20), Equable with definite wetter season (0.20-0.49), Season with short dry periods (0.50-0.79), Seasonal (0.80-1.00), Season with dry periods (1.00-1.29), Most rainfall in less than eight weeks (1.30-1.65) and all rain in less than three weeks (>1.65). Almost all stations in the state have non-significant seasonality trend except Khandha and Vyara (Fig. 3.1). All stations except Bharuch showed high variability in seasonality indicating lack of reliability in timing and quantum of rainfall in the whole state. Only western part of South Gujarat has seasonal rainfall distribution. While, most part of the state falls under the category of seasonal rainfall regime with dry periods (index 1.0-1.3), North-Central zone covering parts of Kutch, Banaskantha, Patan, Surendranagar and Ahmedabad districts falls under the rainfall regime distributed to less than eight weeks (index 1.3-1.4). In general, gradual changes in seasonality index from south-east part to north-western parts of the state follows rainfall quantum pattern up to some extent i.e. areas having more rainfall normal have relatively better temporal distribution during monsoon. In the whole state, monsoon rainfall seasonality follows pattern of seasonal rainfall amount from South-East to North-West of the state i.e. seasonal-seasonal with dry period pattern (almost all rainfall in less than eight weeks).

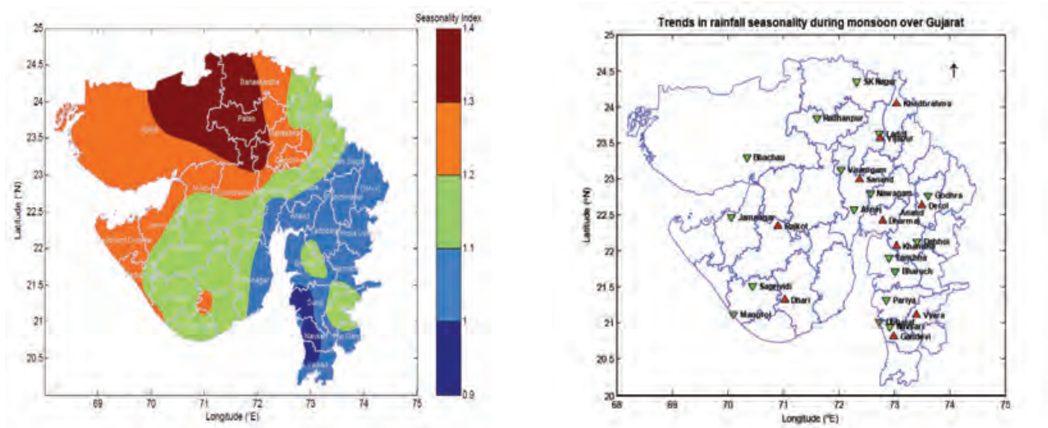


Fig. 3.1: The maps showing (a) seasonality index (SI_{mi}) and (b) trends in rainfall seasonality of monsoon over Gujarat state

Akola

Analysis of rainfall, rainy days and extreme rainfall events of both annual and monsoon rainfall were worked out using rainfall data (1971-2016) of 118 talukas in Vidarbha region. The Mann-Kendall test using trend/change detection software was performed to evaluate the trend of rainfall, rainy days and extreme events for rainfall > 75 & < 100 mm and ≥ 100 mm).

Nearly 91 per cent of the talukas (108) in Vidarbha region had no significant trend in annual rainfall. Among the remaining talukas, 3% (3) showed significant positive trend, and 6% (7) showed significant negative trend (Fig. 3.2a). The negative trend observed is significant at more number of talukas of which maximum (3) being in Yavatmal district. As regard to rainfall during South West monsoon (Fig. 3.2b), 93% talukas (110) in Vidarbha region had no significant trend. Among the remaining talukas, 4% (5) of the talukas showed significant positive trend, and 3% (3) of them showed significant negative trend.

Similarly, about 91 per cent (107) of the talukas in Vidarbha region showed no significant trend, 7% (9) of talukas showed significant positive trend and 2% (2) showed significant negative trend in the number of rainy days (Fig. 3.2c). Among the talukas in different districts, 4 talukas in Akola district, 2 in Gadchiroli, 2 in Nagpur and 1 in Amravati district showed positive trend in the number of rainy days. However, only 2 talukas, one each in Bhandara and Gadchiroli districts showed significant negative trend. During southwest monsoon season, 90 per cent of talukas did not show any trend in rainy days. The remaining 10% of the talukas showed significant positive trend and none of them showed decreasing trend (Fig. 3.2d). Among the talukas in different districts, 3 talukas in Akola, 3 talukas in Amravati, 2 in Buldana, 2 in Gadchiroli and 2 in Nagpur districts showed positive trend.

Regarding extreme rainfall events of > 75 & < 100 mm rainfall, on annual basis, 90 per cent (106) of the talukas in Vidarbha region showed no significant trend, 1% (1) of talukas showed significant positive trend and remaining 9% (11) showed significant negative trend (Fig. 3.2e). Regarding rainfall events of > 75 & < 100 mm rainfall during SWM season, 89 per cent (105) of the talukas in Vidarbha region showed no significant trend, 2% (2) of talukas showed significant positive trend

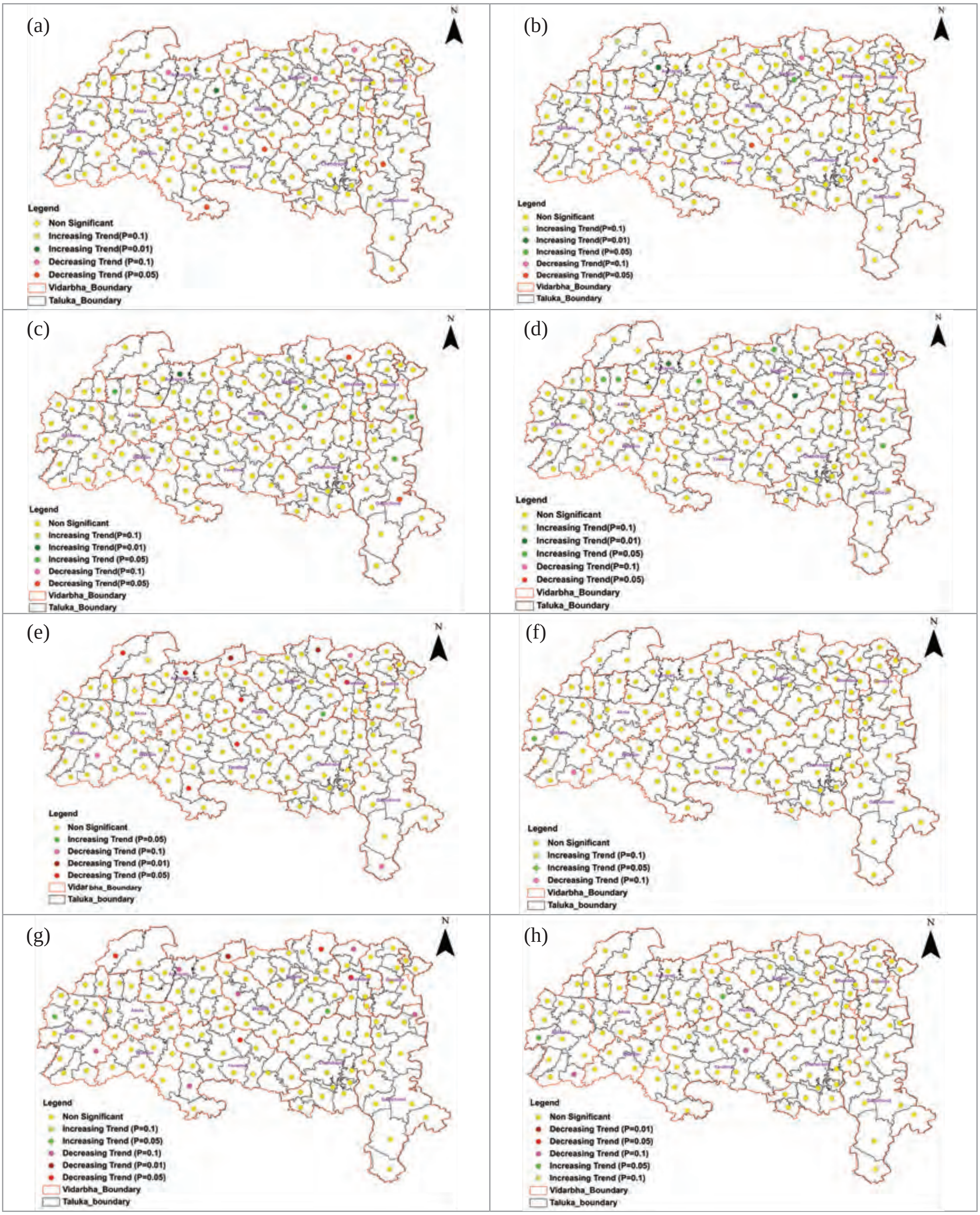


Fig. 3.2: Trends of (a) Annual rainfall, (b) South-west monsoon, (c) Annual rainy days, (d) Rainy days during S-W monsoon, (e) Days with > 75 & < 100 mm rainfall annually (f) Days with ≥ 100 mm rainfall annually (g) Days with > 75 & < 100 mm rainfall during S-W monsoon (h) Days with ≥ 100 m rainfall during S-W monsoon rainfall in different taluks of Vidarbha.

and 9% (11) showed significant negative trend (Fig. 3.2f). In case of extreme rainfall events of ≥ 100 mm rainfall per year, 96 per cent (114) of the talukas in Vidarbha region showed no significant trend, 2% (2) of talukas showed significant positive trend and 2% (2) showed significant negative trend (Fig. 3.2g). For extreme rainfall event of ≥ 100 mm rainfall, during SWM season, 96 per cent (114) of the talukas in Vidarbha region showed no significant trend, 2% (2) of talukas showed significant positive trend and 2% (2) showed significant negative trend (Fig. 3.2h).

Bangalore

In India, the state of Karnataka stands first as highest number of districts declared as drought hit. During 2000-2014 (15 years), Karnataka was declared most drought hit (16 districts/year), which is the highest followed by Uttar Pradesh and Rajasthan with an average of 15 districts per year.

To understand the drought scenario in Karnataka state, an analysis was done using data over the period of 2001 to 2016. According to the data of drought affected areas over the past 16 years, only coastal districts which generally record heavy rainfall didn't face drought. However, some of these areas also becoming increasingly vulnerable to drought. The worst drought affected regions are from North Interior Karnataka. Some districts in South Interior Karnataka, such as Chikkaballapur, Kolar and parts of Mysuru and Chamarajanagar too have been recording drought years at an alarming frequency.

Table 3.1: Drought years during 2001-16 in Karnataka

No of drought years	(%) period	Districts
11	79	Gulbarga, Kolar
10	71	Bagalakot, Bangalore, Belgaum, Bellary, Bidar, Bijapur Rural Tumkur, Mysore, Mandya, Koppal, Gadag, Hassan, Davanagere, Chitradurga
9	64	Bangalore Urban, Chamarajanagar, Dharwad, Haveri, Raichur
8	57	Chikmagalur
6	43	Ramanagara
5	36	Chikkaballapur, Shimoga
4	29	Uttarakannada
3	21	Yadagiri
2	14	Kodagu

Further, taluk level analysis indicated that several taluks of the state are becoming vulnerable to drought conditions every year. During 2001-2016, all taluks in the state received normal rainfall for only two years. Out of the 176 taluks in the state, 109 faced drought for at least four years between 2011 and 2015. The taluks with the highest probability for drought (86 per cent) include Chikkaballapur, Aland and Jewargi in Kalaburagi district and Shirahatti in Gadag district. Shockingly, 135 of the 176 taluks had a drought probability of over 50 per cent and large number of them have suffered droughts for at least eight years out of past 12 years.

Faizabad

Frequency of days with heat and cold waves in eastern plain zone of Uttar Pradesh was estimated using 30 years data (1985-2015). The analysis (Table 3.2) revealed that on an average five days of heat waves per annum were recorded in Eastern Plain Zone of U.P. Maximum days with heat waves were experienced in month of May (1.6 days) followed by June (1.5 days). During the period of September to February there was no heat wave where as the chances of heat wave occurrence in March and August was very rare. Similarly, cold waves of 2.7 days per year were recorded over the period of December to February. The frequency is maximum in January (1.6) and minimum for December (0.5). There was only one incidence of cold wave in the month of November over the last 30 years.

Table 3.2: Frequency of days of heat and cold wave in eastern plain zone of UP

Frequency of days of heat waves and cold waves				
Month	**Days of heat waves**	**Days of heat wave per year**	**Days of cold waves**	**Days of cold wave per year**
March	2	0.1	0	0.0
April	22	0.8	0	0.0
May	49	1.6	0	0.0
June	47	1.5	0	0.0
July	26	0.9	0	0.0
August	08	0.3	0	0.0
September	0	0.0	0	0.0
October	0	0.0	0	0.0
November	0	0.0	1	0.01
December	0	0.0	15	0.5
January	0	0.0	48	1.6
February	0	0.0	18	0.6
Annual	154	5.2	81	2.7

The extreme minimum temperature (^{0}C) recorded during 1985-2015 shows a decreasing trend with a long term normal value of 3 ^{0}C (Fig. 3.5). Similarly the decadal variation of frost indicates an increasing trend since the decade of 1986-1995. The total number of frost days during the last 30 years (1986-2015) was 134, out of which January received 97 days where as November and February were frost free months.

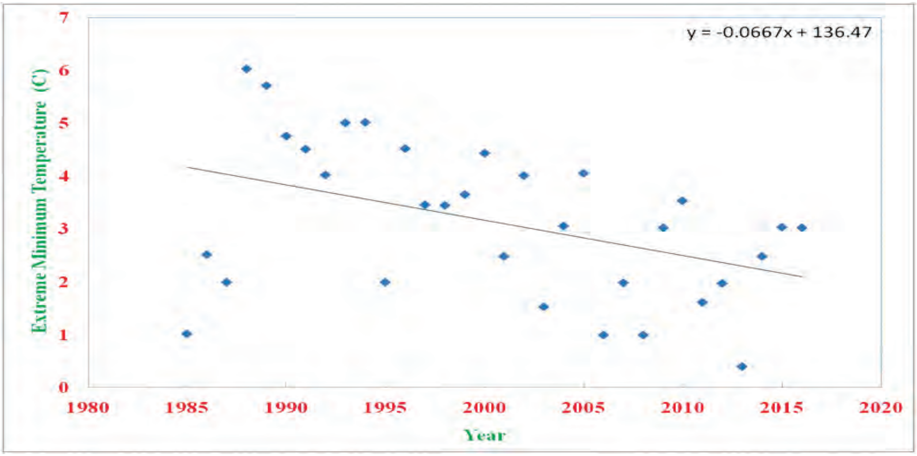


Fig. 3.5: Trend of extreme minimum temperature (1986-2015)

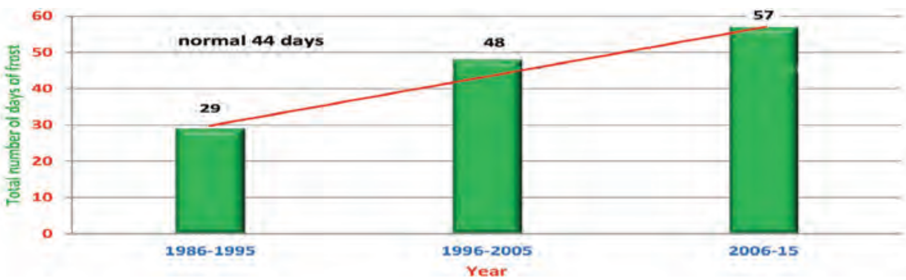


Fig. 3.6: Decadal trend of total number of frost days

Hisar

Extreme weather event analysis of five locations of Haryana was done using RClimDex 1.0 software. Spatial dynamics of climate change indices indicate that spatial distribution of very wet days and extremely wet days in northern most parts of Haryana had highest rainfall occurrence of 240-275 & 72-85 mm. The western parts had the least rainfall occurrence of 100-135 & 30-41 mm on very wet and extremely wet days (Fig. 3.7). Absolute indices for spatial distribution indicate that maximum amount of rainfall received on a single day and consecutive five days total was higher in the northern most parts with corresponding values of 106-126 mm and 185-205 mm for RX1day and RX5day, respectively. The western parts of the state have the lowest rainfall amount which varied from 68-81 mm and 105-125 mm for RX1day and RX5day, respectively (Fig. 3.8).

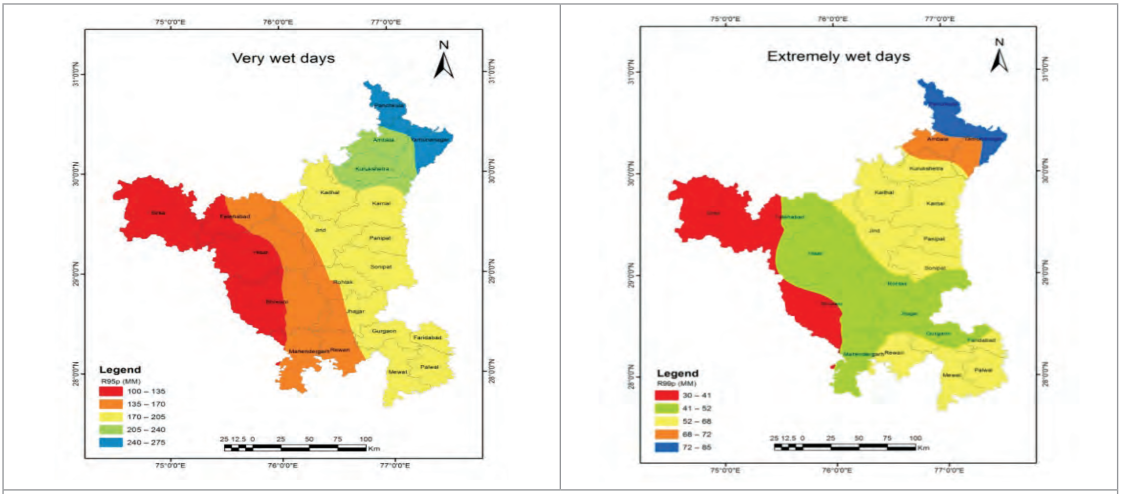


Fig. 3.7: Spatial distribution of very wet days (R95p) and extremely wet days (R99p) in mm/year for Haryana (1985-2014)

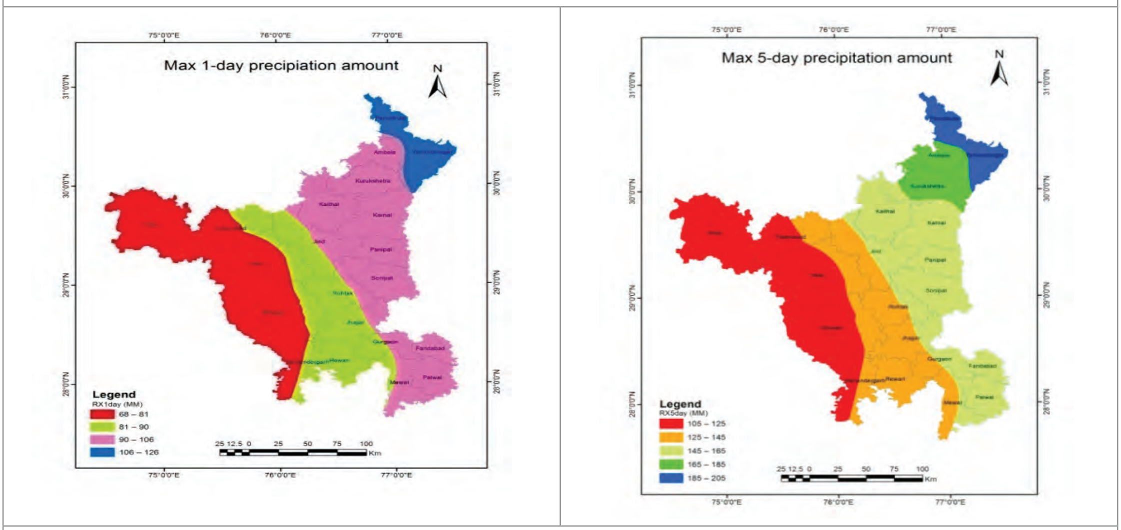


Fig. 3.8: Spatial distribution of maximum 1-day precipitation amount (RX1day) and Maximum 5-day precipitation amount (RX5day) in mm/year for Haryana (1985-2014)

Absolute temperature indices related to coldest nights, hottest nights, coldest days and hottest days are presented in Fig. 3.9. In almost all parts of western Haryana, coldest nights have 0.0-1.1 ^{0}C (TNn). In central belt of state coldest nights have 1.1-2.2 ^{0}C, whereas extreme northern districts of Panchkula, Yamunanagar and Ambala were with coldest nights of 2.2-3.3 ^{0}C. The spatial distribution of coldest days (TXn) followed similar trend as coldest nights. The northern most places have 11.3-12.0, whereas, the highest frequency was observed in western parts of the state. From the spatial distribution of hottest nights (TNx), it can be seen that the northernmost parts *viz.*, Yamunanagar has least frequency of hot nights, while western parts has highest frequency. Similarly, the spatial distribution of hottest days (TXx) followed a similar pattern as noted for TNx. Yamunanagar areas has least frequency (28.3-29.5 ^{0}C), whereas, western parts of the state has highest frequency (45.5-46.0 ^{0}C).

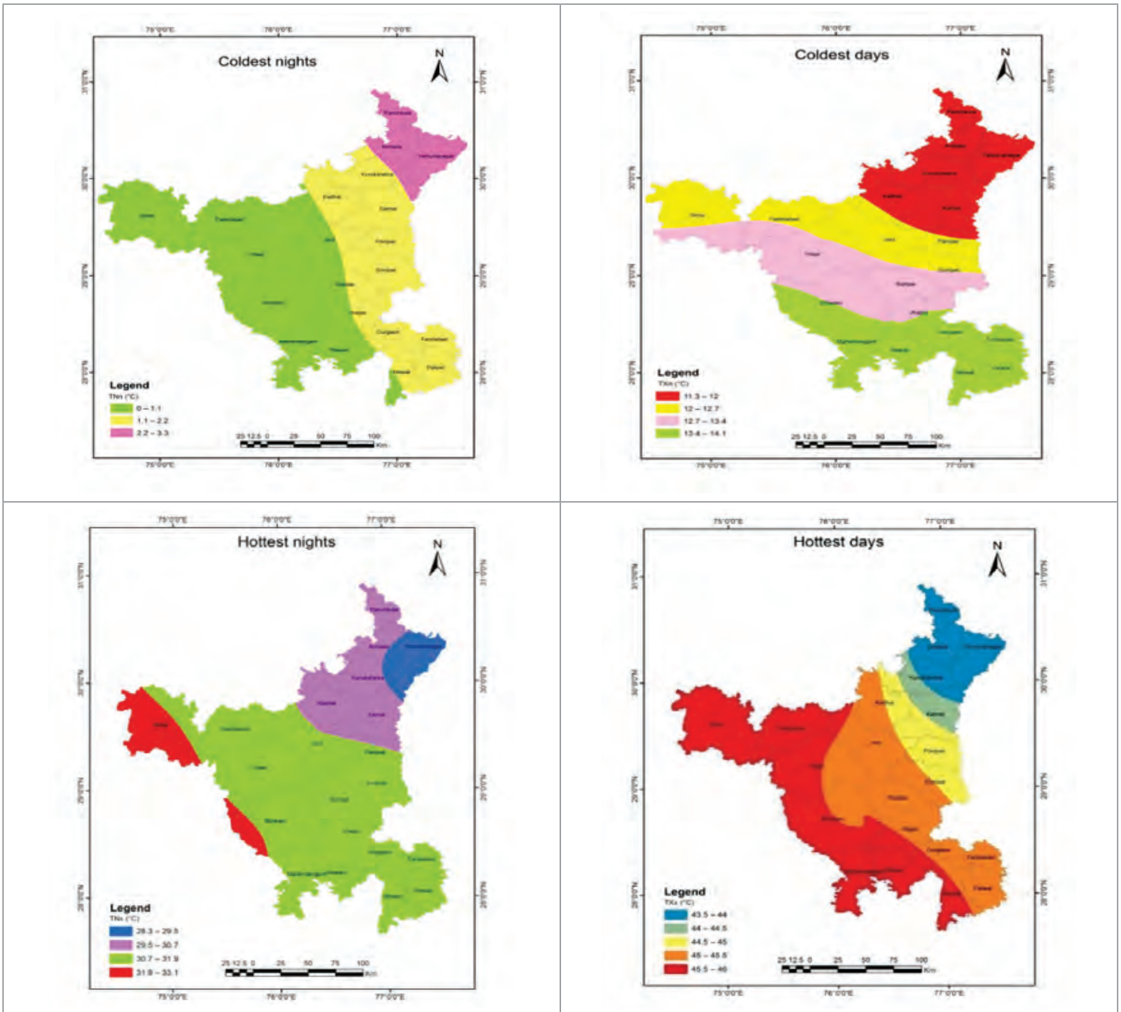


Fig. 3.9: Spatial distribution of coldest nights (TNn), coldest days (TXn), hottest nights (TNx) and hottest days (TXx) in ^{0}C/year

Trend of rainfall and temperature related climate change indices in Haryana

To detect and estimate trends of climatic parameters on annual, seasonal and monthly time-scales, the non-parametric Mann-Kendall test for the trend and Sen's non-parametric method for the magnitude of the trend was used. Calculations were performed using the Excel template MAKESENS (Mann-Kendall test for trend and Sen's slope estimator). Annual trends of rainfall and temperature related climate change indices were computed and depicted in Table 3.3.

Table 3.3: Trend of annual rainfall and temperature indices at five stations in Haryana

Variables	Indices	Ambala	Bawal	Hisar	Karnal	Sirsa	Units
	CDD	0.61	0.14	0.20	-0.46	-0.64	days
	CWD	-1.15	0.99	-0.28	-1.11	-0.83	days
	R10mm	-0.43	**1.83**[e1]	1.33	-0.20	-0.79	days
	R20mm	-1.18	**2.21**[d2]	1.83	-0.18	0.04	days
	R95p	0.43	**2.09**[d1]	0.70	-0.76	0.29	mm
Precipitation	R99p	**2.12**[d2]	**2.14**[d2]	-0.62	-0.13	0.99	mm
	R2.5mm	-0.04	**2.43**[d2]	1.56	-0.72	-0.39	days
	Rx1day	1.34	**2.44**[d1]	-0.11	0.29	0.61	mm
	RX5day	-0.36	**2.02**[d1]	0.43	-0.18	-0.02	mm
	SDII	-0.12	1.66	1.48	0.11	0.89	mm/day
	PRCPTOT	-0.11	**2.36**[d1]	1.57	-0.18	0.14	mm
	TN10p	-0.3	-1.03	-1.52	-1.62	-0.62	days
	TN90p	-0.32	0.75	1.45	0.00	**4.07**[a2]	days
	TX10p	-0.32	**2.12**[d1]	1.50	0.46	0.50	days
	TX90p	-0.11	-0.96	-1.07	-0.68	-0.71	days
	TNn	-0.61	**-2.82**[c2]	**-1.72**[e]	**-2.27**[d1]	-0.84	^{0}C
	TNx	**-2.11**[d]	-0.30	0.14	**-1.88**[e]	**2.46**[d2]	^{0}C
Temperature	TXn	**-2.64**[c1]	**-3.16**[c2]	**-3.27**[c2]	**-2.55**[d1]	**-3.86**[a2]	^{0}C
	TXx	1.47	-0.38	-0.18	0.79	0.00	^{0}C
	SU25	-0.11	-0.41	-0.16	0.25	-0.20	days
	TR20	**2.00**[d1]	0.39	1.46	**1.83**[e1]	**3.15**[c2]	days
	DTR	-0.07	**-2.39**[d1]	**-2.50**[d1]	**-2.09**[d]	**-3.16**[c2]	^{0}C
	WSDI	0.90	-0.22	0.07	0.06	-0.54	days
	CSDI	-0.23	-0.43	-1.82	-1.02	-1.66	days

MKT = [a]Significance level ± 99.9%, [c]Significance level ± 95%, [d]Significance level ± 90% [e]Significance level ± 85%

Sen's = [1] 95% confidence interval, [2] 99% confidence interval

Where, CDD, consecutive dry days; CWD, consecutive wet days; R10mm, number of heavy rainfall days; R20mm, number of very heavy rainfall days; R95p, very wet days; R99p, extremely wet days; R2.5mm, number of rainfall days; RX1day, maximum 1-day rainfall amount; RX5day, maximum 5-day rainfall amount; SDII, simple daily intensity index; PRCPTOT, annual total wet days rainfall amount; TN10p, cool nights; TN90p, warm nights; TX10p, cool days; TX90p, warm days; TNn, coldest nights; TNx, hottest nights; TXn, coldest days; TXx, hottest days; SU25, summer days; TR20, tropical nights; DTR, diurnal temperature range; WSDI, warm spells duration index; CSDI, cold spell duration index.

Jammu

In Jammu region, variability in annual rainfall varies from 1143.6 to 2077.8 mm across six locations of Jammu region. The average annual rainfall (mm) and coefficient of variation (CV) of Jammu, Samba, Katra, Baderwah, Batote and Banihal were found to be 1173.4 (23.9), 1143.6 (20.8), 2077.8 (21.1), 1305.7 (18.7), 1624.2 (21.2) and 1343.6 (25.0), respectively (Table 3.4).

Out of the annual rainfall, about 74.0, 77.2, 70.9, 40.8, 38.6, 32.3 per cent and 20.5, 18.5, 24.2, 59.1, 61.4, 67.7 per cent rainfall is received during *kharif* and *rabi* seasons in Jammu, Samba, Katra, Baderwah, Batote, Banihal, respectively (Table 3.4). In subtropical region (Jammu & Samba) and intermediate region (Katra) of Jammu division the standard deviation and coefficient of variation are less as compared to temperate region (Bhaderwah, Batote & Banihal) during *kharif* season, while during *rabi* season CV was found to be more at different locations of Jammu, Samba, Katra than Bhaderwah, Batote & Banihal (Table 3.4).

Table 3.4: Descriptive statistics of Annual and seasonal rainfall in Jammu region.

Particulars	Jammu	Samba	Katra	Bhaderwah	Batote	Banihal
Annual (mm)	1173.4	1143.6	2077.8	1305.7	1624.2	1343.6
SD (±) mm	280.5	238.1	438.5	244.7	345.0	336.5
CV (%)	23.9	20.8	21.1	18.7	21.2	25.0
***Kharif* Season (mm)**	868.9	882.7	1472.8	532.8	627.1	433.6
SD (±) mm	228.2	206.5	399.7	143.7	185.1	187.5
CV (%)	26.3	23.4	26.9	27.0	29.5	43.2
% of Annual	74.0	77.2	70.9	40.8	38.6	32.3
***Rabi* Season (mm)**	240.6	211.5	503.3	770.3	998.4	910.4
SD (±) mm	136.4	119.7	207.1	233.9	273.4	239.5
CV (%)	56.7	56.6	44.3	30.4	27.4	26.3
% of Annual	20.5	18.5	24.2	59.1	61.4	67.7

Over the last 35 years, deviation of yearly rainfall from average annual rainfall varied from -30.1 to 63.6% in Jammu district (Fig. 3.10). Out of these 35 years, about 7 years (1987, 1989, 1999, 2002, 2004, 2005 & 2009) have more than 20% deficient rainfall and another 7 years (1986,1990, 1996, 1997, 2003, 2012 & 2015) received surplus rainfall (≥ 20 %). In rest of the 20 years, the deviation of average annual rainfall from its average was between -19 to +19% in Jammu district (Fig. 3.10). At Samba location out of 29 years, the deviation of annual from the normal varies from -34.1 to 59.6%. The maximum deficient and surplus rainfall were observed in 2009 (-34.1 %) and 1990 (+59.6 %). Out of these 29 years, 5 years were found deficient while 5 years were surplus rainfall years. The intermediate (Katra) region received highest annual rainfall as compared to other locations. The deviation in rainfall from normal varied from -34.3 to 53.6% during last 36 years and out of these, 7 years received deficient (≥ -20 %) and 5 years received surplus (≥ 20%) rainfall. In Baderwah, Banihal and Batote (temperate region) the rainfall deviation from normal varied from -42.8 to 53.6, -47.3 to 59.2 and -40.5 to 49.8% during 38, 44 and 39 years, respectively. The number of deficient and excess (≥ 20 %) rainfall years were three, ten & six and six, nine & seven in Baderwah, Banihal & Batote, respectively.

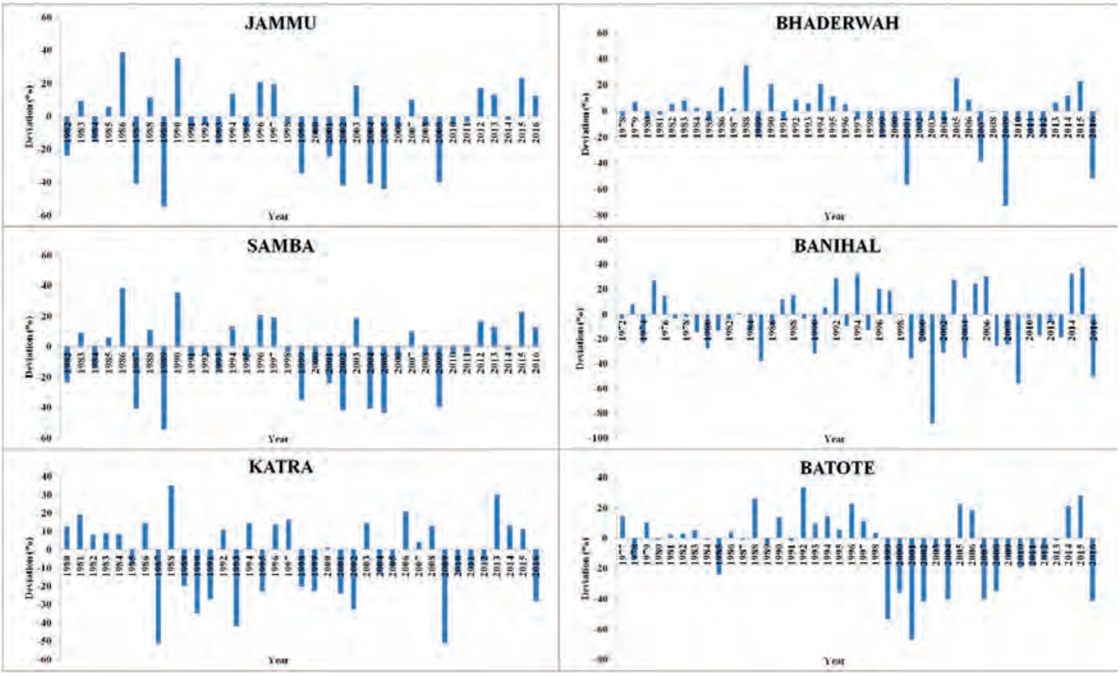


Fig. 3.10: Mean deviation (per cent) from the normal rainfall in various locations of Jammu region

Jorhat

During the period of 1981-2010, annual rainfall received at Tinsukia varied between 1794 mm to 2779 mm. The highest amount of rainfall was recorded in 1995 whereas highest number of rainy days was observed in 2005. During 1983-1998, 12 number of heavy rainfall events occurred in this district which is lower than other districts of Assam. Average annual days of heavy rainfall events (> 80 mm but < 100 mm) recorded during 24 hours at Tinisukia are 4.2. The highest number of heavy rainfall events of 12.0 were recorded during both 1983 and 1998. (Fig. 3.11)

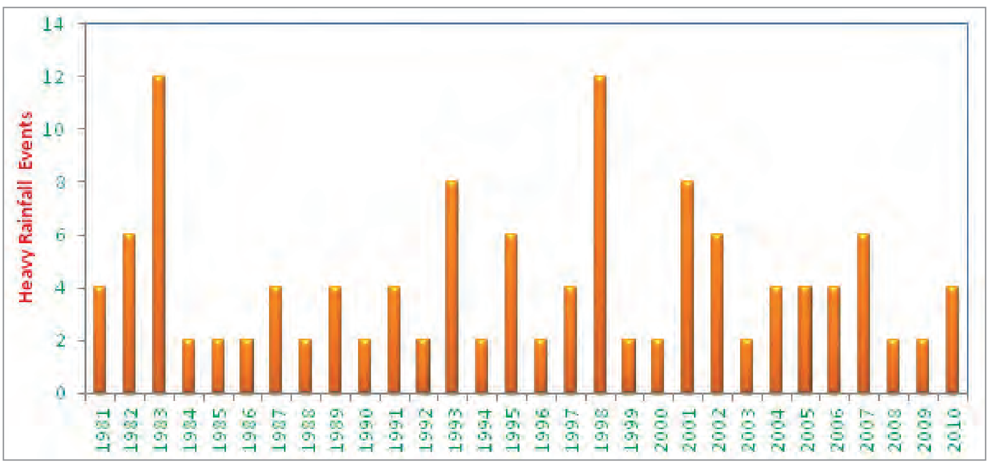


Fig. 3.11: Number of heavy rainfall events in Tinisukia district

The initial and conditional probabilities of getting dry or wet weeks was carried out using Markov Chain analysis. The limit for determining dry and wet weeks for Tinsukia was considered as 10 mm rainfall in a week. The duration of the analysis was 1981-2010 (30 years). The result indicated higher possibility of dry weeks during reproductive stage of *kharif* rice in Tinsukia district (Fig. 3.12).

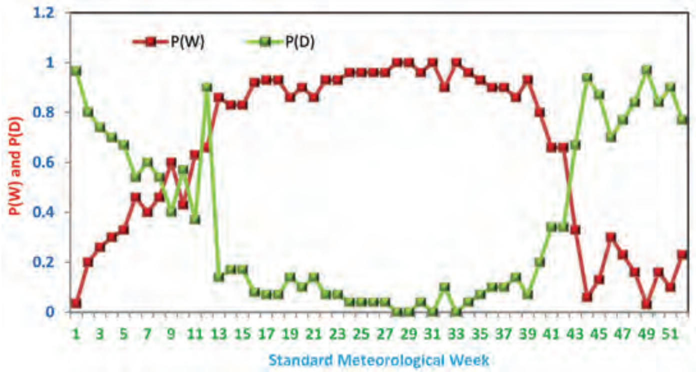


Fig. 3.12: Probability of dry and wet weeks in Tinsukia

Ludhiana

The baseline (1961-1990) and simulated (2021-2100) climatic data for different agro-climatic regions of Punjab was downscaled using PRECIS (Providing Regional Climates for Impact **S**tudies) model prepared by IITM, Pune. The daily simulated data for temperature and rainfall for the baseline period (1961-1990); under A1B scenario for mid-century (2021-2050); and under A1B (2071-2098), A2 and B2 (2071-2100) scenarios for the end of 21 century were downscaled. The differences existed between the averages of the actual and simulated data for the baseline period implied that these differences may occur in the future model data also. Therefore bias removal in the model data was done by deriving different correction functions for temperature (using Leander and Buishand method and difference method) and rainfall (using modified difference method and difference method).

The trend analysis revealed that by the end of 21century, the maximum temperature has been predicted to increase at the rate of 0.03 to 0.05 ^{0}C yr^{-1} under AIB and A2 scenarios and 0.01 to 0.03 ^{0}C yr^{-1} under B2 scenario (Fig. 3.13); the minimum temperature by 0.03 to 0.06 ^{0}C yr^{-1}, 0.02 to 0.05 ^{0}C yr^{-1} and 0.01 to 0.03 ^{0}C yr^{-1} under AIB, A2 and B2 scenarios, respectively (Fig. 3.14); the rainfall to increase by 0.13 to 6.99 mm yr^{-1}, 1.90 to 4.13 mm yr^{-1} and 0.01 to 4.27 mm yr^{-1} under AIB, A2 and B2 scenarios, respectively at all the stations under different agro-climatic regions of Punjab state whereas a decreasing trend has been predicted by the end of 21 century at the rate of 1.37 and 0.63 mm yr^{-1} under A2 and B2 scenario, respectively at Jalandhar; and 0.30 mm yr^{-1} under A2 scenario at Patiala (Fig. 3.15).

