

All India Coordinated Research Project on Agrometeorology

Annual Report 2017-18

AICRPAM



ICAR-Central Research Institute for Dryland Agriculture
Santoshnagar, Hyderabad-500 059 (TS)



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Citation: Vijaya Kumar P., Bal, S.K., Subbarao A.V.M., Sarath Chandran M.A., Dhakar Rajkumar. (2018). All India Coordinated Project on Agrometeorology, Annual Report (2017-18), ICAR-Central Research Institute for Dryland Agriculture, Hyderabad, pp 144.

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Printed at:

Balaji Scan Pvt. Limited,

11-2-1145, Beside Matas Temple, Nampally,

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कार्यकारी निदेशक

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Foreword

Weather continues to play a dominant role in agricultural production despite many technological advances made in Indian agriculture. Every year some or other extreme weather events like drought, cyclone, hailstorm, unseasonal rain, heat/cold waves etc. damage crops and horticultural system and cripple the economy of the farming communities. Though South West monsoon in the year 2017 over the country was normal, six meteorological sub-divisions of the country witnessed deficit rainfall. The second half of the season (Aug-Sep) received below average rainfall leading to mid-season drought in many parts of the country, viz., parts of north, north-west and north-east. Therefore, Agro-meteorological research and extension services assumes great significance in this era of climate change and ever-increasing extreme weather events.

In this background, the All India Coordinated Research Project on Agrometeorology (AICRPAM) with its network of 25 coordinated centres located in different agroclimatic zones of the country is playing a significant role in identifying regions vulnerable to climate change/variability, development of adaptive strategies and dissemination of micro-level agromet advisories. It is also undertaking research on the impacts of temperature and rainfall patterns on crops through modeling, designing contingency crop plans for different rainfall situations. The project also has developed weather insurance products and decision support systems for crop management and forewarning of pests and diseases through its network centers located in different agroclimatic zones of the country.

The efforts of AICRPAM project over the years have culminated in developing website for informing about crop and weather conditions and issuing agromet advisory services to different clientele including farmers, researchers and planners etc. Effective collaboration between AICRPAM and IMD was initiated for improving the content and outreach of the agromet advisory services for minimizing climate risks in agriculture. The efforts of the cooperating centres of AICRPAM in pursuing the assigned research programs are commendable.

The Annual Progress Report of 2017-18 comprises of the results of agrometeorological research carried out during *kharif* 2017 and *rabi* 2017-18 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 staff at the Coordinating Unit for bringing out this excellent report. I am of the opinion that the information provided in the report will be useful for researchers and policy makers for mitigating extremes of weather in Indian agriculture.

K. SAMMI REDDY

ICAR-CRIDA, Hyderabad

Date: November 10, 2018

Acknowledgement

I express my heart felt gratitude to Indian Council of Agricultural Research for providing financial and administrative support to the project during the year 2017-18. The encouragement and guidance received from Dr. Trilochan Mohapatra, Hon'ble Director General & Secretary (DARE) and Dr. K. Alagusundaram, Acting Deputy Director General (NRM) during the reporting period is highly acknowledged. The constant support and guidance being extended by Dr. S. Bhaskar, Assistant Director General (AAF&CC) to the project is gratefully acknowledged. The help and encouragement received from Dr. K. Sammi Reddy, Acting Director, CRIDA for the effective functioning of the project is acknowledged.

I thank Agrometeorologists and staff of all 25 cooperating centres for successfully conducting the research programs for the year 2017-18 and also contributing the research results for the annual progress report.

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



P. Vijaya Kumar

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1. Introduction

The All India Coordinated Research Project on Agrometeorology (AICRPAM) was initiated by ICAR in May 1983 with the establishment of Coordinating Cell at the Central Research Institute for Dryland Agriculture, Hyderabad and 12 Cooperating Centres at various State Agricultural Universities. After a detailed review and evaluation on the progress made by the project and realizing the importance of agrometeorological research support for enhancing food production, ICAR had extended the Cooperating Centres to 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, Rakh Dhiansar (Chatha/Jammu), Ranchi, Ranichauri, Samastipur, Solapur, Thrissur and Udaipur. The Quinquennial Review Team 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 (All centres)

- Development of database (Block, Tehsil or Mandal level) on climate and crop statistics (district level)

Agroclimatic Analysis

- 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 on livestock, poultry and fish (During the reporting year)

2) Crop Weather Relationships

3) Crop Growth Modeling

4) Weather Effects on Pests and Diseases

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

5) Agromet Advisory Services (All Centres)

- Monitoring of crop and weather situation, twice in a week and its updation 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 1.1: Zone-wise technical program of AICRPAM centers for three different themes during 2016-18.

S. No	Zones	Centre	Crop Weather Relationship Studies		Crop Growth Modeling	Weather Effects on Pests & Diseases
			<i>Kharif</i> Varieties	<i>Rabi</i> Varieties		
1.	Arid and Semi Arid: Black soil	Akola	Soybean: JS 335, JS 9305, TAM5 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/PomegranatePowdery 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
2.	Arid and Semi Arid : Redsoil	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
		Anantapur	Pigeon pea: PRG 176, LRG 41, LRG 52 Groundnut: K6, Kadri-harithandhra, Dharami & 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
		Anand	Pearl millet: GHB 558, GHB 744, GHB 538	Mustard: Bio 902, GM-3, GDM-4	Pearl millet	Mustard - Aphid
3.	Western Arid and Semi Arid: loamy soil	Hisar	Pearl millet: GHB 558, HSB-67, HHB-272, Guava: Hisar Safeda	Barley: BH 393, BH 902, BH 946, BH 885 Potato: Kufri Surya, Kufri Bahar, Kufri Pushkar	Pearl millet	Mustard - Aphid, Wheat - Yellow rust
		Udaipur	Soybean: JS-335, Pratap Soya, RKS-45	Mustard: Bio-902, Giriraj, Swarna Jyoti	Mustard	Mustard- Aphid

S. No	Zones	Centre	Crop Weather Relationship Studies		Crop Growth Modeling	Weather Effects on Pests & Diseases
			Kharif Varieties	Rabi Varieties		
4.	Sub-Humid alluvium-IGP	Faizabad	Maize: PMH 4, Naveen, UMC-1, Gaurav	Mustard: NDR-8501, NDRS-2001-1, Narendra Ageti Rai-4	Rice	Chickpea - Pod borer
		Kanpur	Maize: PMH 4, Azad 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
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- <i>Heliothis</i>
		Raipur	Rice: MTU-1010, Chhattisgarh Sugandhit Dhan, IGKV R-1	Chickpea: JG-14, Indira Chana-1, Vaibhav	Rice	Rice – Yellow Stem Borer, Leaf folder, Brown Plant Hopper Chickpea- <i>Heliothis</i>
6.	East and NE-Hot Sub Humid (Moist) : Deep loamy to clayey alluvium	Ranchi	Rice: MTU 1010, Naveen, Sahbhagi	Chickpea: JG 14, Birsra Channa 3, GNG 1581	Rice	Rice – BLB, Brown spot
		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 Hima-layan- 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
		Dapoli	Rice: Jaya, Karjat-5, Palghar-1, Swarna, Karjat-2	Spice: Pepper: Panniyur-1, Shakti, Thevam	Rice	Rice – Stem borer, Blue Beetle BPH
8.	Coastal (western ghat) – Hot humid to per humid : Laterite and coastal alluvium	Thrissur	Rice: Jyothi, Kanchana and Jaya	Spice: Pepper: Panniyur1 to Panniyur 8 (8 varieties)	Rice	Rice – Stem borer, Leaf roller Pepper – Pollu Beetle

2. Weather during 2017

A brief account of onset, progress and withdrawal with rainfall distribution details of southwest monsoon as well as post monsoon seasons of the year 2017 for the country as a whole and 25 centres of AICRPAM are presented hereunder:

Onset of Southwest Monsoon

The southwest monsoon set in over Kerala on 30th May 2017, 2 days ahead of its normal date (1 June). The southwest monsoon season rainfall over the country as a whole was normal. However, the season observed intra seasonal variation where the first half of the season received normal rainfall [June (105 % of LPA) & July (100 % of LPA)] and the second half received below normal rainfall [August & September (88 % of LPA each)]. The rainfall for the season was normal over all the homogenous regions of the country. Spatially, the highest rainfall (100% of LPA) was received by homogeneous region of South Peninsula and lowest rainfall (90% of LPA) was received by Northwest India. The homogeneous regions of East & Northeast India and Central India received seasonal rainfall of 98% and 94% of LPA, respectively. The rainfall received during the first half (1 June to 31 July) was normal (102% of LPA), while second half (1 August to 30 September) was below normal (88% of LPA).

The country as a whole received below or near normal rainfall on many days during the season. On only about 8 occasions, it was more than one and half times its normal value. During third week of June, second week of July and from August to mid of September, it was almost below normal.

Rainfall distribution during monsoon season

The seasonal (June to September) rainfall received at 36 meteorological sub-divisions of the country during the 2017 SW monsoon season are given in the table below along with respective long period average (LPA) values and deviations from normal.

Most of the subdivisions of the country received excess/ normal rainfall. However, some subdivisions of north and central India viz. Punjab, Haryana, Chandigarh & Delhi, East & West Uttar Pradesh, East Madhya Pradesh and Vidarbha received deficient rainfall. During the season, out of 36 meteorological subdivisions, 5 subdivisions received excess rainfall, 25 received normal rainfall and the remaining 6 subdivisions received deficient rainfall.

During the season, 14 low pressure systems (1 Deep Depression, 2 Depressions, 6 well marked low pressure areas & 5 low pressure areas) formed against an average of 6 Depressions and 8 low pressure systems

Withdrawal of southwest Monsoon

Withdrawal of southwest monsoon from some parts of Punjab, Haryana, most parts of west Rajasthan, some parts of Kutch and north Arabian Sea on 27th September. It further withdrew from remaining parts of Punjab, Haryana, Chandigarh & Delhi, west Rajasthan, Kutch, entire

Table 2.1: Rainfall at 36 meteorological sub-divisions during monsoon season (Jun–Sep 2017)

S. No.	Centre	Actual (mm)	Normal (mm)	Excess or deficit (mm)	Deviation (%)
1	Andaman & Nicobar Islands	1526	1683	-157	-9
2	Arunachal Pradesh	1584	1768	-11	-10
3	Assam & Meghalaya	1743	1793	-10	-3
4	Nagaland, Manipur, Mizoram, Tripura	1830	1497	25	22
5	Sub-Himalayan West Bengal & Sikkim	2047	2006	2	2
6	Gangetic West Bengal	1139	1168	-3	-2
7	Odisha	1053	1150	-9	-8
8	Jharkhand	988	1092	-10	-10
9	Bihar	937	1028	-9	-9
10	East Uttar Pradesh	650	897	-7	-28
11	West Uttar Pradesh	536	769	-31	-30
12	Uttarakhand	1199	1229	-2	-2
13	Haryana, Chandigarh & Delhi	359	466	-26	-23
14	Punjab	390	492	-22	-21
15	Himachal Pradesh	716	825	-13	-13
16	Jammu & Kashmir	544	535	2	2
17	West Rajasthan	366	263	39	39
18	East Rajasthan	567	616	-8	-8
19	West Madhya Pradesh	738	876	-16	-16
20	East Madhya Pradesh	796	1051	-24	-24
21	Gujarat Region	998	915	9	9
22	Saurashtra, Kutch & Diu	646	477	35	35
23	Konkan & Goa	3214	2915	10	10
24	Madhya Maharashtra	853	729	17	17
25	Marathwada	642	683	-6	-6
26	Vidarbha	731	955	-23	-23
27	Chhattisgarh	1041	1153	-10	-10
28	Coastal Andhra Pradesh	669	581	14	15
29	Telangana	665	755	-13	-12
30	Rayalaseema	507	398	27	27
31	Tamil Nadu & Pondicherry	414	317	31	31
32	Coastal Karnataka	2593	3084	-16	-16
33	North interior Karnataka	521	506	3	3
34	South interior Karnataka	665	660	2	1
35	Kerala	1857	2040	-9	-9
36	Lakshadweep	1108	999	11	11

Jammu & Kashmir, Himachal Pradesh, some parts of Uttarakhand, West Uttar Pradesh, most parts of East Rajasthan, some parts of West Madhya Pradesh, North Gujarat region, Saurashtra and some more parts of North Arabian Sea started on 30th September. It further withdrew from remaining parts of Uttarakhand, West Uttar Pradesh and East Rajasthan, some parts of East Uttar Pradesh and some more parts of North Madhya Pradesh and Gujarat on 11th October.

Post-Monsoon (October-December 2017)

Rainfall activity over the country during the season as a whole was below normal (88% of LPA). It was normal during the months of October and December (101% and 98 % of its LPA respectively) and below normal during November (49% of LPA). Eastern/Northeastern region, South Peninsular Region and Islands received large excess/excess/normal rainfall, while remaining parts of the country received deficient/large deficient rainfall.

Rainfall activity over core region of the south peninsula (comprising of 5 subdivisions viz. Coastal Andhra Pradesh, Rayalaseema, Tamil Nadu & Puducherry, South Interior Karnataka and Kerala was below normal (86% of Long Period Average (LPA)). It was normal during October and December (96% of LPA and 89% of LPA, respectively) and was below normal during November (69% of LPA).

Out of 36 meteorological subdivisions, one subdivision received large excess rainfall, 4 received excess rainfall, 14 received normal rainfall, 8 subdivisions received deficient rainfall and remaining 9 subdivisions received large deficient rainfall.

Rainfall at cooperating centers

During the year 2017, 7 out of 25 centers of the All India Coordinated Research Project on Agrometeorology, viz., Anantapur, Bangalore, Bijapur, Hisar, Palampur, Ranichauri and Udaipur received excess rainfall, 14 centers viz., Anand, Bhubaneswar, Chatha (Jammu), Faizabad, Jabalpur, Jorhat, Kovilpatti, Mohanpur, Parbhani, Raipur, Ranchi, Samastipur, Solapur and Thrissur received normal rainfall and remaining 4 centers received either deficient or scanty rainfall (Table 2.2).

Table 2.2: Annual rainfall received at AICRPAM centers during 2017

S. No.	Center	Actual (mm)	Normal (mm)	Departure (%)
1	Akola	536	799	-33
2	Anand	727	853	-15
3	Anantapur	721	590	22
4	Bangalore	1116	916	22
5	Bhubaneswar	1604	1502	7
6	Bijapur	765	594	29
7	Chatha	1059	1124	-6
8	Dapoli	3634	3529	3
9	Faizabad	883	1002	-12
10	Hisar	583	479	22
11	Jabalpur	1061	1253	-15
12	Jorhat	2292	1924	19
13	Kanpur	670	869	-23
14	Kovilpatti	802	714	12
15	Ludhiana	566	733	-23
16	Mohanpur	1534	1539	0
17	Palampur	2946	2332	26
18	Parbhani	996	881	13
19	Raipur	776	1145	-32
20	Ranchi	1580	1398	13
21	Ranichauri	1562	1270	23
22	Samastipur	1135	1235	-8
23	Solapur	587	721	-19
24	Thrissur	2361	2757	-14
25	Udaipur	815	601	36

3. Agroclimatic Characterization

Anantapur

Trend analysis of long term rainfall data (1877-2016) of Anantapur district (Table 3.1) has revealed no significant trend in annual and southwest monsoon rainfall. The total period was divided into 3 time scales and trend analysis was done for every 50 years. During the period 1877-1926 and 1927-1976, the annual (-0.4, -1.1) and SW monsoon (-0.15, -0.2) season rainfall has shown non-significant decreasing trend. During 1977-2016, annual rainfall (0.04) has shown increasing non-significant trend and southwest monsoon (-0.02) has shown decreasing non-significant trend (Table 3.1).