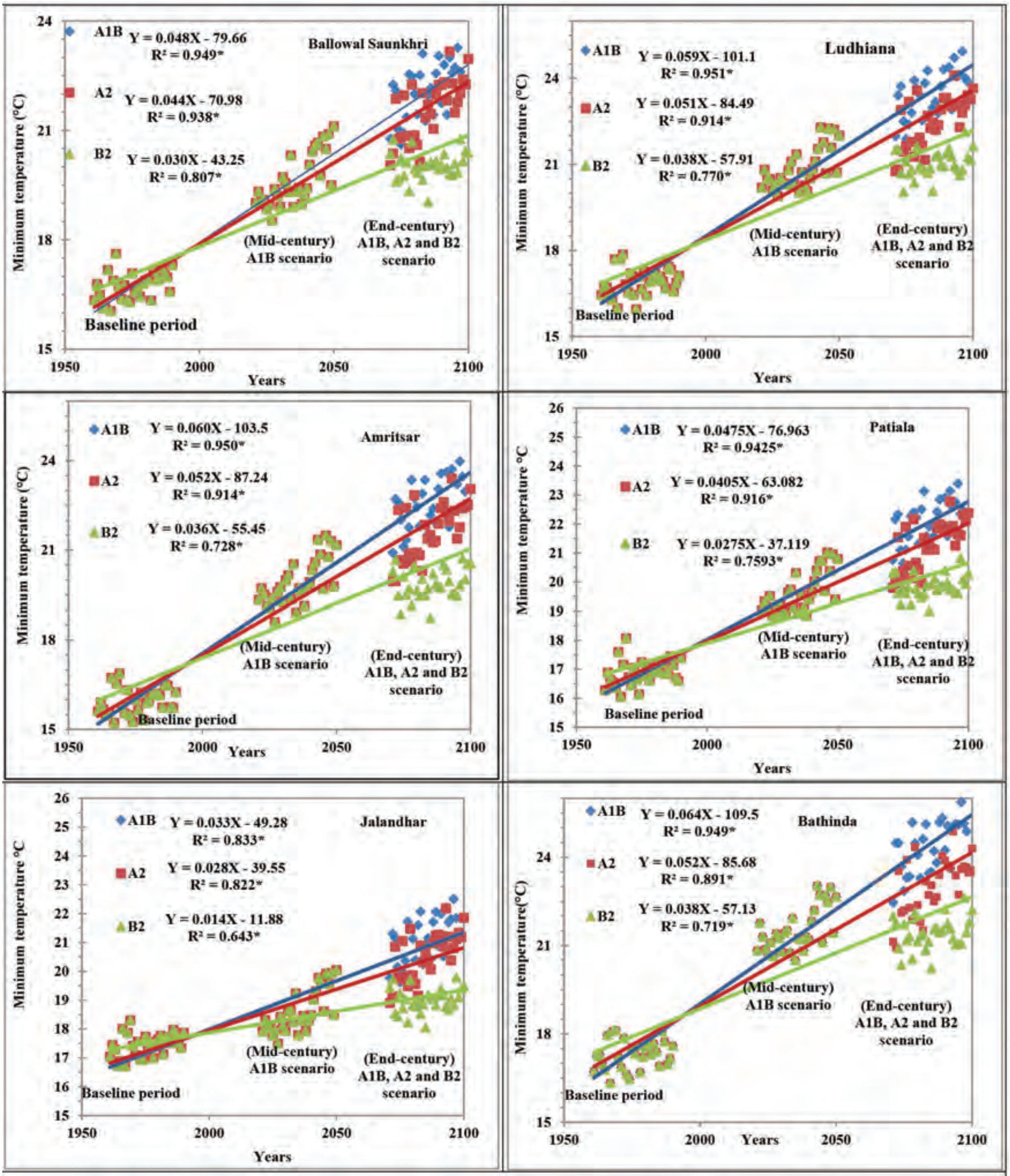


Fig. 3.13: Projected changes in minimum temperature in Punjab state

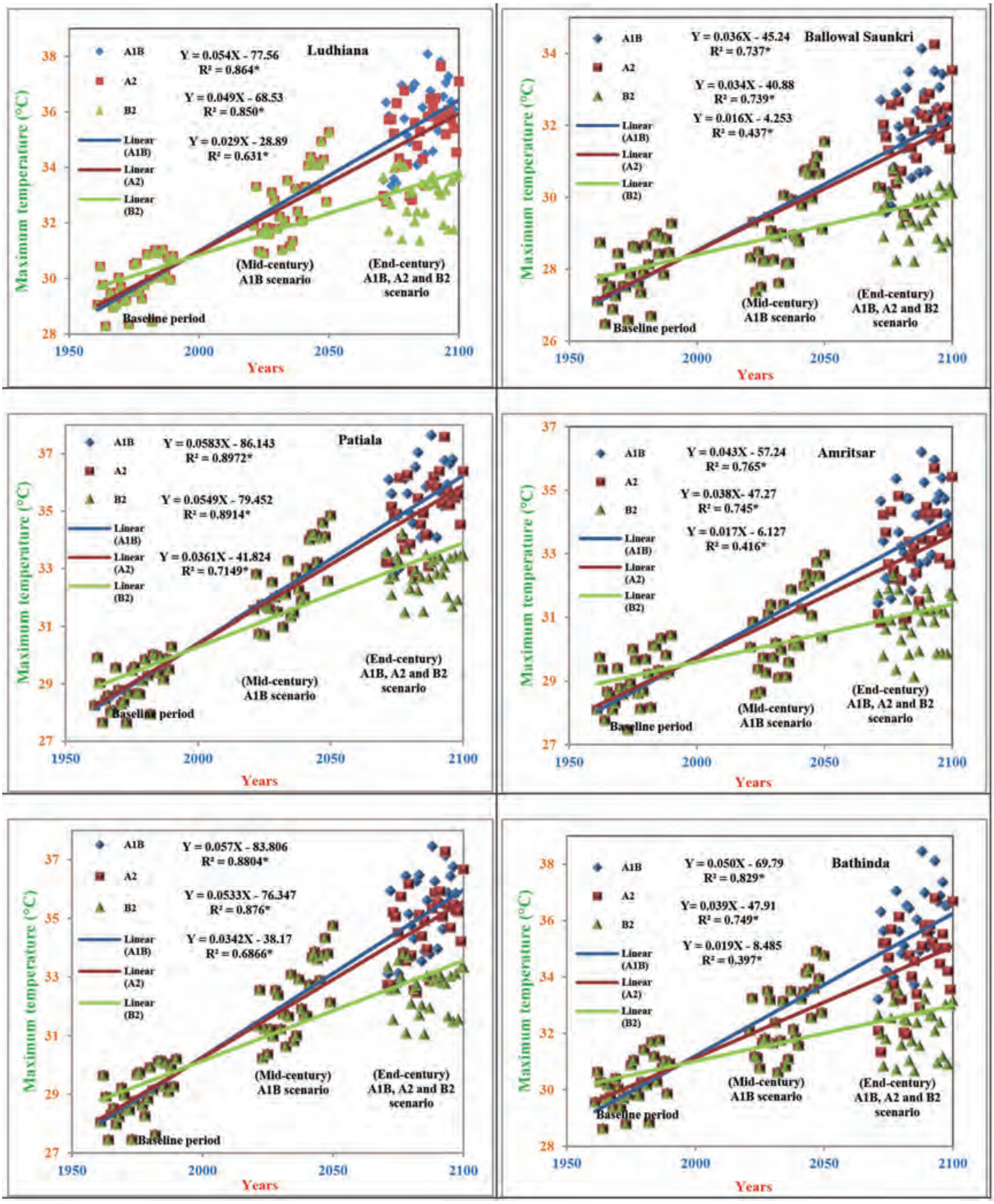


Fig. 3.14: Projected changes in maximum temperature in Punjab state

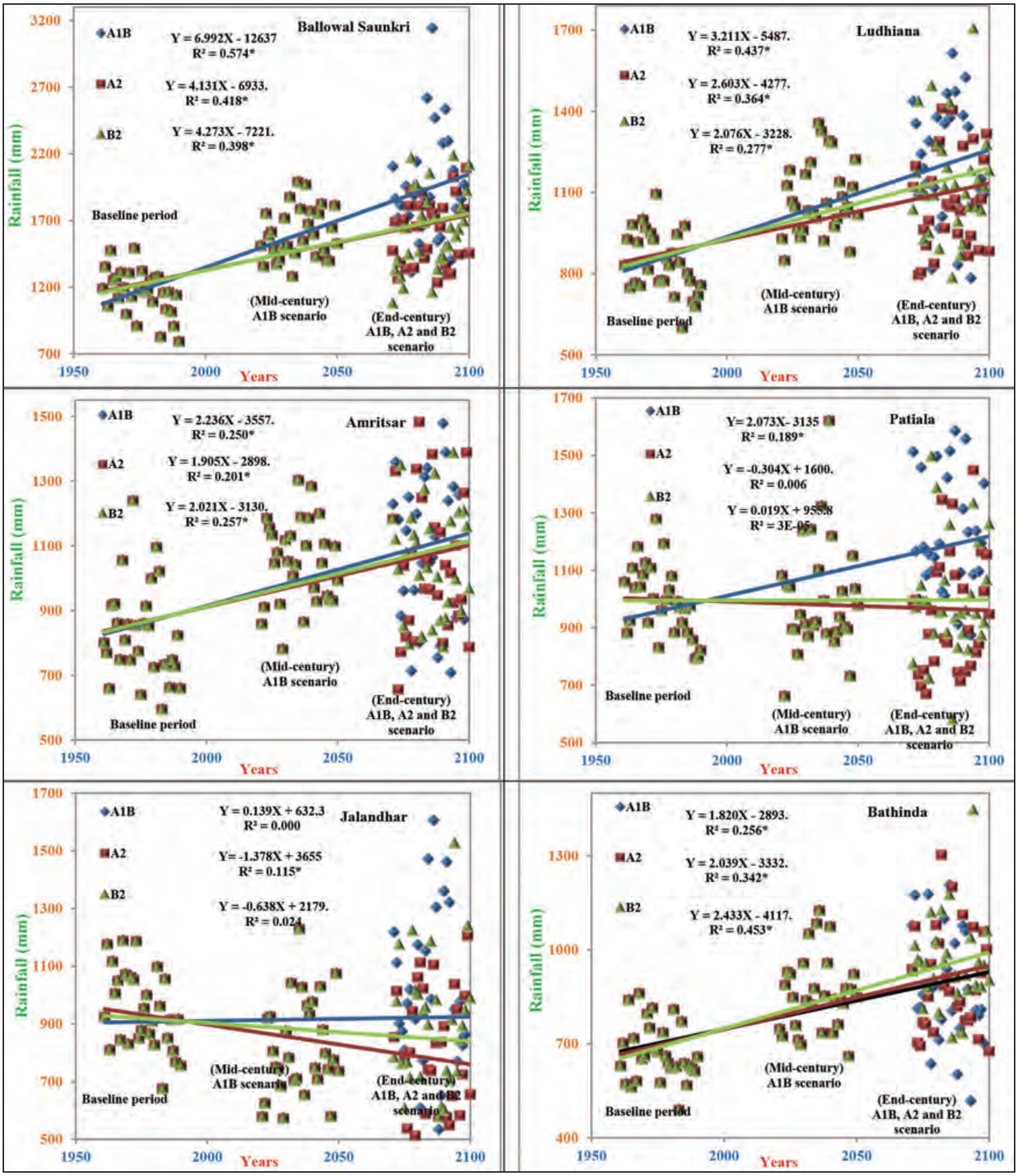


Fig. 3.15: Projected changes in rainfall in Punjab state

Mohanpur

Climate categorization was done for the state of West Bengal based on MAI. The water balance elements *viz*., precipitation, potential evapotranspiration (PE), actual evapotranspiration (AE), water surplus (WS) and water deficit (WD) were computed following the procedure of Thornthwaite and Mather (1955). Based on Aridity index and Humidity index, the moisture index was calculated and based on moisture index values different climatic types of West Bengal were classified. The criteria for designating climatic types against Moisture index (Im,%) were Per-humid (A), Im > 100; Humid (B4), Im=80-100; Humid (B3), Im=60-80; Humid (B2), Im=40-60; Humid (B1), Im=20-40; Moist sub-humid (C2), Im=0-20; Dry sub-humid (C1), Im=0-33.3; Semi-arid (D), Im=-33.3 to -66.7; Arid (E), Im<-66.7.

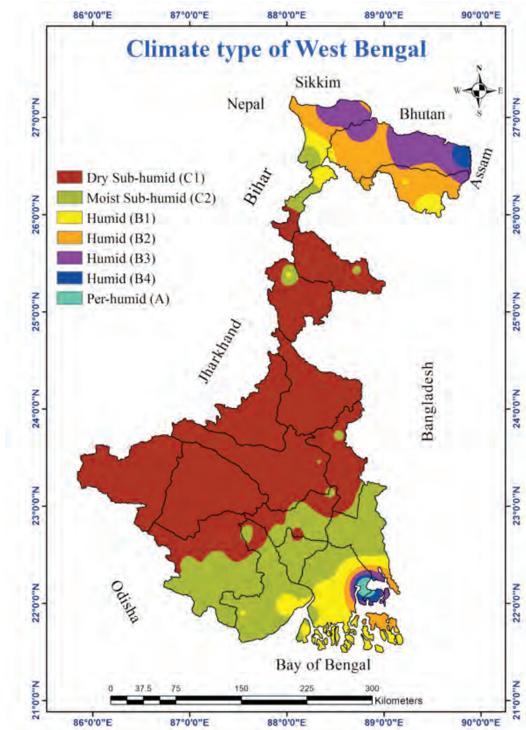


Fig. 3.16: Moisture index based climatic classification of West Bengal

Mainly four climatic types were observed within the geographical boundary of West Bengal, namely dry sub-humid, moist sub-humid, humid and per-humid (Fig. 3.16). Based on Im value the humid type is subdivided into four categories and all the categories (B1, B2, B3 and B4) are observed in the State. Major portions of the State comes under dry sub-humid zone where the major soil types are old alluvial, new alluvial and red-lateritic zones of West Bengal. In the southern part of the State (East and West Midnapur, Howrah, Hooghly and north 24 Praganas) the moist sub-humid zone is observed, where Im values varied between 0-20%. The humid (B1 type of climate) observed mainly in south 24 Parganas district. In northern West Bengal (parts of Darjeeling, Jalpaiguri and Coochbehar district) the humid (B2) climate is observed. Humid (B3) climate is mainly observed in Darjeeling and Jalpaiguri districts. The areas under humid (B4) climate and per-humid (A) climate are scarce, although observed in the state. As Im value never falls below -33.3%, the semi-arid and arid types of climate are not observed in the state.

Monthly variation

Decadal variation of monthly rainy days and rainfall at Mohanpur centre during the period 1960-2016 (Fig. 3.17) showed that number of rainy days declined in decade after decade while June and July didn't show significant change. However, increasing trend of rainy days was observed in August, September and October. Variation of rainy days in the post-monsoon months was negligible (Fig. 3.17a). In case of monthly total rainfall, the changing pattern is different. The total rainfall declined gradually during May. In contrast, during June to November months, the total monthly rainfall increased gradually from decade to decade. The average rainfall during last few years (2010-2016) showed a declining trend compared to the period 1990-2016. The variation of rainfall in December, January and February months was negligible (Fig. 3.17b).

Seasonal variation

Differences of rainy days during different seasons over the period 1991-2016 compared to 1960-1990 was negligible. However, small increase was observed during both monsoon and post-monsoon season (Fig. 3.18a). The average seasonal rainfall increased during 1991-2016 compared to 1960-1990. The amount of rainfall during monsoon and post-monsoonal season increased by 90 and 45 mm, respectively in the period 1991-2016 compared to 1960-1990 (Fig. 3.18b).

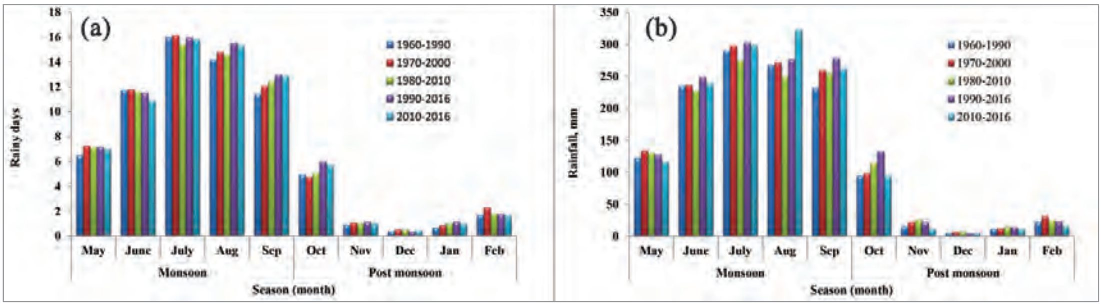


Fig. 3.17: Decadal variation of monthly (a) rainy days and (b) rainfall during different months at Mohanpur station

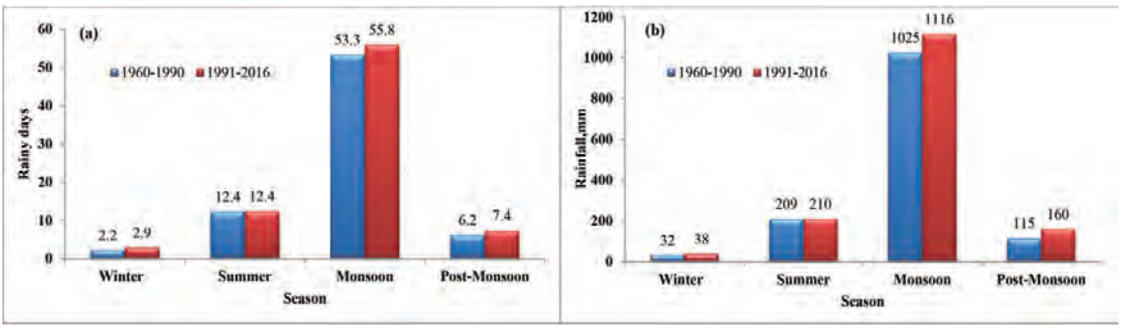


Fig. 3.18: Seasonal variation of (a) rainy days and (b) rainfall during different time periods at Mohanpur station

Raipur

Delineation of production and productivity zones

Rice

Rice production zones were classified on the basis of coverage of crop in different districts during 2012, 2013 and 2014. Primary zone is consisting of those districts which are covering 50% of the area under the respective crops. Next 35% of crop coverage of districts is called secondary zone and rest of the districts will be termed as tertiary districts. In case acreage is less than 1000 thousand hectare, it will be termed as other district (Fig. 3.18).

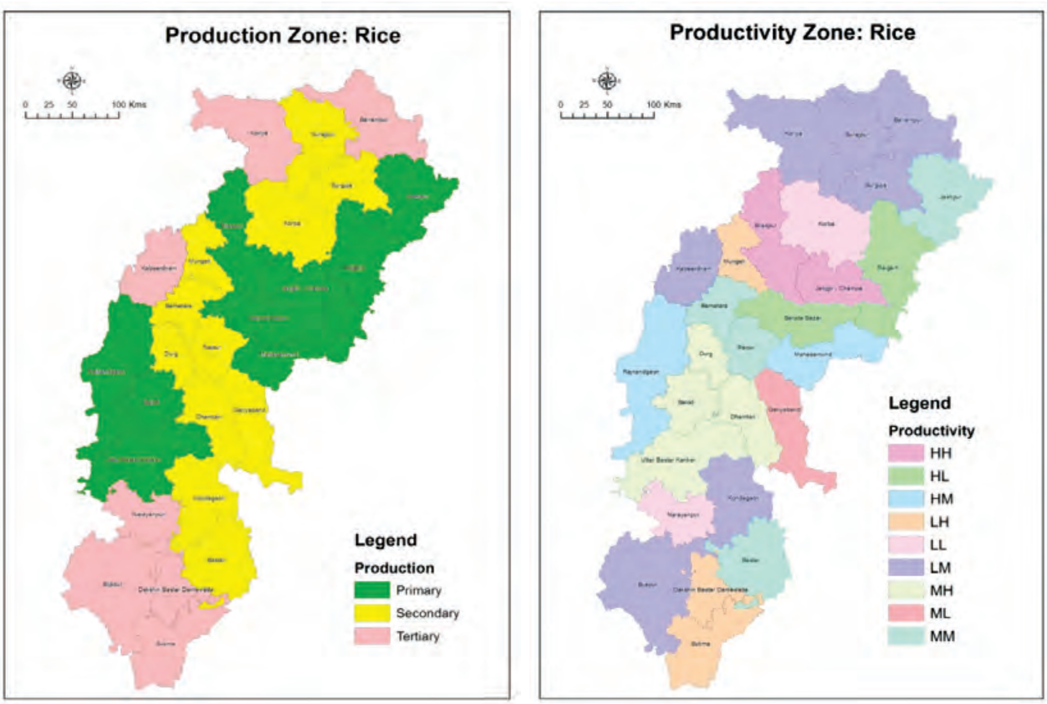


Fig. 3.19: Delineation of different (a) production zones and (b) productivity zones of rice in Chhattisgarh

It is well evident from Fig. 3.19a that production zones of rice crop is mainly concentrated in Centrally located districts *viz*. Rajnandgaon (7%), Janjgir-champa, Mahasamund *etc.* The primary zone covers about 65% area under rice and only Jashpur district covers 181 thousand hectares accounting for 5% of rice acreage of state. In secondary zone, about 11 districts cover remaining 35% of rice growing area. In Kabirdham, Balrampur, Sukma, Korea, Dantewada, Bijapur and Narayanpur, there is lesser coverage and extent of rice crop. It can be very well interpreted that rice crop covering approximately 3895 thousand hectares of crop area which is about 81 per cent area under *kharif* crops. The total area under rice in Chhattisgarh is approximately 3.9 million ha during *kharif* season. The area under rice fluctuates between 36.81 and 38.32 lakh hectares during 1999 to 2013.

Regarding productivity zones, criterion for categorization of rice crop area (Lakh ha) was high (> 2), medium (1.25-2) and Low (< 1.25); for Yield it was high (> 1800), medium (1500-1800) and Low (< 1500) (kg ha^{-1}). Janjgir-Champa and Bilaspur are the districts which are covered under HH category (Fig. 3.19b). These are the districts which are covered under primary zone and because of canal network and favourable weather conditions are giving high yields as well. However, Mahasamund and Rajnandgaon districts are covered under HM category, technological interventions have to be made to raise the yield levels in these two districts. In Raigarh and Balodabazar though coverage is high, yield levels are low because of change in climatic pattern. Therefore, efforts should be made to diversify the cropping pattern by replacing rice with pulses and oilseed crops in these two districts. Gariyaband is coming under ML category which mean rice crop coverage is under medium category with low productivity. This district has potential for pigeonpea and other *kharif* oilseeds, millets and pulses crops. Korba and Narayanpur are covered under LL category, hence these are the districts which should be targetted for crop diversification, particularly, in upland situations.

Wheat

Chhattisgarh state occupies an average 104 thousand hectares area under wheat crop with a production of 139 thousand tonnes and effectively contributing to the government policy to increase cropping intensity of the state. Bastar, Kondagaon and Narayanpur districts covered under Mahanadi Reservoir Project (MRP) are having higher productivity (more than 1.8 ton per hectare). Wheat is an important crop in Bemetara (14% coverage of state area), Rajnandgaon (13%), Balrampur (9%), Bilaspur (8%) and Kabirdham (8%) districts which is mainly grown under assured irrigated or partially irrigated condition. Rice-wheat cropping sequence is prevailing in Mahanadi Reservoir Project (MRP) area, however it is also grown in area where irrigation facilities are available like tubewell and perennial nalas **(**Fig. 3.20a). However, agriculturally developed districts in central part region are found to have medium productivity. In addition districts like Durg, Bilaspur, Mungeli and Surguja are also having low productivity. The reason for high productivity in South Chhattisgarh areas can be attributed to favourable weather parameters in this region.

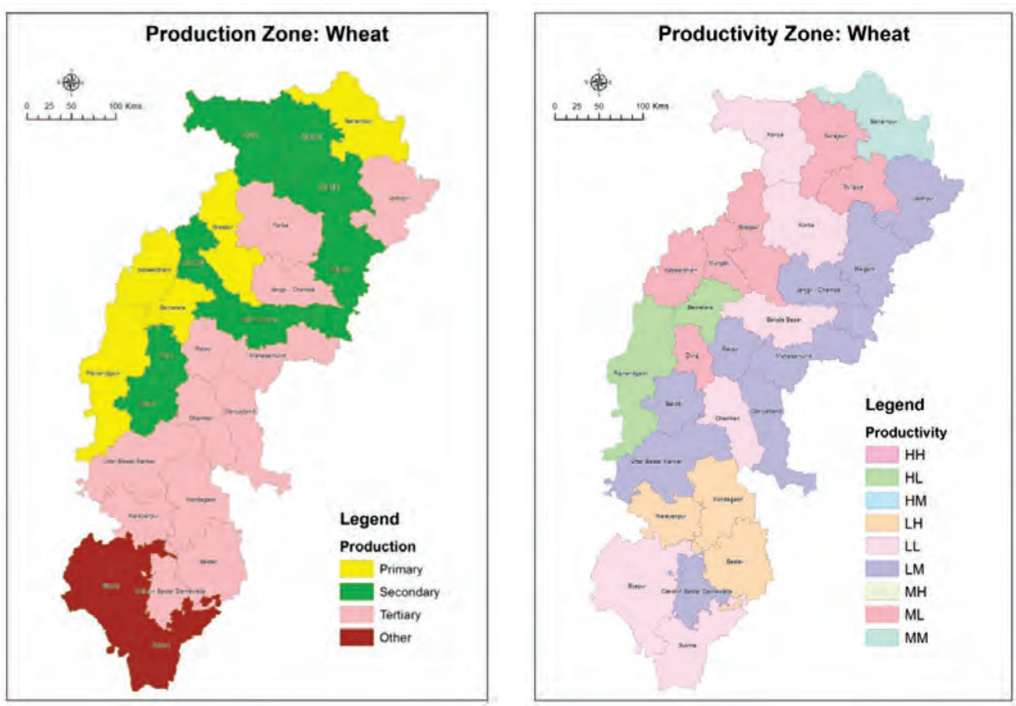


Fig. 3.20: Delineation of different production and productivity zones of wheat in Chhattisgarh

Regarding productivity zones, criterion for categorization in wheat crop for area (Lakh ha) was high (> 10000), medium (5000-10000) and Low (< 5000); for Yield (kg ha^{-1}) it was high (> 1800), medium (1500-1800) and Low (< 1500). There are districts like Bemetara and Rajnandgaon which are having wide coverage of wheat crop (> 10000 ha) with low productivity (< 1500 kg ha^{-1}). District Balrampur is having the medium coverage with medium productivity. Though there is fair expansion of this crop in districts namely Bilaspur, Kabirdham, Surajpur, Durg, Mungeli, Surguja, the productivity is not even 1.5 tonne per ha. The acreage and productivity of this crop is very low in districts like Korba, Balodabazar, Koriya, Bijapur and Sukma. Hence under diversification program, pulse crops like chickpea and oilseed crops should replace wheat in these areas. On the other hand, there are districts like Kondagaon, Bastar and Narayanpur which are having higher productivity but low acreage. (Fig. 3.20b).

Ranchi

Long term analysis of rainfall data (1986-2014) showed the average annual rainfall of Dumka region to be 1281 mm (76 rainy days) with 28 per cent coefficient of variation. The highest annual rainfall of 2256 mm (76 rainy days) was recorded in the year 2006 and lowest rainfall of 731 mm (38 rainy days) was recorded in year 1987. The seasonal rainfall analysis of the region in terms of winter (January - February), summer (March – May), SW monsoon *i.e. kharif* (June - September) and NE monsoon (October - December) revealed that the region enjoys a well defined pattern of seasonal rainfall. Rainfall has not been found much dependable in any season, as their CV values were higher than the threshold level (50 per cent except in *kharif* season). The CV of 35 per cent recorded in *kharif* indicated a reliable rainfall receipt in Dumka. In Dumka, the highest rainfall of 299.4 mm was received during July month followed by September (271.1 mm) with 51 and 65 per cent coefficient of variation, respectively. The CV during November to May was higher than the threshold level (100%) and highest being in December indicated higher variation in rainfall in winter season. Coefficient of variation of monthly rainfall for Dumka revealed that among all the months, variability was lower in June to September months. The summer and winter rainfall is meager and highly variable and thereby, sowing of second crop during winter season without supplementary irrigation would be risky. Under the rainfed situation of the region, second crop like pulses (chick pea and field pea) oilseed (linseed, safflower, niger) could be grown utilizing residual soil moisture in low land rainfed rice fields.

Analysis on commencement, withdrawal and duration of rainy season and its variability at Dumka station showed that earliest start of rainy season in the region had occurred during 23 week (4-10 June), latest by 27 week (2-8 July) and normal start of rainy season was found to be 25 week (18–24 June). The normal cessation of rainy season was by 43 week. The length of rainy season ranged from 14-29 weeks with a mean of 18 week and CV values of 18% for Dumka. The probability of weekly rainfall amount at 25, 50, 75 and 90% probability levels at Dumka station is presented in table 3.5 showed that assured rainfall amount decreases with the increase in probability level from 25 to 90%. Monsoon is normally well established over the station by the 23 week. At Dumka, rainfall of 50.9, 23.8 and 8.9 mm is likely to occur at 25, 50 and 75% probability level in the onset week of monsoon. Based on the probability of rainfall at 50% level one can expect 23.8 mm in 5 years out of 10 years in the 23 week. After 38 week assured rainfall amount shows decreasing trend in Dumka region. Rainfall at probability of 75% is also called as dependable precipitation and be recommended to use for the purpose of planning and design in agriculture. However, in high value moisture sensitive crops, a 90% value may be better and in less moisture consuming crops, a 50% level may be appropriate.

Table 3.5: Weekly rainfall amount (mm) at different probability level (%) at Dumka

SMW	Probability level			
	25%	50%	75%	90%
22	40.0	15.9	4.6	0.3
23	50.9	23.8	8.9	0.3
24	51.2	23.8	8.8	0.3
25	98.7	50.8	22.0	0.2
26	92.4	53.6	27.8	0.3
27	83.0	48.5	25.3	0.0
28	114.1	52.6	19.2	0.0
29	99.0	55.0	26.7	0.3
30	81.3	45.4	22.3	0.3
31	78.1	50.7	30.6	0.3
32	69.0	33.0	12.8	0.2
33	72.4	43.1	23.1	0.3
34	90.4	49.9	24.0	0.0
35	62.4	31.0	12.7	0.0
36	66.9	38.9	20.3	0.3
37	87.7	48.5	23.5	0.3
38	112.3	46.7	14.4	0.3
39	94.8	38.6	11.5	0.2
40	60.1	24.5	7.3	0.3
41	41.6	17.0	5.1	0.0
42	32.9	10.2	1.9	0.0

During 1986-2014, 11 and 4 mild and moderate drought years were recorded, respectively. Years of moderate meteorological drought were 1987, 1994, 1996 and 2003. Rest of the 14 years showed an increase in annual rainfall. Probabilities of occurrence of mild meteorological droughts at Dumka, are considerably high (38%) but these situations hardly affect the cropping activities in the region. The probabilities of occurrence of moderate meteorological droughts are 14%. The zero probability of occurrence of severe meteorological drought, seem to be a positive weather condition thereby indicating almost assured rainfall. However, the agricultural droughts, occurring even during the good monsoon years, would be of much concern for developing proper cropping strategies for the station.

Prevalence of agricultural drought was also worked out and found that during *kharif* season, 10 out of 29 years encountered agricultural drought which were most frequently observed in late (37-40 SMW) stages of *kharif* crops in general and which coincided with the reproductive stages of rice in particular. Occurrence of late drought are more frequent in Dumka region. Thus, the farmers would not bother much for creating irrigation source to mitigate the early season agricultural drought, as it does not happen there. However, to save the crop from agricultural drought at reproductive stage, farmers of Dumka, will have to give due importance to rainwater harvesting during the good rainfall spells prior to 37th week.

Samastipur

Distribution and variability of rainfall in Bihar

The average annual as well as average rainfall occurring during different crop growing seasons across various districts under different agroclimatic zones were worked out. Fig. 3.21a illustrating *kharif* season rainfall revealed that all the districts under Zone IIIB and Zone IIIA (except Jamui district), some districts *viz.* Siwan, Saran, Vaishali, Begusarai, Darbhanga under Zone I and Saharsha district under Zone II receive rainfall in the range of 750-1000 mm. The districts of West Champaran, Araria and Purnia received *kharif* rainfall of 1250-1500 mm. Rainfall amounts lying in the range of 1000-1250 mm were observed in the remaining districts of the state. If we consider 50 mm rainfall as weekly water requirement for *kharif* rice based on ET requirement, a rice crop of 17 week-duration (119 days) will require 850 mm rainfall during its entire growing period. Similarly, a rainfall amount of 1050 mm will be adequate for a rice crop of 21 week-duration. Variability in *kharif* season rainfall has also been presented in Fig. 3.21b.

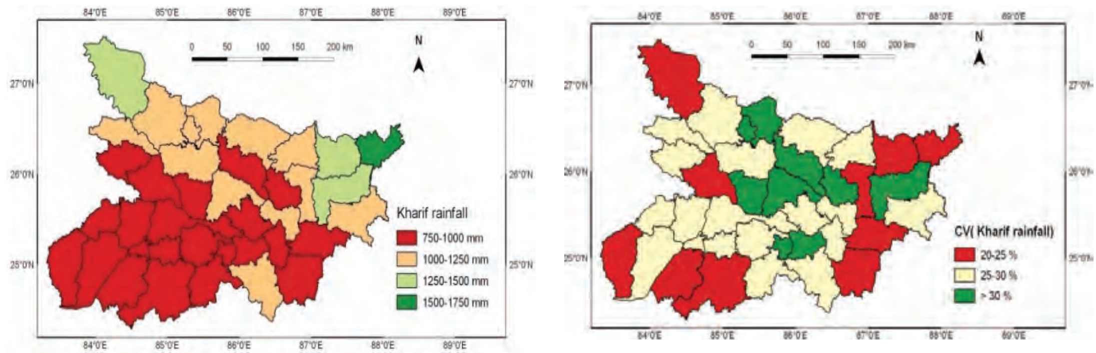


Fig. 3.21: Average rainfall during *kharif* season (a) and its coefficient of variation (b) in different districts of Bihar

Assured Rainfall at Different Probability Levels

Rainfall amount likely to be received at 25, 50 and 75 per cent probability levels were estimated for various districts of Bihar using rainfall data of three rain-gauge stations from each individual district through incomplete gamma distribution analysis. At these three probability levels, starting week, ending week, and the duration in weeks with two threshold values of rainfall *viz.* 20 mm per week (suitable for growing upland crop) and 50 mm per week (suitable for growing transplanted rice) were determined and presented in Table 3.6. Optimum sowing weeks for sowing of rainfed crops based on 20 mm weekly rainfall have been worked out at 50 and 75 per cent probability levels (Fig. 3.22a-b).

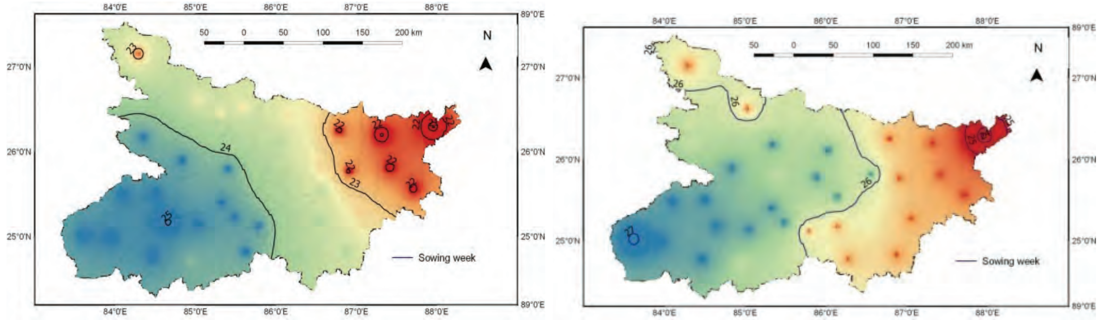


Fig. 3.22: Sowing week (in SMW) with 20 mm assured rainfall at (a) 50% probability level and (b)75% probability over Bihar

At 50 per cent probability level, all the districts under Zone I registered water availability period ranging from 15 weeks in Vaishali to 19 weeks in West Champaran district. In Zone II, Araria district recorded the longest crop growing period (21 weeks) and the shortest (16 weeks) in Khagaria district. Such duration of water availability was found to prevail for 15 to 17 weeks in the districts under Zone IIIA and 13 to 16 weeks under Zone IIIB with a majority of the districts recording 14-week growing period. Thus, it is evident that at 50 per cent probability level, the length of rainfed crop growing period was the maximum in the districts under Zone II and the minimum was observed in the districts under Zone IIIB. Considering the entire state as a whole, at 50 per cent probability level, the longest water availability period of 22 weeks was observed in Kishanganj district in Zone II as against the shortest period of 13 weeks in Arwal district situated in Zone IIIB. Spatial distribution of duration of crop growing period at 50 per cent probability level has been given in Fig. 3.23a, which could help in selection of right type of crops to be grown under rainfed condition across various parts of the state. Map on duration of cropping periods at 75 per cent probability level have been presented in Fig. 3.23b.

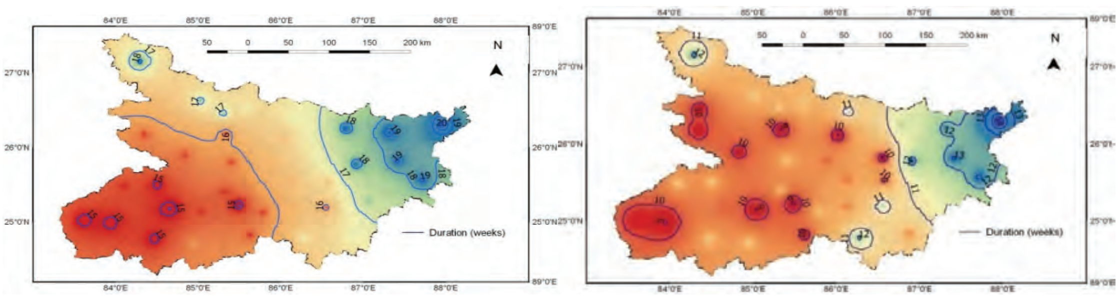


Fig. 3.23: Spatial depiction of the duration of crop growing period (weeks) having 20 mm assured rainfall for consecutive weeks at (a) 50% probability level and (b) 75% probability level over Bihar

Considering the evapotranspiration and percolation losses of 3 and 4 mm per day, respectively from rice fields in eastern India, the water requirement of rice without water stress is taken as 50 mm per week. Keeping this threshold in view, duration of receiving 50mm per week periods at 50 per cent probability level over various districts of Bihar were worked out (Table 3.6). The duration of assured rainfall period varied from 4 to 13 weeks in Zone I. In Zone II, the duration of growing period varied from 7 to 17 weeks over different districts of Zone II. The stable rainfall periods were 5-9 weeks in Zone IIIA and 1-8 weeks in Zone IIIB at 50 per cent probability level. The duration with 50 mm weekly rainfall for consecutive weeks has been presented in Fig. 3.24, which shows the homogeneous regions with identical crop duration.

Table. 3.6: Start, end and duration of water availability period with 20 and 50 mm threshold weekly rainfall at different probability levels in various districts of Bihar

Zone/district	20 mm threshold rainfall at 25% probability			20 mm threshold rainfall at 50% probability			20 mm threshold rainfall at 75% probability			50 mm rainfall at 50% probability		
	Start week	End week	Duration (week)	Start week	End week	Duration (week)	Start week	End week	Duration (week)	Start week	End week	Duration (week)
Zone I (North west alluvial plains)												
Darbhanga	20	42	23	24	39	16	27	34	8	27	32	6
Samastipur	20	42	23	24	39	16	27	36	10	27	34	8
Muzaffarpur	20	41	22	25	39	15	27	34	8	27	34	8
Madhubani	19	41	23	23	39	17	26	37	12	27	34	8
E. Champaran	20	41	22	23	40	18	25	35	11	26	34	9
Goapalganj	20	42	23	25	39	15	26	35	10	27	34	8
Saran	21	42	22	25	39	15	27	35	9	27	34	8
Sitamarhi	18	41	24	23	39	17	26	36	11	26	34	9
Sheohar	19	41	23	23	40	18	26	36	11	26	34	9
Siwan	21	41	21	25	39	15	26	34	9	27	34	8
Vaishali	21	42	22	25	39	15	26	36	11	27	30	4
W. Champaran	17	42	26	22	40	19	25	37	13	25	37	13
Begusarai	20	42	23	24	39	16	27	36	10	27	34	8
Zone II (North east alluvial plains)												
Araria	16	42	27	20	40	21	25	37	13	25	37	13
Katihar	17	42	26	21	40	20	25	38	14	26	37	9
Khagaria	20	41	22	24	39	16	26	34	9	27	34	8
Kishanganj	16	42	27	19	40	22	21	39	19	23	39	17
Madhepura	18	41	25	21	40	20	25	38	14	28	35	9
Saharsha	20	42	23	23	39	17	27	34	8	28	34	7
Supaul	18	42	25	21	40	20	25	37	12	26	37	12
Purnia	17	42	26	21	40	20	25	38	14	25	37	13
Zone IIIA (South Bihar alluvial plains)												
Banka	21	42	22	24	40	17	25	34	10	28	34	7
Bhagalpur	19	42	24	24	40	17	25	35	11	26	34	9
Jamui	21	42	22	24	40	17	25	37	13	26	34	9
Lakhisarai	21	41	21	24	39	16	25	34	10	26	30	5
Sheikhpura	21	41	21	25	39	15	25	35	11	26	31	6
Munger	19	41	23	24	39	15	26	37	12	28	35	9
Zone IIIB (South Bihar alluvial plains)												
Gaya	23	40	18	24	39	16	26	36	11	28	34	7
Auranagabd	23	40	18	25	38	14	27	37	11	27	34	8
Jahanabad	23	40	18	25	39	15	27	34	8	28	-	1
Kaimur	23	40	18	25	38	14	28	36	9	28	34	7
Nalanda	23	40	18	25	38	14	27	34	8	29	-	1
Nawada	23	41	19	25	39	15	26	34	9	28	29	2
Rohtas	23	40	18	25	38	14	27	34	8	28	34	7
Bhojpur	23	40	18	25	38	14	27	37	11	28	33	6
Buxar	23	40	18	25	39	15	27	37	11	28	34	7
Arwal	24	41	18	26	38	13	27	36	10	27	30	4
Patna	22	41	20	25	39	15	27	37	11	28	34	7

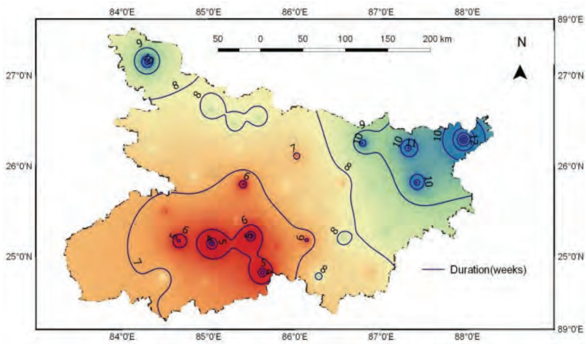


Fig. 3.24: Spatial depiction of the duration of crop growing period (weeks) with 50 mm assured rainfall for consecutive weeks at 50% probability level over Bihar

Thrissur

Extreme temperature events

The trend in hot days was analyzed for all the four seasons as per IMD guidelines *i.e.*, whenever the maximum temperature remains 40 ^{0}C or more and minimum temperature is 5 ^{0}C or more above normal, it may be defined as Hot Day. Since, that conditions is not that frequently occurring in Kerala, we considered the hot day as the day having maximum temperature more than 1 ^{0}C above the daily normal. A significant increasing trend was observed in the number of hot days for two districts *viz.* Thiruananthapuram and Wayanad during south-west monsoon (SWM) season and in all four districts during north-east monsoon (NEM) season. In winter season considerable variability was observed in winter hot days throughout Kerala except Thrissur district (Table 3.7).

Table 3.7: Trend in number of hotter days during four seasons in different districts of Kerala

Districts/Season	SWM	NEM	Winter	Summer
Palakkad (Central zone)	1.14	3.70***	1.87***	-0.18
Thrissur (Central zone)	0.63	2.24**	0.33	-2.11***
Thiruananthapuram (South zone)	2.07*	3.52***	1.54**	1.36
Wayanad (High range zone)	1.57*	2.45***	2.16*	0.02

Level of significance ***(**0.1), ** (0.05), *** (0.01)*

In winter season, the highest number of hot days was seen in the year 2009 for high range zone, and in the year 2013 for both Thrissur and Palakkad and in the year 2016 for Thiruvanathapuram (Fig. 3.25a). A consistent increase in hot days during the NEM season is evident (Fig. 3.25b). In summer season, the highest number of hot days is observed in the year 2016 for all the districts except Thrissur (Fig. 3.25c). The highest number of hot days during SWM season (Fig. 3.25d) is observed in 2015 for both central zone districts Thrissur and Palakkad in the year 2016 for southern zone district Thiruvananthapuram.

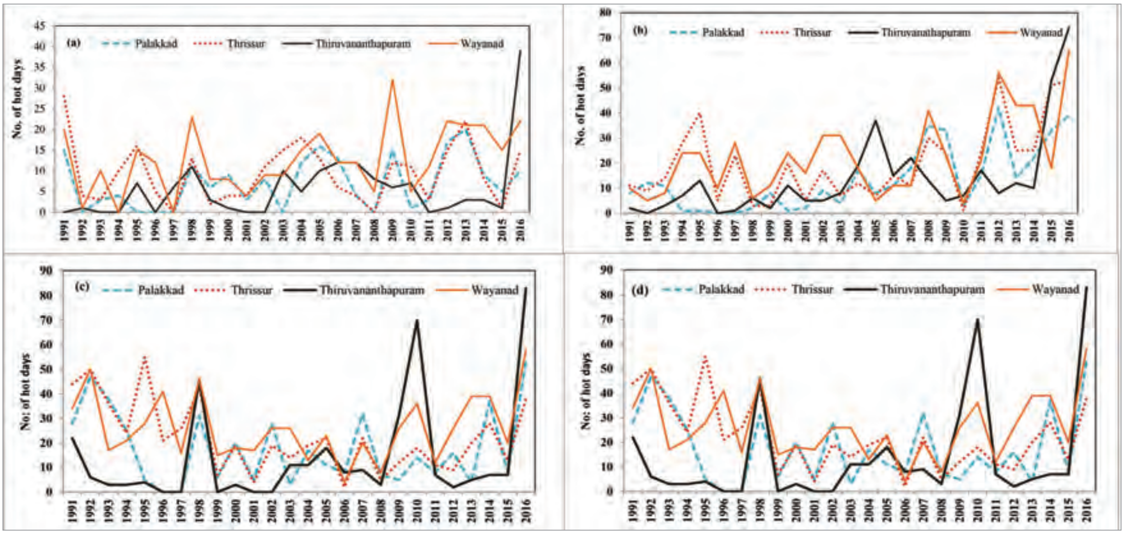


Fig. 3.25: Inter-annual variability of no of hot days in (a) winter, (b) NEM, (c) summer and (d) SWM in Kerala

El Niño effect on rainfall

The percentage change in annual and seasonal rainfall during El Niño and La Niña years of Kerala was analyzed using IITM's sub divisional rainfall data from 1951 to 2014 and is presented in the Fig. 3.26. The south west monsoon (-4.11%) and summer (-2.26%) rainfall is below normal during El Niño years. The rainfall during NEM season was observed to be above normal (3.06%) during El Niño years. Contradictory to El Niño years, the annual (0.32%) and southwest monsoon (2.19%) rainfall was found to be above normal during La Niña years while northeast monsoon rainfall is below normal (7.76%) during La Niña years.

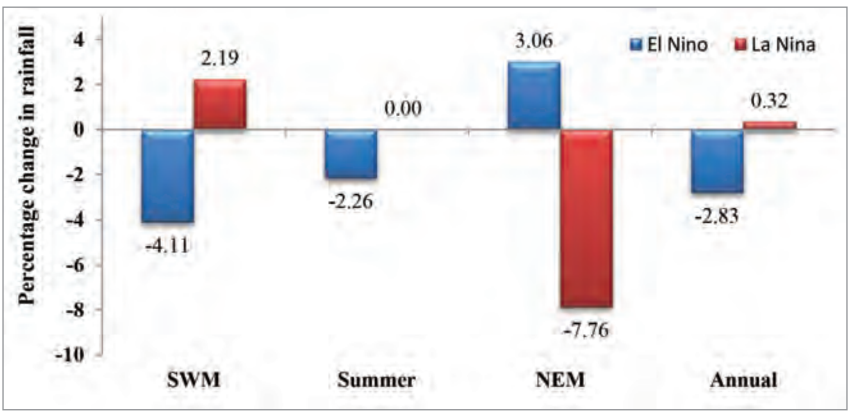


Fig. 3.26: Percentage deviation from normal in annual and seasonal rainfall of Kerala during El Niño and La Niña years

Out of nine El Niño years, four were deficient years and five were excess years. Both the weak El Niño years and two strong El Niño (out of three) were excess rainfall years, while the three out of four moderate El Niño years were deficient years (Fig. 3.27a). Southwest monsoon rainfall was maximum in 2007 (Fig. 3.27b), a normal year and minimum in 2002, a moderate El Niño year. Out of two weak El Niño years, one was deficient and one was excess monsoon year. Out of four moderate El Niño years, three were deficient monsoon years and both the strong El Niño years were excess monsoon years. The highest northeast monsoon rainfall has occurred in 2010 (Fig. 3.27c), a normal year and lowest in 1988, a La Niña year. In general El Niño is positively influencing the NEM rainfall over Kerala. Out of nine El Niño years, five were excess monsoon years and one was normal year. However, two highest summer rainfall years occurred in the weak El Niño years (Fig. 3.27d).

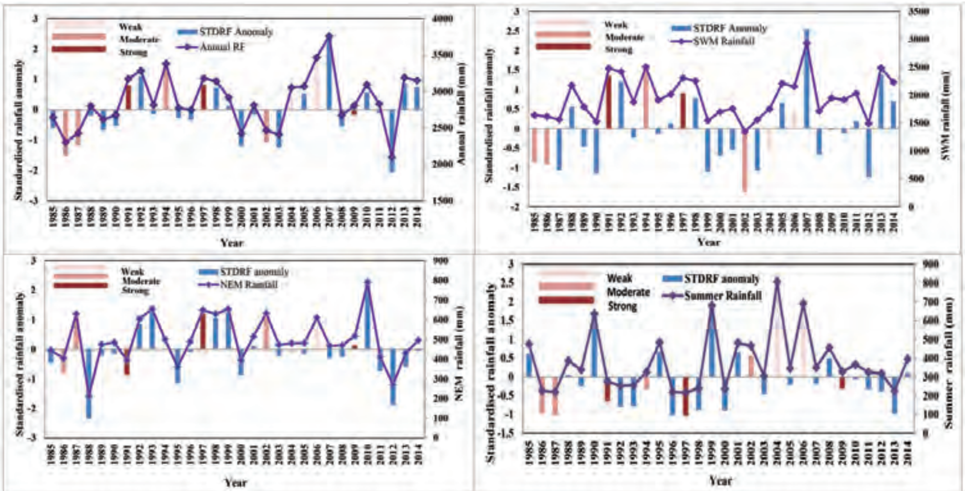


Fig. 3.27: Inter-annual variability of (a) annual (b) SWM (c) NEM and (d) summer rainfall from 1985 to 2014

Effect of El Niño on temperatures

The annual and seasonal maximum and minimum temperature anomaly in El Niño and La Niña years is shown in Fig. 3.28.

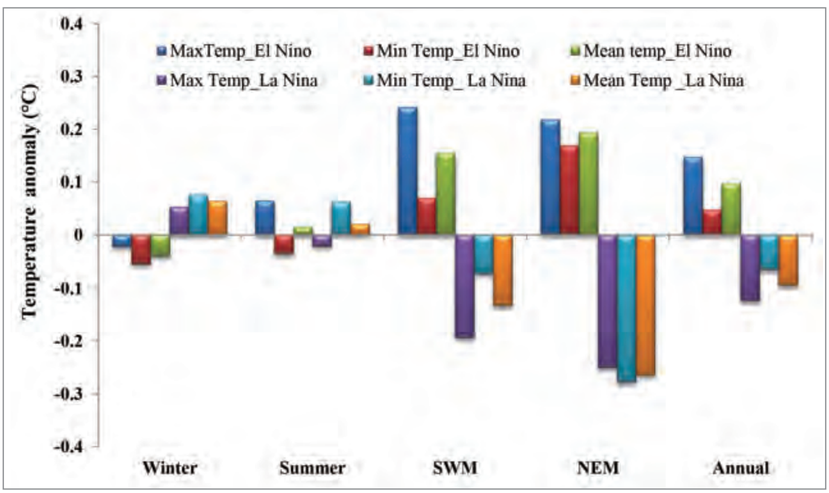


Fig. 3.28: Annual and seasonal maximum, minimum and mean temperature anomaly in Kerala

Annual minimum, maximum and mean temperatures are above normal during El Niño years, while they are below normal during La Niña years. During SWM and NEM season also, temperatures followed the same pattern with above normal temperature in El Niño years and below normal in La Niña years. Even though, the rainfall situation is contradictory in southwest and northeast monsoon season, the maximum, minimum and mean temperature is above (below) normal during El Niño (La Niña) years in both the seasons. The difference in temperature of El Niño and La Niña years was more pronounced in NEM season.

Annual, SWM and NEM mean temperature anomaly in all the districts was positive. Temperature anomaly is negative during winter season in all the districts, except Thrissur and Thiruvananthapuram.

Udaipur

Analysis of annual rainfall to workout trends of different rainfall spells was done across the time period 1970-2014, based on selected 32 districts of Rajasthan. The Mann-Kendall test using trend/ change detection software was performed to evaluate the trend of different rainfall spells (> 2.5 mm for 10 days), ≥ 10 mm for 7 days, ≥ 25 mm for 3 days, ≥ 50 mm for 2 days and ≥ 100 mm for 1 day). The trend statistics of longest rainfall spell, total spells and total rainfall days under different intensity classes are detailed in Table 3.8, 3.9 and 3.10, respectively. Longest spell of > 10 mm rainfall has significant decreasing trend at Jalore whereas the trend in other districts was not significant. A significant decreasing trend was observed in Karauli and Nagaur districts for rainfall > 25 mm and in Jalore for rainfall > 100 mm (Table 3.8).

For total number of spells with rainfall > 2.5 mm for 10 days, three districts *viz.* Ajmer, Sirohi and Tonk showed significant decreasing trend. For total number of spell of > 25 mm for 3 days, Bhilwara, Dausa, Jaipur and Nagaur showed significant decreasing trend. However, under total spell with > 50mm for 2 days only one district *i.e.* Ajmer showed significant decreasing trend. Only two districts, Ajmer and Jalore showed significant decreasing trends under total spell > 100 mm for one day (Table 3.9). With respect to total days under different intensity classes (Table 3.10), Bikaner, Kota and Tonk showed significant decreasing trends under < 2.5 mm for ten days, Tonk under > 10mm for seven days, Dausa, Sikar, Tonk and Udaipur under > 25 mm for 3 days, Kota, Tonk and Udaipur under > 50 mm for two days and Jalore under > 100 mm for one day.

As far as shifts in annual rainfall and rainy days in different districts of Rajasthan are concerned, out of 33 districts in the state, 17 (51.5%) districts exhibited higher annual rainfall during last 15 years *i.e.* 2001-2015 as compared to 1970-2000 (Table 3.11). However, 48.5 per cent districts showed less annual rainfall in 2001-2015 against 1970-2000. The coefficient of variation also decreased in the present time period (2001-2015) as compared to previous period of (1970-2000). Annual rainfall showed positive shift during 2001-2015. With respect to rainy days, 12 districts (36.4%) showed decreasing annual rainy days during later phase (2001-2015) as compared to 1970-2000. However, 15 per cent of districts showed no shift in annual rainy days.

Table 3.8: Trend statistics of longest rainfall spell under different intensity classes at 32 selected districts of Rajasthan (Mann Kendall Test) (1970-2014)

District	Longest spell				
	(< 2.5 mm)	(> 10mm)	(> 25 mm)	(> 50 mm)	(> 100 mm)
Ajmer	+0.01 (*)	-0.66	-1.51	-1.37	-1.99 (*)
Alwar	-0.75	-0.41	-0.60	+0.16	+0.78
Banswara	+0.10	-0.41	-0.73	-0.57	+0.62
Baran	-2.27	-0.98	-0.73	-0.66	-0.46
Barmer	+1.27	+1.33	+0.94	-0.79	+0.00
Bharatpur	-0.39	-0.34	-1.13	-1.26	+0.64
Bhilwara	-1.49	-0.82	+0.42	+0.90	-0.15
Bikaner	-1.33	-0.84	-0.48	+0.23	+0.58
Chittorgarh	+0.09	+0.58	-0.08	+0.58	+0.70
Churu	-0.17	-	-0.79	+1.14	-0.69
Dausa	-1.38	-	-2.36	+0.00	+0.66
Dholpur	+1.06	-0.86	-0.52	+0.43	-0.32
Dungarpur	+1.32	+0.38	+0.11	+0.65	-0.88
Sri Ganganagar	-0.48	+0.16	-0.38	+0.99	-1.35
Hanumangarh	+0.94	+0.96	+1.13	+0.54	-0.10
Jaipur	-1.71(***)	-0.73	-1.51	-1.03	-0.86
Jaisalmer	+2.40 (*)	+1.15	+0.16	+1.32	+0.30
Jalore	-1.04	-1.88 (+)	-0.62	-0.97	-2.15 (*)
Jhalawara	-0.02	+0.27	+1.59	+0.02	-1.26
Jhunjhunu	+0.59	-0.14	+0.65	+0.18	-1.04
Jodhpur	+0.44	-0.80	-1.10	-0.64	-0.70
Karauli	+0.35	0.84	-1.65 (+)	-0.75	-1.19
Kota	-1.34	0.58	0.61	-1.42	-0.93
Nagaur	-0.23	-1.20	-2.10 (*)	-0.28	-0.81
Pali	-1.10	-1.10	+0.11	+0.85	+0.05
Pratapgarh	-0.02	+1.49	+0.61	+0.90	+0.22
Rajsamand	-0.67	+1.04	+0.77	+0.89	+0.92
Sawaimadhopur	-0.48	-1.18	+0.25	-0.13	+0.47
Sikar	-1.23	-0.77	-2.49(*)	-1.09	+0.72
Sirohi	-1.25	-0.95	-0.48	-1.23	-1.27
Tonk	-1.55	-1.57	-1.07	-1.62	-0.71
Udaipur	-0.67	+1.04	-0.02	+1.22	+0.52

**Significant (P= 0.05), ** Significant (P= 0.1), ***Significant (P= 0.01)*

Table 3.9: Trend statistics of total number of spell under different intensity classes at 32 selected districts of Rajasthan (1970-2014)

District	Total spell (< 2.5 mm for 10 days)	Total spell (> 10 mm for 7 days)	Total spell (> 25 mm for 3 days)	Total spell (> 50 mm for 2 days)	Total spell (> 100 mm for 1 day)
Ajmer	-1.27 (**)	-1.40	-1.06	-1.99 (*)	-2.04 (*)
Alwar	-1.19	-1.19	+0.04	+1.06	+0.98
Banswara	+0.61	-1.19	-0.28	-0.44	+0.39
Baran	-2.97	-0.18	+0.00	-1.09	-0.24
Barmer	-1.27	+1.04	+1.02	-0.10	-0.05
Bharatpur	+0.04	+0.03	-1.17	-0.77	+0.81
Bhilwara	+0.16	+1.50	+2.26 (*)	+1.59	-0.13
Bikaner	+0.19	-1.04	+0.41	+0.41	+0.58
Chittorgarh	-0.02	-0.80	-0.24	+0.69	+1.09
Churu	-1.35	+0	+0.57	+0.91	-0.69
Dausa	-1.50	+0	-2.15 (*)	-0.64	+0.47
Dholpur	-1.37	+0.54	-0.58	+0.11	+0.07
Dungarpur	+0.45	+0.69	+0.49	+1.22	-0.48
Ganganagar	+0.35	+0.27	-1.50	-1.04	-1.35
Hanumangarh	-1.27	+1.12	+1.12	-1.19	-0.10
Jaipur	-0.99	+0.20	-1.78 (***)	-1.19	-0.89
Jaisalmer	-1.27	+1.04	-1.42	+0.18	+0.28
Jalore	+1.04	+0.00	-0.32	-1.37	-2.13 (*)
Jhalawara	-0.42	-0.10	+1.07	-0.46	-0.73
Jhunjhunu	-1.12	+1.35	-0.58	+1.10	-1.04
Jodhpur	-1.12	-1.27	-1.62	-0.62	-0.70
Karuli	-0.14	+0.19	-1.06	-0.83	-0.89
Kota	-0.82	-1.46	+0.04	-1.42	-1.22
Nagaur	-1.27	-0.69	-2.43 (*)	+1.49	-0.98
Pali	-1.50	-0.12	-1.50	+0.82	+0.19
Pratapgarh	+0.42	-0.72	+1.38	+1.06	+0.66
Rajsamand	+1.50	+0.96	+1.43	+1.59	+0.92
Sawaimadhopur	-0.80	-1.62	+0.41	-0.26	+0.75
Sikar	-1.27	-0.80	-0.02	-0.49	+0.56
Sirohi	-1.66 (***)	-1.11	-1.61	-1.09	-1.34
Tonk	-1.68 (***)	+0.34	-1.17	-0.29	+0.65
Udaipur	-1.42	+1.42	-1.89 (***)	+0.34	+0.58

**Significant (P= 0.05), **Significant (P= 0.1), ***Significant (P= 0.01)*

Table 3.10: Trend statistics of total days under different intensity classes at 32 selected districts of Rajasthan (1970-2014)

District	< 2.5 mm for 10 days	> 10 mm for 7 days	> 25 mm for 3 days	> 50 mm for 2 days	> 100 mm for 1 day
Ajmer	-0.14	-0.03	-0.38	-1.39	-1.52
Alwar	+0.07	+0.45	+0.09	0.55	0.96
Banswara	-0.96	+0.45	-0.06	-0.47	0.72
Baran	-1.58	-1.24	-0.59	-0.87	-0.37
Barmer	-0.39	+0.63	+1.24	-0.21	0.00
Bharatpur	+0.89	+0.81	+0.86	-0.26	0.81
Bhilwara	-1.18	-0.62	-0.39	-0.55	-0.13
Bikaner	-1.84 (***)	-0.89	+0.50	0.16	0.58
Chittorgarh	+0.33	+0.62	-0.20	0.34	0.87
Churu	+1.00	-	0.92	0.85	-0.69
Dausa	-0.68	-	-1.38 (*)	0.65	0.47
Dholpur	+0.90	+0.87	+0.26	1.82	-0.04
Dungarpur	+0.07	+0.56	+1.11	0.53	-0.06
Ganganagar	-0.28	+0.24	+1.19	0.51	-1.35
Hanumangarh	+0.90	+0.73	-0.72	0.10	-0.10
Jaipur	-0.83	-0.80	-0.47	-1.67 (***)	-0.93
Jaisalmer	+0.64	-0.09	-0.12	1.48	0.30
Jalore	+0.36	-0.29	+0.55	0.21	-2.13 (*)
Jhalawara	+0.93	+1.47	+1.35	0.97	-0.81
Jhunjhunu	+0.39	+0.06	+0.04	0.04	-1.04
Jodhpur	-0.31	-1.10	-0.57	-0.35	-0.04
Karuli	+0.23	-1.39	-1.53	-0.88	-1.02
Kota	-2.10 (*)	-1.37	-1.10	-2.96 (**)	-1.13
Nagaur	+0.45	-0.58	-0.89	0.30	-0.98
Pali	+0.25	+0.25	+0.83	0.31	0.11
Pratapgarh	-0.74	+0.44	+1.26	2.03 (*)	0.73
Rajsamand	+0.93	+0.32	+0.39	0.56	0.92
Sawaimadhopur	+0.78	+1.13	+0.93	0.60	0.60
Sikar	-0.65	-0.95	-1.86(***)	-0.94	0.68
Sirohi	+0.46	-0.26	-0.25	-0.59	-1.42
Tonk	-1.90 (***)	-1.66 (***)	-2.25 (*)	-2.74 (**)	-0.71
Udaipur	+0.38	+0.67	+1.77 (***)	2.26 (*)	0.58

**significant (P= 0.05), ** significant (P= 0.1), ***significant (P= 0.01)*

Table 3.11: Shift of annual rainfall (mm) and rainy days in different districts of Rajasthan

S. No.	Districts	Rainfall (1970-2000)			Rainfall (2001-2015)			Rainy days (1970-2000)			Rainy days (2001-2015)		
		Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
1	Ajmer	575	206	36	504	144	29	31	8	26	29	5	19
2	Alwar	655	221	34	706	219	31	37	10	27	38	8	22
3	Banswara	1082	403	37	1083	513	47	41	10	24	38	10	26
4	Baran	850	289	34	826	330	40	38	8	23	36	9	25
5	Barmer	312	150	48	329	151	46	17	5	32	18	5	27
6	Bharatpur	622	214	34	644	188	29	32	8	25	33	6	18
7	Bhilwara	671	217	32	628	218	35	31	8	26	29	6	21
8	Bikaner	292	123	42	298	133	45	18	7	35	18	6	34
9	Bundi	704	193	27	687	145	21	33	8	24	35	8	24
10	Chittorgarh	806	211	26	813	174	21	36	8	21	36	6	17
11	Churu	386	152	40	450	148	33	22	8	37	28	7	26
12	Dausa	669	231	35	591	207	35	34	8	25	32	9	29
13	Dholpur	704	253	36	705	273	39	36	8	23	37	8	21
14	Dungarpur	773	279	36	843	360	43	33	10	29	32	8	25
15	Ganganagar	288	139	48	319	117	37	18	7	38	19	7	36
16	Hanumangarh	255	115	45	279	103	37	15	6	38	18	6	33
17	Jaipur	613	219	36	585	202	34	33	9	28	32	8	24
18	Jaisalmer	206	106	52	244	133	55	11	5	44	13	5	35
19	Jalore	423	210	50	418	195	47	21	8	37	22	7	30
20	Jhalawara	921	278	30	984	342	35	38	8	20	39	8	21
21	Jhunjhunu	394	169	43	414	184	44	24	8	32	27	8	30
22	Jodhpur	376	163	43	340	151	44	21	7	33	20	6	29
23	Karauli	770	257	33	675	241	36	36	8	23	36	8	23
24	Kota	716	254	35	627	279	44	34	9	27	30	10	35
25	Nagaur	417	214	51	365	154	42	22	7	30	22	6	28
26	Pali	433	212	49	423	152	36	22	7	32	21	5	23
27	Pratapgarh	929	291	31	992	307	31	40	9	24	38	8	22
28	Rajsamand	551	173	31	610	174	29	30	7	23	33	6	17
29	Swaimadhupur	798	240	30	877	251	29	37	9	23	40	9	24
30	Sikar	514	239	47	479	249	52	27	9	34	26	11	44
31	Sirohi	595	314	53	611	262	43	25	8	31	26	7	26
32	Tonk	630	240	38	581	254	44	31	9	28	31	9	28
33	Udaipur	631	184	29	672	173	26	33	8	24	33	7	21

4. Crop Weather Relationship Studies

Among the numerous factors that farmers take into account for decision making regarding crop production, weather parameters are of principal importance, due to their highly variable nature. Recent research suggests that climate variability adds more uncertainty to weather parameters, by which crops are experiencing more extreme weather events. For a country like India, where a major part of population is involved in agriculture and allied sectors, knowledge about how weather influences crop production can be a critical input. Understanding of how different climatic factors affect growth and yield of major crops in India is an objective of AICRPAM and all the 25 cooperating centers have been undertaking field experiments to study the same. The salient research achievements reported by each center is explained briefly hereunder:

Kharif 2016

Rice

Faizabad

Three cultivars of rice *viz*., Sarjoo-52, NDR-359 and Swarna were exposed to three growing environments (transplanted on July 5, 20 and August 4 2016) to study the crop weather relationships. Effect of cultivars and growing environments on radiation use efficiency was studied and the results are presented in Table 4.1.

Paddy transplanted on July 5 recorded highest RUE of 2.5 g MJ^{-1}, followed by July 20 and August 4. Among cultivars, Sarjoo-52 recorded highest RUE (2.8 g MJ^{-1}) followed by NDR 359 and Swarna. Higher RUE recorded in July 5 sown crop (among dates of sowing) and Sarjoo-52 (among cultivars) was reflected in grain yield also, as they recorded highest grain yield of 4.07 and 3.94 t ha^{-1}, respectively.

Table 4.1: Effect of paddy cultivars and growing environments on radiation use efficiency (g MJ^{-1}) and grain yield (t ha^{-1}) at Faizabad during *kharif* 2016

	RUE (g MJ^{-1}) under different days after transplanting							Grain yield (t ha^{-1})
Treatments	**15**	**30**	**45**	**60**	**75**	**90**	**Harvest**	
Growing Environment								
July 5	1.9		2.1	2.7	2.7	2.7	2.5	4.07
July 20	1.7	1.9	2.6	2.4	2.6	2.3	2.3	3.56
August 4	1.3	1.2	2.1	2.1	2.2	2.7	2.1	3.24
Varieties								
Sarjoo-52	1.9	1.8	2.3	2.6	2.9	2.7	2.8	3.94
NDR 359	1.4	1.6	2.5	2.6	2.6	2.7	2.4	3.75
Swarna	1.6	1.8	2.1	2.7	2.4	2.3	2.3	3.54

Kanpur

Crop-weather relationship study in rice was conducted by exposing four cultivars (NDR-359, CSR-27, Sarjoo-52 and Swarna) to different growing environments through transplanting of crop on three dates (6, 16 and 26 July 2016). Effect of cultivars and date of transplanting on yield, heat use efficiency, 1000 grain weight was studied and the results are presented in Table 4.2.

Table 4.2: Effect of cultivars and date of transplanting in paddy yield, HUE and 1000 grain weight at Kanpur during *kharif* 2016

Treatment	1000 grain wt.(g)	Yield (kg ha^{-1})	HUE (kg ha^{-1} ^{0}C - day^{-1})	Cumulative rainfall (mm)
6 July	28.6	4350	4.25	617.2
16 July	28.5	3860	3.84	596.1
26 July	26.8	2670	3.68	504.0
SE±(d)	0.19	0.35	-	
CD at 5%	0.48	0.87	-	
NDR-359	29.7	4180	4.25	572.3
CSR-27	28.2	3420	3.72	572.4
Sarjoo-52	27.7	3680	4.03	572.4
Swarna	26.4	3230	3.73	572.4
SE± (d)	0.24	0.84	-	
CD at 5%	0.49	1.72	-	

Among three dates of transplanting, highest heat use efficiency, yield and 1000 grain weight was recorded in rice transplanted on 6 July. The values gradually decreased as transplanting was delayed. Rice transplanted on 6 July received the highest accumulated rainfall of 617.2 mm, which might have contributed to higher yield. Among cultivars, NDR-359 recorded highest HUE, yield and 1000 grain weight, followed by Sarjoo-52.

Ludhiana

Effect of different levels of shade (at different crop growth stages) and nitrogen levels on two paddy cultivars (PR-122 and PR-123) was studied during *kharif* 2016. Different levels of shade included 50% reduction in sunlight from 15-45 DAT, 45-75, DAT 75-105 DAT and control (no shade); nitrogen treatments included recommended N and recommended N + 3% urea during mid-season stress. The results are presented in Table 4.3.

The analysis (Table 4.3) revealed that imposing shade during 15-45 days after transplanting (DAT) resulted in reduction of crop duration by two days. It was observed that days taken from tillering to flag leaf emergence was shortened by eight days for PR-122 and by 6 days for PR-123, irrespective of the nitrogen treatments, when shade was imposed during 15-45 DAT. In contrary, there was a delay of 2-3 days during flag leaf emergence to booting for both the varieties under this treatment, compared to no shade treatment (control). The crop duration was 2-4 days and 4-6 days more when crop was imposed with shade during 45-75 DAT and 75-105 DAT, respectively compared to non-shaded treatment. The increase in crop duration was attributed to prolonged grain filling stage. However, foliar application of urea had no effect on crop phenology under all the shaded treatments.

Table 4.3: Effect of different levels of shading and nitrogen on rice phenology at Ludhiana during *kharif* 2016

Stages	S_0: No Shade				S_1: 50% reduction in sunlight during 15-45 DAT				S_2: 50% reduction in sunlight during 45-75DAT				S_3: 50% reduction in sunlight during 75-105 DAT			
	PR 122		PR 123		PR 122		PR 123		PR 122		PR 123		PR 122		PR 123	
	N_0	N_1	N_0	N_1	N_0	N_1	N_0	N_1	N_0	N_1	N_0	N_1	N_0	N_1	N_0	N_1
Transplanting	30(30)	30(30)	30(30)	30(30)	30(30)	30(30)	30(30)	30(30)	30(30)	30(30)	30(30)	30(30)	30(30)	30(30)	30(30)	30(30)
Tillering	28(58)	28(58)	28(58)	28(58)	28(58)	28(58)	28(58)	28(58)	28(58)	28(58)	28(58)	28(58)	28(58)	28(58)	28(58)	28(58)
Flag leaf emergence	26(84)	26(84)	24(82)	24(82)	18(76)	18(76)	18(76)	18(76)	26(84)	26(84)	22(80)	22(80)	26(84)	26(84)	24(82)	24(82)
Booting	18(102)	18(102)	15(97)	15(97)	20(96)	20(96)	18(94)	18(94)	17(101)	17(101)	14(94)	14(94)	18(102	18(102)	15(97)	15(97)
Panicle emergence	7(109)	7(109)	6(103)	6(103)	9(105)	9(105)	5(99)	5(99)	4(105)	4(105)	5(99)	5(99)	8(110)	8(110)	6(103)	6(103)
Anthesis	3(112)	3(112)	3(106)	3(106)	3(108)	3(108)	3(102)	3(102)	4(109)	4(109)	5(104)	5(104)	3(113)	3(113)	3(106)	3(106)
Start of grain filling	10(122)	10(122)	7(113)	7(113)	7(115)	7(115)	7(109)	7(109)	9(118)	9(118)	10(114	10(114	8(121)	8(121)	7(113)	7(113)
End of grain filling	13(135)	13(135)	16(129)	16(129)	16(131)	16(131	19(128	19(125	17(135	17(135	18(132	18(132	18(139	18(139	18(131	18(131
Physiological maturity	4(139)	4(139)	5(134)	5(134)	5(136)	5(136)	5(133)	5(130)	5(140)	5(140)	5(137)	5(137)	6(145)	6(145)	7(138)	7(138)

N_0: Recommended N **N_1: Recommended N + 3% for urea mid-season stress**

(Values in parenthesis denotes cumulative number of days)

Grain yield was reduced under all the shaded treatments compared to non-shaded treatments (Table 4.4). Highest yield reduction was recorded when crop was exposed to shade during 15-45 DAT, followed by shade imposed during 45-75 DAT. Among cultivars, PR-122 recorded highest yield reduction (27%) when exposed to shade during 15-45 DAT. Biomass also showed similar trend. Highest biomass yield reduction was recorded for cultivar PR-123, when exposed to shade during 15-45 DAT (16.5%). Maximum reduction in harvest index was recorded in cultivar PR-122 when exposed to shade during 45-75 DAT (11%).

Table 4.4: Effect of different levels of shading and nitrogen on rice yield, biomass and harvest index at Ludhiana during *kharif* 2016

Treatments	Actual value under no shade	Per cent change as compared to no-shade treatment		
		Shade from 15-45 DAT	Shade from 45-75 DAT	Shade from 75-105 DAT
Grain yield (t ha^{-1})				
No shade	6.98	-18.3	-14.5	-9.8
Varieties				
PR 122	7.20	-17.8	-19.4	-11.5
PR123	6.75	-18.8	-9.2	-7.9
Nitrogen levels				
Recommended N	6.86	-18.0	-15.7	-9.9
Recommended N + 3% Urea spray during middle of stress	7.09	-18.5	-13.2	-9.6
Biomass yield (t ha^{-1})				
No shade	17.53	-15.6	-12.3	-4.2
Varieties				
PR 122	17.82	-14.8	-8.5	-2.9
PR123	17.24	-16.5	-16.3	-5.5
Nitrogen levels				
Recommended N	17.41	-17.6	-12.2	-5.6
Recommended N + 3% Urea spray during middle of stress	17.65	-13.6	-12.5	-2.9
Harvest index (%)				
No shade	39.7	-2.8	-1.3	-5.6
Varieties				
PR 122	40.4	-3.1	-11.1	-8.8
PR123	39.1	-2.6	8.7	-2.3
Nitrogen levels				
Recommended N	39.4	-0.3	-2.8	-4.5
Recommended N + 3% Urea spray during middle of stress	40.1	-5.3	0.1	-6.6

Mohanpur

A field experiment in split plot design with following treatments was conducted during *kharif* 2016 (Main plot: four dates of sowing (16 June; 1, 16 and 31 July 2016); Sub-plot: three paddy cultivars (Swarna, Satabdi and Nayanmani). Influence of growing environments and cultivars on grain yield is presented in Table 4.5.

Table 4.5: Variation of yield (kg ha^{-1}) under different dates of sowing and cultivars for *kharif* rice, 2016 at Mohanpur

DoT	Grain Yield (t ha^{-1})			
	Swarna	Satabdi	Nayanmani	Mean
D1 (16 June)	3070	3124	4030	3408
D2 (1 July)	5553	4615	3570	4580
D3 (16 July)	4108	4162	4089	4120
D4 (31 July)	2936	2813	4395	3381
Mean	3917	3678	4021	

It was observed that among cultivars, Nayanmani recorded the highest yield when sown on 16 June and 31 July. Swarna and Shatabdi recorded highest yield when sown during 1 and 16 July, respectively. Relationship between accumulated intercepted PAR and biomass of rice cultivars were studied and the results obtained for Nayanmani is depicted in Fig. 4.1.