Table 3.1: Trend analysis of Annual Rainfall (mm) and South West Monsoon Rainfall (mm) in Anantapur district (1877-2016)

Start year	End year	Annual Rainfall (mm)		SW Monsoon Rainfall (mm)	
		Test Z	Significance	Test Z	Significance
1877	1926	-0.4	NS (Decreasing)	-0.15	NS (Decreasing)
1927	1976	-1.1	NS (Decreasing)	-0.2	NS (Decreasing)
1977	2016	0.04	NS (Increasing)	-0.02	NS (Decreasing)

* S – Significant; NS – Non Significant

Deviation of southwest monsoon rainfall (1877-2017) from it's LPA of 319 mm was computed at Anantapur and plotted (Fig. 3.1). It was observed that in 50 percent of the years rainfall received during the SWM at Anantapur was normal. However in 26 percent of the years, it experienced deficit rainfall and in 24 percent of the years it experienced excess rainfall.

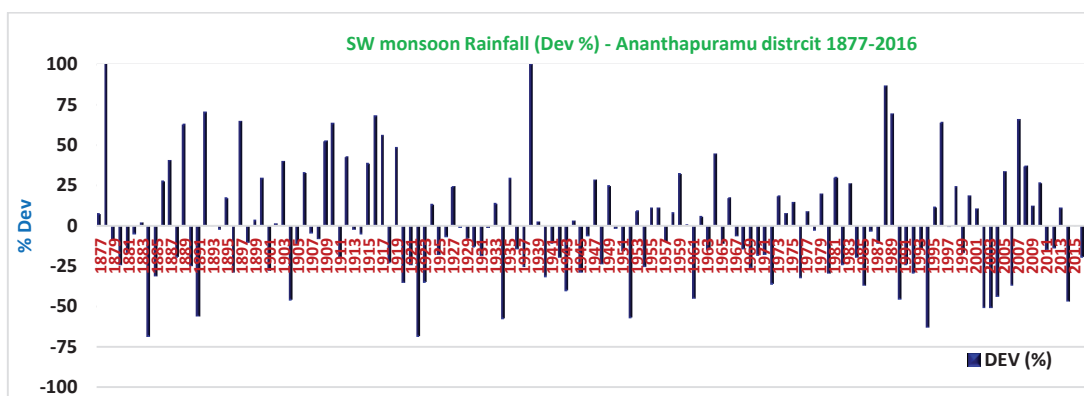


Fig 3.1 : Distribution of SWM rainfall (1877-2017) at Anantapur

Anand

Determining onset of SWM monsoon for Gujarat state through Agroclimatic approach

Monsoon onset in India is determined by IMD using meso scale first rainfall and other related parameters. Suitability of most *kharif* crops and sowing time depends on location specific onset of rainy season with sufficient amount of rainfall to sustain initial growth of the crop. Agroclimatic approach is more suitable to determine onset of rainy season, which is crucial information for agricultural purposes. This effective rainy season onset considering *kharif* season sowing is referred as agroclimatic onset here after. The agroclimatic approach defines the onset as the optimal date that ensures sufficient soil moisture during sowing and early growing period to avoid crop failure after sowing. The agroclimatic onset criteria used in the study is based on the concept developed by Sivakumar, (1988) and work of Marteau *et al.*, (2009).

Considering the quality and length of available data, 26 stations were considered for the study (Table). The agroclimatic onset was determined by defining onset date as the first wet day of the 3 days wet spell receiving at least 20 mm without 10 day dry spell (<2.5 mm) starting from 1st June. Year wise onset dates were determined over the time series of each station. The onset time presented as days since 1st June. IMD's normal onset of monsoon for Gujarat state is between 15-30 June. Time of effective first rainfall receipt for sowing of *kharif* crops shows large variation at all the stations. The variation in the date of onset at Anand during last 60 years is given in Figure. 3.2. The mean day of agroclimatic onset at Anand is 22nd June (given as horizontal line in Figure 3.2). This date indicates that the normal starting of *kharif* season (Fig.3.2) is about 7 days later than the normal onset of monsoon (Fig.3.2), and can be considered for crop. Similarly, station-wise agroclimatic onset date along with number of days of its occurrence after 1 June, and onset day of the year (DoY) shown in Table 2 revealed that the onset date ranges from June 10 (at Pariya) to July 03 (at Bhachau) over the entire state. The mean date of all the stations can be considered as onset date for the state which is June 22 (174th day of year). The map (Fig.3.3) depicts spatial variation of agroclimatic onset dates over different parts of Gujarat state. The onset dates suggest the starting of *kharif* season in systematic progression from South Gujarat to Kutch and North Gujarat.

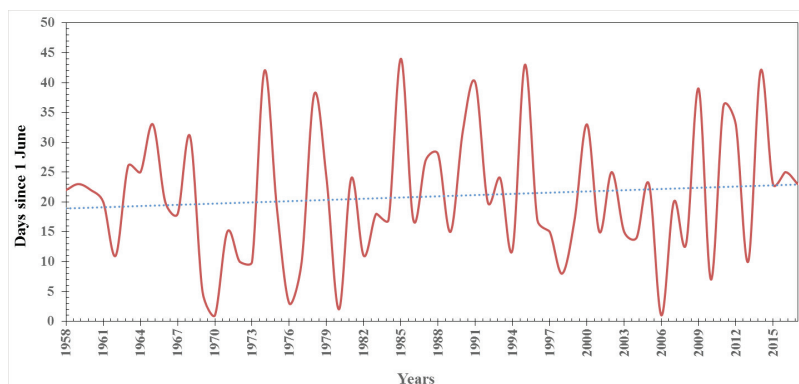


Fig. 3.2: Variation in agroclimatic onset during year 1958 to 2017 at Anand
(horizontal line is mean date of onset i.e. 22 June)

Agroclimatic onset of *kharif* season progresses from South East to North West of the state. South Gujarat has early onset on 8th June and it cover the entire state with its latest onset in Kutch on 3rd July. Time of receipt of effective first rainfall for sowing of *kharif* crops shows large variation at all the stations. Agroclimatic onset follows same pattern as meteorological onset of monsoon but with some lag period. Finally, it is advised that Agroclimatic onset can be considered for starting of *kharif* season.

Bangalore

Revisiting of Agroclimatic zones (ACZ) and sub zones delineation

Considering changes in rainfall trends, an attempt has been made to check if Tiptur taluk of Tumkur district and Arasikere taluk of Hassan district belongs to the presently grouped central dry zone. The central dry zone (CDZ) has hot, dry, semi-arid climate with low rainfall pattern ranging from 450 to 715 mm. CDZ is characterized by low cropping intensity (114%) and subsistence level. Length of growing period (LGP) is around 90 to 150 days so that mono-cropping system of short duration millets and pulses prevails in large. As the soils of CDZ are almost same as that of Southern dry zone (SDZ) rainfall and the cropping pattern were considered as deciding factors for re-delineation. K-mean cluster analysis on rainfall pattern and cropping system classified these two taluks into a separate group. Higher Ratio (0.644) of between sum of squares to total sum of squares clearly explains that these three taluks does not match to the criteria of CDZ. Tiptur and Arasikere have growing period of 150-180 days with potentiality of double cropping system. Most of the Arasikere area has double cropping system. Average (1980 - 2013) annual rainfall of Tiptur and Arasikere is 770 mm and 960 mm. Rainfall of SDZ ranges from 700 to 890 mm. SDZ has hot, moist, semi arid climate. Results from k-mean cluster analysis and field data on cropping

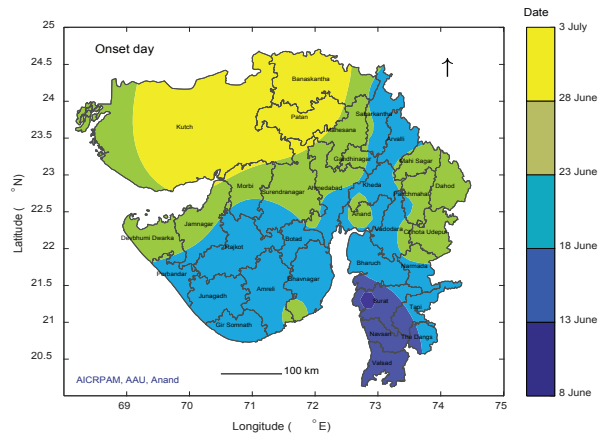


Fig. 3.3: Normal onset time (date) of rainy season in Gujarat through agroclimatic approach

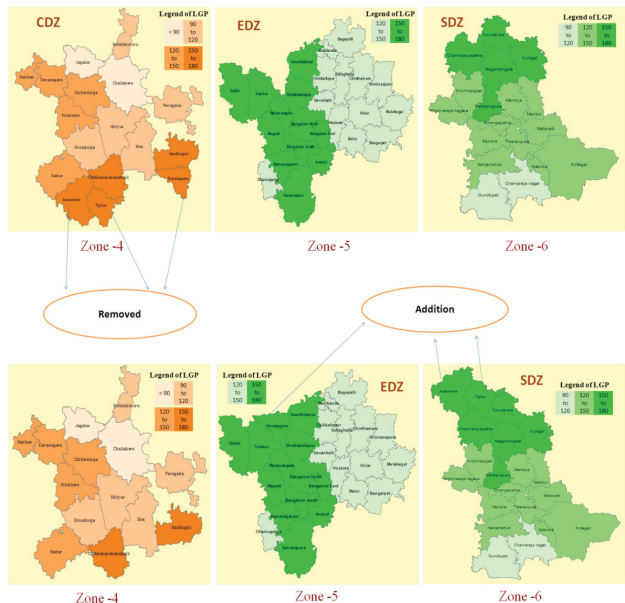


Fig. 3.4: Revisit of delineation of Agroclimatic zone and sub zones

systems implies that Tiptur and Arasikere have to be grouped under SDZ. Newly delineated zone boundaries are presented in the following figure. Accordingly the status report of ACZ's (which are serving as a research base throughout the country since late 80's) in Karnataka have been updated and re-delineated in 2017 (Fig. 3.4).

LGP as criteria for sub zone delineation

Sub division of each ACZ into sub zone based on LGP goes a long way in deciding the cropping systems. where ever LGP is more than 150 days double cropping is possible even under rainfed situation. Accordingly the farmers in agroclimatic sub zones having more than 150 days of LGP who are advised to go for double cropping with a short duration pulse in May sowing window and second crop of finger millet or horse gram in August sowing window. The following are the recommended double cropping systems

1. Green gram followed by finger millet or horse gram
2. Cowpea followed by finger millet or horse gram
3. Black gram followed by finger millet or horse gram
4. Field bean followed by finger millet or horse gram
5. Potato followed by finger millet or horse gram
6. Sesamum followed by finger millet or horse gram

Drought Index at Taluk level

Drought affected areas in Karnataka state were identified at taluk level with high spatial and temporal resolution rainfall data obtained from its network of telemetric rain gauges during the years 2001-2015 (Fig. 3.5). The figure indicates that out of these fifteen years, three years (2005, 2007 & 2010) experienced no drought. Of the remaining 12 years, 2003 was a severe drought year, since 162 Taluks out of 176 Taluks of the state (92%) were under drought. In 2002 and 2012, 159 taluks (90%) and 157 (89%) Taluks respectively were affected by drought. Among these 12 years, 2001 & 2014, the drought was less intense (18-19%) and only 33 to 34 taluks were affected.

Frequency of drought (2001-2015): Chikkaballapur experienced drought for 9-11 years (Fig-5a) with 79% probability while other parts of the EDZ experienced drought in at least 5 years with average of around 9 years in 16 years.

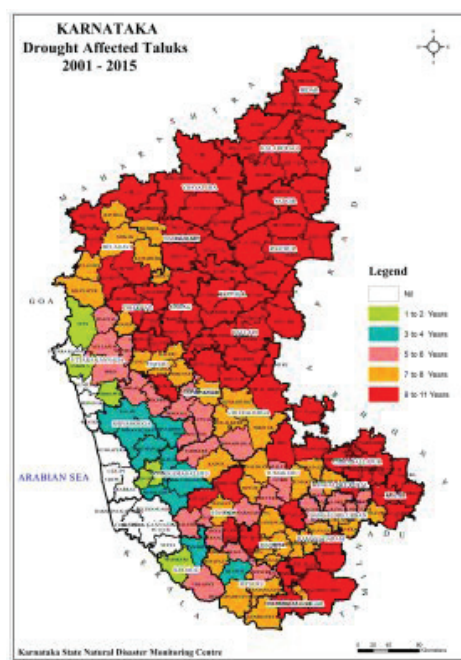


Fig.3.5: Frequency of drought affected taluks in Karnataka

Bhubaneswar

Annual rainfall trends in different blocks of Bhadrak district of Odisha

Block level rainfall data of 23 years (1995 – 2017) of Bhadrak district were subjected to Mann-Kendall test for detecting trend in annual rainfall at three different significance levels i.e. 90%, 95% and 99%. Decreasing trend of annual rainfall was observed in two blocks viz. Bhadrak (at 90% significance) and Basudevpur (at 99% significance). No significant trend was observed in remaining five blocks, namely Bhandaripokhari, Bonth, Chandbali, Dhamnagar and Tihidi (Table 3.2).

Table 3.2: Annual rainfall trend in different blocks of Bhadrak district, Odisha

BLOCK	Significant at the level			Not significant	Remarks
	90%	95%	99%		
Basudevpur	-	-	✓	-	Decreasing
Bhadrak	✓	-	-	-	Decreasing
Bhandaripokhari	-	-	-	✓	-
Bonth	-	-	-	✓	-
Chandbali	-	-	-	✓	-
Dhamnagar	-	-	-	✓	-
Tihidi	-	-	-	✓	-

Probability of annual rainfall

Probability analysis of rainfall offers a better scope for assessing the minimum assured rainfall to help in crop planning. Probability of block level annual rainfall was computed using incomplete gamma distribution method of probability analysis at three levels -90%, 75% and 50%. The results presented in the Table 3.3 indicated that, at 90% probability rainfall was below 1100 mm at almost all blocks, except Basudevpur block (1222 mm). Lowest amount of at 90% probability rainfall (754 mm) was observed at Dhamnagar block. At 75% probability, rainfall was above 1300 mm at only one block, namely, Basudevpur (1486 mm). The rainfall was below 1100 mm for the blocks, namely, Bonth, Tihidi, Bhandaripokhari and Dhamnagar. At 50% probability, rainfall was above 1200 mm in all blocks. At 50% probability highest rainfall was observed in Basudevpur block (1821 mm) and lowest in Bhandaripokhari block (1214 mm).

Table 3.3: Rainfall (mm) at three probability levels at different blocks of Bhadrak district, Odisha

BLOCK	90% Probability	75% probability	50% probability
Bhadrak	1086	1245	1439
Bhandaripokhari	827	998	1214
Basudevpur	1222	1486	1821
Bonth	940	1099	1296
Chandbali	1045	1234	1470
Dhamnagar	754	958	1225
Tihidi	861	1048	1286
District	962	1152	1393

Vijayapura

Characteristics of seasonal rainfall in high acreage districts of Green gram with medium and low productivity

As no district in the category of High area and High productivity was found, rainfall characteristics of the districts with High area. Moderate productivity (HM) are considered as the threshold productivity for comparing with the characteristics in high and low productivity. The deviations in rainfall characteristics HL districts are inferred as the constraints. The rainfall characteristics of the two sets of districts are presented in Table 3.4.