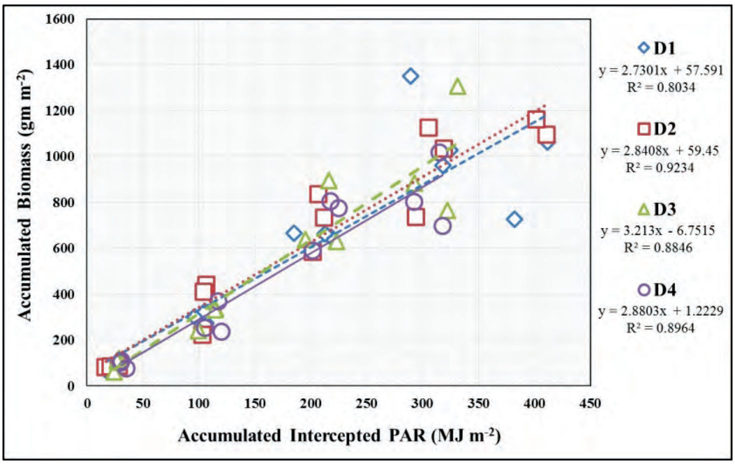


Fig. 4.1: Relationship between cumulative intercepted radiation and biomass of Nayanmani variety during *kharif* 2016 at Mohanpur

The highest RUE value (3.21 gm MJ^{-1}) was observed under third DOT. Higher biomass with less accumulated intercepted PAR in the initial phase of crop growth may be the reason for higher RUE. Other two varieties showed similar relationship, although the estimated RUE values were less than *Nayanmani*.

Raipur

Effect of growing environments and cultivars on paddy yield, heat and radiation use efficiencies was studied using 3 dates of sowing (1, 15 and 30 June 2016) and three paddy cultivars (Swarna, Mahamaya and MTU-1010). Effect of dates of sowing and cultivars on yield and yield attributes is given in Table 4.6.

Table 4.6: Yield of rice varieties as influenced by different growing environments and cultivars at Raipur during *kharif* 2016

Varieties	D1 (1 June)			D2 (15 June)			D3 (30 June)			Mean yield (t ha^{-1})
	Yield (t ha^{-1})	RF_{veg} (mm)	RF_{reprod} (mm)	Yield (t ha^{-1})	RF_{veg} (mm)	RF_{reprod} (mm)	Yield (t ha^{-1})	RF_{veg} (mm)	RF_{reprod} (mm)	
Swarna	5.73	1049.8	149.6	6.78	1171.0	3.8	5.59	1083.6	0	6.05
Mahamaya	4.01	784.0	415.4	5.90	900.0	274.8	5.24	985.2	98.4	5.08
MTU-1010	2.65	729.0	372	4.87	767.2	403.8	3.77	873.4	210.2	3.76
Mean	4.56			5.93			4.92			

(RF_{veg}: cumulative rainfall during vegetative stage; RF_{reprod}: cumulative rainfall during reproductive stage)

The results indicated that highest grain yield was obtained for cv. Swarna sown on 15 June (6.78 t ha^{-1}), followed by cv. Mahamaya sown on same date (5.9 t ha^{-1}). This may be due to the fact that Swarna sown on 15 June received the highest rainfall as well as distribution during its vegetative stage (1171 mm), compared to other cultivars. HUE of different paddy cultivars as affected by growing environments is presented in Table 4.7.

Table 4.7: Heat use efficiency (g m^{-2} ^{0}C-day^{-1}) of rice varieties as influenced by different growing environments at Raipur in *kharif* 2016

Stages	D_1			D_2			D_3		
	Swarna	Maha-maya	MTU-1010	Swarna	Maha-maya	MTU-1010	Swarna	Maha-maya	MTU-1010
15 DAT	0.05	0.05	0.05	0.14	0.14	0.13	0.28	0.29	0.32
30 DAT	0.17	0.18	0.18	0.21	0.28	0.23	0.43	0.86	0.68
45 DAT	0.36	0.80	0.77	0.36	0.32	0.22	0.46	0.56	0.57
60 DAT	0.36	0.56	0.37	0.55	0.80	0.70	0.71	0.79	0.67
75 DAT	0.55	0.66	0.62	0.66	0.73	0.66	0.81	0.88	0.86
90 DAT	0.67	0.55	0.54	0.70	0.86	0.88	0.72	0.66	0.65
Maturity	0.65	0.39	0.42	0.44	0.62	0.70	0.55	0.49	0.52

D_1-01/06/2016, D_2- 15/06/2016, D_3- 30/06/2016

Highest heat use efficiency at maturity was recorded for MTU-1010 sown on 15 June, followed by Swarna sown on 1 June. Among different growing environments, crop sown on 15 June recorded highest HUE. Influence of dates of sowing and cultivars on radiation use efficiency was also studied and the results are presented in Table 4.8.

Table 4.8: Radiation use efficiency (g MJ^{-1}) of rice varieties as influenced by different growing environments in *kharif* 2016

Stages	D_1			D_2			D_3		
	Swarna	Maha-maya	MTU-1010	Swarna	Maha-maya	MTU-1010	Swarna	Maha-maya	MTU-1010
15 DAT	0.12	0.13	0.12	0.33	0.33	0.32	0.93	0.95	1.07
30 DAT	0.41	0.43	0.44	0.58	0.77	0.64	1.31	2.61	2.05
45 DAT	0.96	2.15	2.05	1.00	0.90	0.62	1.41	1.72	1.74
60 DAT	0.96	1.51	1.00	1.56	2.27	1.99	2.13	2.36	2.01
75 DAT	1.52	1.83	1.73	1.87	2.07	1.89	2.44	2.65	2.60
90 DAT	1.86	1.52	1.49	2.03	2.49	2.56	2.10	1.91	1.88
Maturity	1.73	1.08	1.15	1.12	1.67	1.97	1.35	1.29	1.44

D_1: 01/06/2016, D_2: 15/06/2016, D_3: 30/06/2016

For the crop sown on 1 June, Swarna recorded highest RUE of 1.73 g MJ^{-1} at maturity, followed by MTU-1010 (1.15 g MJ^{-1}). Under 15 June sown crop, MTU-1010 recorded highest RUE (1.97 g MJ^{-1}), followed by Mahamaya (1.67 g MJ^{-1}). The cultivar MTU-1010 recorded the highest RUE (1.44 g MJ^{-1}) under 30 June sowing also.

Ranchi

Crop-weather relationship studies in rice were undertaken using a field experiment in split-plot design with three growing environments or dates of sowing (8, 18 and 28 June) as main plot treatments and three rice cultivars (Sahbhagi, Naveen and Swarna) as sub-plot treatments. Effect of treatments on yield and yield attributes are presented in Table 4.9.

Table 4.9: Yield and yield attributes of paddy cultivars as influenced by different sowing dates at Ranchi during *kharif* 2016

Treatments	Effective tillers m^{-2}	No. of grain ear^{-1}	1000 gr wt (g)	Yield (t ha^{-1})	HI (%)
Date of Sowing					
08-June	243	145	21.5	4.55	38
18-June	219	124	22	4.23	40
28-June	253	148	22	4.39	43
S Em	7.12	6	0.26	0.19	1.5
C D at 5%	21.3	18.1	NS	NS	NS
Variety					
Sahbhagi	223	124	25	4.06	44
Naveen	236	133	21.8	4.61	37
Swarna	255	161	18.7	4.50	39
S Em	7.12	6	0.26	0.19	1.5
C D at 5%	21.3	18.1	0.8	NS	4.6
Interaction					
S Em	12.3	10.4	0.46	0.33	2.6
C D at 5%	NS	31.4	NS	NS	8
CV%	8.9	13	3.6	1.32	11.5

The results indicated that there was no significant difference between dates of sowing or cultivars in case of grain yield. Among dates of sowing, highest grain yield was recorded in crop sown on 8 June (4.55 t ha^{-1}). Harvest index was highest for crop sown on 28 June. Among cultivars, Naveen recorded highest grain yield of 4.61 t ha^{-1} and Sahbhagi recorded highest harvest index of 44%. Effect of dates of sowing and cultivar on heat and radiation use efficiencies are presented in Table 4.10.

Table 4.10: Heat and Radiation Use Efficiency of rice cultivars under different sowing dates at Ranchi during *kharif* 2016.

Sowing Date	Heat Use Efficiency (kg ha^{-1} ^{0}C-day^{-1})			Radiation Use Efficiency (g MJ^{-1})		
	Sahbhagi	Naveen	Swarna	Sahbhagi	Naveen	Swarna
8 June	2.0	2.6	2.5	2.0	2.3	1.9
18 June	1.8	2.2	2.3	2.1	2.2	1.8
28 June	1.8	2.1	2.1	2.2	1.9	1.9

It was observed that HUE decreased as the sowing progressed for all the three cultivars. Highest HUE was recorded for crop sown on 8 June for all the three cultivars. Such a trend was not observed in case of RUE. For cultivar Sahbhagi, crop sown on 28 June recorded highest RUE (2.2 g MJ^{-1}) and for Naveen, crop sown on 8 June recorded the highest RUE. For cultivar Swarna, there was not much difference in RUE among different dates of sowing.

Samastipur

Effect of growing environments and cultivars on yield, yield attributes and HUE was studied using a field experiment with four dates of sowing (31 May, 15 June, 30 June and 15 July 2016) and four cultivars (Rajendra Bhagwati-1, Rajendra Bhagwati-2, Saroj and Swarna). Effect of growing environments and cultivars on growth, grain yield, yield attributes and HUE are presented in Table 4.11.

Table 4.11: Effect of sowing dates and cultivars on growth, yield attributes and grain yield of rice cultivars at Samastipur during *kharif* 2016

Treatment	Final plant height (cm)	Tillers per hill	Panicle length (cm)	Grains per Panicle	Grain yield (t ha^{-1})	HUE (kg ha^{-1} ^{0}C-day^{-1})
Sowing dates						
31.05.16	82.6	10	21.5	47.7	1.74	0.7
15.06. 16	85.4	9	22.2	57.1	2.49	1.0
30.06.16	84.1	8	21.3	52.3	1.66	0.7
15.07. 16	80.8	8	22.5	62.0	1.42	0.6
CD (P=0.05)	NS	NS	NS	NS	0.55	-
Varieties						
Rajendra Bhagawati-1	86.4	8.3	23.7	51.4	1.94	0.8
Rajendra Bhagawati-2	90.5	7.6	23.0	50.0	2.32	1.0
Saroj	78.3	9.8	20.4	52.8	1.55	0.7
Swarna	77.7	8.9	20.3	64.8	1.50	0.6
CD (P=0.05)	5.1	1.2	1.8	11.1	0.55	-

The results indicate that crop sown during 15 June recorded highest grain yield (2.49 t ha^{-1}) and that sown on 15 July recorded the lowest yield (1.42 t ha^{-1}). Among cultivars, Rajendra Bhagawati-2 recorded highest yield of 2.32 t ha^{-1}, which was considerably higher than other three cultivars. Similar trend was also observed in the case of heat use efficiency. Effect of maximum and minimum temperature during ear head formation to maturity and total seasonal rainfall on yield was studied and the results are presented in Table 4.12.

Table 4.12: Effect of rainfall and temperature on yield of rice during *kharif* 2016 at Samastipur

Date of sowing	50% ear head to maturity		Rainfall (mm)	Percentage of unfilled grain per panicle	Yield (t ha^{-1})
	Max temp range (^{0}C)	Min temp range (^{0}C)			
31 May	24.5-35.6 (32.1)	20.5-27.2 (24.0)	873.8	29.1	1.74
15 June	24.5-35.6 (32.0)	19.6-27.2 (23.2)	829.5	30.5	2.49
30 June	23.6-27.1 (31.6)	16.7-27.2 (20.5)	766.1	31.6	1.66
15 July	25.6-32.6 (29.7)	12.7-20.6 (16.9)	606.8	38.0	1.42

(Figures in the parenthesis indicate mean temperatures)

The normal (15 June) sown crop recorded the highest yield due to favorable temperature prevailing during 50% flowering to maturity stage and lower percentage of unfilled grains per panicle. The percentage of unfilled grains per panicle increased and yield decreased as the sowing was delayed beyond 15 June due to receipt of lesser rainfall and drop in maximum and minimum temperatures during 50% ear head to maturity stage with each delay in sowing.

Thrissur

Correlation studies between grain yield of paddy cultivar Jyothi and phenophase-wise weather parameters were conducted to study the crop-weather relationship and the results are presented in Table 4.13.

Table 4.13: Correlation between grain yield and phenophase-wise weather parameters in rice cultivar Jyothi at Thrissur during *kharif* 2016

YIELD	TMAX	TMIN	RH1	RH2	VP1	VP2	RF	RD	BSS
P1	-0.396**	-0.172	0.252*	0.533**	-0.257*	0.161	0.433**	0.433**	-0.497**
P2	-0.266*	-0.307**	0.186	0.307**	-0.249*	0.097	0.201	0.181	-0.181
P3	-0.482**	-0.497**	0.345**	0.495**	-0.469**	-0.086	0.378**	0.415**	-0.483**
P4	-0.408**	-0.459**	0.389**	0.237*	-0.530**	-0.296**	0.476**	0.530**	-0.329**
P5	-0.462**	-0.116	0.344**	0.432**	-0.097	0.018	0.360**	0.281*	-0.406**
P6	-0.601**	-0.388**	0.536**	0.423**	-0.167	-0.340**	0.353**	0.442**	-0.252*

[P1: Transplanting to active tillering; P2: Active tillering to panicle initiation; P3: Panicle initiation to booting; P4: Booting to heading; P5: Heading to 50% flowering; P6: Flowering to physiological maturity]

The results indicated that grain yield had significant negative correlation with Tmax throughout the crop growth and it was highest during flowering to physiological maturity. Except transplanting to tillering and heading to 50% flowering, Tmin also showed significant negative correlation with grain yield. Morning and evening RH during all the stages, except morning RH during active tillering to panicle initiation, showed significant positive correlation with grain yield. Rainfall during all the stages also showed significant positive correlation with grain yield, except that of active tillering to panicle initiation.

Jabalpur

A field experiment was carried out on direct seeded rice involving three dates of sowing (21 June, 6 July and 21 July 2016 – D1, D2 and D3, respectively) and three cultivars (Sahbhagi, IR-36 and Kranti). Rice cultivar Kranti recorded highest accumulated GDD when sown on 21 June, among all cultivars (Fig. 4.2). It was observed that crop sown on 21 June had highest accumulated GDD across the cultivars. The value decreased gradually as sowing got delayed.

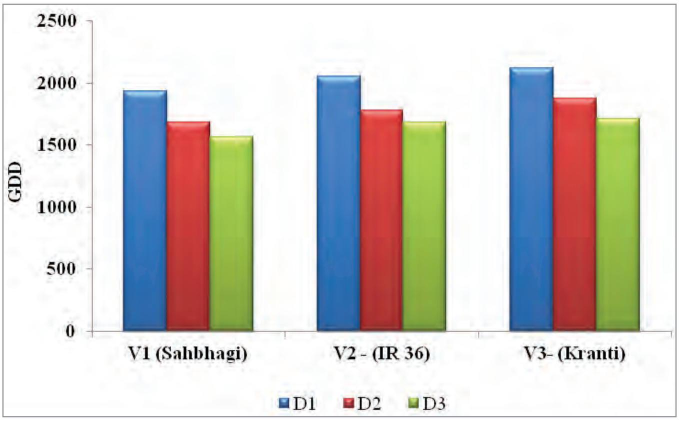


Fig. 4.2: Variation of accumulated GDD from sowing to maturity of paddy cultivars sown on different sowing dates at Jabalpur during *kharif* 2016

Effect of treatments on leaf chlorophyll content was also studied and the results indicated that at 30 and 60 DAS, crop sown on 21 June has slightly higher per cent of chlorophyll content, compared to other sowings. Treatments' effects on chlorophyll content were not statistically significant (Table 4.14).

It was also observed that, among different dates of sowing, crop sown on 21 June recorded highest grain and biological yield across the cultivars. Among cultivars, Kranti sown on 21 June recorded highest grain yield (5.27 t ha^{-1}) and biological yield (11.91 t ha^{-1}) (Table 4.15).

This may be due to the fact that Kranti received highest rainfall during vegetative stage (1513 mm) compared to other cultivars. Similarly, the yield of all the three cultivars was much less when sown on 21 July, which can be attributed to very less (for cv. Sahbhagi) and no rainfall received (for cv IR-36 and Kranti) during reproductive stages. The crop sown on 21 July received the lowest rainfall during vegetative stage also, which might have also contributed to the lesser yield.

Table 4.14: Chlorophyll content (%) in paddy varieties at different days after sowing as affected by cultivars and dates of sowing at Jabalpur during *kharif* 2016

Sowing dates	30 DAS	60 DAS	90 DAS
Sahbhagi			
21 June 2016	38.8	49.0	21.8
06 July 2016	37.1	48.8	19.9
21 July 2016	35.6	47.9	19.7
IR-36			
21 June 2016	34.9	47.3	22.1
06 July 2016	32.4	47.1	21.0
21 July 2016	31.9	45.6	19.7
Kranti			
21 June 2016	38.0	50.6	23.8
06 July 2016	35.6	48.1	22.8
21 July 2016	32.6	44.1	21.2

Table 4.15: Effect of sowing dates and cultivars and rainfall during vegetative and reproductive phases on grain and biological yield of rice at Jabalpur during *kharif* 2016

Treatments	Biological yield ($t\ ha^{-1}$)	Grain yield ($t\ ha^{-1}$)	Rainfall (mm) during vegetative stage	Rainfall (mm) during reproductive stage
D_1V_1	7.73	3.46	1497	98.6
D_1V_2	11.13	4.94	1497.2	80.4
D_1V_3	11.91	5.27	1513	63.8
D_2V_1	5.66	2.81	1332.1	80.4
D_2V_2	7.42	3.22	1337.5	75
D_2V_3	10.1	4.00	1412.5	0
D_3V_1	6.83	2.25	1020	24.2
D_3V_2	8.73	2.34	1045.1	0
D_3V_3	8.79	2.42	1045.1	0

Maize

Jammu

Maize cultivars *viz*., Kanchan-517, Pratap Makka-3 and Kanchan-612 were grown under three growing environments (sown on 15 June, 30 June and 13 July 2016) to study the crop-weather relationships. Relationship between periodic dry matter and accumulated photosynthetically active radiation (APAR) was studied using field experimental data of *kharif* 2015 and 2016. The periodic dry matter of maize ($g\ m^{-2}$) recorded at 10 days interval beginning from 20 days after emergence, was regressed against the respective cumulative intercepted IPAR irrespective of treatments for both 2015 and 2016 (Fig. 4.3)

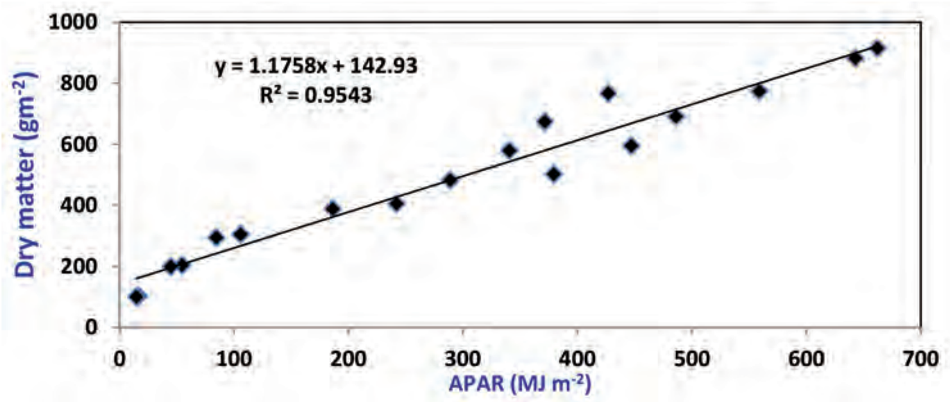


Fig. 4.3: Relationship between periodic dry matter and accumulated intercepted photosynthetically active radiation (APAR) in maize at Jammu (*kharif* 2015 & 2016).

The results indicated that there was a linear relationship between the rate of dry matter production and accumulated IPAR with high coefficient of determination (R^2=0.95). The conversion efficiency of absorbed PAR to the dry matter was estimated as 1.17 g MJ^{-1}.

Pearl millet

Solapur

Crop-weather relationship in pearl millet was studied under three growing environments or dates of sowing (2nd fortnight of June, 2nd fortnight of July and 2nd fortnight of August) and three cultivars (ICTP-8203, Mahyco hybrid and Shanti) during *kharif* 2012-16. Effect of growing environments and cultivars on grain and fodder yield is presented in Table 4.16.

Table 4.16: Pooled grain yield (kg ha^{-1}) of *kharif* pearl millet as influenced by various sowing dates and cultivars at Solapur (2012 to 16)

Treatment	Mean grain yield (kg ha^{-1})	Mean fodder yield (kg ha^{-1})
Sowing dates		
2nd fortnight of June	1501.5	2864.2
2nd fortnight of July	1829.2	3890.4
2nd fortnight of August	1008.0	2442.0
Mean	1446.2	3065.6
Cultivars		
ICTP-8203	1298.6	2831.5
Mahyco hybrid	1425.3	2927.2
Shanti	1614.8	3437.9
Mean	1446.2	3065.6
S.E.± (Sowing dates)	156.75	288.6
C.D. at 5%	511.2	941.1
S.E.± (Varieties)	35.24	88.2
C.D. at 5%	102.9	257.4
S.E.± (SD X V)	61.04	152.8
C.D. at 5%	NS	NS

The pooled results indicate that crop sown during second fortnight of July registered highest mean grain and fodder yield (1829 and 3890 kg ha^{-1}, respectively). Among cultivars, Shanti recorded highest grain and fodder yield (1615 and 3438 kg ha^{-1}, respectively). Radiation use efficiency (RUE) of pear millet as influenced by sowing dates and cultivars during *kharif* 2012-16 was analyzed and the results are presented in Table 4.17.

Table 4.17: Radiation use efficiency (g MJ^{-1}) as influenced by sowing dates and cultivars in *kharif* pearl millet at Solapur (2012-16)

Sowing	Phenological stage						
Time	Emer.	PI	Flag leaf	50% flowering	Soft dough	Hard Dough	Phy. maturity
S_1V_1	0.07	0.19	0.73	0.98	0.73	0.61	0.44
S_1V_2	0.07	0.25	0.85	1.34	1.00	0.84	0.63
S_1V_3	0.09	0.32	0.95	1.57	1.04	0.94	0.79
S_2V_1	0.11	0.31	0.93	1.72	1.42	1.27	1.02
S_2V_2	0.14	0.36	1.51	1.87	1.66	1.35	1.21
S_2V_3	0.11	0.33	1.56	2.28	1.73	1.49	1.19
S_3V_1	0.14	0.55	1.26	1.21	1.15	1.19	0.74
S_3V_2	0.33	0.43	0.98	1.31	1.35	1.24	0.86
S_3V_3	0.14	0.37	1.37	1.62	1.52	1.3	1.17

(S1: 2nd fortnight of June, S2: 2nd fortnight of July; S3: second fortnight of August; V1:ICTP-8203, V2: Mahyco hybrid, V3: Shanti)

Cultivar Mahyco hybrid sown during second fortnight of July recorded the highest mean RUE of 1.21 g MJ^{-1}, followed by Shanti sown on second fortnight of July. The pooled analysis shows that second fortnight of July is the best sowing time for pearl millet at Solapur for achieving higher grain, fodder yield and RUE in all the three varieties.

The relationship between consumptive use of moisture (CUM) and grain yield was also studied and the result is presented in Fig. 4.4, which showed a linear relationship. The CUM of 362 mm was found to be optimum for getting higher grain yield, after which a reduction in yield was observed.

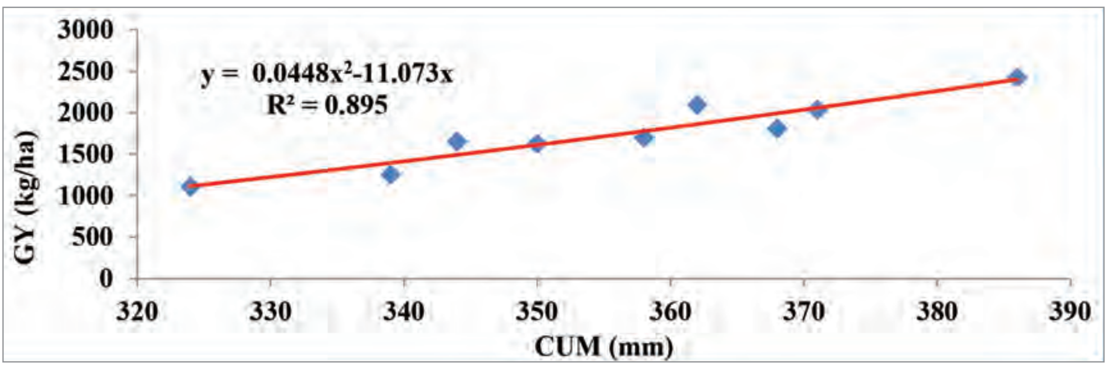


Fig. 4.4: Relationship between consumptive use of moisture (CUM) and grain yield in pearl millet at Solapur (Pooled data of *kharif* 2012-16)

Finger millet

Ranichauri

Crop weather relationship studies in finger millet was taken up by conducting a field experiment involving three dates of sowing (6, 18 and 26 June 2016) and three cultivars (PRM-1, Local and PRM-2) during *kharif* 2016. The crop duration of finger millet was 131, 124 and 122 days for first, second and third sowing dates, respectively. Thermal time of growing degree days (GDD) for occurrence of different growth stages of crops sown under three dates of sowing were recorded and are presented in Table 4.18.

Table 4.18: Growing Degree Days requirement at different phenological stages of finger millet at Ranichauri during *kharif* 2016

Crop growth stages	Occurrence of growth stages (DAS)			Accumulated Growing degree days (degree-days)		
	D1	D2	D3	D1	D2	D3
Emergence	15	14	11	157.5	156.5	118.0
CRI	27	24	27	290.5	259.5	285.0
Terminal spikelet (Jointing)	45	41	41	473.0	430.5	424.3
End of vegetative phase	62	56	62	646.1	581.2	641.0
50% flowering	84	78	76	872.6	807.1	781.3
Beginning of grain filling	102	95	89	1050.4	974.0	905.4
End of grain filling	114	105	101	1155.8	1058.1	1010.0
Physiological maturity	125	119	116	1255.1	1172.4	1119.6
Harvesting	131	124	122	1296.5	1206.2	1149.3

It can be inferred from the table that the early sown crop accumulated highest GDD till maturity due to longer duration (131 days), compared to crop sown during 18 and 26 June. Effect of treatments on grain yield of finger millet is presented in Fig. 4.5. During first and third dates of sowing, the yield of PRM-2 was much higher compared to other two cultivars. The grain yield of all the three cultivars sown on 18 June was almost on par.

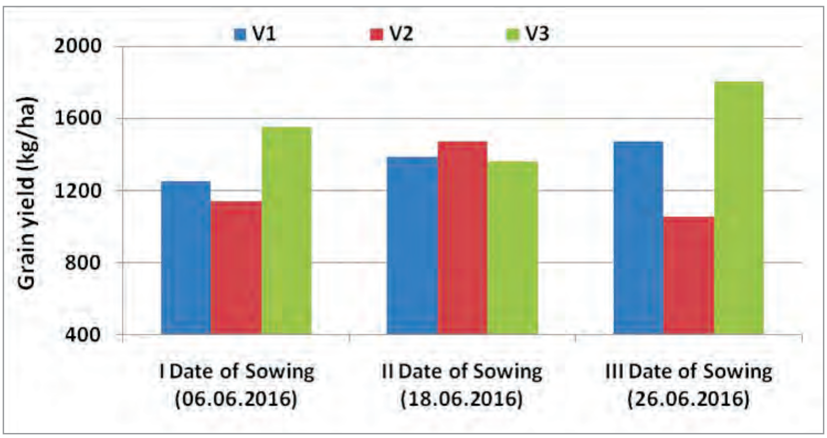


Fig. 4.5: Effect of dates of sowing and cultivars on grain yield of finger millet at Ranichauri during *kharif* 2016

Pigeon pea

Bangalore

Pigeonpea cultivars TTB-7, BRG-1 and BRG-2 were grown under three growing environments (sown on 22, 24 and 30 SMW) and three spacing (60 cm x 22.5 cm; 90 cm x 22.5 cm and 120 cm x 22.5 cm) to study the influence of cultivars, spacing and sowing time on yield and growth parameters. The spacing was found to be significant with respect to leaf area (Table 4.19) at 90, 120 DAS and at harvest stage. The third spacing (120 x 22.5 cm) recorded more leaf area compared to first (60 x 22.5 cm) and second spacing (90 x 22.5 cm) at 120 DAS and at harvest stage. Among the varieties, TTB-7 variety recorded significantly more leaf area during all growth stages compared to BRG-1 and BRG-2. The date of sowing had significant influence on the leaf area at all the growth stages. It was noticed that second date of sowing recorded more leaf area at all growth stages except at 90 DAS and at harvest.

Table 4.19: Leaf area (cm^2) as influenced by different spacing, varieties and dates of sowing of Pigeon pea at Bangalore during *kharif* 2016

Treatment	30 DAS	60 DAS	90 DAS	120 DAS	Harvest
Spacing					
S1 (60x22.5)	82.1	614.0	1436.6	1849.7	1297.9
S2 (90x22.5)	77.8	647.6	1702.8	2025.6	1518.3
S3 (120x22.5)	77.7	577.3	1622.7	2391.7	1803.4
Significance	NS	NS	S	S	S
SEm±	3.5	27.3	70.4	76.0	88.9
CD (0.05 P)	10.0	77.4	199.8	215.8	252.4
Varieties					
V1 (TTB-7)	93.1	704.0	1961.2	2376.5	1764.1
V2 (BRG-1)	75.8	654.5	1408.9	2067.6	1566.1
V3 (BRG-2)	68.8	480.5	1392.0	1822.8	1289.5
Significance	S	S	S	S	S
SEm±	3.5	27.3	70.4	76.0	88.9
CD (0.05 P)	10.0	77.4	199.8	215.8	252.4
Date of sowing					
D1 (30/5/2016)	62.5	457.7	1376.6	2596.1	2058.1
D2 (16/6/2016)	98.8	741.0	1854.4	2127.9	1521.1
D3 (29/7/2016)	76.3	640.2	1531.1	1543.0	1040.4
Significance	S	S	S	S	S
SEm±	3.5	27.3	70.4	76.0	88.9
CD (0.05 P)	10.0	77.4	199.8	215.8	252.4

The highest average grain yield was observed in the first date of sowing (904.7 kg ha^{-1}) followed by second and third date sown crop 861 kg ha^{-1} and 292.5 kg ha^{-1} respectively (Table 4.20). The lower grain yield for late sown crop is attributed to prolonged drought situation during pod formation (no rainfall was received). Among varieties BRG-2 and BRG-1 were recorded maximum yield of 867 kg ha^{-1} and 722 kg ha^{-1} respectively when compared to TTB-7 with 469 kg ha^{-1}.

Table 4.20: Effect of date of sowing, varieties and spacing on grain yield (kg ha^{-1}) of Pigeon pea at Bangalore during *kharif* 2016

Varities	S1 (60x22.5)				S2 (90x22.5)				S3 (120x22.5)			
	TTB-7 (v-1)	BRG-1 (v-2)	BRG-2 (v-3)	Mean	TTB-7 (v-1)	BRG-1 (v-2)	BRG-2 (v-3)	Mean	TTB-7 (v-1)	BRG-1 (v-2)	BRG-2 (v-3)	Mean
D1 (30/5/2016)	530.1	1396.4	1529.6	1152.1	443.5	1166.2	1104.4	904.7	364.3	1287.9	681.4	777.8
D2 (16/6/2016)	622.7	1188.0	767.3	859.3	592.9	782.5	1207.5	861.0	728.5	942.3	764.1	811.6
D3 (29/7/2016)	388.8	473.6	240.1	367.5	369.9	218.5	289.2	292.5	186.4	176.5	173.9	178.9
Mean	513.9	1019.3	845.7	793.0	468.8	722.4	867.0	686.1	426.4	802.2	539.8	589.5

Particulars	Spacing (S)	Variety (V)	DOS	SXV	SXD	VXD	SXVXD	CV
Sem	81.7	81.7	81.7	141.6	141.6	141.6	245.2	61.6
CD (0.05P)	231.9	231.9	231.9	401.7	401.7	401.7	695.8	

Spacing S_1:60 cm x 22.5 cm, S_2:90 cm x 22.5 cm, S_3:120 cm x 22.5cm; DOS : Date of Sowing

Soybean

Akola

Soybean cultivars JS-335, JS-9305 and TAMS 98-21 were grown on four growing environments (sown on 26, 27, 28 and 29 SMW) to study the crop weather relationships. Different water use indices across the total growing period of soybean as influenced by different treatments were estimated and the results are presented in Table 4.21.

Table 4.21: Influence of cultivars and growing environments on water use and water productivity in soybean at Akola during *kharif* 2016

Treatment	Seed yield (kg ha^{-1})	Eta (mm)	WP (kg ha-mm^{-1})
Sowing time			
26 SMW (28 June)	2359	328.3	7.19
27 SMW (05 July)	2189	307.4	7.13
28 SMW (14 July)	1531	291.3	5.26
28 SMW (20 July)	1383	275.1	5.03
Variety			
JS-335	2021	300.1	6.66
JS-9305	1911	297.9	6.34
TAMS-98-21	1665	303.6	5.45

It was observed that crop water use, water productivity and seed yield were highest in crop sown during 26 SMW, followed by crop sown during 27 SMW. Sowing of soybean beyond 5 July causes drastic reduction in yield as well as water productivity. Among the cultivars, JS-335 recorded highest water productivity, crop water use and yield.

Parbhani

A field experiment with split-plot design was taken up during *kharif* 2016 with four dates of sowing (4, 11, 18 and 25 July 2016) as main plot treatments and four cultivars as sub-plot treatments (MAUS-158, MAUS-71, MAUS-81 and JS-335). Correlation coefficients were worked out between seed yield and phenophase-wise average weather parameters and the results are presented in Table 4.22.

Rainfall showed significant positive correlation with seed yield during emergence to seedling stage, seedling to branching stages and all the three stages from pod development to maturity, for all the four cultivars. But, maximum temperature showed significant negative correlation with seed yield during seedling to branching stage and branching to flowering stage and during pod development to full seed stage. Minimum temperature showed significant positive correlation with seed yield during emergence to seedling, seedling to branching, pod development to full grain and up to dough stage. Number of bright sunshine hours had highly significant positive relationship with yield during flowering to pod formation and seed formation to pod development stages for all the varieties.

Table 4.22: Correlation between seed yield of soybean and phenophase-wise weather variables prevailed during *kharif* 2016 at Parbhani

Parameters	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}
MAUS 158										
Rainfall	-0.46**	0.92**	0.61**	0.12	-0.92**	0.25	-0.93**	0.85**	0.74**	0.53**
T.max	-0.52**	0.34*	-.59**	-0.56**	0.99**	0.53**	0.86**	-0.96**	-0.75**	0.73**
T.min	-0.13	0.79**	0.96**	0.01	-0.42**	0.22	-0.98**	0.99**	0.88**	0.83**
BSS hrs/day	-0.62**	-0.79**	-0.84**	-0.54**	0.93**	-0.52**	0.95**	-0.94**	-0.71**	-0.63**
MAUS 71										
Rainfall	-0.44**	0.91**	0.64**	0.16	-0.91**	0.21	-0.94**	0.82**	0.76**	0.57**
T.max	-0.56**	0.38*	-0.59**	-0.60**	0.99**	0.54**	0.88**	-0.96**	-0.79**	0.69**
T.min	-0.08	0.78**	0.97**	0.05	-0.41**	0.18	-0.97**	0.99**	0.89**	0.85**
BSS hrs/day	-0.64**	-0.80**	-0.84**	-0.61**	0.91**	-0.49**	0.96**	-0.95**	-0.75**	-0.66**
MAUS 81										
Rainfall	-0.44**	0.95**	0.55**	0.05	-0.94**	0.27	-0.93**	0.88**	0.73**	0.47**
Tmax	-0.47**	0.31*	-0.64**	-0.51**	0.99**	0.57**	0.84**	-0.97**	-0.73**	0.76**
Tmin	-0.19	0.84**	0.94**	-0.01	-0.49**	0.27	-0.97**	0.99**	0.88**	0.79**
BSS hrs/day	-0.56**	-0.82**	-0.87**	-0.54**	0.95**	-0.51**	0.93**	-0.95**	-0.68**	-0.57**
JS-335										

Rainfall	-0.44**	0.92**	0.60**	0.12	-0. 92**	0.23	-0.94**	0.86**	0.75**	0.53**
Tmax	-0.52**	0.35*	-0.61**	-0.57**	0.99**	0.55**	0.87**	-0.96**	-0.76**	0.72**
Tmin	-0.13	0.81**	0.96**	0.02	-0.44**	0.22	-0.97**	0.99**	0.89**	0.83**
BSS hrs/day	-0.61**	-0.81**	-0.85**	-0.58**	0.93**	-0.51**	0.95**	-0.95**	-0.72**	-0.62**

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

P_1- Sowing to emergence
P_2- Emergence to seedling
P_3-Seedling to branching
P_4-Branching to flowering
P_5-Flowering to pod formation
P_6-Pod formation to grain formation
P_7-seed formation to pod development
P_8-Pod development to pod containing full grain size
P_9-Pod containing full grain size to dough stage
P_{10}-Dough stage to maturity

Vijayapura

Crop weather relationship studies in soybean was undertaken with a field experiment in RBD with three growing environments or dates of sowings (30 June, 12 July and 2 August 2016) and three cultivars (JS 335, DSb-21 and DSb-23-2). Absorbed photosynthetically active radiation (APAR) was measured using a line quantum sensor and the effect of treatments of APAR was studied and the results are presented in Fig. 4.6.

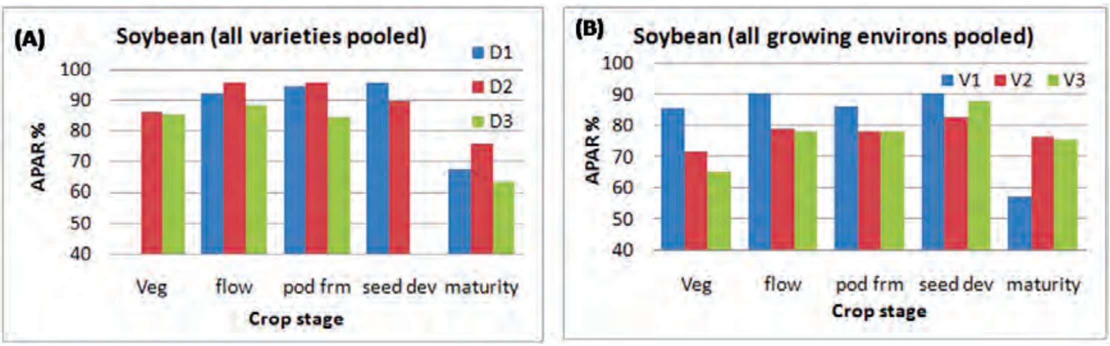


Fig. 4.6: Effect of (A) cultivars and (B) sowing dates on absorbed PAR in soybean at Vijayapura during *kharif* 2016.

Highest APAR was recorded under second growing environment during flowering, pod formation and pod filling stages, while in seed development stage, the highest APAR was recorded under first growing environment. Among the cultivars, JS 335 recorded highest APAR till seed development stage, while during maturity, the APAR was highest for Dsb-21 and Dsb-23-2.

Jabalpur

Crop weather relationship studies in soybean was undertaken by conducting a field experiment, in which three cultivars (JS-20-29, JS-20-34 and JS-97-52) were subjected to four different growing environments or dates of sowing (17 June, 30 June, 12 July and 26 July 2016). Association between seed yield and absorbed PAR of three cultivars was studied and the results are depicted in Fig. 4.7.