Table 3.4: Districts covered in different crop productivity zones

Crop	HH	HM	HL
Green gram	-	Dharwad, Kalaburgi	Bidar, Gadag

Analysis of monthly rainfall was carried out in the major green gram growing districts under following levels of productivity (Table 3.4) to find out the rainfall constraints for low yield of green gram.

Table 3.5: Rainfall characteristics of districts with High acreage, Medium and Low productivity of Green gram

Month/ combination of months	Rainfall Statistics						
	Mean (mm)			Std dev (mm)		CV (%)	
	HL	HM	(HL-HM)	HL	HM	HL	HM
May	51.1	49.1	2.0	31.1	25.6	60.9	52.3
Jun	95.7	114.5	-18.8	42.0	58.7	43.9	51.3
Jul	124.2	126.1	-1.9	59.3	51.7	47.8	41.0
Aug	141.1	140.7	0.4	50.8	66.2	36.0	47.0
Sept	136.6	153.0	-16.3	56.7	71.6	41.5	46.8
May -Jun	146.8	163.6	-16.8	55.6	64.8	37.9	39.6
May-Jul	175.3	175.2	0.1	69.0	59.0	39.4	33.7
Jun-Jul	219.9	240.6	-20.7	66.7	86.2	30.3	35.8
MJJ	271.0	289.7	-18.7	77.7	91.2	28.7	31.5
MJJA	412.0	430.4	-18.3	88.0	143.6	21.3	33.4

It is noticed from Table 3.5 that, the low yield districts have the characteristic of lower rainfall in the month of June by about 19 mm, which is about sixteen percent lower than the rainfall with moderate yield in districts. On the other hand, even though rainfall in July is nearly equal in both categories, the rainfall in low yield districts has greater variability by about seven percent, making the green gram production more vulnerable to dry periods in the vegetative period.

Dapoli

Long term rainfall (1972-2017) and temperature (1983-2017) data pertaining to Dapoli was analysed for drought years, extreme daily rainfall as well as temperature events and interannual variability of temperatures.

Droughts

Annual rainfall data was analysed to identify years with different intensity of meteorological drought at Dapoli center. Out of the 46 years, no drought in 40 years (87%) and moderate drought in (6) years were observed in Dapoli. No severe drought was experienced at Dapoli (Table 3.6).

Table 3.6: Drought characterization at Dapoli center (1972-2017)

S.No.	Drought condition	Years	No. of Years	Percentage
1.	No. Drought	1973 to 1980, 1982 to 1985, 1988 to 2000, 2002 to 2014, 2016, 2017	40	86.96
2.	Moderate Drought	1972, 1981, 1986, 1987, 2001, 2015	6	13.04
3.	Severe Drought	-	-	-
Total			46	100

Extreme daily rainfall events

Rainfall data of Dapoli center (1972-2017) was analysed to identify extreme daily rainfall events (mm). The analysis showed that in 24 percent of years Dapoli experienced highest single day rainfall greater than 300 mm in a year 42% of years between 200-300mm and lesser than 200mm in remaining 34% of years. As highest single-day rainfall in a year exceeds 200mm in 66% of the years, there is a need to follow soil water conservation methods in this region.

Long-term trends in Maximum and Minimum Temperatures at Dapoli

It is observed from the long-term trends in temperatures at Dapoli the maximum and minimum temperatures are increasing at the rate of 0.028 and 0.047 °C/ year, respectively. At Dapoli it is observed that in both the cases the increase has started from 2002 for maximum temperature and 2001 for minimum temperature (Fig. 3.6 and Fig. 3.7.)

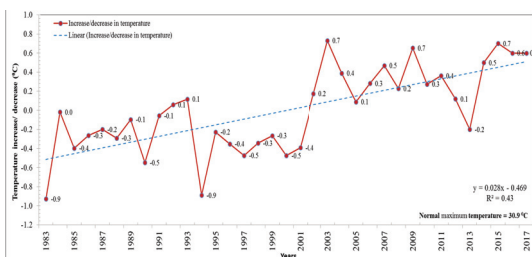


Fig. 3.6: Trend in maximum temperature (°C) at Dapoli

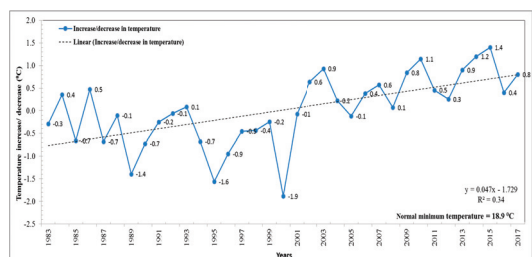


Fig. 3.7: Trend in minimum temperature (°C) at Dapoli

Faizabad

Seasonal rainfall variability of Eastern Uttar Pradesh

Seasonal rainfall variability of Eastern U.P. was computed for two non equal time periods (16 and 20 year) and presented in Table 3.7. The analysis indicated that in all the seasons the rainfall has shown declining trend. The percent decrease observed in winter season was highest (-7.5%) followed by post monsoon (-5.9%) which is coinciding with the growing period of *rabi* wheat / chickpea crops in this area.

Table 3.7: Seasonal rainfall variability over two different time scales in Eastern U.P.

Season	1980-96	1997-2017	% decrease
Winter	22.5	20.7	-7.5
Summer	37.2	35.0	-5.3
Monsoon	887.8	841.0	-5.3
Post monsoon	47.8	45.0	-5.9

Jammu

Conditional probability of dry and wet spells in Jammu province

Probability of getting two consecutive wet (P2W) and dry (P2D) weeks for different amounts of rainfall (10, 20 and 30 mm) at different stations of Jammu region viz., Jammu, Samba, Katra, Bhaderwah, Batote and Rajouri was analyzed by using long term data. As these areas are mostly located in hilly terrain and fall under mid altitude intermediate zone of Jammu region, the crops, in this region, are generally grown under rainfed condition.

At Jammu, the probability of getting consecutive wet weeks with cumulative rainfall of 10, 20, 30 mm was found to be higher and starting at 24 SMW and ends with 38 SMW during monsoon season (*kharif* season). While in *rabi* season, probability of 30 percent for getting the cumulative rainfall of 10 mm during 6th and 7th SMWs. In case of consecutive dry weeks, more than 50 percent probability of getting less than 20 and 30 mm rainfall observed during 1st to 24th SMWs and 38th to 51st SMWs. The chances of occurrence of dry week preceded by another dry week are less during monsoon periods particularly from 26 to 36th SMW at Jammu (Fig. 3.8). The chances of occurrence of wet week preceded by another wet week (PWW) with cumulative rainfall of 10, 20 and 30 mm amounts are high (60 to 80 percent) during rainy season particularly in 28th to 34th SWM at Samba. The lowest probability of getting consecutive cumulative rainfall of 10, 20 and 30 mm amount in wet followed by wet week were found from 13th to 23rd SMW and 38th to 51st SMW are very low (less than 5 percent).

The analysis shows that less chances of occurrence of consecutive dry weeks are about 0 to 10 percent for 10 & 20 mm and 3 to 27 percent of 30 mm from 25th to 36th SMW. The probability of getting consecutive wet weeks (PWW) at Katra varies between 50 to 97 percent for getting 20 mm rainfall during 23rd to 37th SMWs and for obtaining 30 mm rainfall is in between 45 to 89 percent during 25th to 37th SMWs. Similarly, the probabilities of occurrence of two consecutive

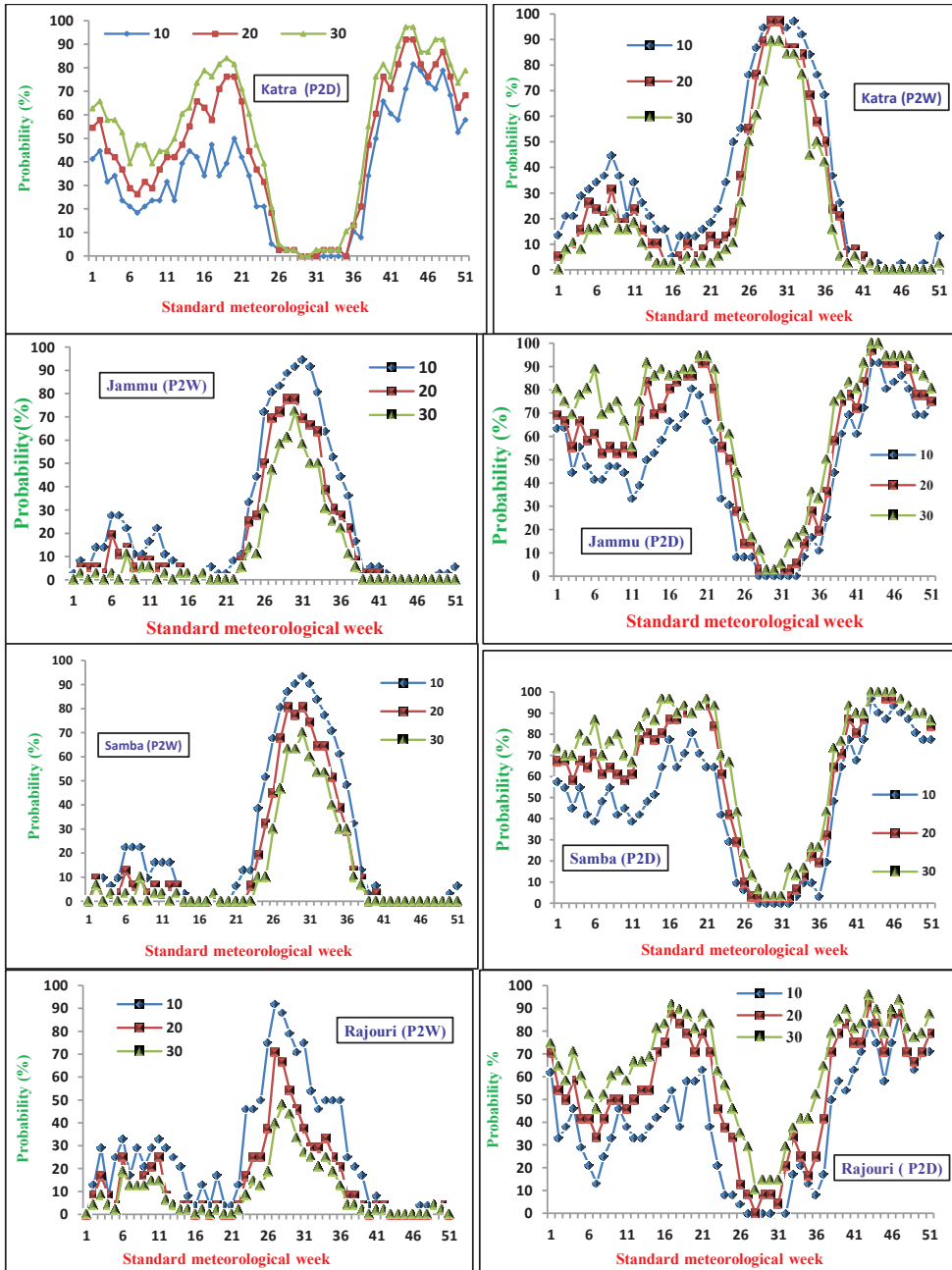


Fig. 3.8: Probability of occurrence of consecutive wet and dry weeks in Jammu region

dry weeks (P2D) of about 30 mm amount of rainfall is also very high (45-87 percent) during 42nd to 51st SMWs period. Further, 40 to 90 percent chances of occurrence of 2 consecutive dry weeks of about 10 mm were found 01st to 20th SMWs. Rainfall data of 28 years was analysed for calculating consecutive wet (PWW) and dry weeks (PDD) at Rajouri. The probability of getting

consecutive wet weeks is varying from 46 to 92 percent during 23rd to 36th SMW. The analysis of consecutive dry spells (Fig. 3.8) reveals that there is 0 to 33 percent from week 1st to 22nd and 0 to 17 percent probability during 39th to 51st SMW. Similarly, the probability of occurrence of more than 30 mm rainfall in two consecutive wet weeks is very low varying from 19 to 48 percent in most of the weeks during 23rd to 36th. The above four locations have exhibited same kind of probability pattern for consecutive wet and dry weeks whereas, the locations selected viz. Bhaderwah, Banihal and Batote have shown a different kind of probability pattern for getting consecutive wet and dry weeks. Consecutive wet weeks (P_{WW}) for Bhaderwah station showed a probability of 23 to 75 percent for the occurrence of two consecutive wet weeks of 10 mm rainfall during 03rd to 35th SMW whereas, probability of occurrence of two consecutive wet week of 20 mm rainfall amount varies from 10 to 50 percent during 01st to 20th and 27th to 36th SMWs. The amount of 30 mm rainfall varies from 8 to 23 percent from 01st to 20th SMWs and 24th to 36th SMWs. Probability of 40 to 90 percent was found for the occurrence of dry week from 38th to 51st SMW. Whereas at Banihal the probability range to get consecutive wet week with 10, 20 and 30 mm of rainfall from 02nd to 14th SMW was in between 30 to 70 percent followed by 5 to 30 percent in the weeks starting from 15th to 34th and 1 to 15 percent during 35th to 51st SMWs. The probability of occurrence of consecutive dry weeks (P_{DD}) receiving less than 20 and 30 mm rainfall varies from 33 to 87 percent during 17th to 51st SMW. However, from 19th to 51st SMW the probability of both P_{DD} is high. At Batote station, the range of probability was found between 43.9 to 68.3 percent and 41.5 to 61 percent for the occurrence of wet followed by wet week of 10 mm spell from 4th to 15th and 24th to 33rd SMW, respectively. However, from 23rd to 36th SMW the probability of P_{DD} is low. The last 12 weeks of the year (41st to 52th SMW) mostly experience moisture stress, as there are more than 40 percent chances of occurrence of 2 consecutive dry weeks.

Jorhat

Probabilities of consecutive wet and dry weeks in Upper Brahmaputra Valley Zone (UBVZ) of Assam

Probabilities of getting consecutive wet and dry weeks were worked out using weekly rainfall data from 1981-2015 applying Markov Chain procedure for the locations Sivasagar, Jorhat, Dibrugarh, Tinisukia, Golaghat.

Probabilities of getting two consecutive dry weeks (2D) at Jorhat got reduced to nil from 23rd SMW and the condition remained same up to 38th SMW. But starting at 43rd SMW, the same goes above 50% and hence, if the transplanting of rice crop got delayed and if long duration cultivars are growing there having ample chance of facing terminal drought in the flowering/grain filling stage of rice at Jorhat. Probabilities of getting three (3D) and four (4D) dry weeks also increases substantially from 43rd SMW at Jorhat (Fig. 3.9).

Probabilities of getting two (2D) consecutive dry weeks at Sivasagar got reduced to 5% from 16th SMW and the condition remained same up to 39th SMW. But starting at 42nd SMW, the same goes above 70% and hence, there was higher possibility of dry spell during reproductive stage of *kharif* rice in Sivasagar district. At Golaghat no consecutive dry weeks were found during

both vegetative and early reproductive stage of *kharif* crops (from 23rd SMW to 37th SMW). But from 42nd SMW onwards the probability going above 50% and hence, short duration varieties of rice crop such as Luit, Kapili, Dichang etc. are preferred to save the crop from terminal drought (Fig. 3.9).

It was found that no chance of early season drought for *kharif* crops at Dibrugarh due to reduced or no probability for consecutive dry weeks. But above 60% probability of occurrence of dry spells observed from 42nd SMW onwards. Ample scope of both mid and late season droughts in late sown rice crop (early part of August) was found at Tinisukia since the probability of getting two (2D) and three (3D) consecutive dry weeks goes above 50% from 38th Standard Meteorological week onwards (Fig. 3.9).