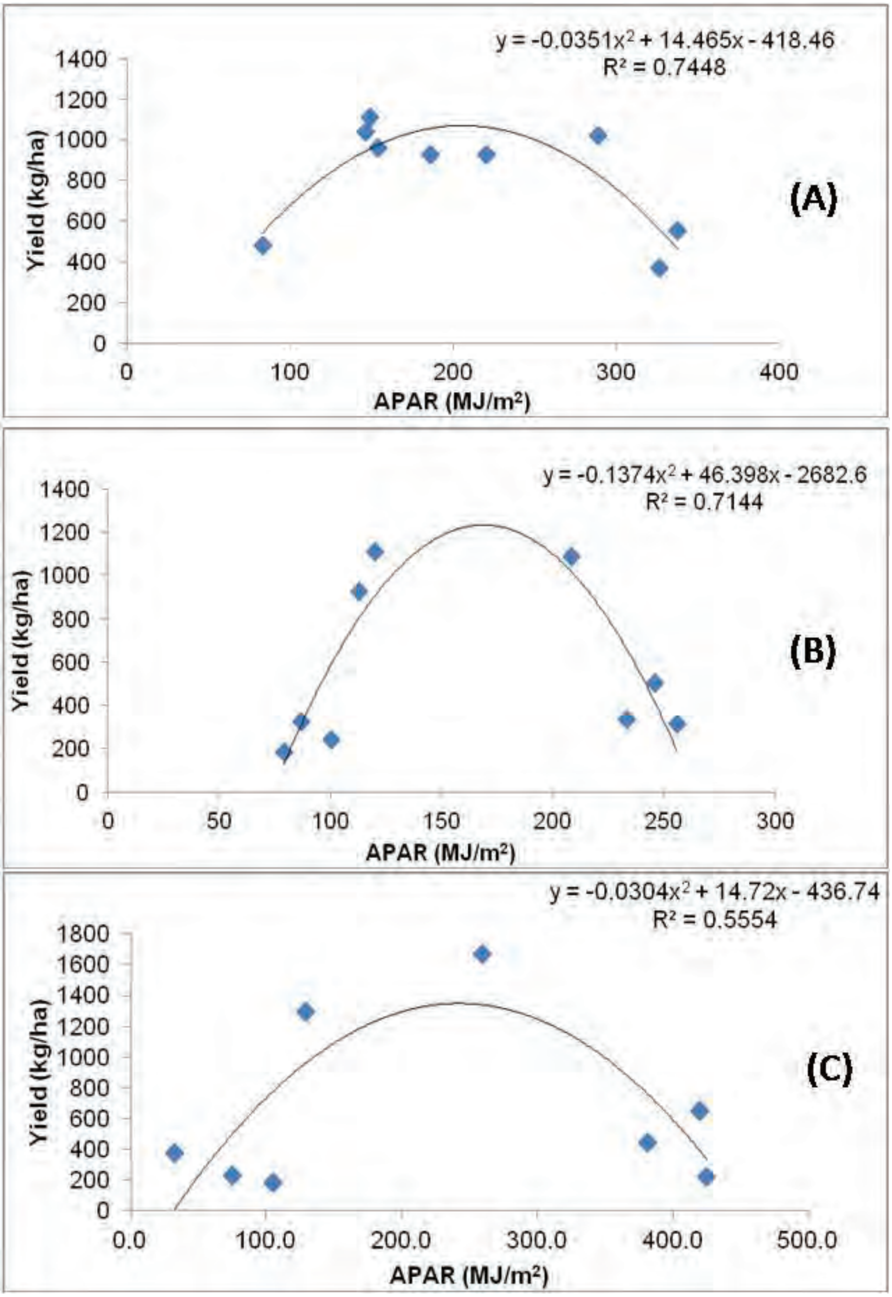


Fig. 4.7: Association of seed yield with APAR of soybean cultivars (A) JS 20-29 (B) JS 20-34 and (C) JS 97-52 at Jabalpur during *kharif* 2016

It can be inferred from the figures that an APAR about 200 MJ m^{-2} was found to be optimum for achieving higher seed yield in soybean at Jabalpur. The rate of decrease in yield above an APAR value of 200 MJ m^{-2} was more for cultivar JS 20-34, compared to other two varieties as suggested by the slope.

Sunflower

Solapur

Crop weather relationship studies in sunflower was undertaken during *kharif* 2012-16 by sowing three cultivars (Bhanu, MSFH-17 and Phule Raviraj) under three sowing dates (2nd fortnights of June, July and August). The relationship between consumptive use of moisture and grain yield is depicted in Fig. 4.8.

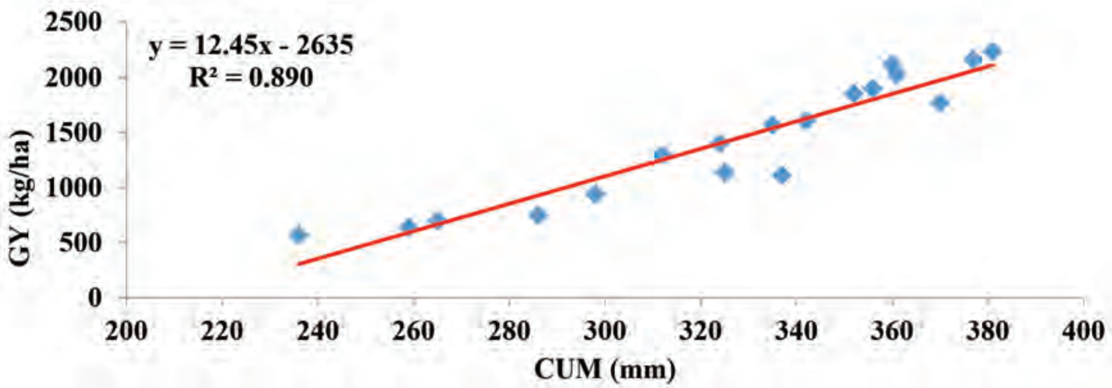


Fig. 4.8: Relationship between consumptive use of moisture with grain yield in sunflower during *kharif* 2012-16 at Solapur

The results indicated that a linear relationship between CUM and grain yield and the correlation was also high ($R^2 = 0.89$). Further the relationship between maximum temperature and minimum temperature with grain yield was also studied and the results are presented in Fig. 4.9 and 4.10.

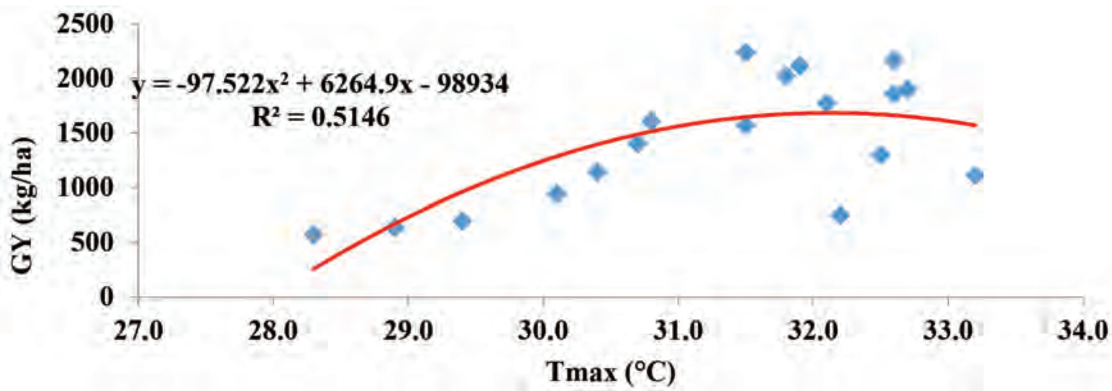


Fig. 4.9: Relationship between average seasonal maximum temperature with grain yield in sunflower during *kharif* 2012-16 at Solapur

The analysis indicated that the seed yield increased up to a maximum temperature value of 32.5 ^{0}C and thereafter a decline in yield was observed.

The analysis indicated that the seed yield increased up to a minimum temperature value of 22 ^{0}C and thereafter a decline in yield was observed.

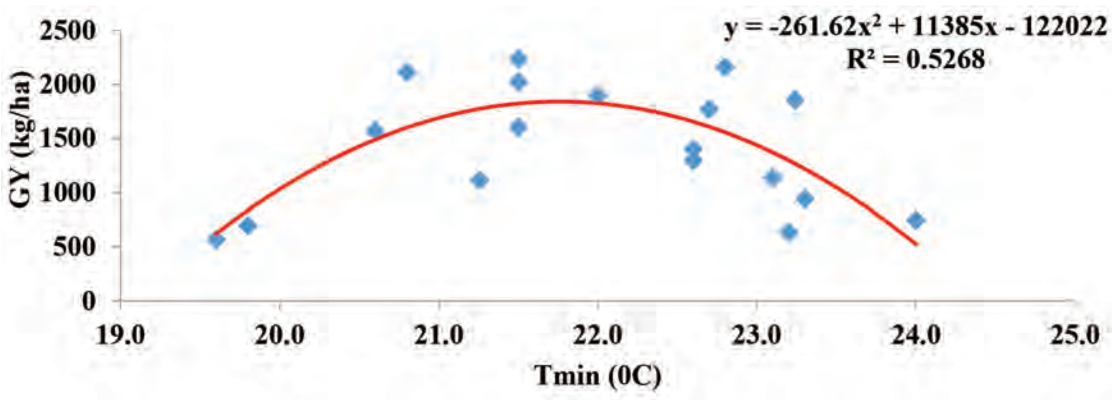


Fig. 4.10: Relationship between average seasonal minimum temperature with grain yield in sunflower during *kharif* 2012-16 at Solapur

Groundnut

Anand

Groundnut cultivars M-335, GG-20 and GG-5 were grown under three growing environments, *viz*., 4 July, 19 July and 3 August 2016 to study the crop-weather relationships. FAO-CROPWAT 8.0 model was used to simulate the average weekly soil moisture at three depths (0-15, 15-30 and 30-45 cm) and it was compared with soil moisture measured by gravimetric method. The results are presented in Fig. 4.11.

The results showed that Cropwat model simulated the total available soil moisture reasonably well, when compared with measured soil moisture in 19 July sown crop. In case of 4 July sown crop, model has overestimated the soil moisture in majority of weeks.

Anantapur

Groundnut cultivars K6, Kadiri Harithandra, Dharani and Anantha were grown under three growing environments 13 July, 21 July and 8 August 2016 to study the crop weather relationships. Water use efficiency for these cultivars under different growing environments and irrigation treatments were estimated. Three protective irrigations (15 mm each) were provided for crops sown during first and second fortnight of July and four protective irrigations (15 mm each) were provided for crops sown during first fortnight of August. The results are presented in Table 4.23.

The results indicated that water use efficiency was higher in crops provided with protective irrigation, compared to rainfed groundnut. Crop water use of all the cultivars were high under irrigated condition compared to rainfed crop. Pod yield was also high for irrigated crops than rainfed in all the growing environments. Highest WUE was recorded for crop sown during first fortnight of August for K6, Kadiri Harithandra and Dharani, whereas for Anantha, crop sown during 2nd fortnight of July recorded highest WUE (Table 4.23).

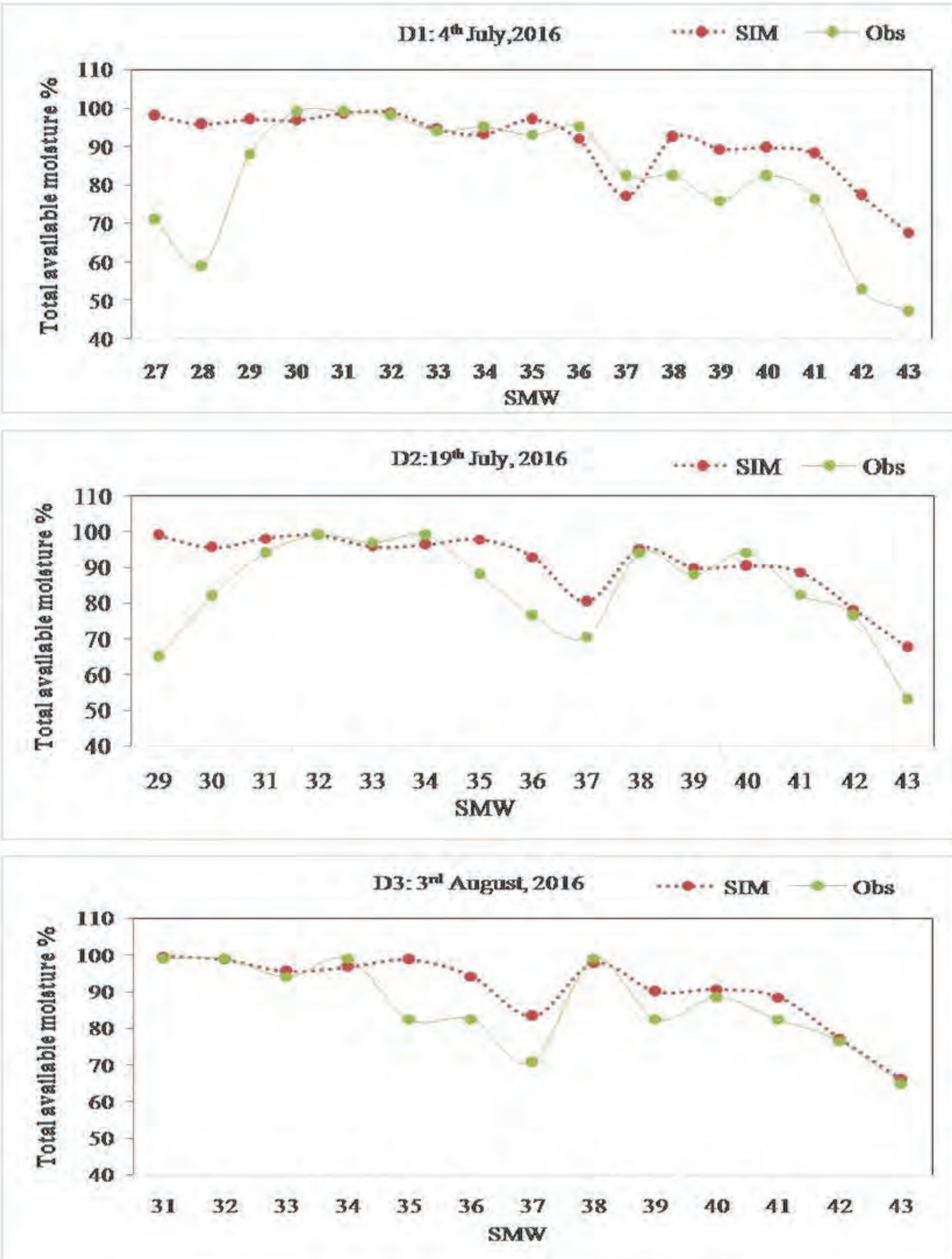


Fig. 4.11: Comparison of measured and simulated total available moisture for groundnut at Anand during *kharif* 2016

Additional yield obtained per mm of protective irrigation provided for each cultivar under different growing environment was also studied. It was observed that highest magnitude of increase in yield per mm of protective irrigation applied was recorded for crop sown during 1st fortnight of July for K6, Kadiri Harithandra and Dharani (in the range of 13-21 kg per mm of irrigation) and crop sown during 2nd fortnight of July for Anantha.

Table 4.23: Water use efficiency of groundnut varieties under rainfed and irrigated condition and growing environments at Anantapur

Sowing Environment	Rainfall (mm)	Protective Irrigation (mm)	Water Use (mm)		Pod Yield (kg ha^{-1})		WUE (kg ha-mm^{-1})	Additional yield per mm of protective irrigation	
Rainfed	Protective Irrigation	Rainfed	Protective Irrigation	Rainfed	Protective Irrigation	Rainfed	Protective Irrigation	Rainfed	
				K6					
1st FN of July	249.7	45	249.7	294.7	568	1276	2.3	4.3	15.7
2nd FN of July	249.1	45	249.1	294.1	828	1454	3.3	4.9	13.9
1st FN of August	125.5	60	125.5	185.5	399	1203	3.2	6.5	13.4
				Kadiri Harithandra					
1st FN of July	249.7	45	249.7	294.7	492	1442	2	4.9	21.1
2nd FN of July	251.9	45	251.9	296.9	648	1472	2.6	5	18.3
1st FN of August	125.5	60	125.5	185.5	382	1018	3	5.5	10.6
				Dharani					
1st FN of July	249.7	45	249.7	294.7	511	1306	2	4.4	17.7
2nd FN of July	249.1	45	249.1	294.1	780	1403	3.1	4.8	13.8
1st FN of August	125.5	60	125.5	185.5	348	993	2.8	5.4	10.8
				Anantha					
1st FN of July	249.7	45	249.7	294.7	695	1311	2.8	4.4	13.7
2nd FN of July	249.1	45	249.1	294.1	658	1402	2.6	4.8	16.5
1st FN of August	125.5	60	125.5	185.5	376	846	3	4.6	7.8

Cotton

Akola

Three cotton cultivars [AKH-081 (*G. hirsutum* type); AKA-7 (*G. arboreum* type) and Balwan NCS 8899 BG-II (Bt Cotton type)] were grown with three planting densities (60 x 10 cm, 75 x 10 cm and 90 x 10 cm) to study the effect of cultivars and spacing on radiation interception and transmission. Incident and transmitted photosynthetically active radiation (PAR) was measured using line quantum sensor and the results are presented in Table 4.24.

Table 4.24: Fraction of intercepted and transmitted PAR as influenced by different treatments in cotton at Akola during *kharif* 2016

Treatment	60 DAE		90 DAE		120 DAE	
	FIPAR	FTPAR	FIPAR	FTPAR	FIPAR	FTPAR
Genotype						
AKH 081	0.60	0.40	0.69	0.31	0.72	0.28
AKA 7	0.51	0.49	0.63	0.37	0.69	0.31
Balwan	0.63	0.37	0.70	0.30	0.74	0.26
Population density						
60 x 10 cm	0.64	0.36	0.72	0.28	0.75	0.25
75 x 10 cm	0.56	0.44	0.67	0.33	0.72	0.28
90 x 10 cm	0.55	0.45	0.65	0.35	0.69	0.31

Fraction of intercepted PAR (FIPAR) increased and fraction of transmitted PAR decreased with increased plant density at all the three stages of crop, *viz*., 60, 90 and 120 days after emergence. Fraction of intercepted PAR was more in Bt cotton Balwan followed by *hirsutum* (AKH-081) and *arboreum* (AKA-7) cotton varieties. Transmitted PAR was maximum in AKA-7 and minimum under Bt cotton Balwan followed by *hirsutum* (AKH-081). Increased light interception by the high density planting treatment was partly offset by the poorer light distribution in the canopy. Further, by studying the relationship between FIPAR and LAI, the light extinction coefficients for three cultivars was characterized and is presented in Fig. 4.12.

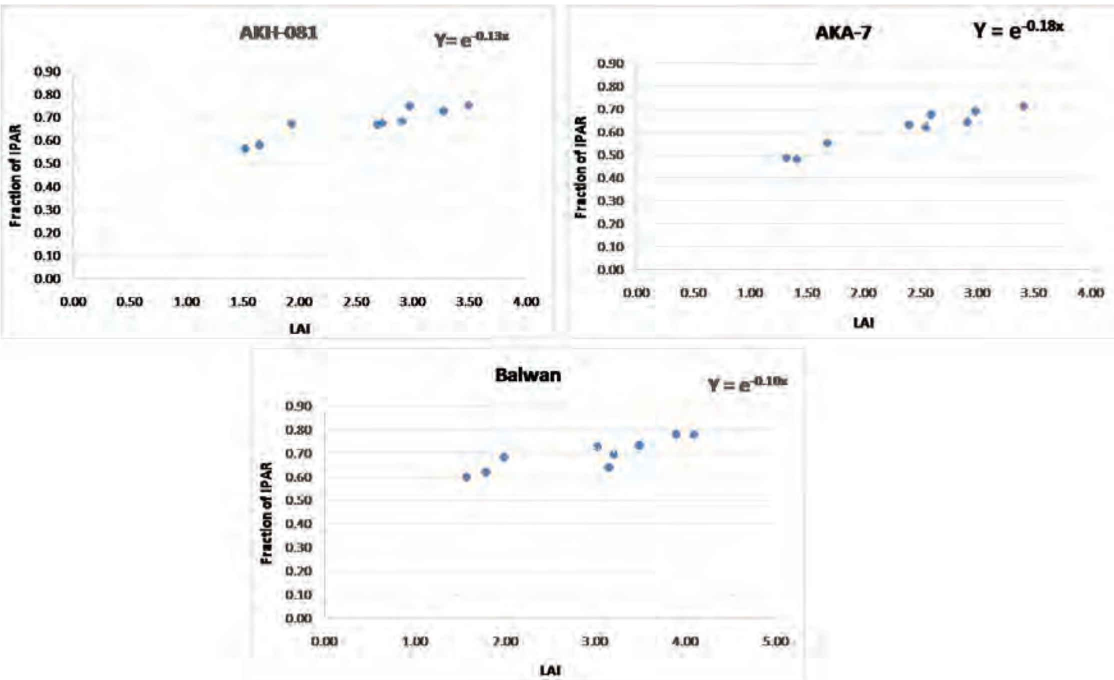


Fig. 4.12: Light extinction coefficients determined by analyzing the relationship between FIPAR and LAI in three cotton varieties at Akola

The results indicated that light extinction coefficient varied among the cotton varieties (0.13 for AKH-081, 0.18 for AKA-7 and 0.10 for Balwan).

Parbhani

Three hybrids of Bt cotton (Ajit 155, Rasi 2 and Mallika) were exposed to three different set of weather conditions by sowing them on four dates (22 and 29 June; 6 and 13 July 2016) to study the crop weather relationship in cotton. Correlations between seed cotton yield and phenophase-wise weather parameters prevailed during crop growing season were worked out and the results are presented in Table 4.25.

The most critical growth stages for rainfall influencing the cotton yield are seedling to square formation (P_3), flowering to boll setting (P_5) and boll setting to boll bursting (P_6) in all the three cultivars.

Table 4.25: Correlation coefficients between weather parameters prevailed in different phenophases and yield of three cotton varieties at Parbhani during *kharif* 2016

Ajit 155	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}
Rainfall (mm)	0.49	0.69*	0.86**	-0.83**	0.14	0.99**	0.63*	-	-	-
T.max (^{0}C)	0.23	0.88**	-0.59*	-0.25	0.97**	-0.96**	0.99**	-0.32	0.42	-0.99**
T.min (^{0}C)	0.77**	0.84**	0.87**	0.15	-0.24	0.98**	0.98**	0.44	-0.95**	-0.99**
BSS (hrs/day)	-0.25	-0.79**	-0.78	-0.67	0.72*	-0.96**	-0.63*	0.39	-0.59*	-0.96**
Rashi 2										
Rainfall (mm)	0.20	0.51	0.95**	-0.96**	0.38	0.95**	0.59*	-	-	-
T.max (^{0}C)	0.37	0.98**	-0.77**	-0.21	0.92**	-0.89**	0.94**	-0.59*	0.14	-0.96**
T.min (^{0}C)	0.88**	0.67*	0.68*	0.04	0.08	0.91**	0.94**	0.48	-0.93**	-0.94**
BSS (hrs/day)	-0.11	-0.87**	-0.92**	-0.53	0.46	-0.83**	-0.59*	0.54	-0.42	-0.99**
Mallika										
Rainfall (mm)	0.38	0.65*	0.89**	-0.89**	0.29	0.99**	0.58*	-	-	-
T.max (^{0}C)	0.25	0.94**	-0.70*	-0.18	0.94**	-0.95**	0.99**	-0.47	0.28	-0.99**
T.min (^{0}C)	0.81**	0.75**	0.80**	0.05	-0.09	0.97**	0.96**	0.42	-0.97**	-0.98**
BSS (hrs/day)	-0.23	-0.81**	-0.87**	-0.58	0.59*	-0.92**	-0.57	0.50	-0.56	-0.98**

** = Significant at 5% level,   ** = Significant at 1% level*
P_1 = Sowing to emergence, P_2 = Emergence to seedling, P_3 = Seedling to square formation
P_4 = Square formation to flowering, P_5 = Flowering to boll setting, P_6 = Boll setting to boll bursting,
P_7 = Boll bursting to 1st picking, P_8 = IInd picking, P_9 = IIIrd picking, P_{10} = IVth picking

Seed cotton yield was significantly and positively associated with maximum temperature during emergence to seeding, flowering to boll setting (P_5) and boll bursting to first picking (P_7) for all the three hybrids. Yield showed significant negative correlation with rainfall during square formation to flowering for all the three hybrids. Significant negative correlation of yield with seedling to square formation and boll setting to boll bursting stages for all the three hybrids was also observed.

Rabi 2016-17

Wheat

Raipur

Effect of growing environments and cultivars on yield, yield attributes, heat and radiation use efficiencies of wheat were studied using three dates of sowing (15 and 30 Nov, 15 Dec 2016) and three wheat cultivars (CG 1013, Kanchan, HD 2967) during *rabi* 2016-17. The influence of above mentioned treatments on yield and yield attributes are presented in Table 4.26.

Table 4.26: Yield and harvest index of wheat cultivars as influenced by different growing environments during *rabi* 2016-17 and their relationship with average maximum and minimum temperature during vegetative and reproductive stages at Raipur

Dates of sowing	Grain Yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Average Tmax (^{0}C)		Average Tmin (^{0}C)	
				Vegetative stage	Reproductive stage	Vegetative stage	Reproductive stage
15 November	3.38	3.34	50.4	28.9	30.1	12.0	13.1
30 November	2.87	3.16	47.6	29.0	30.3	12.1	13.5
15 December	2.19	2.21	49.5	29.6	31.3	12.5	14.3
SEm ±	0.12	0.12	0.5				
CD (p=0.05)	0.3	0.36	1.5				
Varieties							
CG-1013	2.99	2.9	50.9				
HD-2967	2.71	2.91	48.1				
Kanchan	2.73	2.89	48.5				
SEm ±	0.12	0.12	0.5				
CD (p=0.05)	0.35	0.36	1.5				
SEm ± (DxV)	0.2	0.21	0.9				
CD(p=0.05)	0.61	0.62	2.6				

The analysis indicated that the highest grain yield was recorded for crop sown on 15 November (3.38 t ha^{-1}) and it gradually decreased with subsequent sowings. Among the cultivars, CG-1013 recorded highest yield (2.99 t ha^{-1}) and yields of HD-2967 and Kanchan were at par (~2.72 t ha^{1}). In case of straw yield, it was observed that November 15 and 30 sown crop recorded higher yield (3.16-3.34 t ha^{-1}), but that of 15 December sown crop was much less (2.21 t ha^{-1}). This may be due to the fact that crop sown on 15 December recorded higher minimum temperature (+1.2 ^{0}C) compared to crop sown on 15 November during reproductive stage. 15 November sown crop also recorded highest harvest index (50.4%), but there was not much difference among dates of sowings or cultivars. HUE of different wheat varieties as affected by growing environments has been shown in Table 4.27.

Table 4.27: Effect of different growing environments on HUE (g m^{-2} ^{0}C-day^{-1}) of different wheat cultivars during *rabi* 2016-17 at Raipur

Treatments	Days after sowing							
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	Maturity
D1 V1	0.14	0.19	0.25	0.48	0.93	1.43	1.59	1.48
D1 V2	0.17	0.25	0.24	0.47	0.92	1.38	1.66	1.36
D1 V3	0.11	0.21	0.23	0.49	0.89	1.47	1.59	**1.53**
D2 V1	0.09	0.19	0.30	0.82	1.03	1.35	1.77	**1.90**
D2 V2	0.09	0.15	0.29	0.56	1.03	1.36	1.79	1.86
D2 V3	0.11	0.14	0.30	0.63	0.95	1.34	1.51	1.45
D3 V1	0.06	0.12	0.29	0.54	1.18	1.30	1.51	1.55
D3 V2	0.05	0.13	0.29	0.57	1.00	1.20	1.60	**1.62**
D3 V3	0.05	0.15	0.30	0.52	1.01	1.19	1.66	1.61

D1-15/11/2016, D2- 30/11/16, D3- 15/12/2016, V1-CG-1013, V2- HD-2967, V3- Kanchan

The results indicated that HUE at maturity ranged from 1.36 to 1.90 g m^{-20} day^{-1} across different dates of sowing and varieties. Highest HUE of 1.90 g m^{-2} ^{0}C-day^{-1} was recorded for CG-1013 sown on 30 November 2016 and lowest for HD-2967 sown on 15 November 2016. Radiation use efficiency of different wheat varieties as affected by growing environments has been shown in Table 4.28.

Table 4.28: Effect of different growing environment on RUE (g MJ^{-1}) of different wheat cultivars during *rabi* 2016-17 at Raipur

Treatments	Days after sowing							
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	Maturity
D1V1	0.21	0.28	0.33	0.68	1.31	2.05	2.34	2.22
D1V2	0.24	0.35	0.31	0.63	1.25	1.89	2.34	2.39
D1V3	0.16	0.29	0.30	0.66	1.21	2.03	2.26	2.51
D2V1	0.14	0.28	0.51	1.28	1.64	2.23	3.11	2.86
D2V2	0.13	0.20	0.45	0.81	1.52	2.09	2.90	2.90
D2V3	0.16	0.18	0.44	0.85	1.30	1.90	2.31	2.42
D3V1	0.10	0.18	0.45	0.86	1.95	2.29	2.82	2.39
D3V2	0.08	0.19	0.41	0.84	1.54	1.98	2.80	2.58
D3V3	0.08	0.19	0.41	0.72	1.45	1.82	2.83	2.78

(D1-15/11/2016, D2- 30/11/16, D3- 15/12/2016, V1-CG-1013, V2- HD-2967, V3- Kanchan)

Highest RUE at maturity was recorded in HD-2967 (2.90 g MJ^{-1}) sown on 30 November and the lowest was recorded in CG-1013 (2.22 g MJ^{-1}) sown on 15 November 2016. It was observed that second date of sowing (30 November 2016) recorded highest average RUE, compared to other two dates of sowing.

Ranchi

Effect of growing environments and cultivars on yield, heat and radiation use efficiencies in wheat was studied using field experiment with factorial RBD design with three dates of sowing (20 November, 5 and 20 December 2016) and three wheat cultivars (HUW-468, K-9107 and Birsa Genhu-3). Effect of treatments on grain yield, heat and radiation use efficiencies was also studied and the results are presented in Table 4.29.

Table 4.29: Heat (HUE) and radiation (RUE) Use Efficiency of wheat cultivars under different sowing dates at Ranchi during *rabi* 2016-17

Sowing Date	Variety	HUE (kg ha^{-1} ^{o}C-day^{-1})	RUE (kg ha^{-1} MJ^{-1})	Yield (kg ha^{-1})
20 November	HUW 468	3.2	2.3	4580
	K9107	2.4	1.7	3527
	BG 3	3.2	2.2	4542
05 December	HUW 468	3.3	2.3	4752
	K9107	2.7	1.9	4000
	BG 3	3.0	2.1	4362
20 December	HUW 468	2.4	1.7	3274
	K9107	1.8	1.3	2645
	BG 3	2.3	1.7	3237

Grain yield of crop sown on 20 November and 5 December were almost on par (4.22 and 4.37 t ha^{-1}, respectively), but crop sown on 20 December recorded lowest yield (3.05 t ha^{-1}) (Table 4.29). Among the cultivars, HUW 468 recorded highest (4.20 t ha^{-1}) and K 9107 recorded lowest (3.39 t ha^{-1}) grain yield. It was observed that crop sown on 20 November and 5 December recorded higher HUE, RUE and thereby achieving higher grain yield compared to late sown crop (sown on 20 Dec). HUE ranged from 1.8 to 3.2 kg ha^{-1} ^{0}C-day^{-1} and RUE ranged from 1.3 to 2.3 (kg ha^{-1} MJ^{-1}). Among cultivars, HUW 468 recorded highest HUE, RUE and grain yield.

Samastipur

Effect of dates of sowing and cultivars on grain yield, yield attributes, heat use efficiency and accumulated growing degree days was studied using five dates of sowing (15 and 25 November; 5, 15 and 25 December 2016) and three wheat cultivars (RW 3711, HD 2824 and HD 2733) during *rabi* 2016-17. The effect of treatments on growth, yield, yield attributes, HUE and accumulated GDD are presented in Table 4.30.

Table 4.30: Effect of dates of sowing and cultivars on growth, yield attributes, grain yield, HUE and aggregate GDD of wheat at Samastipur during *rabi* 2016-17

Treatment	Grain yield (t ha^{-1})	HUE (kg ha^{-1} ^{o}C-day^{-1})	Aggregate GDD	Average Tmax (^{0}C)	
Sowing dates				Vegetative stage	Reproductive stage
15.11. 16	2.90	1.5	1910.1	19.48	23.15
25.11.16	2.87	1.6	1753.6	18.96	22.89
05.12. 16	2.57	1.5	1711.3	19.76	23.73
15.12. 16	2.30	1.4	1693.6	21.65	24.75
25.12.16	1.82	1.1	1639.0	23.63	26.23
CD (P=0.05)	0.41		48.9		
Varieties					
RW3711	2.60	1.5	1728.5		
HD2824	2.42	1.4	1737.4		
HD2733	2.46	1.4	1758.7		
CD (P=0.05)	NS		NS		

The results indicate that crop sown on 15 November recorded highest grain yield of 2.9 t ha^{-1} and the yield decreased gradually as the sowing got delayed. The lowest grain yield of 1.82 t ha^{-1} was recorded in crop sown on 25 December, which may due to higher average maximum temperature experienced during vegetative and reproductive stages (Compared to 15 November sown crop, 25 December sown crop experienced 4 and 3 ^{0}C higher temperature during vegetative and reproductive stages, respectively). Aggregate GDD also showed the same trend. Among the cultivars, RW 3711 recorded the highest grain yield of 2.6 t ha^{-1} and HUE of 1.5 kg ha^{-1} ^{0}C- day^{-1}. But, among different dates of sowing, highest HUE was recorded for crop sown on 25 November (1.6 kg ha^{-1} degree day^{-1}).

Udaipur

Effect of mean temperature during reproductive phase of wheat on grain yield was studied using a field experiment with four sowing dates (5 November, 20 November, 5 December and 20 December) and five cultivars (HI-1544, MP-1203, Raj-4037, Raj-4238 and HD-296). Effect of mean temperature during vegetative and reproductive phases of wheat on grain yield was studied. It was found that influence of mean temperature during vegetative phase has non-significant negative relationship with grain yield. The effect of mean temperature during reproductive phase of wheat on grain yield is depicted in Fig. 4.13, 4.14 and 4.15. The results indicated that there was a gradual reduction in yield as the mean temperature increased during reproductive stage of crop. The magnitude of yield reduction from low temperature regime to high temperature was highest in HI 1544 (1762 kg ha^{-1}), followed by Raj-4037 (1673 kg ha^{-1}) and MP-1203 (1403 kg ha^{-1}).

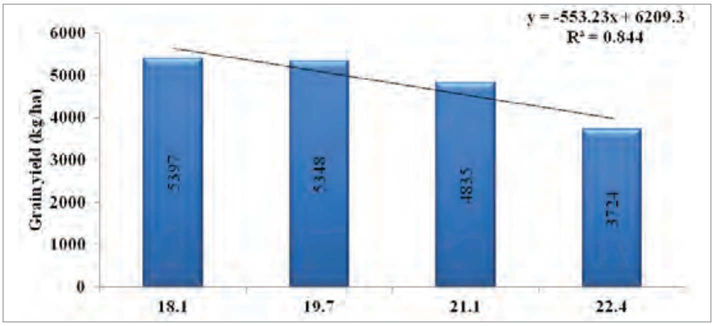


Fig. 4.13: Effect of mean temperature during reproductive period on grain yield of wheat cv Raj-4037 at Udaipur (mean of *rabi* 2007-08 to 2016-17)

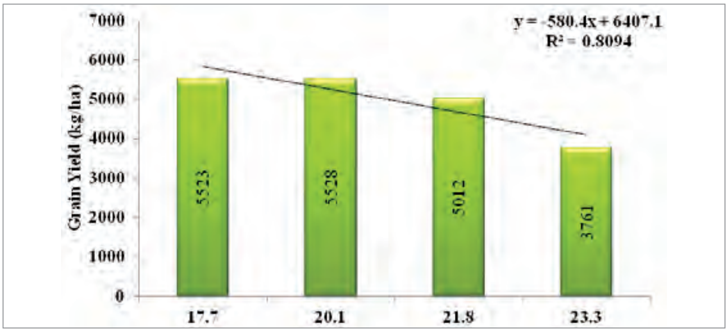


Fig. 4.14: Effect of mean temperature during reproductive period on grain yield of wheat var HI-1544 at Udaipur (mean of *rabi* 2007-08 to 2016-17)

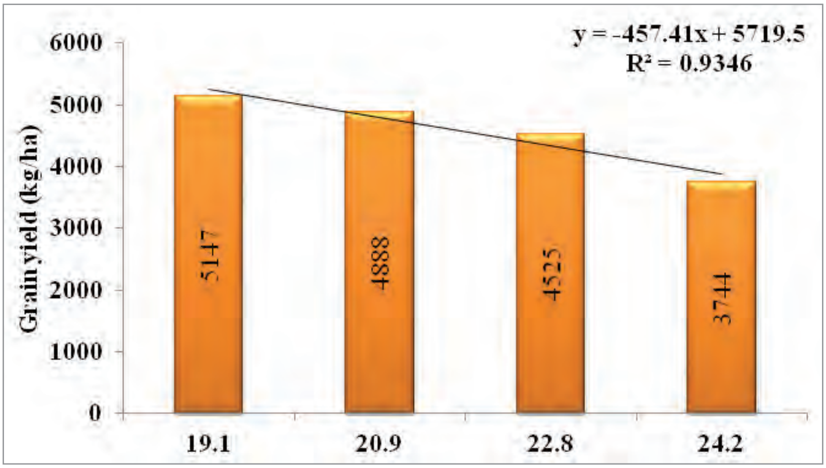


Fig. 4.15: Effect of mean temperature during reproductive period on grain yield of wheat var MP-1203 at Udaipur (mean of *rabi* 2007-08 to 2016-17)

Anand

Crop weather relationship study in wheat was conducted in a field experiment under four thermal regimes or dates of sowing (28 October, 15 November, 30 November and 15 December 2016) and four cultivars (GW-332, GW-496, GW-366 and GW-1139. Correlation study between grain yield and phenophase-wise weather parameters was also conducted and the results are presented in Table 4.31.

Table 4.31: Correlation coefficient between wheat yield and phenophase-wise weather parameters of wheat cultivar GW-366 at Anand during *rabi* 2016-17

Phenological phase	BSS	Tmax	Tmin	RH (morn)	RH (after noon)
Seedling	-0.04	-0.09	0.03	0.26	0.19
Crown Root Initiation	-0.10	-0.16	-0.04	0.45**	0.26
Tillering	-0.44*	-0.25	0.15	0.50**	0.31
Booting	-0.29	-0.40*	0.07	0.37*	0.57**
Flowering	-0.14	-0.18	-0.06	0.25	0.32
Milk	-0.10	-0.10	0.11	0.32	0.39*
Dough	0.09	-0.08	-0.08	0.46**	0.28

*(n=32, * significant at 5% level, ** significant at 1% level)*

The results indicated that morning RH during crown root initiation had a significant positive (P=0.01) correlation with grain yield. Bright sunshine hours during tillering had significant negative (P=0.05) correlation, suggesting the crop prefer cloudy weather during tillering. At the same time, morning RH during crown root initiation, tillering and dough stages had significant (P=0.01) positive correlation with grain yield, which may be due to the dew effect. Tmax during booting showed significant negative (P=0.05) relation with grain yield. Afternoon RH during booting, milk stages showed significant positive correlation (P=0.01) with grain yield.

Palampur

Crop weather relationship studies in irrigated wheat were taken up in a field experiment containing three growing environments (25 October, 25 November and 25 December 2016) and four cultivars (HPW 349, HS542, HS490 and VL 907) during *rabi* 2016-17. Variation in total days taken for completion of different phenophases by these cultivars sown on different dates is presented in Table 4.32.

Table 4.32: Total number of days taken for completion of different phenophases in irrigated wheat at Palampur

Treatment	Emergence	Tillering	Heading	50% grain filling	Physiological maturity
V1 D1	11	54	120	138	172
V1 D2	11	52	117	137	149
V1 D3	11	53	104	121	131
V2 D1	9	53	119	137	171
V2D2	9	52	118	138	151
V2 D3	11	53	105	120	132
V3 D1	9	53	118	137	171
V3 D2	9	53	116	137	150
V3 D3	13	57	107	119	132
V4 D1	10	54	121	138	172
V4 D2	8	52	118	136	149
V4 D3	13	57	107	119	131

(V1: HPW 349, V2: HS542, V3: HS490, V4: VL 907; D1: 25 October, D2: 25 November, D3: 25 December)

From Table 4.32, it is clear that large variation for time taken to achieve different phenological stages existed among different cultivars and within a same cultivar under different sowing dates. It was observed that main difference was noticed in time taken during tillering to heading and heading to 50% grain filling. For example, cultivar HPW 349 took 120, 117 and 104 days to complete heading in three different dates of sowing. Almost 40 days, on an average, difference to achieve physiological maturity was noticed by the cultivars sown on different dates. Effect of treatments on grain yield, biological yield and straw yield is presented in Table 4.33.

The highest grain yield and biological yield were recorded for wheat cultivar VL-907 sown on 25 October (4.71 and 14.03 t ha^{-1}, respectively). One reason for this may be due to the factor that VL-907 has taken the maximum number of days (172) from sowing to maturity, when sown on 25 October, along with HPW-349.

Table 4.33: Treatment wise mean grain, straw and biological yield of irrigated wheat at Palampur during *rabi* 2016-17

Treatment	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})	Straw yield (kg ha^{-1})
V1D1	10.10	1.85	8.25
V1D2	10.10	3.09	7.02
V1D3	8.69	2.86	5.84
V2D1	13.18	3.93	9.26
V2D2	9.54	2.46	7.07
V2D3	8.42	1.85	6.57
V3D1	12.63	3.14	9.48
V3D2	10.94	3.54	7.41
V3D3	7.29	2.47	4.83
V4D1	14.03	4.71	9.32
V4D2	9.54	2.53	7.02
V4D3	7.80	1.96	5.84

(V1: HPW 349, V2: HS542, V3: HS490, V4: VL 907; D1: 25 Oct, D2: 25 Nov, D3: 25 Dec)

Rabi Sorghum

Solapur

Field experiments were conducted during *rabi* season of 2012-13 to 2016-17 using four sowing windows (36, 38, 40 and 42 SMW) and thee sorghum cultivars (M-35-1, Mauli and Yashoda). Correlation study between consumptive use of moisture (CUM) and grain yield was conducted and the results are presented in Fig. 4.16. The CUM of 240 mm was found to be optimum for getting higher grain yield, after there was a reduction in sorghum yield.

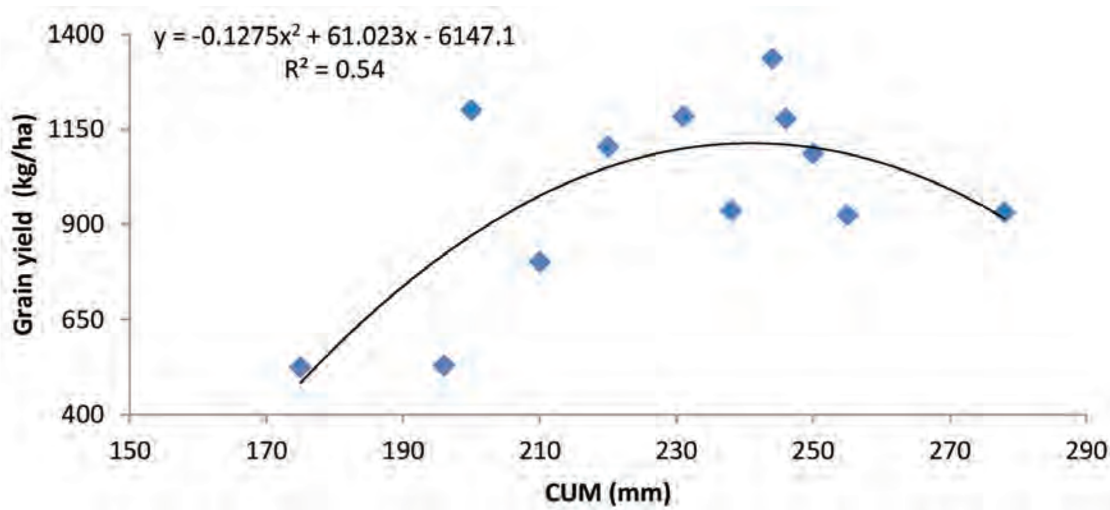


Fig. 4.16: Correlation between consumptive use of moisture and grain yield in *rabi* sorghum at Solapur during 2012-13 to 2016-17.

Relationship between average seasonal maximum and minimum temperature with grain yield was also studied and the results are presented in Fig. 4.18 (A) and (B).

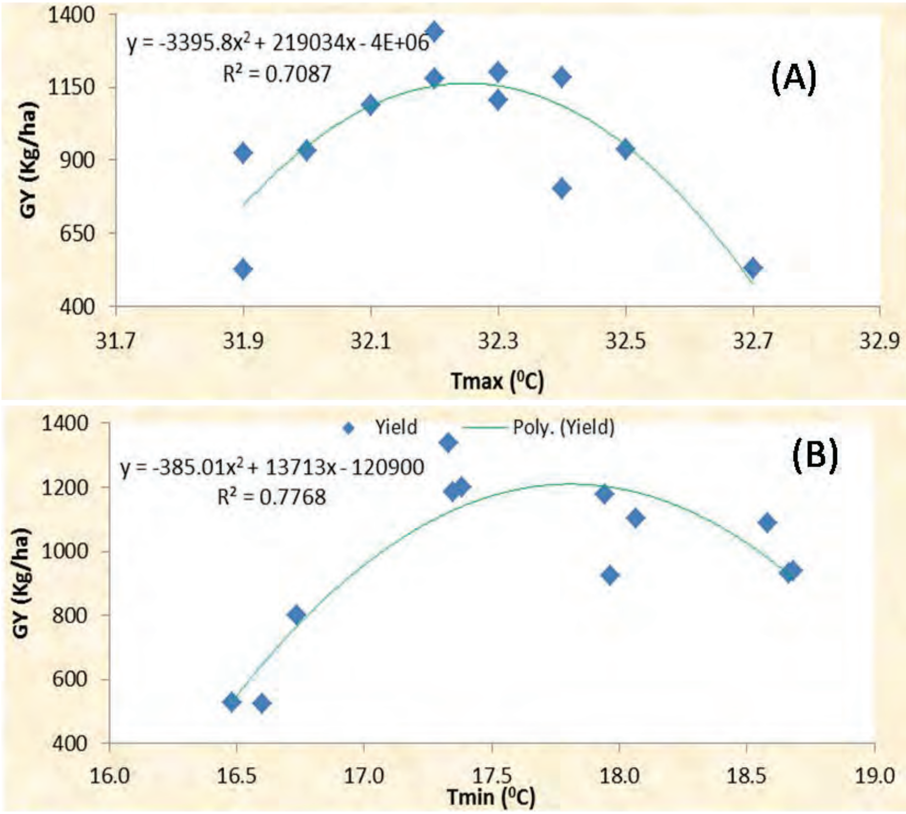


Fig. 4.17: Relationship between grain yield of *rabi* sorghum with (A) average season maximum temperature and (B) average seasonal minimum temperature at Solapur during *rabi* 2012-13 to 2016-17

The analysis indicated that the grain yield increased up to maximum temperature of 32.3 ^{0}C and minimum temperature of 18 ^{0}C and decreased thereafter.

Chickpea

Akola

Chickpea cultivars JAKI-9218, Akash and Vijay were grown under three growing environments for studying the crop-weather relationships. Heat use efficiency, HUE (kg ha^{-1} ^{0}C-day^{-1}) with respect to seed yield and biomass production (seed + straw) under different sowing time (Table 4.34) showed marginal difference among the different sowings with numerically maximum HUE in terms of seed (1.22 kg ha^{-1} ^{0}C day^{-1}) under 43 SMW (28 October) sowing and for biomass (2.68 kg ha^{-1} ^{0}C day^{-1}) under 44 SMW (04 November) sowing.

Table 4.34: Heat use efficiency of chickpea varieties in terms of seed and biomass production (kg ha^{-1} ^{0}C-day^{-1}) under different dates of sowing

Varieties	Sowing date			
	D1- 43 MW (28.10.16)	D2 44 MW (04.11.16)	D3 45 MW (11.11.16)	Mean
V_1 - JAKI-9218	1.38	1.33	1.26	1.32
	2.95	**2.75**	**2.74**	**2.82**
V_2 – Akash	1.35	1.19	1.16	1.23
	2.76	**2.65**	**2.61**	**2.67**
V_3 – Vijay	0.94	1.04	1.16	1.04
	2.21	**2.63**	**2.52**	**2.45**
Mean	1.22	1.19	1.19	
	2.64	**2.68**	**2.63**	

(Bold numbers indicate HUE in terms of biomass)

Solapur

Crop-weather relationship studies in chickpea were taken up by conducting a field experiment involving four sowing dates (38, 40, 42 and 44 SMW) and two cultivars (Vijay and Dig Vijay) during *rabi* season of 2012-13 to 2016-17 and the pooled results are presented here under. Relation between consumptive use of moisture and yield presented in Fig. 4.18 indicated that CUM of 250 mm was found to be optimum for getting higher seed yield.

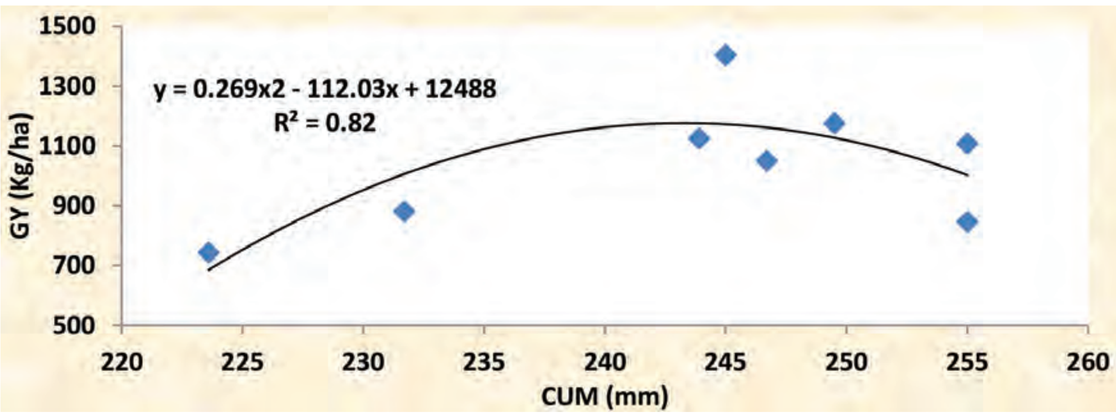


Fig. 4.18: Relation between consumptive use of moisture and grain yield at Solapur during *rabi* 2012-13 to 2016-17

Potato

Hisar

Potato cultivars Kufri Bahar, Kufri Pushkar and Kufri Surya were exposed to four growing environments (sown on first and second fortnights of November and December) to study the crop weather relationship. Effect of cultivar and growing environments on tuber yield and yield attributes were studied and presented in Table 4.35.

Table 4.35: Effect of planting dates and cultivars on yield and yield attributes of potato at Hisar during *rabi* 2016-17

Treatment	No of tubers plant^{-1}	Tuber weight (g tuber^{-1})	Tuber yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index (%)	Average Tmax during reproductive stage (^{0}C)
Main plot treatment						
1st FN of Nov	8.9	122.1	27004.9	40541.7	66.9	22.1
2nd FN of Nov	9.4	135.8	30132.7	43305.1	70.0	24.2
1st FN of Dec	8.3	105.0	25967.8	37133.1	69.8	29.3
2nd FN of Dec	7.9	89.2	24901.0	32414.2	77.1	33.1
CD at 5%	0.7	14.3	1377.6	3237.3	6.0	
Sub plot treatment						
K. Bahar	7.1	105.8	24146.7	34012.7	71.6	
K. Pushkar	8.5	115.1	26884.9	38765.4	69.9	
K. Surya	10.3	118.1	29973.2	42267.4	71.3	
CD at 5%	0.4	10.6	686.62	1379.84	NS	

The delayed planting (first and second fortnight of December) had poor yield attributes along with the tuber yield and the differences were significant. Among the planting dates, higher number of tubers per plant (9.4) was recorded in crop sown on second fortnight of November, whereas among varieties higher number of tubers per plant (10.3) recorded in K. Surya. Tuber weight, tuber and haulm yield and harvest index were higher (135.8 g tuber^{-1}, 30132.7 kg ha^{-1}, 43305.1 kg ha^{-1} and 70.0%, respectively) in D2 planting as compared to other dates. This was due to comparatively higher average maximum temperature during reproductive stages of D3 and D4. Among the varieties, tuber weight, tuber and haulm yield were significantly higher in K. Surya (118.1 g, 29973.2 kg ha^{-1} and 42267.4 kg ha^{-1}, respectively) as compared to K. Pushkar and K. Bahar. Effect of cultivars and growing environments on radiation use efficiency of potato was also studied and the results are presented in Table 4.36.

Table 4.36: Radiation Use Efficiency (RUE) of potato cultivars at various phenophases under different growing environments at Hisar during *rabi* 2016-17

Treatment	RUE (g MJ^{-1})				
	Emergence	Stolonization	Tuber initiation	Tuber bulking	Physiological maturity
Main-plot treatment					
1st FN of Nov-D1	0.58	1.33	1.34	1.56	2.80
2nd FN of Nov-D2	0.62	1.66	1.63	1.82	3.67
1st FN of Dec-D3	0.60	1.49	1.23	1.57	3.60
2nd FN of Dec-D4	0.53	1.88	1.53	1.99	4.93
CD at 5%	0.18	0.33	0.03	NS	0.08
Sub-plot treatment					
K. Bahar	0.48	1.13	1.16	1.90	3.27
K. Pushkar	0.61	1.44	1.39	1.63	3.40
K. Surya	0.67	1.79	1.48	1.74	3.34
CD at 5%	0.02	NS	NS	0.21	0.02

The potato crop sown during second fortnight of November (D4) was most efficient in PAR utilization in comparison with crop sown on other three dates. The intercepted PAR was lower in D4 due to lower LAI, but RUE was higher because of lower dry matter. Among cultivars, Kufri Bahar had higher RUE at maximum LAI stage, followed by Kufri Surya and Kufri Pushkar. At physiological maturity, Kufri Pushkar had highest RUE as compared to other varieties.

Mohanpur

A field experiment with three dates of sowing (17 November, 02 and 17 December 2017) and three potato cultivars (Jyoti, Chandramukhi and Ashoka) was taken up during *rabi* 2016-17 to study the crop weather relationship. Relationship between cumulative intercepted PAR and periodic biomass was studied for cv Chandramukhi and the results are presented in Fig. 4.19.

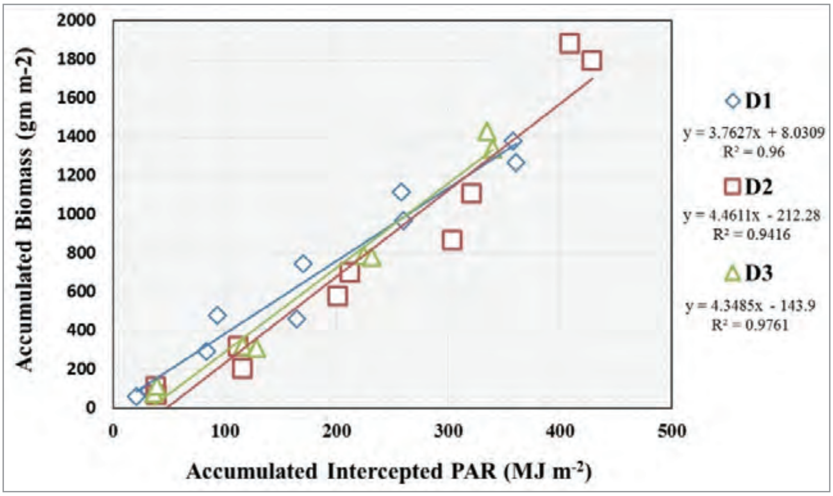


Fig. 4.19: Relationship between cumulative intercepted PAR and biomass of cultivar Chandramukhi of potato at Mohanpur during *rabi* 2016-17.

The highest RUE (4.46) was observed when the crops were planted during the first week of December, followed by 17 December. It can be observed from Fig. 4.16 that RUE of cv Chandramukhi varied among different dates of sowing initially, up to an intercepted PAR value of 300 MJ m^{-2} and an accumulated biomass of 1200 g m^{-2}.

Perennial crops

Guava

Hisar

Crop-weather relationship studies were conducted in Guava orchard (planted in 2011) with cultivar Hisar Safeda, with a planting density of 275 per hectare. The rainy season crop was most efficient in utilizing the thermal time with highest thermal use efficiency (TUE) followed by spring and winter (Table 4.37). Similar trend was observed in case of water and radiation use efficiencies also.

Table 4.37: Effect of seasons on different efficiencies computed for Guava at Hisar during 2016-17

Parameters	Fruiting season		
	Rainy	Winter	Spring
Yield (kg ha^{-1})	12513	8800	5225
TUE (kg ha^{-1} ^{0}C-day)	5.12	3.36	4.00
WUE (kg $ha^{-1}mm^{-1}$)	27.22	16.53	25.18
RUE (kg ha^{-1} MJ^{-1})	28.24	15.37	10.97

TUE: Thermal use efficiency; WUE: Water use efficiency; RUE: Radiation use efficiency

Pepper

Thrissur

Influence of weather parameters on growth and development of pepper was studied using an experiment in CRD design with eight pepper varieties (Panniyur 1 to 8) under five replications. Correlation studies between weather parameters during different phenophases and plant growth traits like number of leaves produced, number of laterals produced, number of nodes produced, number of orthotropic branches produced, number of adventitious roots produced, intermodal length of main shoot and laterals and leaf area development were estimated for all the black pepper varieties and the significant results are presented in Table 4.38.

Table 4.38: Correlation coefficients between different weather parameters and plant growth traits in pepper at Thrissur

Weather element	Plant characters	P1	P2	P3	P4	P5	P6	P7	P8
Tmax	No of leaves produced	-0.55**	-0.51**	-0.40*	-0.58**	-0.66**	-0.56**	-0.57**	-0.53**
	Lateral internodal length			-0.78**	-0.77**	-0.50	-0.76**	-0.12	-0.78**
	No of laterals					-0.44*	-0.49*	-0.43*	-0.43*
	Main internodal length		0.64*					0.66*	0.67*
	Lateral internodal length			-0.78**	-0.77**		-0.76**		-0.78**
	Adventitious roots produced	-0.78**	-0.73**				-0.82**		-0.68*
Tmin	No of orthotropic branches		0.79**			0.59*		0.67*	
	Lateral internodal length							0.77**	
	Adventitious roots produced			0.66*	0.68*				
Rainfall	No of leaves produced	0.68**	0.65**	0.56**	0.67**	0.76**	0.68**	0.67**	0.60**
	No of laterals				0.52**	0.42*	0.67**	0.57**	0.46*
	No of nodes	0.81**		0.69*	0.87**	0.92**	0.91**	0.89**	0.83**
	Main internodal length			-0.67*	-0.58*		-0.72**	-0.63*	-0.58*
	Lateral internodal length		0.59*				0.58*		0.61*

**-Significant at 5% **-Significant at 1%*

The results indicated that rainfall had highly significant (P = 0.01) positive correlation and Tmax has significant negative correlation with number of leaves produced for all the cultivars (Panniyur 1 to 8). Maximum temperature has significant negative correlation with intermodal length of P3, P4, P6 and P8. Main internodal length is the only trait which showed significant positive correlation (P = 0.05) with Tmax for P2, P7 and P8). Tmin showed significant positive correlation with number of orthotropic branch produced in P2, P5 and P7.

5.1 *Kharif* 2016

Soybean

Akola

Soybean simulation model (DSSAT v 4.5) was calibrated and validated using data from the field experiment. Crop phenology was well predicted by the model in all three cultivars *viz*., JS-335, JS-9305 and TAMS 98-21. The model predicted the seed yield accurately in JS-335 than in JS-9305. The percentage error (PE) was 5.65 and 13.28, respectively, for JS-335 and JS-9305. The DSSAT Soybean simulation model can be further validated and also used for sensitivity analysis under climate change scenario.

Simulation of yield using DSSAT soybean model by providing daily protective irrigation of 50 mm from 01 - 26 September under the environmental modification option to soybean crop (JS-335 cultivar) during dry spell in different dates of sowing resulted in better yield than observed (Table 1). Late sown soybean crop (29 SMW) benefitted more almost 15% than the crops sown earlier with daily irrigation. Out of all 26 days, first 3 days daily irrigation fetched more yield in the crop, however relative advantage was observed more in late sown crop.

Table 5.1: Yield dynamics under environmental modification in the form of varying single irrigation application on soybean seed yield during *kharif* 2016

Sowing time	Seed yield (kg ha^{-1})																			
	Simulated (rainfed)	Simulated (Daily protective irrigation of 50 mm)																		
		*1	2	3	4	5	6	7	8	9	10	11	12	13	14	19	20	21	25	26
26 MW	2407	3039	3042	3050	3024	3021	2963	2886	2798	2769	2683	2640	2561	2482	2412	2419	2419	2416	2405	2409
		6.08	**6.08**	**6.10**	**6.05**	**6.04**	**5.93**	**5.77**	**5.60**	**5.54**	**5.37**	**5.28**	**5.12**	**4.96**	**4.82**	**4.84**	**4.84**	**4.83**	**4.81**	**4.82**
27 MW	2165	2778	2882	2868	2847	2810	2779	2772	2715	2649	2587	2508	2341	2238	2193	2126	2168	2166	2167	2167
		5.76	**5.76**	**5.74**	**5.69**	**5.62**	**5.56**	**5.54**	**5.43**	**5.30**	**5.17**	**5.02**	**4.68**	**4.48**	**4.39**	**4.25**	**4.34**	**4.33**	**4.33**	**4.33**
28 MW	1754	2722	2723	2708	2590	2524	2447	2365	2319	2261	2173	2145	2062	1938	1847	1749	1751	1752	1753	1752
		5.44	**5.45**	**5.42**	**5.18**	**5.05**	**4.89**	**4.73**	**4.64**	**4.52**	**4.35**	**4.29**	**4.12**	**3.88**	**3.69**	**3.5**	**3.5**	**3.5**	**3.51**	**3.5**
29 MW	1647	2699	2698	2640	2532	2437	2364	2291	2210	2127	2044	1962	1891	1823	1728	1639	1641	1638	1644	1643
		5.40	**5.40**	**5.28**	**5.06**	**4.87**	**4.73**	**4.98**	**4.42**	**4.25**	**4.09**	**3.92**	**3.78**	**3.65**	**3.46**	**3.28**	**3.28**	**3.28**	**3.29**	**3.29**

*Bold figures indicate yield productivity kg m^{-3}(irrigation), * 1-26 days (September)*

Jabalpur

An experiment was conducted on soybean cultivar JS 20-29 at Jabalpur. Crop and weather data was collected and compiled in the minimum data set format for DSSAT soybean model. Further, the DSSAT CROPGROW Soybean model was calibrated for the cultivar JS 20-29 and the fifteen genetic coefficients developed for Jabalpur location were presented in the Table 5.2.

Table 5.2: Genetic coefficients developed for soybean cv. JS 20-29 at Jabalpur

Symbol	Description	Genetic Coefficients of variety JS 20-29
	Development aspects	
CSDL	Critical Short Day Length below which reproductive development progresses with no day length effect (for short day plants) (hour)	11.81
PPSEN	Slope of the relative response of development to photoperiod with time (positive for short day plants) (1/hour)	0.200
EM-FL	Time between plant emergence and flower appearance (R1) (photothermal days)	15.7
FL-SH	Time between first flower and first pod (R3) (photothermal days)	4.5
FL-SD	Time between first flower and first seed (R5) (photothermal days)	11.7
SD-PM	Time between first seed (R5) and physiological maturity (R7) (photothermal days)	37.5
FL-LF	Time between first flower (R1) and end of leaf expansion (photothermal days)	18
SFDVR	Seed filling duration for pod cohort at standard growth conditions (photothermal days)	22.0
PODUR	Time required for cultivar to reach final pod load under optimal conditions (photothermal days)	7
	Growth aspects	
LF-MAX	Maximum leaf photosynthesis rate at 30 C, 350 vpm CO_2, and high light (mg $CO_2/m^2/s$)	1.030
SLAVR	Specific leaf area of cultivar under standard growth conditions (cm^2/g)	375
SIZLF	Maximum size of full leaf (three leaflets) (cm^2)	137.0
XFRT	Maximum fraction of daily growth that is partitioned to seed + shell	1.0
WTPSD	Maximum weight per seed (g)	0.180
SDPDV	Average seed per pod under standard growing conditions (#/pod)	1.70

Rice

Faizabad

Experimental field data of rice crop under three dates of sowing *viz*. 5 July, 20 July and 4 August with two different cultivars namely Sarjoo-52 and NDR-359 was collected and compiled in a minimum data set format for four years 2013, 2014, 2015 and 2016. DSSAT Rice model was calibrated with the first three years data and validated with 2016 data at Faizabad. The summarized results are presented below;

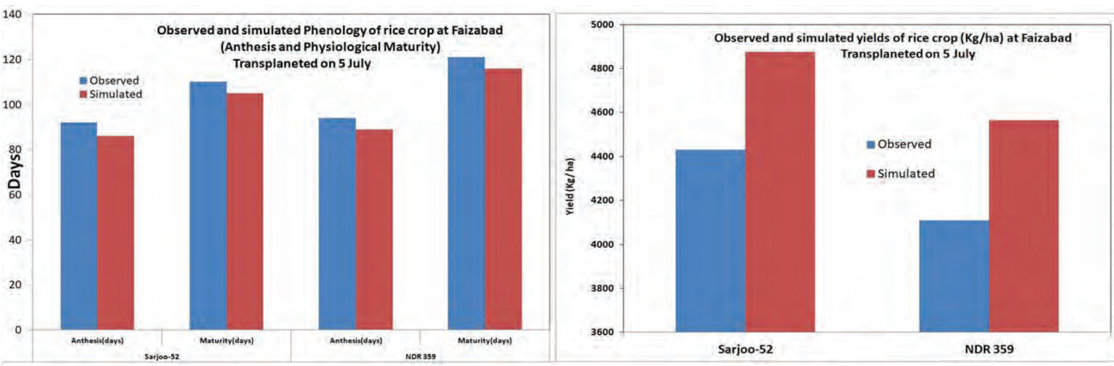


Fig. 5.1: Simulated vs. observed phenology and grain yield of two rice varieties transplanted on 5 July at Faizabad

The absolute error between observed and simulated phenology of rice crop was 5 to 6 days (Fig. 5.1) and the simulated yields of rice were less than the observed grain yield. But in case of crop transplanted on 20 July transplanted phenology and yields were simulated within the reasonable limits of 2 to 7 per cent (Table 5.3)

Table 5.3: Simulated vs. observed phenology and grain yield of two rice varieties transplanted on 20 July at Faizabad

Variety	Phenophases	Observed	Simulated	Error (%)
Sarjoo-52	Panicle initiation	85	90	-5.8
	Maturity	112	118	-5.3
	Yield(kg ha^{-1})	4130	4410	-6.7
NDR 359	Panicle initiation	90	95	-5.5
	Maturity	118	122	-3.3
	Yield(kg ha^{-1})	4564	4876	2.4

Jorhat

Sali rice variety TTB-404 field experiment data was collected for two years (2014-2015) at Jorhat centre under three environments. Soil profile data and weather data file were prepared and incorporated in the DSSAT rice model for the respective years. Gencalc module of DSSAT model was used in to generate genetic coefficient for the variety TTB-404. DSSAT Rice model was calibrated for Sali rice (Table 5.48a) and the statistical results of rice phenology (anthesis, maturity and yield) is shown in Table 5.4b.

Table 5.4: Genetic coefficients estimated for Sali rice cultivar TTB-404 with statistical results of simulated phenology at Jorhat

(a) Calibrated genetic coefficients estimated for Sali rice							
P1	P20	P2R	P5	G1	G2	G3	G4
723.2	11.80	195.3	295.7	46.0	0.022	1.00	0.95
(b) Statistical results of simulated phenology							
Variable Name	Observed	Simulated	RMSE	D-stat			
Anthesis day	81	83	2.0	0.6			
Maturity Yield (kg ha^{-1})	4277	3952	449	0. 34			
Maturity day	114	110	3.53	0.56			

Thrissur

CERES-Rice model of DSSAT v 4.6 was used to develop genetic coefficients rice cultivars *viz.* Jyothi and Kanchana at Thrissur center. Experimental crop data of rice and weather data for the years 2013 & 2014 was collected and compiled in the minimum data set format to calibrate the rice model for Thrissur location. The genetic coefficients were determined using the 'Gencalc' (Genotype Coefficient Calculator) in the DSSAT model. (Table 5.5)

Table 5.5: Genetic coefficients developed for rice cultivars at Thrissur

Variety	P1	P2R	P5	P20	G1	G2	G3	G4	PHINT
Jyothi	553.0	22.3	444.0	10.0	51.0	0.0250	1.10	1.10	82.0
Kanchana	470.7	154.0	443.5	12.3	52.0	0.0220	1.30	1.10	76.0

Maize

Ludhiana

The CERES-maize model was calibrated for the maize crop cultivars *i.e.* PMH 1 and PMH 2 sown under three dates of sowing for two crop years 2014 and 2015. The CERES-Maize model was able to simulate phenological events *i.e.* anthesis date (RMSE = 3.5 day, D-stat = 0.752), maturity date (RMSE = 1.4 day, D-stat = 0.908); yield parameters *i.e.* grain yield (RMSE = 956 kg ha^{-1}, D-stat = 0.592) and biomass yield (RMSE = 1880 kg ha^{-1}, D-stat = 0.628) for maize cultivars under different sowing dates during the two crop years (Table 5.6).

Table 5.6: Statistical comparison of observed and simulated phenology and yield of maize at Ludhiana (Pooled data of *kharif* 2014 and 2015)

Phenology	Mean			Standard deviation		R-Square	RMSE	D-stat.
	Obs	Sim	Ratio	Obs	Sim			
Anthesis day	54	53	0.992	2.3	2.6	0.726	1.4	0.908
Maturity day	85	86	1.012	4.3	3.3	0.376	3.5	0.752
Grain yield (kg ha^{-1})	4840	5094	1.059	610.4	988.1	0.172	955.9	0.592
Biomass yield (kg ha^{-1})	10685	11069	1.033	987.4	2227.9	0.337	1879.8	0.628

The model was used further to assess district wise impact of climate change on duration of the crop and the yields by incorporating data on future projections (Generated by PRECIS model) and the results were presented in Table 5.7.

The results of simulated changes in crop duration of maize crop under different scenarios indicated that maturity period of the maize is expected to decrease during the mid and end of the 21st century under different scenarios of climate change. Under high emission scenario (A1B), the duration of maize in end century is projected to be ≤70 days (table 8) during the crop years 2073, 2078, 2080, 2084-86, 2089-90, 2092-93 and 2096-97 at Ballowal Saunkhri; during 2073-74, 2076-86, 2088 and 2090-98 at Amritsar; during 2073, 2078-79, 2083-87, 2089-90, 2092-93 and 2095-97 at Jalandhar; during 2078-80, 2082-86, 2089-90 and 2092-98 at Ludhiana; during 2078, 2082, 2084, 2085-86, 2088, and 2090-98 at Patiala and during 2071-74, 2076, 2078-88 and 2090-98 at Bathinda.

Table 5.7: Simulated crop duration and grain yield of maize crop using future projections (2071-2100) by CERES-Maize model

Station name	Crop years					
	Crop duration ≤ 70 days			Grain yield (< 500 kg ha^{-1})		
	A1B	A2	B2	A1B	A2	B2
Ballowal Saunkhri	2073, 2078, 2080, 2084, 2085, 2086, 2089, 2090, 2092, 2093, 2096, 2097	2079,2095, 2096,2097	-	2073, 2078, 2084, 2085, 2086, 2089, 2090, 2092, 2093, 2096, 2097	2079, 2096, 2097	2084
Amritsar	2073, 2074, 2076 to 2086, 2088, 2090 to 2098	2070, 2075, 2079, 2090, 2091, 2093, 2095 to 2099	2093	2072 to 2074, 2076, 2078 to 2090, 2092 to 2098	2073 to 2076, 2079, 2088, 2091, 2094, 2096 to 2099	2084, 2093
Jalandhar	2073, 2078, 2079, 2083 to 2087, 2089, 2090, 2092, 2093 and 2095 to 2097	2090, 2091, 2093, 2095 to 2097, 2099	2083	2073, 2078, 2079, 2083 to 2085, 2087 to 2090, 2092, 2093, 2095 to 2098	2091, 2093, 2097, 2099	-
Ludhiana	2078 to 2080, 2082 to 2086, 2089, 2090, 2092 to 2098	2075, 2079, 2084, 2090, 2091, 2093, 2095 to 2099	2084, 2093	2073, 2074, 2078, 2079, 2081, 2083 to 2088, 2093 to 2096, 2098	2073, 2074, 2079, 2091, 2094, 2096	2086, 2093
Patiala	2078, 2082, 2083, 2085, 2086, 2088, 2090 to 2098	2073, 2075 2079, 2090, 2091, 2093, 2095 to 2099	2079, 2093	2078, 2082 to 2088, 2091, 2095, 2098	2073 to 2076, 2088, 2091, 2094, 2096 to 2098	2084, 2093
Bathinda	2071 to 2074, 2076, 2078 to 2088, 2090 to 2098	2073, 2075, 2076, 2078, 2079, 2084, 2086 to 2089, 2092 to 2099	2079, 2081, 2082, 2084, 2086, 2087, 2089, 2091 to 2093, 2097, 2099	2072, 2076, 2080, 2082 to 2084, 2086, 2087 2090 to 2093, 2095 to 2098	2074 to 2076, 2078, 2079, 2084, 2086 to 2099	2082,2084, 2086, 2087, 2089, 2091, 2092, 2097, 2099

The results of the trend analysis for the grain yield of the maize crop under different scenarios during the mid and end of 21 century show negative and linear trends for all the districts under study indicating that the grain yield may decline during the mid century and end century period (Fig. 2). The decline in grain yield of the maize crop by the end of the 21 century will be in the range of -55.6 to -83.2 kg ha^{-1} under A1B scenario followed by -54.5 to -80.1 kg ha^{-1} under A2 and -42.6 to -59.2 kg ha^{-1} under B2 scenario.

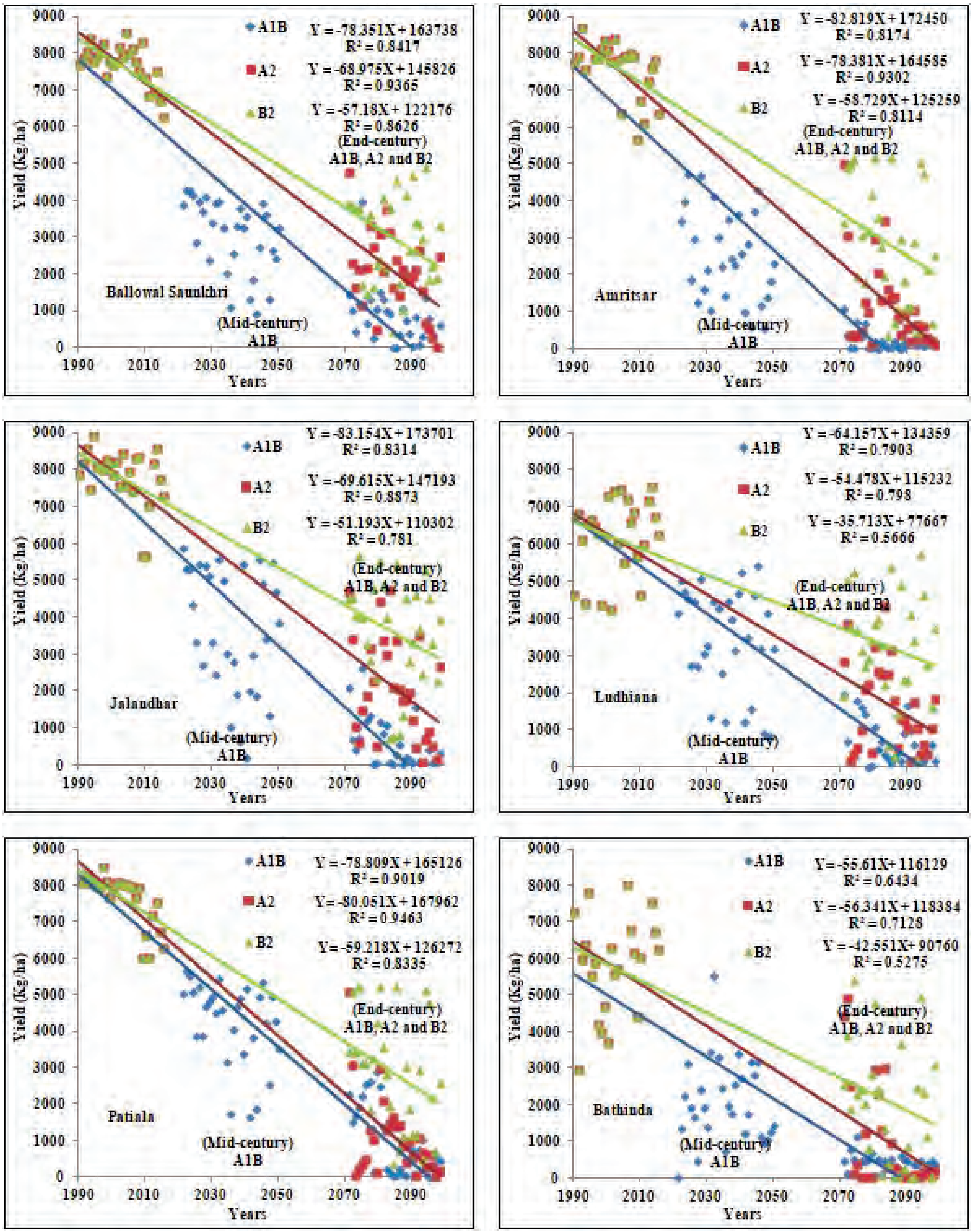


Fig. 5.2: Trends in grain yield of maize simulated during current, mid and end of century in Punjab

5.2 Rabi - 2016-17

Wheat

Ludhiana

Use of CERES-Wheat model for pre-harvesting forecast of wheat yield during 2016-17

The grain yield of wheat during the year 2016-17 was predicted using CERES-Wheat model. The actual weather data of Ludhiana station from mid October to 28 March 2017 and for the remaining period upto maturity, climatological weather data of same station was used for simulating wheat yield. The observed wheat yields as well as crop growth duration under different sowing weeks was compared with yield and duration simulated at Ludhiana station (Table 5.8 and 5.9). The model was run with an assumption that the crop remained free from water, nutrient and biotic stress.