Kanpur

Rainfall probability at Kanpur:

Rainfall probability estimation for any location is useful for agricultural planning. For agricultural planning in Kanpur district, long term (1971-2017) weekly rainfall data from 1 to 52 SMW was analyzed using incomplete Gamma distribution for computing rainfall expected at different probability levels (Fig. 3.10). At 90 per

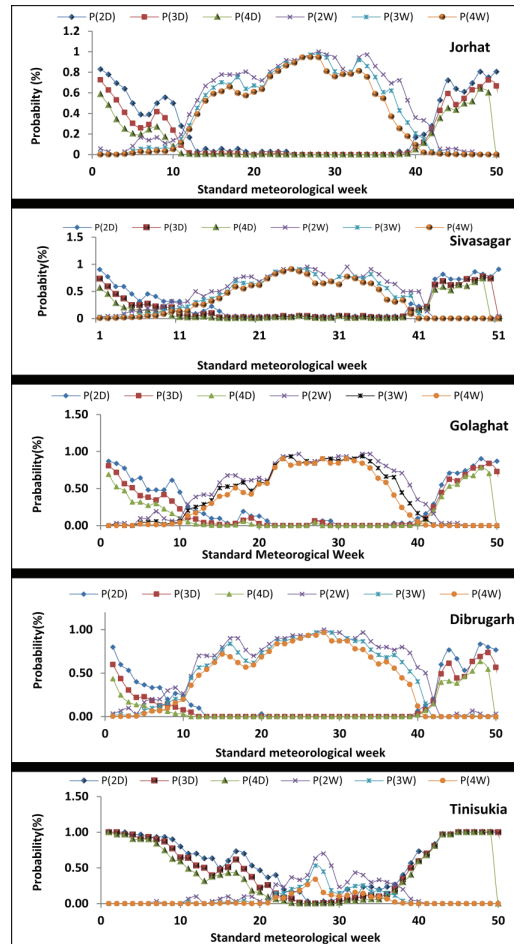


Fig.3.9: Probability of consecutive wet and dry weeks

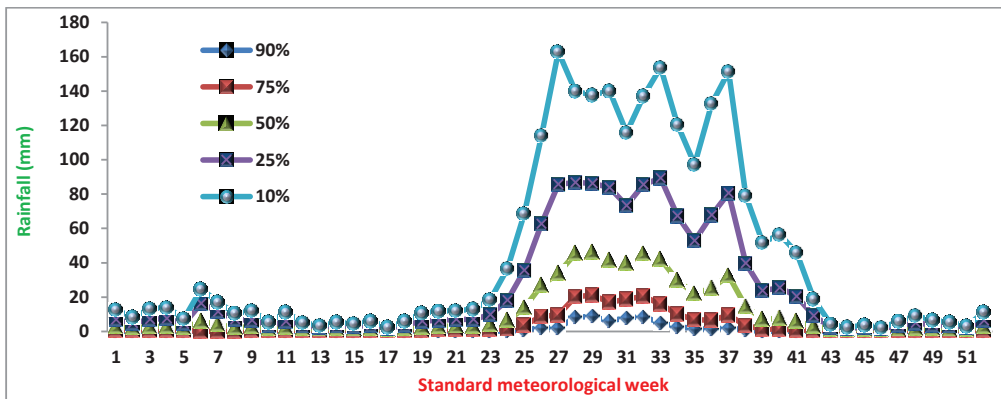


Fig. 3.10: Weekly rainfall expected at 10, 25, 50, 75 and 90 per cent probability

cent probability level, more than 2.5 mm rainfall is expected from 28 to 34 SMW, probability of highest rainfall i.e. 8.4 mm is estimated for 32 week. Results also revealed that at 75 percent probability 14 weeks (SMW 25-38) are expected to receive more than 2.5 mm rainfall. The probability of highest rainfall i.e. 21.1mm is observed during 29th SMW followed by 32nd and 28th SMW. Similarly, more than 2.5 mm rainfall is expected from 19 to 42 SMW at 50 percent probability. At this probability highest rainfall i.e. 46.1 mm will be received on 29 SMW followed by 28 and 32 SMW. It is also noted that more 2.5 mm rainfall is expected under all the SMW except 44,46 and 51, at 25 percent probability and highest rainfall is expected on 33 met week followed by 28 and 29 SMW. At 10 per cent probability, all the met weeks are expected to receive more than 2.5 mm rainfall except 44 and 46 met week.

Drought frequency:

Long term rainfall data of 47 years was analyzed with the help of Weathercock software to assess frequency of meteorological droughts at Kanpur (Fig. 3.11). The results showed that out of 47 years, no drought occurred in 39 years amounting to 83% of total study years. It is also noticed that moderate drought in 7 years and severe drought in 1 year which are 15 % and 2% of the total study period, respectively.

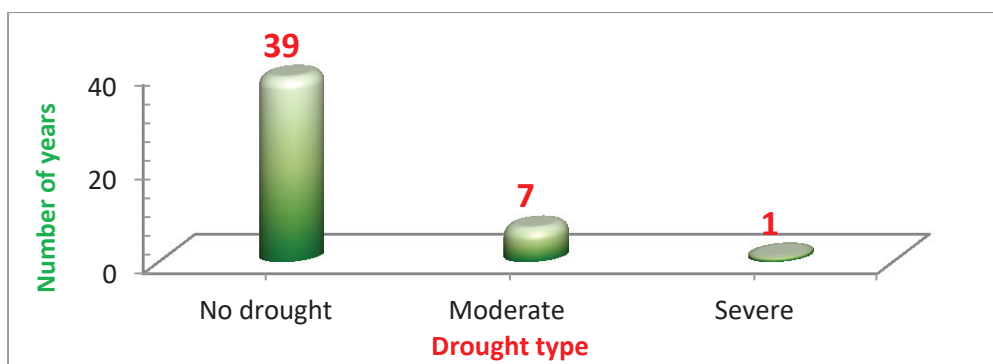


Fig. 3.11: Meteorological drought of different intensities at Kanpur

Agricultural Drought

Rainfall data of Kanpur district (1971-2017) was analysed for assessing the frequency and duration of agricultural droughts (Table 3.8). Out of 47 years, 30 years were observed as agricultural drought years during *kharif* season. Agriculture drought was prolonged for 12 meteorological weeks from 31 to 42 SMW in 1979, while, rainfall was discontinued during 13 weeks in *Kharif* season of the years 1974 and 2015.

In most of the years, agriculture drought was prolonged for 4 weeks, which damaged *kharif* crops at critical stages. The agricultural drought in *kharif* season was experienced from 4 to 5 weeks during 38 to 42 SMW during most of the study years. During these weeks, *kharif* crops like maize, paddy, pulses and oil seeds were in reproductive stages i.e. flowering, milking and dough stages that required more moisture in comparison to other stages.

Table 3.8: Agricultural droughts during *kharif* season at Kanpur district, U.P. during 1971 to 2017

Year	Duration (SMW)	Year	Duration (SMW)	Year	Duration (SMW)	Year	Duration (SMW)
1973	25-29	1984	37-41		37-42	2011	38-42
1974	24-28	1985	24-27	1997	30-33	2012	23-26
	30-33	1987	24-27	1998	39-42		38-42
	35-38		32-35	2000	37-42	2014	25-28
1976	37-42	1988	39-42	2001	35-39	2015	27-31
1977	38-42	1990	37-40	2002	26-30		33-36
1978	39-42	1991	37-42		38-42		39-42
1979	31-42	1992	23-28	2006	37-41	2016	34-39
1982	25-28	1994	39-42	2008	39-42	2017	39-42
	38-42	1995	27-30	2009	23-27	-	-

Length of growing period of *kharif* season

Length of Growing Period (LGP) in Kanpur, Uttar Pradesh was estimated as the period when precipitation exceeds half the potential evapo-transpiration. The LGP was estimated following the FAO (1978) method. After pre-processing of data, computation was made by using Weather Cock software (CRIDA-2011) taking the long term (1971-2017) rainfall and evaporation data. Weekly rainfall and estimated potential evapotranspiration data were used to calculate moisture adequacy index (MAI) using weekly water balance method for soils with different soil moisture holding capacity. It was assumed that the season starts in 22 SMW, when the moisture adequacy index value of two consecutive weeks is ≥ 0.5 , and it ends if MAI is ≤ 0.25 for three consecutive weeks after 43 SMW. The study revealed that average length of growing period ranged from 56 to 112 days (8 -16 weeks) with a mean duration of 80 days (11.5 weeks) at Kanpur district.

Decade-wise rainfall analysis

Decadal mean of annual and seasonal rainfall over the last 5 decades from 1971 to 2017 (Table 3.9) showed negative deviation or lesser annual rainfall from normal since the decade 2001-2010. However, the initial decade 1971-1980, 1981-1990 and 1991-2000 received higher decadal rainfall than normal. The decadal mean annual rainfall was highest (920.5 mm) during 1971-80 and started decrease with each successive decade to reach lowest (788 mm) during 2011-17. On the contrary rainfall during Summer season showed increasing trend in successive decades 1971-1980 to 2011-2017. In other season viz., winter, southwest monsoon and north east monsoon seasons, no study increase or decrease is noticed over all the decades.

Table 3.9: Mean of annual and season-wise decadal rainfall (mm) during 1971-80 to 2011-17

Season	Decadal rainfall (mm)					Normal (mm)
	1971-80	1981-90	1991-2000	2001-10	2011-17	
Winter (Jan-Feb)	20.6	30.1	31.0	23.5	57.7	31.0
Summer (Mar-May)	19.4	24.5	24.6	33.4	49.8	29.2
Southwest (Jun-Sep)	829.7	762.0	766.8	724.3	637.2	753.7
Northeast (Oct-Dec)	50.8	75.8	58.8	37.4	43.3	55.0
Annual	920.5	892.4	881.2	818.6	788.0	868.9

Kovilpatti

Rainfall analysis of Ramanathapuram district of Tamil Nadu

Long-term daily rainfall data (from 1980 to 2008) of different blocks of Ramanathapuram district of Tamil Nadu was analysed. It showed that Ramanathapuram district receives an annual rainfall of 814 mm in 35 rainy days. This district records rainfall of 61.5, 108.3, 103.2 and 541.2 mm during winter, summer, Southwest monsoon and Northeast monsoon seasons, respectively. Places such as Mandapam, Pamban, RS Mangalam, Rameswaram and Ramnathapuram received more than the district's average annual rainfall. With regard to annual rainfall, lower annual rainfall of 553.3 mm was recorded with less number of annual rainy days (26) at Valinockam whereas, higher annual rainfall of 1522.3 mm was received with more number of annual rainy days (46) at Rameswaram. Paramakudi received higher rainfall (180.8 mm) and Valinockam received with lesser rainfall (43.8 mm) during Southwest monsoon season. Rameswaram receives higher rainfall (1169.8 mm) and Kamuthi receives less rainfall (371.6 mm) during Northeast monsoon season.

Trend analysis of annual rainfall

Trend analysis using long term rainfall data (1980 - 2008) of 16 blocks of the Ramanathapuram district using Mann-Kendall test showed that annual rainfall (from 1980 to 2008) of Kadaladi, Mandabam, Paramakudi, Pamban, RS Mangalam, Ramanathapuram, Thangachimadam and Vattanam blocks differed significantly at 0.1 % level of significance. Annual rainfall of all blocks of Ramanathapuram district showed an increasing trend in recent years except Mudukulathur block, which showed decreasing trend.

Trend analysis of annual rainy days

Annual rainy days (from 1980 to 2008) of Kadaladi, Mandabam, Paramakudi, RS Mangalam, Ramanathapuram and Thangachimadam blocks differed significantly at 0.1 % level of significance. Annual rainy day of Ramanathapuram district showed an increasing trend except Morekulam, Theerthandathanam, Thiruvadanai, Valinockam and Vattanam showed decreasing trend in recent years.

Trend analysis of Southwest monsoon rainfall

Southwest monsoon rainfall of Mudukulathur, RS Mangalam and Valinockam blocks was differed significantly at 5 % level of significance. The Southwest monsoon rainfall was not differed significantly for other blocks of Ramanathapuram district. Kadaladi, RS Mangalam, Paramakudi and Thangachimadam blocks showed a increasing trend of SWM rainfall whereas Kamuthi, Mandabam, Morekulam, Mudukulathur, Pamban, Theerthandathanam, Thiruvadanai, Thondi, Valinockam and Vattanam exhibited a decreasing trend in recent years.

Trend analysis for NEM rainfall

Northeast monsoon rainfall of Mandabam, Morekulam, Paramakudi, Pamban, Ramanathapuram and Thondi differed significantly at 5 % level of significance. The NEM rainfall of all blocks of Ramanathapuram district exhibited an increasing trend in recent years.

Ludhiana

Decadal changes in the frequency of extreme temperature and rainfall events in Punjab

a. Changes in frequency of occurrence of extreme maximum ($> 44^{\circ}\text{C}$) temperatures

The decadal occurrence of events (number of days) of extreme maximum temperatures ($> 44.0^{\circ}\text{C}$) during the months of April, May and June and extreme minimum temperature events ($< 0^{\circ}\text{C}$) during the months of January, February and December in eight different locations viz. Ballawal Saunkhri, Amritsar, Ludhiana, Jalandhar, Patiala, Bathinda, Faridkot and Abohar over past four decades (as per availability of instrumental records) in Punjab were analysed. It was observed that, there is an increase in the incidence of the extreme maximum temperature events in these districts of Punjab.

In the agroclimatic zone II (Ballawal Saunkhri), Over the recent period from 2000-09 to 2010-16 occurrence of events with temperature within $> 44^{\circ}\text{C}$ decreased by 8 days. Among the four decades, the days with extreme of maximum temperature $> 44.0^{\circ}\text{C}$ at Amritsar were 57 (1970-79) followed by 47 (2000-09), 45 (2010-16), 25 (1980-89) and 13 (1990-99) in decreasing order; at Ludhiana they were 38 (1970-79) followed by 24 (2000-09), 18 (2010-16), 17 (1980-89) and 11 (1990-99); at Jalandhar they were 24 (1971-79) followed by 23 (1980-89), 16 (1990-99), 7 (2010-14) and 2 (2000-09); at Patiala they were 29 (1990-99) followed by 26 (2010-15), 22 (1970-79), 15 (1980-89) and 14 (2000-09) in decreasing order in agroclimatic region III.

In the agroclimatic region IV (Bathinda) the occurrence of extreme of maximum temperature $> 44.0^{\circ}\text{C}$ was 144 days (1980-89), followed by 98 days (1990-99), 70 days (2010-16), 65 days (2000-09) and 55 days (1977-79) in decreasing order and in agroclimatic region V (Faridkot and Abohar) it was 17 days (2000-09) and 19 days (2010-16) and at Abohar were 21 days (2010-16) and 17 days (2004-09) in decreasing order (Table 3.10).