Table 5.8: Deviation of grain yield of wheat during crop year 2016-17 (Model simulation)

Sowing weeks	Deviation of grain yield (%) from a model simulated normal yield of 4995 kg ha^{-1}					
	Upto 17 Feb 2017	Upto 28 Feb 2017	Upto 5 March 2017	Upto 14 March 2017	Upto 21 March 2017	Upto 28 March 2017
4 week Oct	-2.7	-3.1	-3.1	-2.1	-2.1	-2.1
1 week Nov	-2.5	-4.5	-4.6	-2.6	-2.6	-2.6
2 week Nov	+0.6	-1.1	-2.2	-1.1	-1.1	-1.1
3 week Nov	-1.2	-5.6	-6.1	-3.1	-3.1	-3.1
4 week Nov	-3.7	-6.8	-7.7	-5.7	-5.8	-5.9
1 week Dec	-5.1	-7.2	-8.5	-6.5	-6.7	-6.8
Average (Predicted yield)	-2.4 (4875 kg ha^{-1})	-4.7 (4760 kg ha^{-1})	-5.3 (4730 kg ha^{-1})	-3.5 (4819 kg ha^{-1})	-3.5 (4819 kg ha^{-1})	-3.6 (4815 kg ha^{-1})

Table 5.9: Deviation of crop growth duration of wheat during crop year 2016-17 (Model simulation)

Sowing weeks	Crop growth duration (Days)	Deviation of crop growth duration (days) from the model simulated growth duration					
		Upto 17 Feb 2017	Upto 28 Feb 2017	Upto 5 March 2017	Upto 14 March 2017	Upto 21 March 2017	Upto 28 March 2017
4 week Oct	156	-3	-4	-5	-3	-3	-3
1 week Nov	153	-1	-2	-3	-1	-1	-1
2 week Nov	150	-1	-2	-2	-1	-1	-1
3 week Nov	145	+1	+1	0	0	0	0
4 week Nov	141	+2	+1	0	+1	+1	+1
1 week Dec	136	+3	+2	+1	+3	+3	+3

Effect of rise in intra-seasonal temperature on wheat in major wheat growing locations in India

A study was conducted using DSSAT CERES-Wheat model at seven wheat growing locations *viz*. Palampur, Ludhiana, Kanpur, Faizabad, Udaipur, Ranchi & Raipur in India to analyze the effects of rise in intra-seasonal temperature on productivity, to optimize sowing time for mitigating the effects of rise in intra-seasonal temperature and to identify the most critical phenophase of wheat for temperature rise.

The results showed that among the zones, Central zone was the most susceptible (yield reduced upto 10.2%) to the likely rise in temperature by 3.0 ^{0}C from normal. The Northern hills zone was least susceptible and the wheat yield increased upto 4.1% with likely rise in temperature by 3.0 ^{0}C from normal during early phases of crop growth while during later phases of crop growth the yield decrease was 3.5-5.8%.

Among the sowing dates, the productivity of late sown wheat was effected in Northern hills and North Western plain zones; Timely sown wheat at Kanpur, late sown wheat at Faizabad and early sown wheat at Ranchi, were affected in North Eastern plain zone. Early sown wheat at Raipur and timely sown wheat at Udaipur in the Central zone suffered to a lesser extent as compared to other dates of sowing. In all the zones, barring Northern hills zone the temperature during first fortnight of February was most critical to wheat productivity. In Northern hills zone, second fortnight of March was most critical, as during this period above normal temperature caused reduction in productivity of wheat irrespective of dates of sowing under the study.

Ranchi

Calibration and validation of the CERES Wheat model

The CERES –Wheat model was calibrated with data collected from the field experiments conducted on wheat cultivars *viz*. HUW 468, K9107 and Birsa Genhu 3 during 2009 – 2015 (Table 5.10). A close agreement was obtained between observed and simulated days for anthesis, physiological maturity and yield. The model was able to simulate the anthesis day accurately with an RMSE of 7.4, 5.5 and 5.3 and D-index values of 0.62, 0.69 and 0.58 for HUW 468, K9107 and Birsa Genhu 3, respectively. The per cent deviation between observed and predicted values was within 7%.

Table 5.10: Observed and simulated anthesis days, physiological maturity days and grain yields of selected varieties of wheat

Varieties	Days to anthesis				Days to physiological maturity				Grain yield (kg ha $^{-1}$)			
	O	S	RMSE	D-stat	O	S	RMSE	D-stat	O	S	RMSE	D-stat
HUW468	81	84	5.50	0.62	120	119	3.2	0.91	5002	4795	585.0	0.77
K9107	84	88	5.3	0.69	123	117	6.4	0.77	4250	4338	387.0	0.86
Birsa Genhu 3	82	88	7.4	0.58	121	117	4.7	0.85	5003	5812	878.7	0.72

(O-Observed, S-Simulated)

Further, climate change impact studies were simulated using ECHAM 5 and MK 3.5 climate model data, collected from CCAFS web site. The days taken for the anthesis predicted during decades of mid century showed a likely decrease by 1 to 10 days in all selected varieties of wheat. Predicted reduction was more under ECHAM 5 projection as compared to MK 3.5 9 (Table 5.11). Among the varieties Birsa Genhu 3 showed less variation in days to anthesis during coming decades as compared to current situation.

Table 5.11: Predicted days to anthesis of wheat varieties in the decades of mid century

Days to anthesis										
Varieties	Date of Sowing	ECHAM 5					MK 3.5			
		2010	2020	2030	2040	2050	2020	2030	2040	2050
HUW468	Normal	85	83	83	78	76	87	85	83	81
K9107	Normal	90	88	88	83	80	92	90	88	86
Birsa Genhu 3	Normal	89	88	88	83	80	92	90	88	86

The period of 2020 showed (Table 5.12) the least reduction in days for physiological maturity wheat varieties. Maximum reduction was observed for K9107 over the decades. Duration of maturity decreased from 129 days (2010) to 115days in 2050 for normal sown (20 November) K9107 wheat in ECHAM 5. Rate of reduction would be almost similar by MK 3.5 model. Predicated reduction of 3 to 8 and 4 to 9 days had been noticed for HUW468 and Birsa Genhu 3 in both the models during 2050.

Table 5.12: Predicted days to physiological maturity of wheat varieties in the decades of mid century

Days to maturity										
Variety	Date of Sowing	ECHAM 5					MK 3.5			
		2010	2020	2030	2040	2050	2020	2030	2040	2050
HUW468	Normal	125	126	126	120	117	129	127	125	122
K9107	Normal	129	125	124	119	115	127	125	123	120
BG3	Normal	125	125	125	119	116	127	125	123	121

Simulated grain yield of wheat under different climate change scenarios indicated that among the varieties, HUW468 registered maximum reduction in yield *i.e.* 43% followed by K9107 (27%) and BG3 (24%) and during 2050 under normal sowing by ECHAM 5 (Table 29). MK 3.5 showed 42%, 30% and 23% reduction in yield of HUW468, K9107 and Birsa Genhu 3, respectively. Birsa Genhu 3, showed least deviation in predicted grain yield by both the models over the decades. The reduction in yield would be due to shortening of crop duration.

Table 5.13: Predicted change in yield of wheat cultivars in coming decades (ECHAM 5 scenarios)

Varieties	Date of Sowing	Normal Year	Yield (kg ha^{-1})				% change in yield			
			2020	2030	2040	2050	2020	2030	2040	2050
HUW468	Normal	6411	4189	4189	3777	3683	-35	-35	-41	-43
K9107	Normal	4884	3909	3896	3655	3582	-20	-20	-25	-27
Birsa Genhu 3	Normal	5895	5250	5236	4562	4487	-11	-11	-23	-24

Table 5.14: Predicted change in yield of wheat cultivars in coming decades (MK 3.5 scenarios)

Varieties	Date of Sowing	Normal Year	Yield (kg ha^{-1})				% change in yield			
			2020	2030	2040	2050	2020	2030	2040	2050
HUW468	Normal	6411	4292	4166	3979	3745	-33	-35	-38	-42
K9107	Normal	4884	3884	3872	3539	3431	-20	-21	-28	-30
Birsa Genhu 3	Normal	5895	5238	5170	4778	4567	-11	-12	-19	-23

6. Weather Effects on Pests and Diseases

Hisar

Influence of weather parameters on leaf hopper and white fly infestation in cotton

Historical data on leaf hopper (jassids) and white fly infestation in cotton was collected over the years in two different cultivars *viz*., HS-6 (17 years) and RCH 134 (7 years). The bi-variate correlation analysis between weather variables and pest infestation was performed using pooled data and results are presented in Table 6.1. Overall analysis showed that increase in maximum temperature had negative influence on leaf hooper and white fly infestation in cotton while increase in minimum temperature had positive effect. Evening relative humidity had more positive association with pest infestation than morning relative humidity. Cloudiness (in terms of low sun-shine hours) has positive association with leaf hooper infestation whereas it had no influence on white fly infestation in cotton.

Table 6.1: Pearsons' correlation coefficient between weather parameters and leaf hopper and white fly infestation in cotton at Hisar

Weather variables	Leaf hopper		White fly	
	HS-6[a]	RCH 134[b]	HS-6[a]	RCH 134[b]
Maximum Temperature	-0.12	-0.15	-0.10	-0.13
Minimum Temperature	0.18	0.33	0.11	0.13
Rainfall	0.13	0.17	0.10	0.09
Relative humidity (morning)	0.04	0.16	0.12	0.17
Relative humidity (evening)	0.18	0.38	0.15	0.22
Wind speed	0.02	0.06	0.01	0.01
Sun-shine hours	-0.15	-0.30	0.01	-0.03

(Data used: [a]1999-2016; [b]2007-08 & 2012-16)

Weather based statistical models for the prediction of incidence of karnal bunt disease in wheat

In order to find out meteorological parameters which have significant effects on incidence of karnal bunt disease in wheat, the weekly weather variables were correlated with disease incidence using historical experimental data. It was found that different combinations of weather variables like maximum (Tmax) and minimum (Tmin) temperatures, rainfall (RF), rainy days (RD), evaporation (EP), wind speed (WS), sun-shine hours (SSH) and relative humidity (RH) for the duration of 6 to 12 standard meteorological weeks (SMW) had significant effect on disease incidence. The weather based regression models were developed for the prediction of karnal bunt disease in wheat for Karnal, Hisar, Rewari and Sirsa districts of Haryana. The regression models and data used for their development are provided in Table 6.2.

Table 6.2: Weather based regression models for the prediction of incidence of karnal bunt disease of wheat in Haryana

Location	Data used	Regression model	R^2
Karnal	1981-82 to 2015-16	$Y=0.110+0.0413*RD_6+0.0325*Tmin_8-0.0144*Tmax_9+0.052*RD_{11}+0.0283*RD_{12}$	0.64
Hisar	1980-81 to 2015-16	$Y=0.197+0.0130*RF_9-0.069*EP_{10}-0.0028*Tmax_{11}+0.0485*RD_{12}+0.005273*RHe_{12}$	0.69
Rewari	1989-90 to 2015-16	$Y=-0.637+0.195*Tmax_6+0.0205Tmin_6+0.0231*SSH_{10}-0.02407*RF_{11}+0.895*RD_{11}$	0.66
Sirsa	1997-98 to 2015-16	$Y=0.3485-0.020*Ep_6+0.033*RD_6+0.101*RD_{10}-0.140*WS_{11}+0.014*RF_{11}$	0.84

(Subscript in the model equations represent the corresponding SMW)

Kanpur

Effect of delayed sowing on stem borer infestation in rice

A field experiment with four varieties of rice (NDR-359, CSR-27, Sarjoo-52 and Swarna) and three dates of sowing (6, 16 and 26 July) was conducted during 2016 *kharif* season. Weekly larval population of rice stem borer per square meter was observed in all the treatments and population for the season was computed and results are presented in Fig. 6.1. The results revealed that timely planted rice crop is less susceptible to stem borer infestation than that of delayed planting. It may be attributed to average lower diurnal temperature range and higher cumulative rainfall received during 28-41 SMW in timely planted crop than delayed one (Table 6.3). Among the varieties, NDR-359 was found to be most susceptible under timely planted conditions whereas Swarna is more susceptible than other varieties under delayed planting.

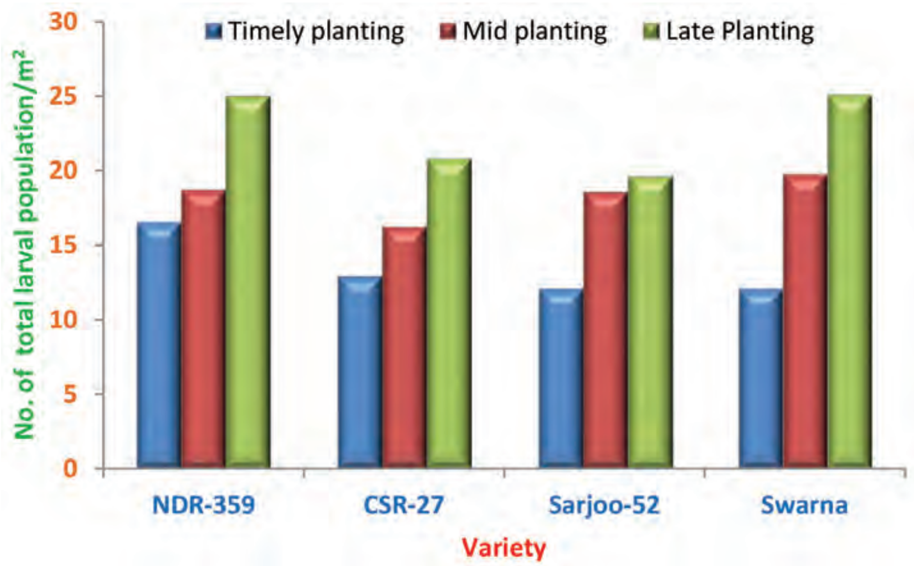


Fig. 6.1: Effect of planting dates on stem borer infestation in different varieties of paddy at Kanpur

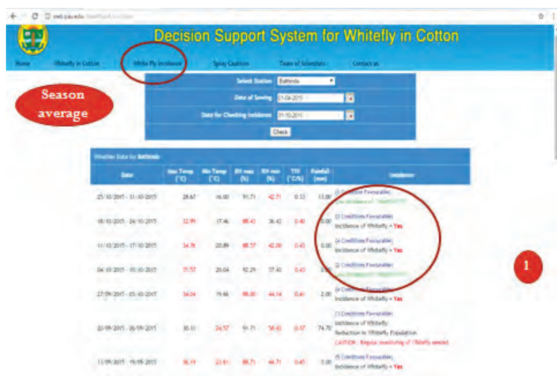
Table 6.3: Average weather conditions prevailed during 28-41 SMW under different planting time of paddy at Kanpur

Planting time	Tmax	Tmin	Tmean	RH-I	RH-II	RHmean	RF	BSS	DTR
Timely planting (28-41 SMW)	32.89	25.24	29.09	87.81	70.57	79.20	377.90	4.99	7.65
Mid planting (29-41 SMW)	32.89	25.17	29.06	87.72	69.70	78.72	300.30	4.92	7.72
Late Planting (30-41 SMW)	33.05	24.44	28.78	87.39	66.33	76.88	270.10	5.48	8.61

Ludhiana

Development of decision support system for predicting the whitefly infestation in cotton

Weather based thumb rules had been developed using historical datasets of whitefly population in cotton and measured weather variables. Using these thumb rules, the decision support system (DSS) is developed for predicting the whitefly infestation in cotton at different locations of Punjab. This DSS was validated using real time weather data of 2016 and can predict the infestation as well as suggest the spray schedule according to the white fly population. The web page screenshot of DSS is shown through following photographs.



Mohanpur

A field experiment was conducted at Mohanpur in order to understand the effect of weather parameters on mustard aphid infestation. Five sticky traps were installed in the field for recording of aphid count during the season. The observations were taken during the period of 5 December, 2016 to 15 February 2017. Weekly weather parameters like Tmax, Tmin, DTR and BSS were regressed against the corresponding weekly aphid count (Fig. 6.2) and also the weekly aphid count was regressed against these weather parameters at the lag of one week (Fig. 6.3). The results revealed that diurnal temperature range more strongly influenced the aphid infestation more stronger than either maximum temperature or minimum temperature. However, increasing minimum temperature of previous week had larger negative effect on aphid population. Maximum temperature of corresponding week had positive effect on the aphid populations in mustard crop. Similarly, BSS of same week had positive influence on the buildup of aphid population in mustard than that of previous week.

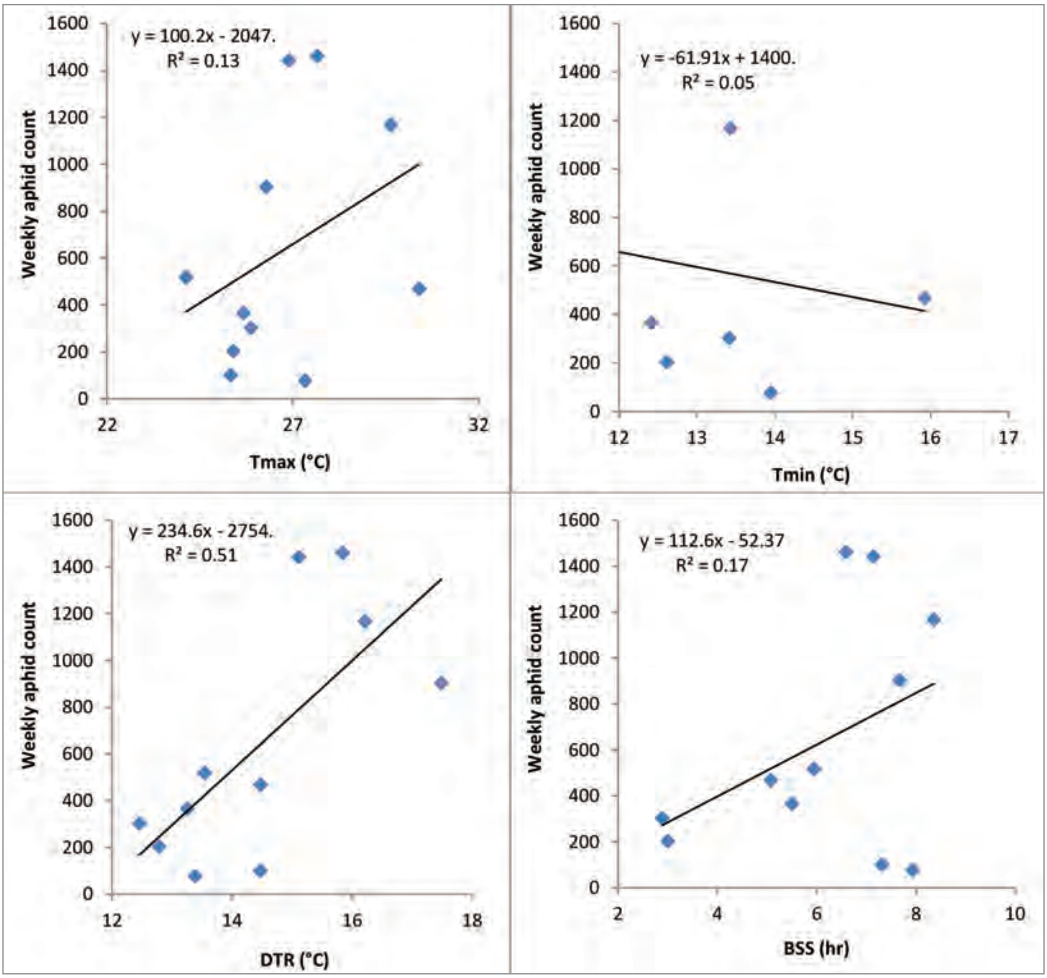


Fig. 6.2: Effect of weekly weather parameters on aphid population in mustard crop at Mohanpur

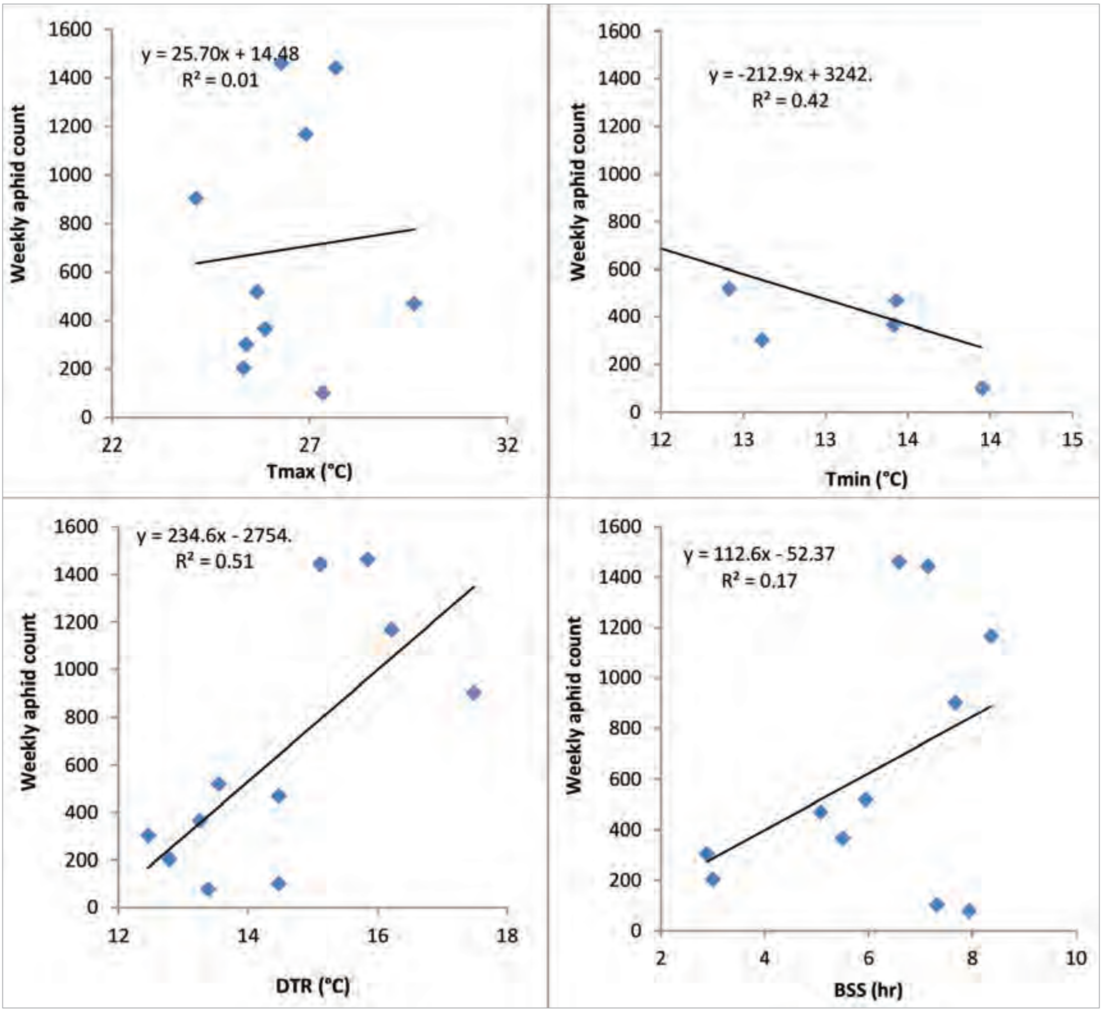


Fig. 6.3: Effect of weather parameters of the previous week on aphid population in mustard at Mohanpur

Palampur

Historical data on the incidence of rice blast disease and weather for the last 32 years (1984-2014 & 2016) was collected. Based on severity level of the disease, three years *i.e.* 1984, 1986 and 1992 were identified as "blast years" and remaining as "non-blast years". It was seen that the incidence of disease usually occurs during 25 July to 5 August. The details of year-wise actual date of disease incidence and disease development phase are given in Table 6.4.

Average weather parameters for the disease incidence window (25 July - 5 August) were calculated for the blast years as well as non-blast years and results are presented in Table 6.5. The results indicated that lower maximum and minimum temperature coupled with high rainfall and cloudiness during the 25 July - 5 August favoured the blast disease incidence in rice at Palampur.

Table 6.4: Historical data on the dates of incidence of blast disease in rice crop at Palampur

Year	Date of Disease incidence	Disease development phase
2004	25th July	25th July-30th August
2005	5th August	5th August-29th August
2006	28th July	28th July- 31st August
2007	31st July	31st July-26th August
2008	1st August	1st August- 29th August
2009	3rd August	3rd August - 31st August
2010	2nd August	2nd August - 30th August
2011	22nd July	22nd July - 23rd August
2012	27th July	27th July - 30th August
2013	9th August	9th August - 19th September
2014	28th July	28th July - 19th September
2016	30th July	30th July - 8th September

Table 6.5: Average weather parameters during disease incidence period (25 July- 5 August) for blast and non-blast years

Particulars	T_{max} (^{0}C)	T_{min} (^{0}C)	Mean (^{0}C)	RH (%)	Rainfall (mm)	Rainy days	Cloud (hrs)	Days with RH ≥ 90%	Days with $T_{min} \leq 20\,^oC$
Blast years	25.0	19.1	22.1	85	330.9	11	142	9	10
Non blast years	26.2	20.0	23.1	85	286.0	10	126	7	7

The average temperature is also calculated for the disease development phase for blast and non-blast years and results are provided in Table 6.6. The results showed that mean temperatures were same for the both conditions. It implies that congenial weather during disease incidence phase determines the further development of disease.

Table 6.6: Average weather parameters during disease development phase for blast and non-blast years

Particulars	Temperature (^{0}C) during disease development phase		
	Maximum	Minimum	Mean
Blast years	25.8	19.4	22.6
Non blast years	26.0	19.3	22.8

Raipur

Developing forewarning models for yellow stem borer in rice

The observation on adults of yellow stem borer was collected from the light traps installed in the paddy field. The meteorological parameters were correlated along with adult count of yellow stem borer to identify the most influencing weather parameter. Stepwise multiple linear regression method was applied to identify best suited model using selected weather variables at different time lags to predict yellow stem borer infestation in rice. The forewarning models are given in the Table 6.7. Out of all the 12 regression models, equation 10 was found to be best in view of its higher coefficient of determination (R^2 = 0.71).

Table 6.7: Regression models developed for forewarning of yellow stem borer in rice at Raipur

S. No.	Regression model	R^2
1	Y_{28} = -0.179+3.312 * SSH (1 week lag)	0.23*
2	Y_{29} = -54.5895 + 1.885999 * SH (1Week lag) + 0.369703 * RH-I (2 week lag) + 0.935439 * T-MAXI (2week lag)	0.18*
3	Y_{30} = -175.248+1.98 * RH-I (1week lag)	0.36**
4	Y_{32} = -94.984+1.199 * RH-I (4 week lag)	0.24*
5	Y_{33} = 10.309168+0.130849 * Rain (2 week lag)	0.51**
6	Y_{34} = 8.2849734+0.0601031 * RAIN (3week lag)	0.55**
7	Y_{35} = 140.8654+0.46547 * RAIN (4week lag) - 1.85963 * RH-II(1week lag)	0.37**
8	Y_{36} = 208.19664-2.3427053 * RH-II (1 week lag)	0.42**
9	Y_{37} = -63.7767+0.514886 * RH-I (2 week lag) +19.74407 * SSH (2 week lag)	0.55**
10	Y_{38} = -602.0827+27.942022 * T-MAXI. (1 week lag) -2.226066 * RH-II (2 week lag)	0.71**
11	Y_{39} =6218.472-64.6553 * RH-I (4 week lag)	0.32**
12	Y_{40} = 799.3676+65.68396 * T-MAX (2 week lag) + 9.938021 * RAIN (1 week lag)- 42.8026 * RH-II (1 week lag)	0.21*

**Correlation is significant at the 0.01 level (2-tailed).*
**Correlation is significant at the 0.05 level (2-tailed).*
Where, Y is yellow stem borer population and subscripts refers to corresponding SMW

Jabalpur

Three chickpea species *viz.*, Kabuli, Gulabi and Desi were grown in varying environments by sowing the crop at three different dates *i.e.* 11 November, 25 November and 13 December 2016. The larval populations of *Helicoverpa armigera* (Gram pod borer) was monitored and weekly larval population was collected from the plants of 1 meter length from five replications. Correlation analysis between larval population and meteorological parameters was carried out and results are presented in Table 6.8. The results indicated that gram pod borer infestation in Kabuli species of chickpea was less susceptible to weather compared to the infestation in desi chickpea species. In desi species, maximum temperature and sunshine hours had positive influence on larval population whereas higher morning and evening relative humidity had negative influence on the larval population. Evaporation had highly significant positive association than temperature, sunshine hours and RH individually because evaporative demand is the manifestation of integrative effect of temperature, wind speed, vapour pressure and solar radiation.

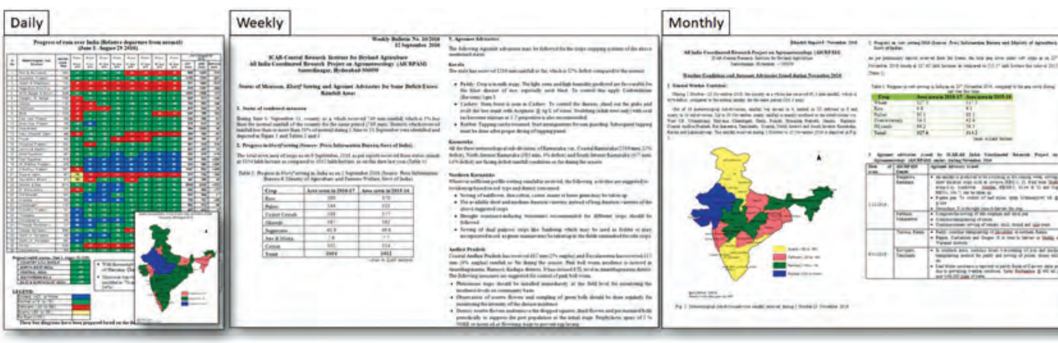
Table 6.8: Pearsons' correlation coefficients between *Helicoverpa armigera* larval population and meteorological parameters in different chick pea species at Jabalpur

Chickpea species	Tmax	Tmin	SSH	RF	RH-I	RH-II	WS	EP	Rainy days
Kabuli	0.13	0.1	0.0	-0.22	-0.43	-0.32	0.16	0.37	-0.26
Gulabi	0.34	0.12	0.347	0.20	-0.41	-.61*	0.0	0.47	0.04
Deshi	0.65*	0.45	0.56*	-0.17	-0.79**	-.70**	0.25	.84**	-0.19

7. Agromet Advisory Services

Agriculture in India which depends on the seasonal rainfall which should be timely otherwise it hampers its production, which in turn affects the economy of the country. On the other hand extreme events like Heavy unseasonal rainfall, floods, droughts, heat and cold waves, frost and hail storms are causing considerable damage to the field and horticultural crops. At this juncture, there is a need to provide good weather forecast based crop and region specific agro advisories, which can help the planners and farmers to take timely action on the field and management front. A timely Agromet advisory can save inputs (seeds, fertilizers, plant protection chemicals etc) as well as the crop (especially at maturity stage). Agromet Advisory Service (AAS) is a part of extension Agrometeorology and defined as "Agrometeorological and agro-climatological information that can be directly applied to improve and/or protect the livelihood of farmers". AICRPAM with the help of its cooperating centers across the country is involved in issuing AAS bulletins twice in a week, in vernacular languages. The dynamic web portal "Crop weather outlook" hosted by AICRPAM-CRIDA updates daily and every week weather, crop information and Agromet advisories of the 25 states where the AICRPAM centers located in.

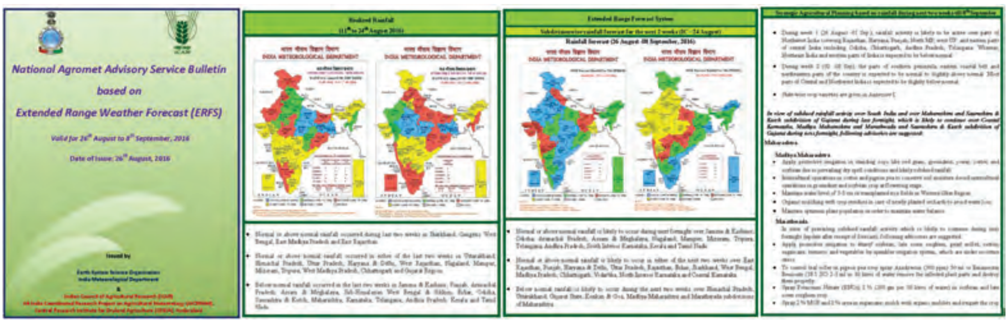
Apart from this, the coordinating unit at CRIDA plays a major role in issuing daily, weekly and monthly bulletins for "NITIAYOG" on status of monsoon, progress in *kharif* sowing and AAS for deficit/excess rainfall areas of the country during southwest monsoon. All this information is dynamically uploaded in the crop weather outlook website hosted by AICRPAM from ICAR-CRIDA.



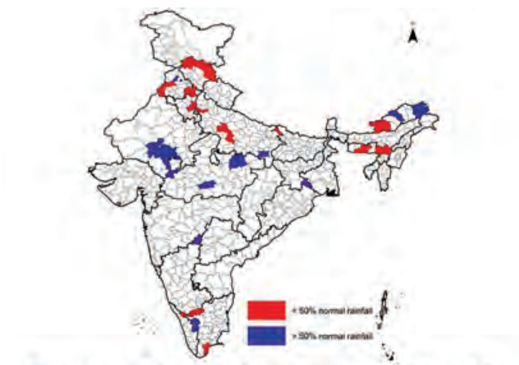
The information flow on Agromet advisories start from the forecast issued by South Asian Climate Outlook Forum (SASCOF) during April of every year on the ensuing southwest monsoon. Though the spatial resolution of the forecast is low, it gives a broad idea about the general performance of the monsoon and probable regions of the country where rainfall will be excess, normal and deficit.

Project coordinating unit of AICRPAM has overlaid the state and district boundaries on the SASCOF's forecast map to generate state and district specific information. This information on district wise and state-wise forecast of rainfall during 2017 Southwest monsoon was shared with state government authorities during interface meeting on preparedness for monsoon 2017. At the AICRPAM unit, daily bulletins explaining the monsoon and rainfall progress at met sub-division level were prepared, based on the data provided by India Meteorological Department (IMD) during June 1 to September 30, 2017.

Weekly weather and crop bulletins on status of monsoon, progress in *kharif* sowing and Agromet advisories for deficit/excess rainfall areas of the country were prepared with inputs from cooperating centers of AICRPAM. Further, weekly 'National Agromet Advisory Services' (NAAS) bulletins were prepared in collaboration with IMD. This bulletin provides realized weekly weather conditions over last week and Extended Range Weather Forecast (ERFS) for next two weeks. AICRPAM provides the Agromet advisories prepared for major crops for coming week by getting the information from AICRPAM centers across the country during *kharif* season and reported to officials of ICAR, Ministry of Agriculture and Farmers Welfare and other stakeholders across the country.



Apart from this, AICRPAM had also provided weekly bulletins on 'Status of monsoon, progress in *kharif* sowing and Agromet advisories for excess/deficit rainfall districts'. Districts which received 50% excess and deficit rainfall were identified on weekly basis for prioritizing areas to implement crop contingency plans.



Districts received > 50% deficit (29) and excess (16) rainfall compared to normal during 1 June-25 September 2016

8. Summary

1. Agroclimatic Characterization

- Higher variability of seasonality index in monsoon rainfall indicates relative lack of reliability both in timing and quantum of rainfall in the state of Gujarat.
- There is no trend regarding amount of rainfall, number of rainy days and occurrence of extreme rain events in more than 90% taluks of Vidarbha region of Maharashtra.
- Analysis of 2000-2014 data indicates that there is more than 85% probability for drought in Chikkalallapur, Aland, and Jewagi taluks in Kalaburagi district and Shivahatti taluk in Gadag district of Karnataka for drought in a year.
- Study of long term data (1985-2015) indicate that Faizabad located in the Eastern Plain Zone of Uttar Pradesh experiences on an average 5 days of heat wave and 3 days of cold wave per year. The extreme minimum temperature is also on a decreasing trend.
- In Haryana, regarding occurrence of extreme events, there is a decreasing trends for extreme minimum temperature and rainfall events indicate enhanced wetting and warming conditions over the entire state.
- Correction functions for temperature (using Leander & Buishand method and difference method) and rainfall (using modified difference method and difference method) was done for PRECIS simulated downscaled data (1961-1990) with the actual observatory data to remove bias for various met stations of Punjab.
- Four climatic types of West Bengal state *viz*. dry sub-humid, moist sub-humid, humid and per-humid dry sub-humid zone having MAI values ranging from 20 to 80. The dry sub-humid climate covers around 50% of the area especially the central part of West Bengal.
- Demarcation of rice and wheat productivity zones were delineated for Chhattisgarh state was undertaken. Areas where scope exists to either increase acreage or productivity were identified.
- Assured Rainfall at 25, 50 and 75 per cent probability levels were estimated for Bihar. At 50 per cent probability level, the longest water availability period of 22 weeks was observed in Kishanganj as against the shortest period of 13 weeks in Arwal district.
- In Kerala, a significant increasing trend was observed in the number of hot days for two districts *viz.* Thiruananthapuram and Wayand during SWM season and in all four districts during NEM season. In general El Niño is positively influencing the NEM rainfall over Kerala.
- Trends of different rainfall spells (1970-2014) in 32 districts of Rajasthan indicates that longest spell of > 10 mm rainfall has significant decreasing trend at Jalore

district only whereas the trend in other districts was not significant. A significant decreasing trend was observed in Karauli and Nagaur districts for rainfall > 25 mm and in Jalore for rainfall > 100 mm.

2. Crop Weather Relationship

Kharif 2016

Rice

- July 5 sown crop (among growing environments) and cv Sarjoo-52 (among cultivars) recorded the highest radiation use efficiency (2.5 and 2.8 g MJ^{-1}, respectively) which was reflected in the grain yield also (4.07 and 3.94 t ha^{-1}, respectively) at Faizabad
- Among different growing environments, rice transplanted on 6 July recorded the highest grain yield, HUE and 1000 grain weight which can be attributed to the highest accumulated rainfall it received during the season (617.2 mm), compared to other growing environments at Kanpur
- Study on effect of different levels of shade imposed during different stages of rice at Ludhiana revealed that number of days taken from tillering to flag leaf emergence was shortened by eight days for PR-122 and by 6 days for PR-123 when shade was imposed during 15-45 days after transplanting. But the crop duration increased by 2-4 days and 4-6 days when crop was subjected to shade during 45-75 DAT and 75-105 DAT, respectively
- Study of relationship between accumulated intercepted PAR and biomass of rice cultivars at Mohanpur revealed that for cv Nayanmani, the highest RUE value (3.213 gm MJ^{-1}) was observed when crop was transplanted on 16 July, which could be due to higher biomass with less accumulated intercepted PAR in the initial phase of crop growth
- At Samastipur, the normal (15 June) sown crop recorded the highest yield due to favorable temperature prevailing during 50% flowering to maturity stage and lower percentage of unfilled grains per panicle. The percentage of unfilled grains/panicle increased and yield decreased as the sowing was delayed beyond 15 June due to increased rainfall and drop in maximum and minimum temperatures during 50% ear head to maturity stage
- Correlation studies between grain yield of paddy cultivar Jyothi and phenophase-wise weather parameters at Thrissur indicated that grain yield had significant negative correlation with Tmax throughout the crop growth and it was highest during flowering to physiological maturity.

Maize

- Study on relationship between periodic dry matter and accumulated photosynthetically active radiation (APAR) at Jammu revealed a linear relationship with high coefficient of determination (R^2=0.95). The conversion efficiency of absorbed PAR to the dry matter was estimated as 1.17 g MJ^{-1}.

Pearl millet

- The relationship between consumptive use of moisture (CUM) and grain yield studied at Solapur indicated a linear relationship and a consumptive use of moisture (CUM) of 362 mm was found to be optimum for achieving higher grain yield.

Finger millet

- Crop-weather relationship studies conducted at Ranichauri showed that early sown crop (6 June) accumulated highest GDD till maturity due to longer duration (131 days), compared to crop sown during 18 and 26 June.