Table 3.10: Decadal changes in extreme maximum temperature ($> 44^{\circ}\text{C}$) events

Location	AGCL	1970-79	1984-89	1990-99	2000-09	2010-15
Ballawal Saunkhri	II	-	10	19	8	13
Amritsar	III	57	25	13	47	45
Ludhiana	III	38	17	11	24	18
Jalandhar	III	24	23	16	2	7
Patiala	III	22	15	29	14	26
Bathinda	IV	55	144	98	65	70
Faridkot	V	-	-	-	17	19
Abohar	V	-	-	-	17	21

b. Changes in frequency of occurrence of extreme minimum temperatures ($< 0^{\circ}\text{C}$)

The decadal occurrence of extreme of minimum temperature (minT) events (number of days) during the months of January, February and December with minT particularly $< 0^{\circ}\text{C}$ was calculated in the same locations mentioned above. In the agroclimatic zone II (Ballawal Saunkhri) the occurrence of minimum temperature (minT) $< 0^{\circ}\text{C}$ decreased by 14 and 1 days,

respectively in the Agroclimatic zone II. Among the four decades, the number of extreme minimum temperature events of $< 0^{\circ}\text{C}$ Min T at Amritsar were highest (50 days) during 2000-09, 0 days during 1970-79 followed by 29 days during 1990-99, 22 days during 2010-16 and 0 days during decades to 1980-89 in decreasing order. At Ludhiana only two decades were recorded, 6 days during 2000-09 and 6 and 1 day of minT $< 0^{\circ}\text{C}$ during 1980-89 experienced. At Jalandhar there were 23 days during 2000-09 followed by 16 days during 1971-79, 16 days through 1980-89, 5 days during 1990-99 and 0 days for the period of 2010-14; At Patiala in agroclimatic region III, during 2000-09, only 2 days of minT $< 0^{\circ}\text{C}$ were experienced and no such events in rest of the decades. In agroclimatic Zone IV, Bathinda experienced days with minT $< 0^{\circ}\text{C}$, 13 days (1980-89), followed by 12 days (2000-09), 8 days (1977-79), 4 days (2010-16) and 2 days (1990-99) in decreasing order. Under agroclimatic zone V (Faridkot and Abohar) it was observed that no occurrence of extreme of minimum temperature $< 0^{\circ}\text{C}$ in both the decades (Table 3.11).

Table 3.11: Decadal changes in extreme minimum temperature ($< 0^{\circ}\text{C}$) events

Location	AGCL	1970-79	1984-89	1990-99	2000-09	2010-15
Ballowal Saunkhri	II	-	0	4	4	3
Amritsar	III	0	0	29	50	22
Ludhiana	III	0	1	0	6	0
Jalandhar	III	16	16	5	23	0
Patiala	III	0	0	0	2	0
Bathinda	IV	8	13	2	12	4
Faridkot	V	-	-	-	0	0
Abohar	V	-	-	-	0	0

c. Changes in the frequency of occurrence of extreme rainfall events ($> 200\text{ mm}$)

The number of extreme rainfall (number of days) events of rainfall $> 200\text{ mm}$ were computed at eight different locations (Ballowal Saunkhri, Amritsar, Ludhiana, Jalandhar, Patiala, Bathinda, Faridkot and Abohar) over past four decades (as per availability of instrumental records) in Punjab (Table 3.12). In the Agroclimatic Zone II (Ballowal Saunkhri) among all the decades the occurrence of extreme rainfall events (in number of days) during 1984-89, 1990-89, 2000-09 and 2010-15 at Ballowal Saunkhri were 33, 56, 34 and 26 days, respectively. In the Agroclimatic Zone III (Amritsar, Ludhiana and Jalandhar), among all the decades the occurrence of extreme rainfall events during 1970-79, 1980-89, 1990-99, 2000-09 and 2010-16 at Amritsar were 24, 35, 28, 29 and 24 days, respectively; during 1970-79, 1980-89, 1990-99, 2000-09 and 2010-16 at Ludhiana were 26, 30, 36, 35 and 17 days, respectively and during 1971-79, 1980-89, 1990-99, 2000-09 and 2010-14 at Jalandhar were 18, 32, 61, 68 and 21 days, respectively. During the decades 1970-79, 1980-89, 1990-99, 2000-09 and 2010-15 at Patiala they were 25, 37, 44, 30 and 16 days, respectively. Within the agroclimatic Zone IV (Bathinda) and agroclimatic zone V (Faridkot and Abohar), among all the decades the occurrence of extreme rainfall events (number of days) during 1980-89, 1990-99, 2000-09 and 2010-16 at Bathinda were 20, 30, 16 and 14 days, respectively; during 2000-09 and 2010-16 at Faridkot they were 17 and 16 days, respectively and during 2004-09 and 2010-16 at Abohar they were 6 and 6 days, respectively.

Table 3.12: Decadal changes in extreme rainfall events (number of days) of >200mm in Punjab

Location	AGCL	1970-79	1984-89	1990-99	2000-09	2010-15
Ballowal Saunkhri	II	-	33	56	34	26
Amritsar	III	24	35	28	29	24
Ludhiana	III	26	30	36	35	17
Jalandhar	III	18	32	61	68	21
Patiala	III	25	37	44	30	16
Bathinda	IV	-	20	30	16	14
Faridkot	V	-	-	-	17	16
Abohar	V	-	-	-	6	6

Palampur

Extreme Weather Events

Amidst reports of rising extreme weather events, a year round monitoring and documentation of the same was done from the data (1979-17) recorded from Agrometeorological observatory, CSK HP Agricultural University Palampur. The highest maximum temperature recorded since establishment of the observatory is 38.0 °C on 01.06.2012 with second highest of 37.2 °C on 31.05.1988. The year wise highest maximum temperature attained at Palampur is given in Fig. 3.12. The lowest minimum temperature recorded is -1.0 °C on 12.01.1989 and the second lowest of -0.5 °C on four times in December or January in the years 1985, 1990, 1992 and 2011. The year wise lowest minimum temperature recorded at Palampur is given in Fig. 3.13. The highest single day rainfall recorded is 280.6 mm on 01.08.2003 and the second highest of 268.7 mm on 17.09.2005. The year wise highest single day rainfall recorded at Palampur is given in Fig. 3.14.

Number of hail storm events (since 1990) and dew days (since 1985) are on the rise as evident from Fig. 3.15 & 3.16 at Palampur, in mid hills region of Himachal Pradesh. It may be mentioned that the dew days are increasing at the rate of 3 days per year at this station. The account of number of days with snow at and around Palampur is also given in Fig. 3.17 reveals that snowfall events have become more frequent in the last two decades.

The available records of temperature and rainfall at different locations in the state showed highest temperature of 48.5 °C at Dhaulakuan and second highest temperature 46.2 °C at Akrot. The lowest minimum temperature is -9.0 °C was recorded at Salooni and the second lowest of -4.6 °C at Bajaura. The highest single day rainfall was recorded of 430 mm at Mandi and the second highest of 375 mm was recorded at Salooni.

Parbhani

Length of growing period (LGP) characterization for Marathwada region

The information on LGP is useful for the selection of suitable crops, cropping systems and crop cultivars. Information on the start and end of rainy season helps in planning several field operations like land preparation and harvesting schedule. LGP in different soils with different water holding capacities in various districts of Marathwada region was analysed. It was observed from the results (Table 3.13) that the region has LGP between 120 to 150 days across all districts of Marathwada region.

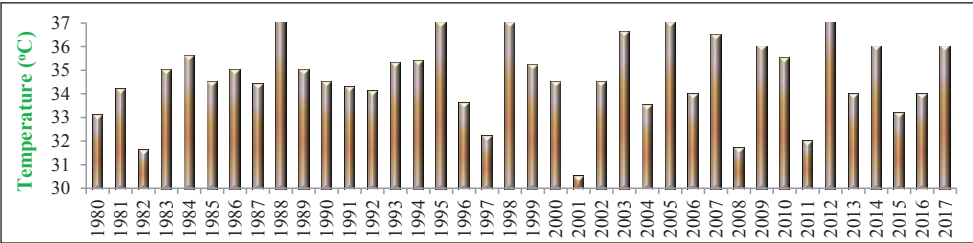


Fig. 3.12: Highest maximum temperature (°C) at Palampur station

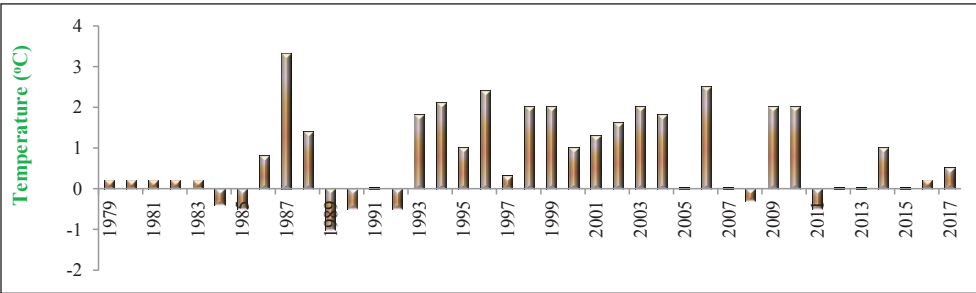


Fig. 3.13: Lowest minimum temperature (°C) in each year at Palampur station

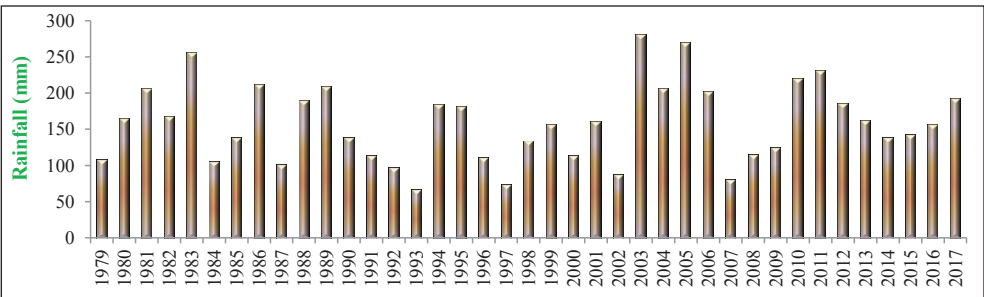


Fig. 3.14: Highest single - day rainfall (mm) in each year at Palampur station

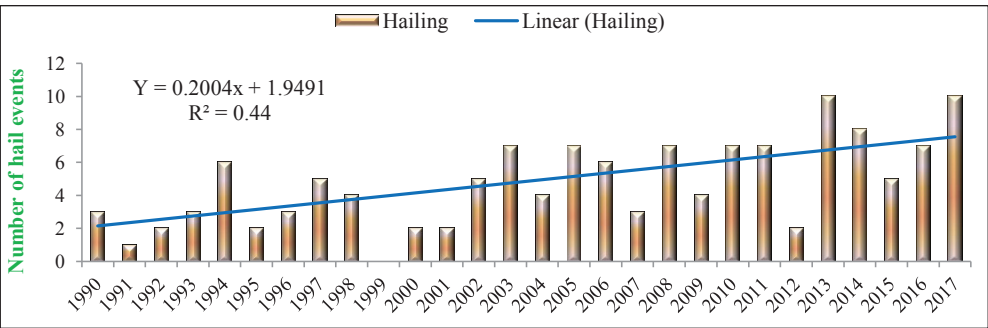


Fig. 3.15: Increasing hailfall events at Palampur in mid hills of HP

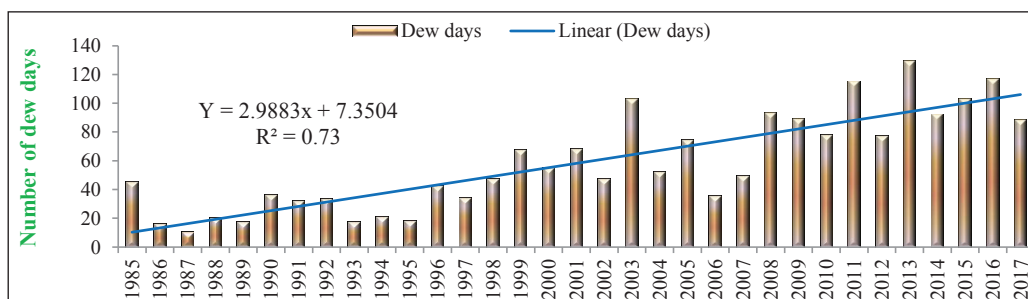


Fig. 3.16: Increasing number of dew days at Palampur in mid hills of HP

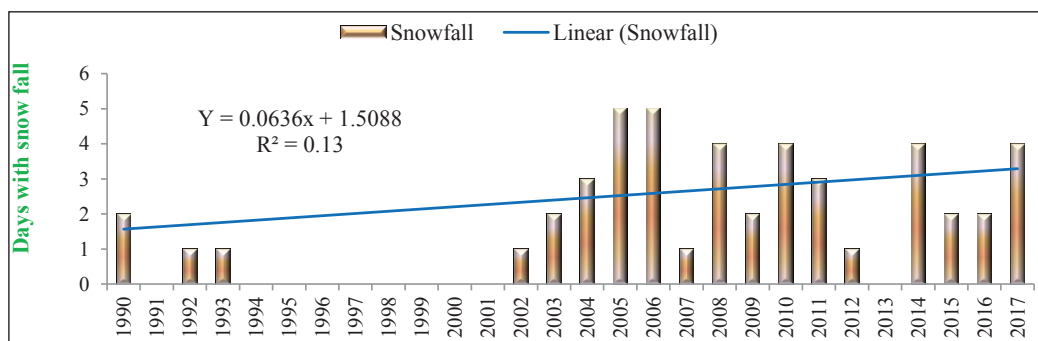


Fig. 3.17: Number of days with snow fall at and around Palampur

Table 3.13: Start, end and duration of crop growing season in soils with different water holding capacities in various districts of Marathwada region

District	50			100			150			200			250		
	Start	End	Duration	Start	End	Duration	Start	End	Duration	Start	End	Duration	Start	End	Duration
Aurangabad	26	43	18	26	45	20	26	47	22	27	49	23	27	51	25
Beed	26	43	18	26	45	20	26	47	22	27	49	24	27	51	25
Hingoli	26	43	18	26	45	20	26	47	22	26	49	24	27	51	25
Jalna	26	43	18	26	45	20	26	47	22	27	49	24	27	51	25
Latur	26	43	18	26	45	20	26	47	22	27	49	24	27	51	25
Nanded	26	43	18	26	45	20	26	47	22	27	49	24	27	51	25
Osmanabad	26	43	18	26	45	20	26	47	22	27	49	23	27	51	25
Parbhani	26	43	18	26	45	20	26	47	22	27	49	23	27	51	25
Average	26	43	18	26	45	20	26	47	22	26.9	49	23.6	27	51	25

Raipur

Dry spells analysis for different districts of Chhattisgarh state

District-wise assessment of dry spells is very important for contingent crop planning. The most crucial indicator in dry spell analysis i.e. longest spell less than critical value is having significant increasing trend at Bijapur, Janjgir-champa, Kondagaon, Korba and Sukma creating stress in rainfed agriculture (Table 3.14). Moreover, Balrampur, Bemetara, Dhamtari, Kawardha, Mahasamund, Raipur, Surajpur and Narayanpur districts showing in decreasing trend are favourable districts for rainfed agriculture. Total spells <critical value are in increasing significantly in Dantewada, Kondagaon and Sukma but are decreasing significantly in Bijapur and

Mungeli. Another crucial measure total days <critical value are showing significant increasing trend at Bijapur, Champa, Kawardha, Mahasamund, Mungeli and Jashpur but are showing significant decreasing trend in Dhamtari, Kondagaon, Rajnandgaon, Sukma and Narayanpur districts. This information can be used to select the crops and their varieties which can sustain intermittent dry spells and have inherent potential for good crop yield. It will also be helpful to determine the frequency of irrigation and water saving techniques.

Table 3.14: Measures of Dry Spells (longest spell, total spell and total days) in different districts of Chhattisgarh

S.No.	Districts	Longest Spell (< Critical Value)	Total Spells (<Critical Value)	Total Days	Longest Spell (>=Critical Value)	Total Spells (>=Critical Value)	Total Days (>=Critical Value)	Highest Value
1	Ambikapur	NS	NS	NS	NS	NS	NS	NS
2	Balod	NS	NS	NS	NS	NS	NS	NS
3	Balodabazar	NS	NS	NS	NS	NS	NS	NS
4	Balrampur	S***Dec	NS	NS	NS	NS	NS	NS
5	Bemetara	S**Dec	NS	NS	NS	NS	NS	S*Inc
6	Bijapur	S***Inc	S *** Dec	S***Inc	S***Inc	S***Dec	S***Dec	S*Dec
7	Bilaspur	NS	NS	NS	S***Dec	NS	NS	NS
8	Champa	S*Inc	NS	S*Inc	S**Dec	S ** Dec	S**Dec	NS
9	Dantewada	NS	S*** Inc	NS	NS	S *** Dec	S***Dec	NS
10	Dhamtari	S**Dec	NS	Dec **	NS	NS	NS	NS
11	Durg	NS	NS	NS	NS	NS	NS	NS
12	Gariyaband	NS	NS	NS	NS	NS	NS	NS
13	Jagdalpur	NS	NS	NS	NS	NS	NS	NS
14	Kanker	NS	NS	NS	NS	NS	NS	NS
15	Kawardha	S**Dec	NS	S*Inc	S*Inc	NS	NS	NS
16	kondagaon	S***Inc	S*Inc	S***Dec	S***Dec	S* Dec	S*Dec	NS
17	korba	S**Inc	NS	NS	NS	NS	NS	NS
18	Koriya	NS	NS	NS	NS	NS	NS	NS
19	Mahasamund	S*Dec	NS	S*Inc	S*Dec	NS	NS	S*Inc
20	Mungeli	NS	S ** Dec	S*Inc	S*Inc	S***INC	S**Inc	S*Dec
21	Raigarh	NS	NS	NS	NS	NS	NS	NS
22	Raipur	S*Dec	NS		NS	NS	NS	NS
23	Rajnandgaon	NS	NS	S**Dec	NS	NS	NS	NS
24	Sukma	S***Inc	S ***Inc	**Dec	S**Dec	S *** Dec	S***Dec	S**Dec
25	Jashpur	NS Inc	NS Dec	Inc **	Dec **	NS Dec	Dec (0.05)	NS Inc
26	Surajpur	NS Dec	NS Dec	NS Inc	NS Dec	NS Dec	NS Dec	Dec (0.05)
27	Narayanpur	NS Dec	NS Dec	Dec (0.05)	NS Dec	NS Dec	NS Dec	NS Inc

* Significant at 10% level ** Significant at 5% level *** significant at 1% level

Samastipur

Dry Spell Analysis for Samastipur and Muzaffarpur districts

Probability of occurrence of dry spells for 2 and 3 consecutive weeks ($P(2D)$) and ($P(3D)$) with a threshold rainfall amount of 10, 20, 30 and 50 mm per week have been determined and the results have been compared with initial probabilities of receiving 10 and 20 mm rainfall per week, $P(W)$. Results (Fig. 3.18a and 3.18b) revealed that the probability of consecutive two-week dry spell increases significantly after 36 SMW. Incidentally, the probability of having 10 mm weekly rainfall, $P(W)$ also decreases significantly after these periods in the respective districts. In Muzaffarpur district, rainfed crops might face moisture stress very early due to occurrence of dry spell after 36 SMW. If such period coincides with a sensitive phenological stage, this can adversely affect the crop yield, but dry period at the ripening stage of the crop particularly for *kharif* maize and short duration rice becomes sometimes beneficial.

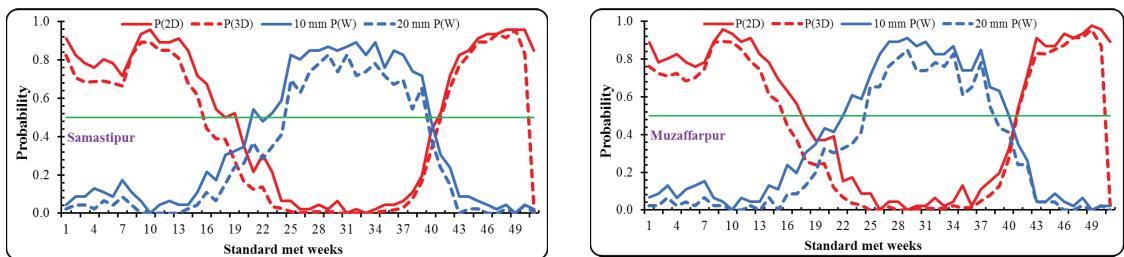


Fig. 3.18: Dry spell analysis for (a) Samastipur and (b) Muzaffarpur

Initial and conational Probability Analysis

The results pertaining to initial and conditional probabilities with threshold weekly rainfall of 10, 20, 30 and 50 mm during summer/*zaid*, *kharif* and *rabi* seasons have been analysed for Samastipur and Muzaffarpur districts of Bihar. The results includes initial probability for a wet week, $P(W)$; conditional probability for a wet week followed by a wet week - $P(W/W)$ and conditional probability of a wet week followed by a dry week - $P(W/D)$ have been presented. The initial probability of receiving 20 mm weekly rainfall, $P(W)$ at 50 per cent probability, *i.e.* 50 out 100 years started at 20 SMW and ended at 39 SMW in Samastipur district, whereas it started at 25 SMW and ended at 38 SMW in Muzaffarpur district. The conditional probability of receiving a wet week followed by wet week, $P(W/W)$ with 20 mm rainfall at ≥ 50 per cent probability prevailed during 25-40 SMW in both Samastipur Muzaffarpur districts.

Solapur

Trend analysis of heavy rainfall events (> 100 mm)

Heavy / Very heavy rainfall events can result in flash floods and impeded drainage depending on the soil type. A study was carried out on extreme weather events induced stress particularly with

reference to cereal based production system for Western Maharashtra region where cereal based cropping system is pre-dominant. Pulses and oilseeds are generally affected due to hampered drainage. When these extremes exceed the tolerance limits, the impact can be severe in terms of production and farm economics. Adaptation and mitigation strategies against flooding recommended is indigenous broad bed furrow maker through tractor as crop management technique and secondary reservoir techniques. Mainly districts of Nashik, Kolhapur, and western part of Sangli are affected by floods though temporary water logging phenomenon in low lying areas. Sorghum, maize, sugarcane crops are getting affected in areas of stream banks during July-Aug when water table is high and situation is aggravated when overflowing occurs more than 100 mm. High rainfall events of more than 100 mm have shown decreasing trend in Ajra and Gadhinglaj tehsils of Kolhapur and Patan tehsils of Satara districts while at Yaval of Jalgaon and Talodatahasil of Nandurbar district experienced increasing trend on annual basis (Fig. 3.19a). Rainfall events of more than 100 mms are decreasing at Ajra of Kolhapur and Patantahasil of Satara district at different levels of significant trend during SWM season (Fig. 3.19b). From the above analysis, it is clearly observed that majority of the stations in this region do not indicate any significant increasing or decreasing trend for heavy rainfall events. This type of information to the stakeholders helps in managing drainage, water harvesting and soil conservation measures.

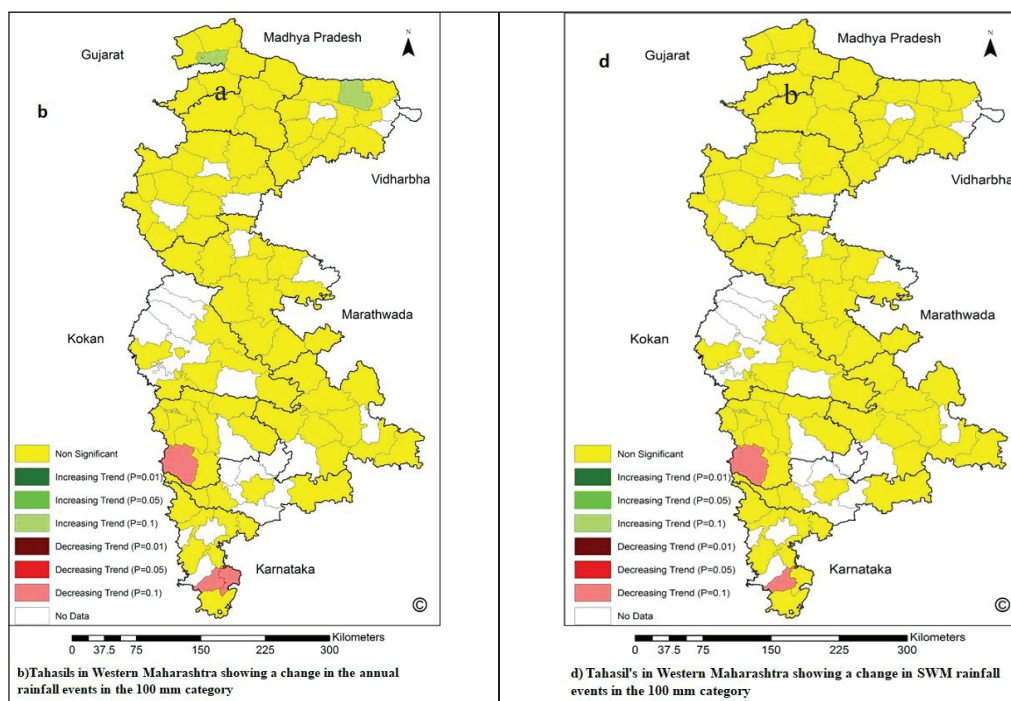


Fig. 3.19: Trends of extreme rainfall (>100mm) events during Annual and Southwest Monsoon season in different Tehsils of western Maharashtra

Thrissur

Standardized Precipitation Index (SPI) analysis for Southern Zone of Kerala

The SPI was calculated for different seasons *viz.* southwest monsoon, northeast monsoon, winter and summer for Southern Zone of Kerala. The monthly rainfall data (1983-2017) of NARP Vellayani, KAU, Thiruvananthapuram was used to calculate SPI. The SPI values were negative (dry condition) for 16 years and positive (wet condition) for 19 years during southwest monsoon season (Fig. 3.20). There were 7 drought events ($SPI \leq -1.00$) during the southwest monsoon at Vellayani *viz.* 1984 (moderately dry), 1985 (moderately dry), 1990 (moderately dry), 2001 (extremely dry), 2002 (extremely dry), 2003 (moderately dry) and 2012 (moderately dry). while during Northeast Monsoon Season, 15 years negative (dry condition) and 20 years positive (wet condition) values of SPI were observed at Vellayani. There were 4 drought events ($SPI \leq -1.00$) observed during the northeast monsoon at Vellayani *viz.* 1986 (moderately dry), 1988 (extremely dry), 2012 (moderately dry) and 2016 (extremely dry).

SPI values for winter season showed that Vellayani experienced 19 years negative (dry condition) and 16 years positive (wet condition) during winter season. There were 5 drought events ($SPI \leq -1.00$) during the winter season at Vellayani *viz.* 1983 (moderately dry), 1987 (moderately dry), 1989 (moderately dry), 1997 (moderately dry) and 2005 (moderately dry).

The SPI values during summer season were negative (dry condition) for 20 years and positive (wet condition) for 15 years. There were 5 drought events ($SPI \leq -1.00$) during the summer season at Vellayani *viz.* 1985 (extremely dry), 1987 (moderately dry) 1992 (severely dry), 1996 (severely dry) and 2000 (severely dry).

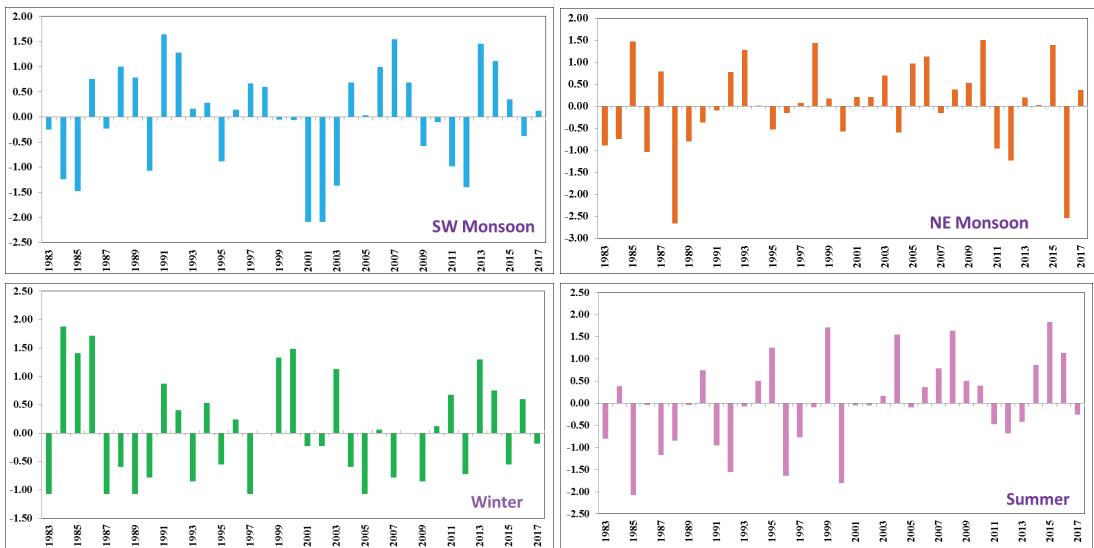


Fig. 3.20: SPI during different seasons at Southern Zone (Vellayani)

Udaipur

Analysis of one-day Extreme rainfall events

Analysis of extreme one day rainfall events across Rajasthan was carried out for the period 1989 to 2017 (28 years). It was found that the amount of highest one-day rainfall in a year changed from location to location and ranged from 196 mm in Hindoli (Bundi) to 773 mm at Mount Abu (Sirohi). Nearly 61% of the years, the highest one day rainfall occurred in July month followed by 36% of the years in August month. Sirohi district experienced 29% of the times the highest one-day rainfall events followed by Bhilwara and Banswara experience those events in 11% of the times during the last 28 year period (Fig. 3.21).

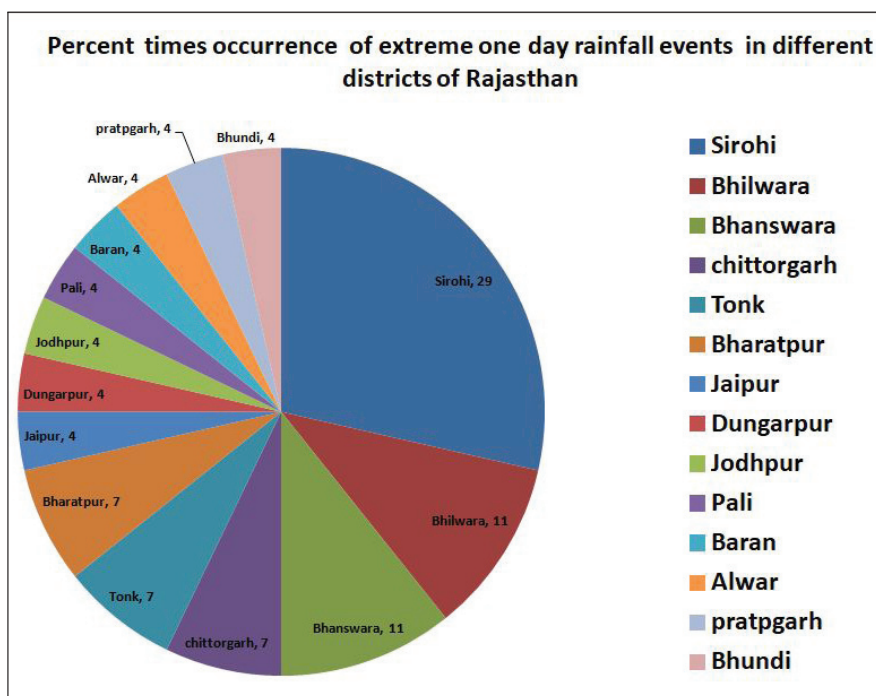


Fig. 3.21: Percentage of years of occurrence of highest one-day rainfall events in different districts of Rajasthan

Analysis of extreme weather events of Rajasthan

To detect the trends in the occurrence of extreme rainfall, length of dry and wet spells using data from 1970 to 2014, software RCLimDex v 1.0 developed by WMO-CLIVAR was used. Temporal homogeneity test was done to detect significant discontinuities or shifts in rainfall time series, using the software RHTestsV3 prior to using the data calculation of indices. A set of four indices were selected to analyze the rainfall behavior viz., the maximum one-day rainfall, daily rainfall intensity, maximum length of dry spell and maximum length of wet spells. The data are analyzed for 217 tehsils of Rajasthan and hence the trends were computed for these tehsils. The geospatial maps were prepared based on these data points by interpolation.