Soybean

- Crop water use, water productivity and seed yield were highest in crop sown during 26 SMW, followed by crop sown during 27 SMW at Akola. Sowing of soybean beyond 5 July causes drastic reduction in yield as well as water productivity. Among the cultivars, JS-335 recorded highest water productivity, crop water use and yield.
- Study on correlation between phenophase-wise weather parameters and seed yield at Parbhani revealed that rainfall showed significant positive correlation with seed yield during emergence to seedling stage, seedling to branching stages and all the three stages from pod development to maturity, for all the four cultivars (MAUS-158, MAUS-71, MAUS-81 and JS-335). But, maximum temperature showed significant negative correlation with seed yield during seedling to branching stage and branching to flowering stage and during pod development to full seed stage
- Relationship between seed yield and absorbed PAR of three cultivars (JS-20-29, JS-20-34 and JS-97-52) was studied at Jabalpur, which indicated that an APAR about 200 MJ m^{-2} was found to be optimum for achieving higher seed yield in soybean at Jabalpur.

Sunflower

- Crop weather relationship studies in sunflower undertaken during *kharif* 2012-16 at Solapur revealed that there was a linear relationship between CUM and grain yield and the correlation was also high (R^2=0.89). An average seasonal maximum temperature of 32.5 ^{0}C and minimum temperature of 22 ^{0}C were found to be optimum for achieving higher yield at Solapur.

Groundnut

- Simulation of average weekly soil moisture at three depths (0-15, 15-30 and 30-45 cm) using FAO-CROPWAT model at Anand showed that model could simulate the average weekly soil moisture satisfactorily in case of crop sown on 19 July. In case of 4th July sown crop, model has overestimated the soil moisture in majority of weeks
- Crop-weather relationship studies conducted at Anantapur showed that water use efficiency was higher in crops provided with protective irrigation, compared to rainfed groundnut

Highest WUE was recorded for crop sown during first fortnight of August for K6, Kadiri Harithandra and Dharani, whereas for Anantha, crop sown during 2 fortnight of July recorded highest WUE.

Cotton

- Light extinction coefficients were developed for three cotton cultivars/hybrids at Akola (0.13 for AKH-081, 0.18 for AKA-7 and 0.10 for Balwan), based on the relation between fraction of itercepted PAR and LAI
- Correlation studies between seed cotton yield and phenophase-wise weather parameters at Parbhani showed that seed cotton yield was significantly and positively associated with maximum temperature during emergence to seeding, flowering to boll setting (P_5) and boll bursting to first picking (P_7) for all the three hybrids (Ajit 155, Rasi 2 and Mallika). Yield showed significant negative correlation with rainfall during square formation to flowering for all the three hybrids.

Rabi 2016-17

Wheat

- The highest grain yield was recorded for crop sown on 15 November (3.38 t ha^{-1}) and it gradually decreased with subsequent sowings at Raipur, which may be attributed to higher minimum temperature (+1.2 ^{0}C) experienced by the crop sown on 15 December during reproductive stage, compared to crop sown on 15 November
- Crop sown on 15 November recorded highest grain yield of 2.9 t ha^{-1} and the yield decreased gradually as the sowing got delayed at Samastipur. The lowest grain yield of 1.82 t ha^{-1} was recorded in crop sown on 25 December, which may due to higher average maximum temperature experienced (4 and 3 ^{0}C higher temperature during vegetative and reproductive stages, respectively), compared to 15 November sown crop, 25 December sown crop experienced
- Study on effect of mean temperature during reproductive phase of wheat on grain yield at Udaipur indicated that there was a gradual reduction in yield as the mean temperature increased during reproductive stage of crop. The magnitude of yield reduction from low temperature regime to high temperature was highest in HI 1544 (1762 kg ha^{-1}), followed by Raj-4037 (1673 kg ha^{-1}) and MP-1203 (1403 kg ha^{-1})
- Correlation study between grain yield and phenophase-wise weather parameters in wheat at Anand revealed that maximum temperature during booting showed significant negative (P=0.05) relation with grain yield
- Study on the effect of growing environments and wheat cultivars on crop phenology at Palampur showed that main difference was noticed in time taken during tillering to heading and heading to 50% grain filling stages of cv. HPW-349 took 120, 117 and 104 days to complete heading when sown on 25 October, 25 November and 25 December 2016, respectively.

Rabi Sorghum

- Study on relationship between consumptive use of moisture (CUM) and grain yield of *rabi* sorghum at Solapur indicated that a CUM of 240 mm was found to be optimum for getting higher grain yield.

Chickpea

- Study on relationship between consumptive use of moisture (CUM) and grain yield of chickpea at Solapur revealed that CUM of 250 mm was found to be optimum for getting higher seed yield.

Potato

- Tuber weight, tuber and haulm yield and harvest index were higher at Hisar (135.8 g/tuber, 30132.7 kg/ha, 43305.1 kg/ha and 70.0%, respectively) in crop planted on second fortnight of November compared to other dates, which may be due to comparatively higher average maximum temperature during reproductive stages of crop sown during first and second fortnights of December.

Perennial crops

Guava

- Crop-weather relationship studies conducted in a 11-year old guava orchard at Hisar (cv. Hisar Safeda) indicated that trees fruiting in rainy season had highest thermal use efficiency (TUE), water and radiation use efficiencies, followed by those fruiting in spring and winter seasons.

Pepper

- Correlation studies between weather parameters during different phenophases and plant growth traits in pepper at Thrissur showed that rainfall had highly significant (P = 0.01) positive correlation and Tmax has significant negative correlation with number of leaves produced for all the cultivars (Panniyur 1 to 8). Maximum temperature has significant negative correlation with internodal length of cv. Panniyur- 3, 4, 6 and 8.

3. Crop growth simulation modeling

Kharif 2016

Soybean

- At Akola, simulation of yield of soybean cv. JS335 by providing daily irrigation of 50 mm in DSSAT model fetched better yields in under dry spell conditions across all sowing environments. Late sown soybean crop (29 SMW) got benefitted by almost 15% than the crop sown earlier with similar irrigation application during dry spell
- Genetic coefficients were developed for rice at Jorhat and Thrissur; and for soybean at Jabalpur.

Maize

- At Ludhiana, under future climate scenarios there will be a decline in maize grain yield by the end of 21 century in the range of -55.6 to -83.2 kg ha^{-1} under A1B scenario followed by -54.5 to -80.1 kg ha^{-1} under A2 and -42.6 to -59.2 kg ha^{-1} under B2 scenarios.

Rabi 2016-17

Wheat

- With a likely rise in temperature by 3.0 ^{0}C from normal at Ludhiana, wheat crop will be most susceptible in the Central zone with a yield reduction by 10.2%. However, the Northern hills zone was least susceptible with increase in yield by 3.5 - 5.8% depending on the crop phase at which temperature rise occurred.
- A multilocational study on increase in temperature and its impact on wheat crop using DSSAT model revealed that in all the zones, barring Northern hills zone the temperature during first fortnight of February was most critical to wheat productivity. However, in Northern hills zone, second fortnight of March was most critical.
- At Ranchi, the simulated wheat yields showed a likely decline under both ECHAM 5 and MK 3.5 projected climate change scenarios. The reduction in yield may be attributed to shortening of crop duration.

4. Weather effects on pests and diseases

Kharif 2016

Cotton

- Correlation study between weather parameters and leaf hopper and white fly infestation in cotton at Hisar indicated that increase in maximum temperature had negative influence on leaf hooper and white fly infestation while minimum temperature had positive effect
- Ludhiana centre has developed a decision support system (DSS) for predicting whitefly infestation in cotton for different locations of Punjab.

Rice

- Effect of delayed sowing on stem borer infestation in rice at Kanpur showed that timely planted rice crop is less susceptible to stem borer infestation than that of delayed planting due to lower diurnal temperature range and higher cumulative rainfall received during 28-41 SMW in timely planted crop than in delayed planting
- The analysis of rice blast disease incidence and weather showed that lower maximum and minimum temperature coupled with high rainfall and cloudiness during the 25 July - 5 August favoured the blast disease incidence in rice at Palampur.

Rabi 2016-17

Wheat

- Weather based statistical models for the prediction of incidence of karnal bunt disease in wheat for Karnal, Hisar, Rewari and Sirsa districts of Haryana were developed using historical data.

Mustard

- Study on weather influence on aphid infestation in mustard at Mohanpur revealed that diurnal temperature range had stronger influence on aphid infestation than either maximum temperature or minimum temperature.

Chickpea

- Correlation study relating weather parameters and pod borer in different chickpea species indicated that gram pod borer infestation in Kabuli species of chickpea was less congenial to weather conditions compared to the infestation in desi chickpea species.

9. List of Research Publications: 2016-17

Coordinating Unit

Papers in peer reviewed journals

Vijayakumar, P., Subbarao, A.V.M., Sarath Chandran, M.A., Venkatesh, H., Rao, V.U.M. and Srinivasa Rao, Ch. (2017). Micro-level agromet advisory services using block level weather forecast – A new concept based approach. *Curr. Sci.,* 112(2): 227-228.

Sarath Chandran, M.A., Subba Rao, A.V.M., Sandeep, V.M., Pramod, V.P., Pani, P., Rao, V.U.M., Visha Kumari, V. and Srinivasa Rao, Ch. (2016). Indian summer heat wave of 2015: a biometeorological analysis using half hourly automatic weather station data with special reference to Andhra Pradesh. *Int. J Biometeorol*. 61 (6): 1063-1072.

Books / Book chapters / Training Manuals

Subba Rao, A.V.M., Sarath Chandran, M.A. and Vijaya Kumar, P. (2016). Fundamentals of Climate Sciences. In: Climate Resilient Agronomy. (eds: B. Venkateswarlu, G. Ravindra Chary, Gurbachan Singh and Y. S. Shivay. Indian Society of Agronomy. pp 13-54.

Srinivasa Rao, Ch., Vijaya Kumar, P., Subba Rao, A.V.M., Sarath Chandran, M.A. and Osman, M. (2016). Impact of drought on agricultural production and policies to combat it in Andhra Pradesh and Telangana. In: Droughts and the way forward. (eds: M.C. Varshneya, A. Javalekar, R.G. Shah, D.B. Patil). Kamdhenu University. pp 148-163.

Vijayakumar, P., Subba Rao, A.V.M and Sarath Chandran, M.A. (2016). Agrometeorological Data Collection, Analysis and Management. Central Research Institute for Dryland Agriculture, Hyderabad- 500 059. 152 p.

Leaflets/Folders

Rao, V.U.M., Bapuji Rao, B., Vijaya Kumar, P., Subba Rao, A.V.M., Sarath Chandran, M.A. and Khandgonda I.R. (2016). *AICRPAM at a glance*. AICRP on Agrometeorology, ICAR-CRIDA. 8 p.

Popular article

Dhakar Rajkumar, Sarath Chandran, M.A., Shivani Nagar and Kumar, S. (2016). Significance of Agrometeorological advisory services in changing climate scenario. *Indian Farming*, 66(8): 44-46.

AICRPAM Centres Publication

Akola

Papers in Peer Reviewed Journals (international/National)

Nath, A., Karunakar, A.P., Kumar, A. and Nagar, R.K. (2017). Effect of sowing dates and varieties on soybean performance in Vidarbha region of Maharashtra, India, *J. Appl. Nat. Sci.,* 9(1): 544-550.

Nath,A., Karunakar, A.P., Kumar, A., Yadav, A., Chaudhary, S. and Singh, S.P (2017). Evaluation of the CROPGRO-soybean model (DSSAT V 4.5) in the Akola region of Vidarbha, India. *Ecol. Env. & Cons*., 23: S153-S159.

Books/Book Chapters/Training manual

Nagdeve, M.B., Ravindra Chary, G., Gabhane, V.V., Karunakar, A.P., Patode, R.S. and Turkhede, A.B. (2017). Crop Contingency and Management Harshwardhan Publication Pvt. Ltd., ISBN 978-93-85882-37-7, pp 1-151.

Nagdeve, M.B., Turkhede, A.B., Karunakar, A.P., Gabhane, V.V. , Sakhare, S.B. and Patode, R.S. (2016) Improved Agronomic Practices for Rainfed Crops in Western Vidabha Zone in Maharashtra. In: “Improved Agronomic Practices for rainfed crops in India” (eds. G. Ravindra Chary, Ch. Srinivas Rao, K.A. Gopinath, A.K. Sikka, B. Kandpal and S. Bhaskar), ICAR-Central Research Institute for Dryland Agriculture, Hyderabad, ISBN 978-93-80883-38-0, pp 230-239.

Papers presented in national and International Symposia/Seminar

Ganvir, M.M., Nagdeve, M.B., Karunakar, A.P., Gabhane, V.V., Patode, R.S., Sakhare, S.B. and Mohod, V. and Potdar, S.S. (2016). Productivity of Custard Apple Based Agro Horticulture System under Dryland Condition in Vidarbha. In: Abstracts of International Conference on “Integrated Land Use Planning for Smart Agriculture – An Agenda for Sustainable Land Management”, November 10-13, Nagpur, India, PS III/8 - 244.

Ganvir, M.M., Nagdeve, M.B., Karunakar, A.P., Gabhane, V.V., Patode, R.S., Sakhare, S.B. and Mohod, V. (2016). Evaluation of row proporation of sorghum and pigeonpea crop in cotton under dryland condition of Vidarbha. In: Abstract of National Seminar on Rainfed Agriculture in India: Perspectives and Challenges, December 7-9, PDKV Akola, pp 171.

Popular article (Marathi)

Ingole, P.G. and Karunakar A.P. (2016). Aapatkalin Pik Vyavasthapan, Krushi Patrika, Dr PDKV, Akola.

Leaflet (Marathi)

Nagdeve, M.B., Turkhede, A.B., Gabhane, V.V., Karunakar, A.P., Ganvir, M., Mali, R. (2016) Jalvayu Parivartan Jokhim Vyavasthapanasath Tristariya Aantarpik Padhdhat (Kapus+Jowar+Tur+Jowar 3:1:1:1). Ghadipatrika DrPDKV/1045/2016.

Nagdeve, M.B., Turkhede, A.B., Gabhane,V.V., Karunakar, A.P., Ganvir, M. and Mali, R. (2016) Koradwahu Shetisaathi Tristariya Aantarpik Padhdhat (Kapus:Soybean: Tur: Soybean 3:2:2:2). Ghadipatrika DrPDKV/1046/2016.

Anand

Papers in Peer Reviewed Journals (International /National)

Mehta, R., Pandey, V., Lunagaria, M.M. and Anil Kumar (2016). Reference and crop evapotranspiration estimation for mustard and chickpea at different locations of Gujarat. *Int. J. Adv. Res. Rev*., 1(6): 48-56.

Papers Presented in National and International Symposia / Seminars

Patel, H.R., Lunagaria, M.M., Karande, B.I., Yadav, S.B. and Pandey, V. (2016). Climate change impact and its adaptation measures of groundnut of Saurashtra region of Gujarat. In: International Conference on “Food, Water, Energy Nexus in Arena of Climate Change”, October 14-16, AAU, Anand, India.

Yadav, S.B., Patel, H.R., Mishra, A.K., Lunagaria, M.M., Karande, B.I., Patil, D.D. and Pandey, V. (2016). Adaptation strategies for minimizing adverse effect of climate change on rice yield in middle Gujarat agro-climatic region. In: International Conference on “Food, Water, Energy Nexus in Arena of Climate Change”, October 14-16, AAU, Anand, India.

Yadav, S.B., Pandey,V., Mishra, A.K., Lunagaria, M.M., Karande, B.I. and Patel, H.R. (2016). Suitability of various adaptation measures for heat (*Triticum aestivum* L.) against climate change at Gujarat. In: National Symposium on “Climate Driven Food Production Systems: Agro-meteorological Interventions”, December 20-22, TNAU, Coimbatore, India.

Popular Articles/Leaflets

Patel, H.R., Lunagaria, M.M. and Pandey, V. (2016). “Aabohava badlav nikrushikshetre vividh asaro and tenaupayo”, *Krushigovidya*.

Anantapur

Papers in Peer Reviewed Journals (International /National)

Malleswari, S.N., Nataraj, K.C., Sunita, N., Narayana Swamy, G. and Vijayasankara Babu, M. (2016). Yield and quality of oriental tobacco as influenced by preceding groundnut crop and integrated nutrient management. *Prog. Res. – An Int. J.,* 11(Sp. IX): 6165 - 6167.

Malleswari, S.N., Narayana Swamy, G., Srinath Reddy, A.B., Nataraj, K.C. and Sahadeva Reddy, B. (2017). Micro level climatic classification of Kurnool district in scarce rainfall zone of Andhra Pradesh. *Prog. Res. – An Int. J., (*Accepted).

Malleswari, S.N., Narayana Swamy, G., Srinath Reddy, A.B., Nataraj, K.C., Sahadeva Reddy, B. and Ravindranatha Reddy, B. (2017). Micro level climatic classification of Ananthapuramu district of Andhra Pradesh. *J. Res. ANGRAU* (Accepted).

Nataraj, K.C., Vijay Sankar Babu, M., Malleswari, S.N., Narayana Swamy, G. and Ravindranatha Reddy, B. (2016). Georeferenced soil fertility status of secondary nutrients in rainfed soils of Anantapur District, Andhra Pradesh. *Prog. Res.– An Int. J.,* 11(Sp. IX): 6174 – 6178.

Nataraj, K.C., Vijaysankar Babu, M., Narayana Swamy, G., Bhargavi, K., Sahadeva Reddy, B. and Srinivasa Rao, Ch. (2016). Nutrient management strategies in groundnut-based crop production systems in dryland regions of Southern Andhra Pradesh. *Ind. J. Fert.,* 12(10): 58-75.

Narayana Swamy, G., Nagavani, A.V., Bhargavi, K., Sahadeva Reddy, B., Vijayasankara Babu, M. and Uma Mahesh, V. (2016). Short term comparison of yield and organic carbon changes under organic production of groundnut in rainfed alfisols of Andhra Pradesh. *Prog. Res. – An Int. J.,* 11(Sp. IX): 6171-6173.

Vijayasankara Babu, M., Nataraj, K.C., Malleswari, S.N., Narayana Swamy, G. and Ravindranatha Reddy, B. (2016). Effect of crop residue mulching and in situ rain water harvesting through micro catchments on yield of rainfed groundnut. *Prog.* Re*s. – An Int. J.,* 11(Sp. IX): 6185 – 6188.

Papers Presented in National and International Symposia / Seminars

Malleswari, S.N., Sudheer, K.V.S., Srinath Reddy, A.B., Reddy, B.S., Reddy, B.R. and Srinivasa Rao, Ch. (2016). Maximising the productivity of rainfed groundnut under different sowing dates through protective irrigation in scarce rainfall zone of Andhra Pradesh. In: 4th International Agronomy Congress on "Agronomy for Sustainable Management of Natural Resources, Environment, Energy and Livelihood Security to Achieve Zero Hunger Challenge", November 22-26, IARI, New Delhi, India.

Malleswari, S.N., Narayana Swamy, G., Srinath Reddy, A.B., Reddy, B.S., Ravindranatha Reddy, B. (2017). Micro level climatic classification and climatic trends in Ananthapuram district of Andhra Pradesh. In: National Seminar on "Agronomic Agriculture and Allied sciences", May 02, RARS Nandyal ANGRAU, Hyderabad, India.

Bangalore

Papers in Peer Reviewed Journals (International /National)

Shivaramu, H.S., Rajegowda, M.B., Soumya, D.V. and Lakshmi, L.N. (2016). Influence of weather and growth parameters on yield of pigeon pea in Alfisols of Karnataka. *Agropedology.,* 26(1): 40-46.

Papers Presented in National and International Symposia / Seminars

Shivaramu, H.S., Rajegowda, M.B. and Naidu, L.G.K. (2016). Climate change in Karnataka state of India. In: International Seminar on "Managing Systems from Source to Sink: Current Theories and Applications", August 19-20, Wayamba University, Sri Lanka.

Shivaramu, H.S., Soumya, D.V., Rajegowda, M.B. and Padmashri, H.S. (2017). Forecasting summer rice yield using statistical model. In: XIII Agricultural Sciences Congress on "Climate Smart Agriculture", February 21-24, UAS, Bengaluru, India.

Shivaramu, H.S., Soumya, D.V., Padmashri, H.S. and Muniratnamma, C.M. (2017). Climatic suitability assessment for groundnut (*Arachis hypogaea*) in alfisols of Karnataka - A regression approach. In: XIII Agricultural Sciences Congress on "Climate Smart Agriculture", February 21-24, UAS, Bengaluru, India.

Shivaramu, H.S., Rajegowda, M.B., Muniratnamma, C.M. and Padmashri, H.S. (2017). Economic impact of weather based agromet advisories in Chikkaballapur district, Karnataka state. In: XIII Agricultural Sciences Congress on "Climate Smart Agriculture", February 21-24, UAS, Bengaluru, India.

Shivaramu, H.S., Nagesha, L., Padmashri, H.S. and Soumya, D.V. (2017). Usability of medium range weather forecast to agriculture in eastern dry zone of Karnataka. In: XIII Agricultural Sciences Congress on "Climate Smart Agriculture", February 21-24, UAS, Bengaluru, India.

Shivaramu, H.S., Padmashri, H.S., Soumya, D.V. and Padmashri, H.S. (2017). Regrouping of NARP zone of Karnataka based on changing climate trends.In: XIII Agricultural Sciences Congress on "Climate Smart Agriculture", February 21-24, UAS, Bengaluru, India.

Popular Articles/Leaflets

Shivaramu, H.S. and Munirathnamma, C.M. (2016). "Poorva Mungaru Aagi-thayaru (Land preparation-cultivation practices for pre monsoon showers)", *Prajavani N*ewspaper.

Shivaramu, H.S. and Munirathnamma, C.M. (2016). "Mungaru male tharali samrudda bele (Suitable crop selection during monsoon)", *Prajavani Newspaper.*

Shivaramu, H.S. and Munirathnamma, C.M. (2016). "Thadavada hingaru sadupayoga hega (Benefits of late North east monsoon)", *Prajavani Newspaper*.

Bijapur

Papers in Peer Reviewed Journals (International /National)

Asha, H.N., Jones Nirmalnath, P., Sagarkar Madhura, A. and Venkatesh, H. (2017). Impact of elevated CO_2 and/or temperature on the AM fungal diversity in groundnut rhizosphere under open top chamber facility. *Int. J. Curr. Microbiol. Appl. Sci.,* 6(1): 882-895.

Books/Book Chapters/Training Manual

Venkatesh, H. (2016). Agricultural drought: Assessment and management in north Karnataka. In "Agricultural Droughts and Way forward", (eds. M.C. Varshneya), ISBN:978-93-5267-836-5, pp 130-147.

Venkatesh, H., Shivaramu, H.S., Raje Gowda, M.B. and Rao, V.U.M. (2016). "Agroclimatic Atlas of Karnataka", University of Agricultural Sciences, Dharwad, 232 p.

Technical Bulletins

Venkatesh, H., Srinivasa Rao, Ch., Janagoudar, B.S., Rao,V.U.M., Hiremath, J.R. and Chowgala, D.C. (2016). "Adoption of micro-level agromet advisories under AICRPAM NICRA: Case Study in Belgaum District". AICRP on Agrometeorology, Vijayapura Centre, UAS, Dharwad.

Dapoli

Papers in Peer Reviewed Journals (International /National)

Jagtap, D.N., Mahadkar, U.V. and Chavan, S.A. (2017). Response of rice variety to different sowing windows under Konkan condition. *Agric. Sci. Digest.,* 37(1): 78-80.

Jagtap, D.N., Chavan,V.G., Mahadkar, U.V. and Chavan, S.A. (2016). Effect of sowing times on the yield and yield attributes of rice (*Oryza sativa L.*) varieties. *J. Ind. Soc. Coastal Agric. Res.*, 34(2): 27-30.

Jagtap, D.N., Mahadkar, U.V. and Chavan, S.A. (2016). Response of rice varieties to establishment methods under Konkan conditions. *J. Ind. Soc. Coastal Agric. Res.,* 34(2): 85-87.

Papers Presented in National and International Symposia / Seminars

Jagtap, D.N., Chavan,V.G., Mahadkar, U.V. and Chavan, S.A., Jadhav, M.S., Pinjari, S.S., Gangawane, S.B. and Rajemahadik, V.A. (2017). Effect of sowing times on the yield and yield attributes of rice (*Oryza sativa L.*) varieties. In: ISASaT's 1st Annual Convention on "Emerging Trends in Agricultural and Allied Sciences", March 16-18, DBSKKV Dapoli, India.

Jagtap, D.N., Mahadkar, U.V., Chavan, S.A., Jadhav, M.S., Pinjari, S.S., Gangawane, S.B. and Rajemahadik, V.A. (2017). Response of rice varieties to establishment methods under aberrant weather conditions. In: ISASaT's 1st Annual Convention on "Emerging Trends in Agricultural and Allied Sciences", March 16-18, DBSKKV Dapoli, India.

Faizabad

Papers in Peer Reviewed Journals (International /National)

Chaudhari, R., Singh, A., Mishra, S.R., Singh, A.K. and Mishra, A.N. (2017). Study of phasic development and growth attributes of rice cultivars at variable weather condition. *Int. J. Curr. Microbiol. Appl. Sci.,* 6(2): 1610-1619.

Singh, A., Mehra, B., Singh, A.K., Mishra, S.R., Mishra, A.N., Khare, N. and Singh, A.(2017). Studies on crop-weather relationship of mustard crop in Allahabad region. *Int. J. Agric. Stat.*, 13(1): 333-335.

Singh, A.K. (2017). Livestock production and management in relation to climatic variability in

Eastern India. *Progr. Res. - Int. J.,* 12(Sp-I): 1256-1259.

Singh, A., Mishra, S.R., Singh, A.K., Mishra, A.N. and Singh, A. (2016). Effect of weather condition on the growth, thermal use efficiency and radiation use efficiency of pigeonpea. *Int. J. Agric. Stat. Sci.,* 12(1): 165-168.

Singh, A., Singh, A.K., Mishra, A.N., Singh, A. and Kumar, R. (2016). Study the crop growth simulation models as tools for Agricultural Meteorology. *Progr. Res. - Int. J.,* 11(2): 1260-1263.

Singh, A., Mishra, S.R., Singh, A.K. and Mishra, A.N. (2016). Micro-climatic study of pigeonpea (Cajanus cajan L.) genotype under variable weather conditions. *Int J. Bio-resource Stress Manage.*, 7(4): 720-724.

Kumar, A., Singh, A., Singh, A.K., Mishra, S.R. and Singh, A. (2016). Effect of different weather parameters on the growth of pod borer (*H. aemigera*) of chickpea (*Cicer arietinum* L.). *Progr. Res. - Int. J.,* 11 (2): 1136-1138.

Singh, A., Singh, A.K., Mishra, S.R., Mishra, A.N., Singh, A. and Gupta, S. (2016). Agricultural Statistics of Area Production and Productivity of rice of different sectors of U.P. *Plant Archi.* (Accepted).

Singh, A., Singh, A.K., Mishra, S.R., Mishra, A.N. and Singh, A. (2016). Yield gap analysis and total rainfall of rice crop of onset of monsoon in different sectors of U.P. *Plant. Archi.* (Accepted).

Singh, A., Singh, A.K., Mishra, S.R., Shahi, U.P. and Gupta, S. (2016). Influence of soil moisture regime and varieties on the performance of chickpea in eastern plain zone of Uttar Pradesh. *Progr. Res. - Int. J.,* 11(5):2909-2912.

Kushwaha, A.K. and Singh, A.K. (2016). To study the yield and dynamics of Bactorial leaf blight in rice crop under variable weather conditions. *Adv. Life Sci. - Int. J.,* 5(22): 10780-10783.

Kushwaha, A. K. and Singh, A. K. (2016). To study the yield attributes, yield and dynamics of gross hopper in rice under variable weather conditions. *Adv. Life Sci. - Int. J.,* 5(22): 10804-10807.

Papers Presented in National and International Symposia / Seminars

Singh, A.K., Singh, A., Mishra, S.R. and Mishra, A.N. (2016). Studies on phenophasic development of chickpea cultivars under variable weather conditions. In: 4th Uttar Pradesh Agriculture Science Congress on "Strategic Governance and Technological Advancement for Sustainable Agriculture", March 2-4, C. S. Azad University of Agriculture and Technology, Kanpur, India.

Singh, A.K., Kumar, N., Singh, A. and Singh, A. (2016). Performance and evaluation of chickpea crop through Crop simulation Model DSSAT. In: 4th Uttar Pradesh Agriculture Science Congress on "Strategic Governance and Technological Advancement for Sustainable Agriculture", March 2-4, C. S. Azad University of Agriculture and Technology, Kanpur, India.

Singh, A.K., Singh, A., Deo, K., Singh, A., Mishra, S.R. and Mishra, A.N. (2016). Trends and variability analysis of rainfall of U.P. in relation to crop planning and Management. In: 4th Uttar Pradesh Agriculture Science Congress on "Strategic Governance and Technological Advancement for Sustainable Agriculture", March 2-4, C. S. Azad University of Agriculture and Technology, Kanpur, India.

Singh, A.K., Singh, A., Singh, A., Mishra, S.R. and Mishra, A.N. (2016). Crop-Weather interaction studies in pigeonpea [Cajanus cajan (L.) Millsp.]. In: 4th Uttar Pradesh Agriculture Science Congress on "Strategic Governance and Technological Advancement for Sustainable Agriculture", March 2-4, C. S. Azad University of Agriculture and Technology, Kanpur, India.

Singh, A.K., Singh, A., Singh, A., Mishra, S.R. and Mishra, A. N. (2016). Effect of different weather condition of chickpea cultivars at varying soil temperature and soil moisture. In: 4th Uttar Pradesh Agriculture Science Congress on "Strategic Governance and Technological Advancement for Sustainable Agriculture", March 2-4, C. S. Azad University of Agriculture and Technology, Kanpur, India.

Popular Articles/Leaflets

Mishra, S.R., Singh, A.K. and Mishra, A.N. (2016). "Mausam Adharit Kheti", Kisan *Gyan*, 1(1): pp 5-8.

Hisar

Papers in Peer Reviewed Journals (International /National)

Dalal, R.P.S., Kumar, A. and Singh, R. (2017). Agrometeorological-heat and energy use of Kinnow mandarin (*Citru*s nobilis Lour * Citrus deliciosa Tenore). *Int. J. Pure App. Biosci.,* 5(2): 506-512.

Dalal, R.P.S., Kumar, A. and Singh, R. (2017). Influence of weather parameters on flowering, fruit growth and yield of Kinnow mandarin (*Citrus nobilisLour * Citrus deliciosaTenore*). *Int. J. Pure App. Biosci.,* 5(2): 497-505.

Nayak, M.K., Singh, D., Kumar, A., Singh, R. and Singh, M. (2017). Effect of growing environments and irrigation levels on phenology and interception of PAR in wheat crop. *Int. J. Pure App. Biosci.,* 5(1): 819-826.

Kumar, S., Nayak, M.K., Singh, D. and Kumar, A. (2016). Correlation study of growth, development and yield with agrometeorological indices under different planting method of rice. *Int. J. Agril. Sci.,* 8(53): 2682-2686.

Kumar, S., Nayak, M.K., Singh, D. and Kumar, A. (2016). Effect of planting methods on growth and agrometeorological indices of rice. *Int. J. Agril. Sci.,* 8 (55): 2954-2959.

Choudhary, D., Singh, R., Pannu, R.K., Singh, D., Sheoran, P. and Kumar, A. (2014). Energy balance and light interception over mustard cultivars in Hisar region. *J. Agrometerol.,* 16: 153-158.

Choudhary, D., Singh, R., Pannu, R.K., Singh, D., Sheoran, P. and Kumar, A. (2014). Validation and sensitivity analysis of InfoCrop (model v.1.0) for phenology, yield and yield attributing characters of Indian mustard cultivars in western Haryana region. *J. Agrometerol.,*16: 159-163.

Papers Presented in National and International Symposia / Seminars

Nayak, M.K., Singh, D., Singh, M., Kumar, A. and Singh, R. (2017). Thermal and radiation use efficiency of wheat under different growing environments and irrigation levels. In: International Conference on "Emerging Areas of Environmental Science and Engineering", February 16-18, GJUS&T, Hisar, India.

Nayak, M.K., Singh, D., Singh, M., Kumar, A. and Singh, R. (2017). Effect of growing environments and irrigation levels on phenology and intercepted PAR of wheat. In: International Conference on "Emerging Areas of Environmental Science and Engineering", February 16-18, GJUS & T, Hisar, India.

Nayak, M.K., Singh, D., Singh, M., Kumar, A. and Singh, R. (2017). Thermal and radiation use efficiency of wheat under different growing environments and irrigation levels. In: National Conference on "Climate Change and Agricultural Production", April 6-8, Sabour, Bhagalpur, India.

Kumar, Y., Singh, R. and Kumar, A. (2017). Evaluation of InfoCrop model for simulation the performance of Indian-Mustard cultivars in western region of Haryana. In: International Seminar on "Oilseed Brassica (ISOB 2017)", February 23-27, Jaipur, India.

Anurag, Kumar, A. and Singh, R. (2017). Rainfall trends at Hisar (Haryana): A long term prospective. In: National Seminar on "Sustainability, Environment and Society", February 11, C.H. Bansilal Government College, Loharu, India.

Jabalpur

Papers Presented in National and International Symposia / Seminars

Agrawal, K.K., Bhan, M. and Dubey, A.K. (2016). Association of weather parameters with grain yield at different phonological stages of rice in M. P. In: 4th International Agronomy Congress on "Agronomy for Sustainable Management of Natural Resources, Environment, Energy and Livelihood Security to Achieve Zero Hunger Challenge", November 22-26, IARI, New Delhi, India.

Bhan, M., Agrawal, K.K. and Dubey, A.K. (2016). Assessing heat unit requirement and grain yield in rice at different sowing dates in Madhya Pradesh. In: 4th International Agronomy Congress on "Agronomy for Sustainable Management of Natural Resources, Environment, Energy and Livelihood Security to Achieve Zero Hunger Challenge", November 22-26, IARI, New Delhi, India, pp.43-44.

Thout, T.N., Bhan, M. and Agrawal, K.K. (2016). Phenological development and yield of wheat cultivars in relation to agrometeorological indices under different sowing windows. In: 4th International Agronomy Congress on "Agronomy for Sustainable Management of Natural Resources, Environment, Energy and Livelihood Security to Achieve Zero Hunger Challenge", November 22-26, IARI, New Delhi, India, pp.90-91.

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Jammu

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Jorhat

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Solapur

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Staff Position at Cooperating Centers During 2016-17

(AICRP on Agrometeorology)

Centre	Positions Sanctioned and Filled (F) / Vacant (V)					
	Agrometeo-rologist	Junior Agronomist	Senior Technical Assistant	Met. Observer	Field Assistant	Junior Clerk
Akola	F	–	–	V	F	–
Anand	F	F	V	F	F	V
Anantapur	F	F	F	F	F	F
Bangalore	F	F	F	F	F	F
Bhubaneswar	F	–	–	V	F	–
Bijapur	F	–	–	F	F	–
Chatha/Jammu	F	–	–	F	F	–
Dapoli	F	–	–	F	F	–
Faizabad	V	F	F	F	F	F
Hisar	F	V	V	V	F	V
Jabalpur	V	F	F	V	V	V
Jorhat	F	–	–	F	F	–
Kanpur	F	–	–	F	F	–
Kovilpatti	F	F	F	F	F	F
Ludhiana	F	F	F	F	F	F
Mohanpur	F	F	F	F	F	F
Palampur	F	–	–	V	V	–
Parbhani	F	–	–	F	V	–
Raipur	F	–	–	F	V	–
Ranchi	V	F	F	V	F	V
Ranichauri	V	V	V	V	V	V
Samastipur	F	–	–	V	F	–
Solapur	F	F	F	F	V	F
Thrissur	F	–	–	V	V	–
Udaipur	F	–	–	V	V	–
Total posts sanctioned	**25**	**12**	**12**	**25**	**25**	**12**
Total posts filled	**21**	**11**	**9**	**15**	**18**	**7**

Centre-wise and Head-wise RE allocation (Plan) : FY 2016-17

(AICRP on Agrometeorology)

(in Rupees)

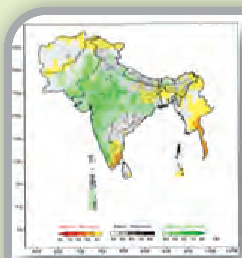
S. No	CENTRE	PAY & ALLOW	TA	RC	IT	NRC-Equip.	IPR/ HRD	NEH	TOTAL ICAR SHARE (75%)
1	Akola	1680000	50000	150000	0	0	0	0	1880000
2	Anand	1200000	50000	150000	0	0	0	0	1400000
3	Anantapur	2160000	50000	150000	50000	0	0	0	2410000
4	Bangalore	1650000	50000	150000	0	150000	0	0	2000000
5	Bhubaneswar	220000	50000	150000	0	200000	0	0	620000
6	Bijapur	1615000	50000	150000	0	200000	0	0	2015000
7	Chatha	1415000	50000	150000	0	300000	0	0	1915000
8	Dapoli	385000	50000	150000	0	0	0	0	585000
9	Faizabad	1895000	50000	150000	0	0	0	0	2095000
10	Hisar	1850000	60000	150000	0	125000	400000	0	2585000
11	Jabalpur	840000	50000	150000	0	0	0	0	1040000
12	Jorhat	730000	50000	150000	0	0	0	500000	1430000
13	Kanpur	1400000	50000	150000	0	150000	0	0	1750000
14	Kovilpatti	2500000	50000	150000	0	0	0	0	2700000
15	Ludhiana	3450000	50000	150000	0	250000	0	0	3900000
16	Mohanpur	2260000	50000	150000	0	200000	0	0	2660000
17	Palampur	1150000	50000	200000	25000	0	0	0	1425000
18	Parbhani	1390000	40000	150000	0	120000	0	0	1700000
19	Raipur	1515000	50000	150000	0	0	0	0	1715000
20	Ranchi	650000	50000	150000	0	0	0	0	850000
21	Ranichauri	0	50000	150000	0	0	0	0	200000
22	Samastipur	1180000	50000	150000	0	180000	0	0	1560000
23	Solapur	1820000	50000	150000	0	0	0	0	2020000
24	Thrissur	645000	50000	150000	50000	0	0	0	895000
25	Udaipur	1400000	50000	150000	0	0	0	0	1600000
26	PC unit	0	91000	450000	0	0	0	0	541000
	TOTAL	**35000000**	**1350000**	**4250000**	**125000**	**1875000**	**400000**	**500000**	**43500000**

XIV Biennial Workshop of AICRP on Agrometeorology

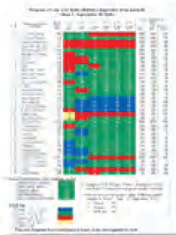
Organized by

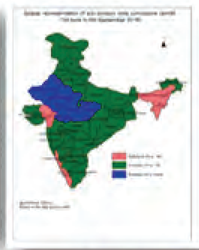
School of Climate Change and Agricultural Meteorology
Punjab Agricultural University, Ludhiana
5-7 December, 2016

Agromet Advisory Services-AICRPAM

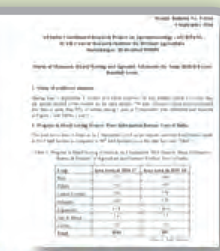


AICRPAM Value addition to SASCOF-8



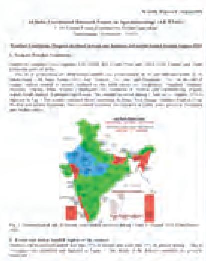


Daily bulletin-Progress of rain over India

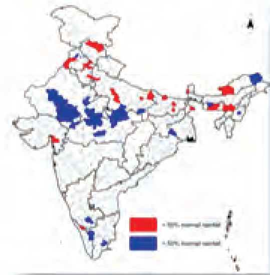


Weekly Bulletin – Status of mons kharif sowing and AAS

Weekly National Agromet Advisory Services (NAAS) Bulletin (Jointly with IMD)



Monthly report to NITI AAYOG – Weather and Crop status



Weekly monitoring : Districts received more than 50% excess & deficit rainfall

All India Coordinated Research Project on Agrometeorology

ICAR- CRIDA, Santoshnagar, Hyderabad – 500059 TS