Episodes of maximum one-day rainfall

Results presented in Figure 1.1 showed that no significant increasing or decreasing trend was noticed in majority of tehsils (193 out of 217 tehsils) regarding maximum one-day rainfall. An increasing trend was observed in 12 tehsils only. These are located in Alwar, Barmer and Churu district (2tehsil) followed by Beawar (Ajmer), Baseri (Dholpur), Bhinmal (Jhalor), Didwana (Nagaur), Fatehgarh (Jaisalmer) and Sangria (Hanumangarh) tehsils. Declining trend was noted in 13tehsils these are located in Jaipur and Tonk district (2 tehsils) and one tehsil in each Barmer, Jalore, Jaipur, Jhalawar, Jodhpur, Karauli, Sikar, Sri Ganganagar and Swai Madhopur district.

Trends in mean daily rainfall intensity

Mean one-day amount of rain was calculated by dividing the annual rainfall by the number of wet days (rainfall > 1 mm) in each year. Out of 217tehsils analyzed only 3 viz., Bhinmal (Jalore), Dausa (Dausa) and Pindwara (Sirohi) showed increasing tendency in mean daily rainfall intensity. On the other hand only 5tehsils viz., Aklera, Jhalarapatan (Jhalawar), Kherwara (Udaipur), Mandawar (Alwar) and Mangrol (Baran) tehsils showed a declining trend.

Trends in maximum length of dry and wet spell during the SWM rainy season

The length of dry spell during crop growing season determines quality as well as the productivity of crops. No significant increasing or declining trend has been noted in 57 per cent tehsils (124 out of 217 tehsils) analyzed. However, an increasing trend has been evident in 93 tehsils out of which maximum tehsils are located in Eastern part of the state. On the other hand, none of tehsils showed declining trend in the state. Thus, it can be inferred that an increasing trend is evident in sufficient number of tehsil of the Eastern region. No significant increasing or declining trend has been noted in 36 tehsils analyzed for wet spell. However, a decreasing trend has been evident in almost in all districts. On the other hand, an increasing trend is not observed in any tehsils of the state for wet spell.

Rainfall trends: Annual rainfall trends at Udaipur for the period from 1971 to 2017 showed increasing trends by 2.51 mm/year. The five year moving average shows cyclic pattern. Annual rainfall is decreasing from 1994 to 2002, thereafter increasing trends has been observed.

Trend analysis of dry spells during South West Monsoon season across India

The dry spell is considered as the period of continuous dry days (rainfall less than 2.5 mm) during a crop season. Dry spells during Southwest monsoon is a regular phenomenon due to the break monsoon conditions. The dry spells of larger durations leads to mid and terminal droughts in agriculture. The analysis of interannual variability of dry spells (> 7 days and > 15 days) during southwest monsoon season was carried out over 1950 stations distributed across the length and breadth of the country. The longterm daily rainfall data from these stations was collected by 25 co-ordinated centres of AICRPAM. The spatial distribution of the stations selected for the study is shown in Fig. 3.22 and the period of the study is 1985-2014. Man Kendall test was carried out to verify the trends of the number of dry spells (>7 and >15 days) during SWM season for these locations and the spatially interpolated maps of the trends are furnished in Fig. 3.23a and Fig. 3.23b. The trend analysis indicates significant increasing trend in the number of dry spells (> 7

days) over the regions of Central Maharashtra (Major parts of Marathwada), Bihar, few pockets of western Maharashtra, Rajasthan and Punjab, whereas significant decreasing trend was noticed over West Bengal. However, no significant trend was observed in the number of dry spells (>15 days), except few pockets in Southwestern Maharashtra and Northern Uttar Pradesh.

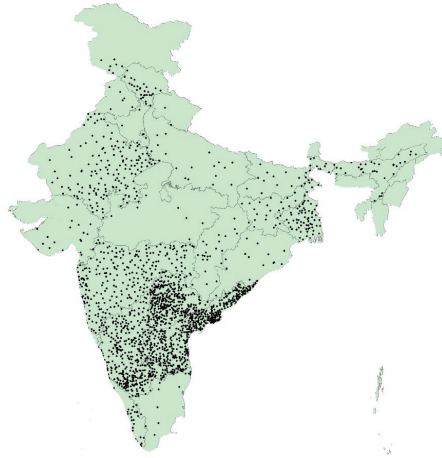


Fig. 3.22: Spatial distribution of the stations selected for the analysis

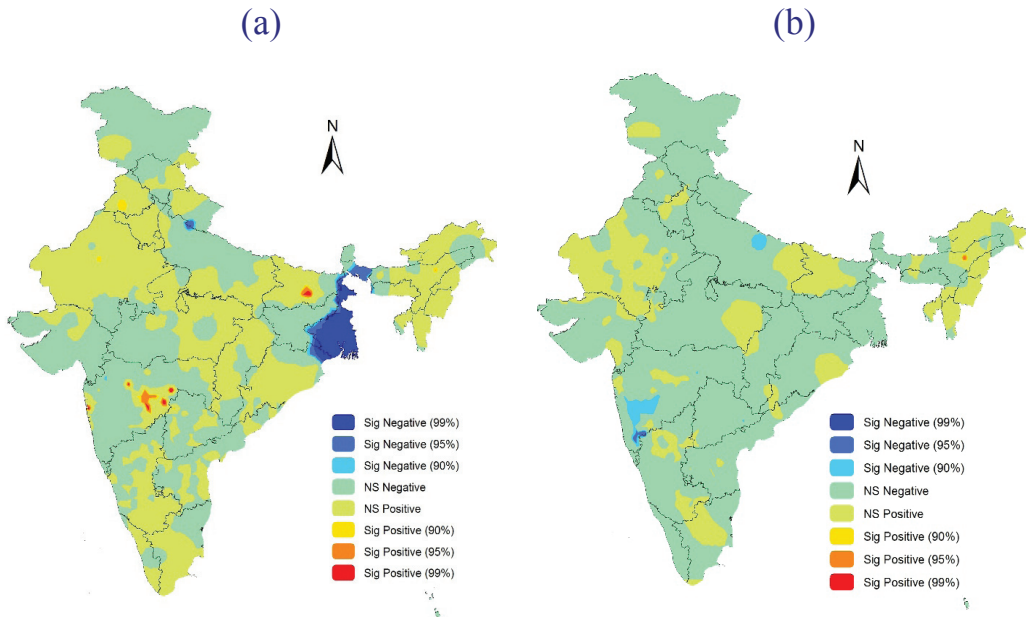


Fig. 3.23 : Spatial distribution of trend in number of dry spells (a) > 7 days and (b) > 15 days duration.

4. Crop Weather Relationship Studies

Many physiological processes in the plants are governed by the micro environment in which they grow. A better understanding of these relationships enable scientists to estimate location specific or regional crop yields in advance. The information also helps in development of genotypes/production systems and in the designing of management strategies both during growing season and post-harvest period. The results of the research carried out under crop-weather-relationship program at different AICRPAM centres are discussed here under:

Kharif 2017

Rice

Jorhat

Effect of microclimatic regimes and cultivars on rice yield was studied by exposing three cultivars (Mahsuri, Swarna Mahsuri and TTB-404) to different growing environments through transplanting it on three dates (26 June, 11 July and 27 July, 2017). Among three microclimatic regimes, highest yield (4066 kg/ha) was recorded in rice transplanted on 26 June which also received highest accumulated rainfall of 1197 mm (Table 4.1). Maximum temperature during the crop growing season was within cardinal range of temperature (27.6-35.1°C) for *kharif* rice. However, minimum temperature was below 15 °C during reproductive stage of late transplanted (late July) crop which might have affected crop yield due to spikelet sterility. Rainfall was not limiting during the crop season. More than 800 mm rainfall occurred during vegetative stage of the crop under different microclimatic regimes. Reduction in grain yield with each delay in sowing was observed due to reduction in rainfall and temperature during reproductive period.

Predictive models involving multiple phasic mean meteorological parameters corresponding to different growth stages were also developed and are presented in Table 4.2. Among the phasic mean meteorological parameters, the best model was developed with minimum temperature during ripening stage with coefficient of determination of 0.91.

Table 4.1: Yield of rice cultivars as influenced by different microclimatic regimes

Treatment	Grain yield (kg/ha)	Harvest Index (HI)	Tmax (°C)	Tmin (°C)	RF (mm)	Tmax (°C)	Tmin (°C)	RF (mm)
Micro climatic regimes			Vegetative Stage			Reproductive stage		
26 Jun	4066	0.36	33.1	25.4	1197	34	22.8	236.3
11 Jul	3678	0.37	33	22.8	880.5	29.9	20.4	138.8
27 Jul	3547	0.39	32.7	24.9	849.3	28.9	14.2	7
Mean	3764	0.37						
SE(MR)	490.3	0.032						
CD at 5%	420.6	0.027						

SE (V): Standard error of variety; SE (MR): Standard error of micro-climatic regimes

Table 4.2: Predictive models involving grain yield and phasic mean meteorological parameters in rice during *kharif* 2017 (Combined over varieties and micro-climatic regimes)

Predictive models			
Phenological events	Models	F	R ²
Vegetative	$Y = 2239.85 + 181.43DTRF$	27.52**	0.8
	$Y = 148.50 RH_{el} - 7609.53$	9.47*	0.58
Reproductive	$Y = 300.27 T_{min} - 3671.2$	7.27*	0.51
	$Y = 4475.12 - 255.77SSH$	7.68*	0.52
Ripening	$Y = 183.40T_{mean} - 998.51$	62.81**	0.9
	$Y = 1014.88 + 133.23T_{min}$	66.75**	0.91

* and ** significant at 5 and 1 percent level, respectively. DTRF: Daily Total Rainfall, RH_{el}: Evening Relative Humidity, Tmin: Minimum temperature, SSH: Sunshine hour, Tmean: Mean temperature.

Ranchi

Crop-weather relationship studies were undertaken using a field experiment in factorial RBD during *kharif* 2017 with three dates of sowing (5 Jun, 15 Jun and 25 Jun) and three rice cultivars (Sahbhagi, Naveen and MTU). Influence of growing environments and cultivars on phenology and grain yield is presented in Table 4.3. Heat unit requirement was also highest for Naveen (1798 to 1972 °C-days) as compared to Sahbhagi (1770 to 1861 °C-days) and MTU1010 (1783 to 1907 °C-days). The comparison made among different varieties and sowing dates revealed that the crop sown on 5 June registered higher efficiency than the crop planted later. The rice variety Naveen was found to be comparatively more efficient in resource utilization.

Table 4.3: Heat, and Radiation Use Efficiency of rice varieties under sowing dates.

Sowing Date/ Parameters	HUE (kg/ha/°Cday ⁻¹)			RUE (g/MJ)		
	Sahbhagi	Naveen	MTU1010	Sahbhagi	Naveen	MTU1010
5 Jun	2.7	2.9	2.7	3.0	3.2	3.0
15 Jun	2.3	2.8	2.5	2.5	3.1	2.7
25 Jun	2.1	2.8	3.0	2.4	3.2	3.3

Impacts of different weather parameters on rice yield showed that grain yield is negatively correlated with maximum temperature at all critical stages of rice (Table 4.4). Grain yield is significantly and positively correlated with rainfall at vegetative stage and negatively associated with rainfall at flowering stage for Naveen. Grain yield is significantly and negatively correlated with sunshine hours at vegetative stage for Sahbhagi.

Table 4.4: Correlation between weather parameters and grain yield of rice (4yrs pooled data).

Parameters/Stages	Vegetative	100% flowering	Milking	Grain filling	Maturity
Sahbhagi					
Max T	-0.35	-0.37	-0.02	0.02	0.01
Min T	0.05	0.16	0.25	0.20	0.09
Rainfall	0.85*	0.54	-0.06	0.39	0.10
SSH	-0.65*	-0.45	-0.16	-0.14	-0.33
Naveen					
Max T	-0.63	0.41	-0.12	0.07	0.27
Min T	-0.13	0.04	0.32	0.14	0.22
Rain	0.89*	-0.76*	0.47	0.25	-0.41
SSH	-0.28	-0.35	-0.13	0.02	-0.32

Raipur

Three cultivars of rice, MTU-1010, Rajeshwari and CG Sugandhit Dhan were exposed to three growing environments (transplanted on 01 Jun, 15 Jun, 30 Jun 2017). Highest grain yield (57.6 q/ha) was recored in 15 Jun transplanted rice followed by 01 June transplanted rice (52.8 q/ha) and the least being in the third date. The higher yield in D2 and D3 which are at par may be attributed to favorable maximum and minimum temperature during milking to maturity (Table 4.5). The lower yield in D1 may be due to unseasonal heavy rainfall in the dough stage.

Table 4.5: Grain yield (q/ ha) of rice varieties under different growing environments in *kharif* 2017

Dates of Sowing	Yield (q/ha)	HUE (g/m ² /°C day)	RUE (g/MJ)	Weather parameters during Reproductive phase		
				Tmax (ML-M)	Tmin (ML-M)	RF (ML-D)
D1	2574	0.72	2.04	32.3	25.1	142.2
D2	4019	1.19	3.36	31.7	24.8	43.8
D3	3895	0.81	2.04	32.5	24.7	31.0
SEm ±	190					
CD (P=0.05)	480					

ML-M, Milking to maturity; ML-D, Milking to Dough

Palampur

Three rice cultivars (Basmati-370, Kasturi Basmati, Pusa Basmati) were grown under three growing environments (transplanted on June 15, June 30 and July 15) in 2017 under a RBD design. In the case of third date of sowing (July 15), there was no panicle initiation in all the three varieties (Table 4.6).

Table 4.6: Dates on which different phenophases were completed

Treatment	Emergence	Tillering	Panicle initiation	Heading	Grain filling	Phy. mat.
D ₁ V ₁	22-Jun	15-Jul	26-Jul	02-Oct	13-Oct	28-Oct
D ₂ V ₁	08-Jul	04-Aug	16-Aug	12-Oct	24-Oct	-
D ₃ V ₁	25-Jul	23-Aug	-	-	-	-
D ₁ V ₂	21-Jun	15-Jul	25-Jul	02-Oct	11-Oct	25-Oct
D ₂ V ₂	07-Jul	02-Aug	15-Aug	08-Oct	17-Oct	30-Oct
D ₃ V ₂	25-Jul	23-Aug	-	-	-	-
D ₁ V ₃	22-Jun	15-Jul	26-Jul	02-Oct	12-Oct	28-Oct
D ₂ V ₃	08-Jul	04-Aug	16-Aug	11-Oct	22-Oct	-
D ₃ V ₃	24-Jul	23-Aug	-	-	-	-

The reason for no panicle initiation was investigated by comparing the temperature data of two locations viz., Palampur and Jammu (Chatha) where the experiments were conducted and are given in Table 4.7. Jammu (Chatha) witnessed 9.0-9.5 °C, higher temperature than Palampur during Sowing to emergence in first date of sowing. The temperature during second and third date of sowing were also respectively higher by 4 and 10 °C than Palampur. On an average, the temperature during emergence to physiological maturity were higher than Palampur by 4.5 to 6.5 °C.

Table 4.7: Comparison of mean temperature observed during different phenophases

Treatment	Jammu (Chatha)					Palampur				
	S-E	E-T	T-P	P-H	H-P	S-E	E-T	T-P	P-H	H-P
D ₁ V ₁	32.3	29.9	29.3	28.3	24.7	22.7	23.5	23.5	22.5	20.3
D ₂ V ₁	28.0	29.7	28.9	28.7	21.2	24.2	23.2	23.5	22.0	-
D ₃ V ₁	33.8	29.5	28.5	26.7	17.2	23.7	23.1	-	-	-
D ₁ V ₂	31.7	29.8	29.2	28.0	26.2	22.7	23.5	23.2	22.5	20.3
D ₂ V ₂	28.0	29.5	28.9	28.5	22.9	24.2	23.2	23.5	22.0	-
D ₃ V ₂	33.7	29.6	28.4	27.4	19.2	23.6	23.1	-	-	-

S-E- Sowing to emergence, E-T- Emergence to tillering, T-P- Tillering to panicle initiation, P-H- Panicle initiation to heading, H-P- Heading to physiological maturity

Maximum grain yield of 33, 183, 83 kg/ha was obtained for Basmati-370, Kasturi Basmati and Pusa basmati, respectively for June 15 sowing which is sub-optimal. The results indicate that the thermal regime (sowing dates) of Palampur location/station is suboptimal for basmati varieties. Hence, the sowing is required to be advanced/preponed to the month of May in order to realize the better/higher temperature conditions so that flowering maturity comes in time.

Mohanpur

A field experiment was conducted for rice with four dates of transplanting [16 Jun (D1), 01 Jul (D2), 16 Jul (D3), 31 Jul (D4)] with three varieties (Swarna, IET 5656; Satabdi, IET-4786; Nayanmani, Local). The rice yield in D1, D2, D3 and D4 were 4365, 3721, 3043 and 289 kg/ha, respectively. It was observed that during flowering to grain filling stage of D2, crops nurtured under low sunshine hour which might affect the grain filling procedure. In addition, due to higher (36-37 °C) maximum temperature, chaffy grain production was more in the year 2017. The maximum temperature under D3 and D4 was higher level up to flowering stage and it was at lower level under D2 and D1. Higher air temperature during panicle imitiation and flowering stage may be the probable causes for having such result (Fig. 4.1).

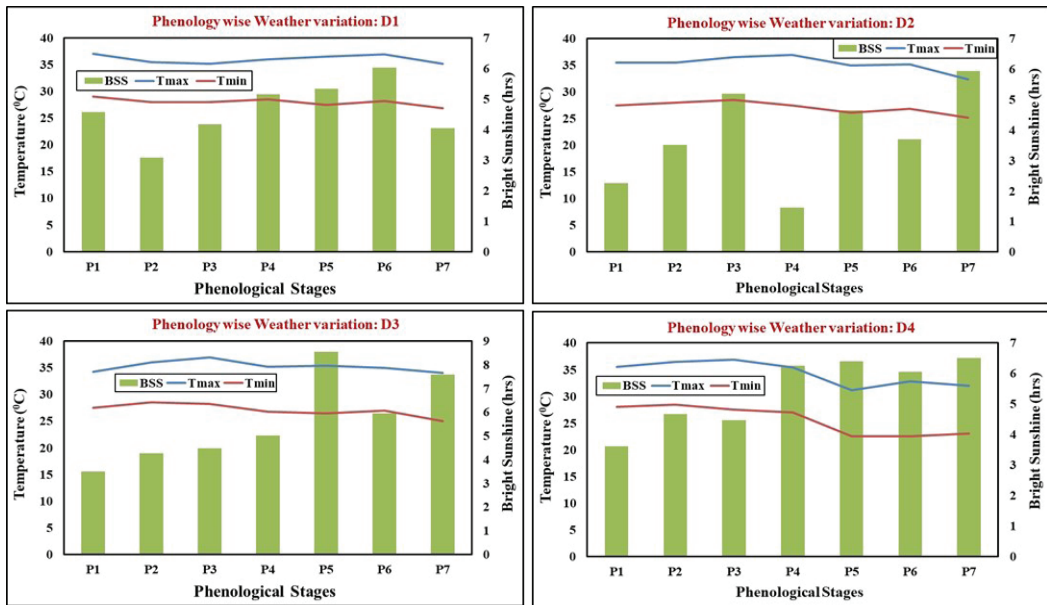


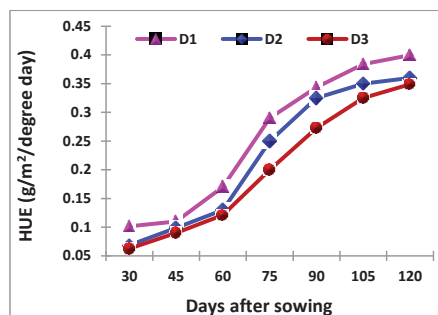
Fig. 4.1: Phenological stagewise variation of bright sunshine hour, maximum and minimum temperature under four dates of transplanting (P₁ = Tillering, P₂ = Panicle Initiation, P₃ = 1st Anthesis, P₄ = Flowering, P₅ = Milking, P₆ = Dough and P₇ = Maturity)

Jammu

Rice cultivars Pusa 1121, Basmati 370 and Local basmati 123 were planted with three methods (Direct seeding, SRI and conventional transplanting) to study the crop weather relationships. The direct seeding was done on three dates (01, 20 June and 10 July), transplanting in SRI method was done on three dates (13 June, 01 and 21 July) transplanting in conventional method was done on (20 June 10 and 30 July). Significant high seed yield was observed when crop was sown early. The rice yield decreases by 14.9 and 28.7 per cent with 20 and 40 days delay in sowing/transplanting, respectively as compared to early sown crop due to reduced GDD, HTU and PTU accumulated at physiological maturity with each delay in sowing (Table 4.8).

Table 4.8: Effect of dates of sowing/ transplanting on yield of rice cultivars during *Kharif* 2017

Treatments	Grain Yield (q/ha)	GDD (°C day)	HTU	PTU
			(°C day hrs)	
D1	30.96	2700	18431	35345
D2	26.95	2446	15981	31290
D3	22.06	2174	13565	26984
CD at 5%	2.25			
V1	32.04	2386	15745	30635
V2	24.44	2454	16045	31353
V3	23.49	2480	16187	31063
CD at 5%	1.24			

**Fig.4.2:** Effect on Heat use efficiency (g/m²/°C day) at fortnight interval under various environments during *Kharif* 2017

The heat use efficiency increases till physiological maturity of the basmati rice crop sown under different treatments. The sowing/transplanting environments significantly affected the heat use efficiency and found highest under early sowing/ transplanting basmati rice crop than the normal and late. The heat use efficiency found maximum were 0.40, 0.36 and 0.35 g m⁻²°C⁻¹ day⁻¹ at 120 days after sowing/transplanted under D1, D2 and D3, respectively (Fig. 4.2).

Dapoli

Rice cultivars Karjat-5, Palghar-1, Jaya, Swarna, Karjat-2 were grown under three growing environments (08, 15, 21 Jun 2017) in a split plot design to understand the response of sowing times on the growth and yield of different rice varieties. Data presented in Table 1 revealed that, the rice crop sown on 23 SMW recorded significantly higher grain yield (5942 kg/ha) over delayed sowing on 25 SMW and it was at par with crop sown during 24 SMW. The rice variety Swarna recorded the significantly higher grain yield of 5851 kg/ha than the remaining varieties except, Jaya and Karjat-5; which were at par with rice variety Swana. The interaction effect between different sowing dates and rice varieties with respect to grain yield found to be significant and depicted in Table 4.9. Maximum heat units of 2215 °C-day was required by 23 SMW transplanted crop and 2319 °C-day for the variety Karjat-2.

Maize

Kanpur

Crop weather relationship in maize was studied under three growing environments i.e., 19, 29 Jun and 09 July with three cultivars (Azad Hybrid-1, Azad Hybrid-2, DKC-7074) during *kharif* 2017. A higher Heat Use Efficiency (HUE) of 7.73 g/m²/°C-day during whole crop season was recorded in 19 June sown crop and it was higher than the HUE in subsequent 10 days delayed sowing. The progressive decrease in total dry matter and yield was observed with each delay after the 19 June sowing. Among the varieties, heat use efficiency of three varieties are influenced by varietal difference and varying thermal environment. Azad hybrid-2 recorded highest HUE (7.87 g/m²/°C-day) followed by Azad hybrid-1 (7.66 g/m²/°C-day) and DKC-7074 (7.35 g/m²/°C-day) during whole crop span (Table 4.10). Due to higher rainfall and temperature, length of cob (cm), number of grains per cob, grain weight per cobe and 100 grain weight (g) as well as

Table 4.9: Grain yield (kg/ha) of rice as influenced by different sowing time and varieties

Sowing dates	Grain yield	Harvest Index (%)	GDD (°C-day)	Crop duration (days)	Weather parameters		
	(kg/ha)				Tmax (°C)	Tmin (°C)	SSH (hr)
S ₁ - 23 SMW (08 Jun)	5942	36.62	2215	133	29.0	23.0	1.9
S ₂ - 24 SMW (15 Jun)	5697	37.08	2190	131	28.8	23.0	2.0
S ₃ - 25 SMW (21 Jun)	4783	37.65	2163	130	28.9	22.8	2.1
SE ±	204	--					
CD at 5%	799	--					
Varities							
V ₁ - Karjat – 5	5621	37.11	2135	128			
V ₂ - Palghar – 1	5087	37.24	2083	125			
V ₃ - Jaya	5831	37.18	2095	126			
V ₄ - Swarna	5851	36.97	2313	139			
V ₅ - Karjat – 2	4981	37.09	2319	139			
SE ±	242	--					
CD at 5%	706	--					
Interaction:							
SE ±	418.65	--					
CD at 5%	1221.96	--					

yield were found significantly superior, when the crop was sown 19 Jun followed by 29 Jun. The lowest yield was recorded under 9 July sowing crop (6290 kg/ha). Among the varieties, Azad hybrid-2 produced significantly higher yield (6470 kg/ha).

Table 4.10: Effect of thermal indices and rainfall on yield of Maize (*Kharif* 2017)

Treatment	Plant height (cm)	100 grain wt.(g)	Yield (kg/ha)	HUE (g/m ² /°C-day)	Temperature (°C)		Rainfall (mm)
					Max.	Min.	
19 June	239.3	25.4	6290	7.73	34.2	25.8	617.2
29 June	222.7	25.3	5920	7.61	33.2	25.3	596.1
09 July	223.8	24.5	5340	7.42	33.9	25.0	504.0
SE±(d)	4.96	0.26	184	-	-	-	-
CD at 5%	12.37	0.64	460	-	-	-	-
Azad Hyd-1	47.7	24.7	5930	7.66	33.8	25.3	597.6
Azad Hyd-2	50.8	26.1	6470	7.87	33.8	25.3	517.5
DKC-7074	42.9	24.3	5150	7.35	33.7	25.4	506.3
SE± (d)	0.86	0.17	136	-	-	-	-
CD at 5%	1.82	0.36	289	-	-	-	-

Kovilpatti

Four maize cultivars (S 6850, NK 6240, RMH 3033, COH(M)-6) were grown under four growing environments (Planting dates viz., 29 Sep (D1), 03 Oct (D2), 09 Oct (D3), 16 Oct (D4)) to study the effect of phenology, thermal requirements and grain yield of prominent *rabi* maize hybrids under rainfed condition. The sowing windows viz., D1, D2 and D3 received equal quantum of rainfall (421.9 mm) and rainy days (17) since the first rainfall was received on 13.10.2017 with 29.5 mm. The D1, D2 and D3 sowings received higher rainfall during seedling, knee high and tasseling stages. D₄ sowing recorded higher rainfall during seedling and knee high stages only. Lesser amount of rainfall was received at irregular intervals throughout the crop growth in D1, D2 and D3 treatments which was not observed in D4. The 09 Oct sown crop recorded the higher grain yield (4871 kg/ha) and stover yield (8870 kg/ha) than the other sowing windows. The lowest grain yield (4345 kg/ha) was registered in the 26 Sep sown crop. Maize hybrid COH (M) 6 recorded the higher grain yield (5650 kg/ha) than other hybrids tested. This was followed by NK 6240 hybrid (Table 4.11).

Table 4.11: Influence of sowing windows on yield of maize hybrids under rainfed condition during 2017-18

Treatments DOS	Grain yield (kg/ha)	Stover yield (kg/ha)	Weather during crop season											
			Seedling stage				Silking stage				Dough stage			
			Tmax	Tmin	SSH	RF	Tmax	Tmin	SSH	RF	Tmax	Tmin	SSH	RF
26 Sep	4345	7904	34.5	24.1	5.1	142	31.7	19.4	6.8	0.2	32.4	18.9	7.4	0.4
03 Oct	4478	8150	34.5	24.1	5.1	142	31.7	19.4	6.8	0.2	32.4	18.9	7.4	0.4
09 Oct	4871	8870	34.5	24.1	5.1	142	31.7	19.4	6.8	0.2	32.4	18.9	7.4	0.4
16 Oct	4752	8648	34.0	24.0	5.5	124	32.3	19.8	7.8	0.0	32.7	18.5	7.8	0.0
CD (5 %)	112	238												
Hybrids														
S 6850	4813	8788												
NK6240	5493	10030												
RMH 3033	5393	9815												
COH (M) 6	5650	10303												
CD (5%)	131	246												

Pearl millet

Hisar

Effect of growing environments and cultivars on yield and radiation balance of Pearl millet was studied in a field experiment with three dates of sowing viz., 25-30 Jun (D1), 10-15 Jul (D2), 25-30 Jul (D3) and three cultivars (GHB-558, HHB 67, HHB-272). The grain yields were decreased with delay in sowing (Table 4.12). The D1 sown crop produced higher yield compared to other dates of sowing. The D₂ sown *bajra* crop had higher Heat use efficiency (HUE) of 0.071 g/m²/°C-day at 14 DAS followed by D₁ and D₃ (Table 4.xx). In rest of the stages, early sown

crop (D₁) has higher HUE from 21 DAS till physiological maturity compared to D₂ and D₃ sown crops. The correlation coefficient between seed yield and minimum temperature was found to be significantly negative (-0.66*) and with rainfall to be significantly positive (0.59*) (Table 4.13).

Table 4.12: Accumulated thermal use efficiency (g/m²/°C-day) under different sowing dates and varieties in *Bajra* during year 2017

	Grain Yield	Accumulated HUE		
	(kg/ha)	(g/m ² /°C-day)		
		14 DAS	42 DAS	PM
D1	3241	0.065	0.671	0.88
D2	3093	0.071	0.521	0.708
D3	2982	0.04	0.434	0.51
CD / ± SD	89.1 (CD)	± 0.016	± 0.120	± 0.185
CV %		27.8	22.1	26.4

Table 4.13: Correlation between weather, yield and yield attributes of pearl millet crop at Hisar

Correlation between weather & yield attributes		
Parameters	Veg. phase	Rep. phase
Tillers/ plant	0.154	0.844*
1000-seed weight (g)	0.18	0.915*
Grain yield (kg/ha)	0.18	0.937*
Stover yield (kg/ha)	0.181	0.925*
Biological yield (kg/ha)	0.181	0.932*

Anand

Pearlmillet varieties GHB-538, HB-558 and GHB-744 were grown under three growing environments (sown on 27 June, 07 & 17 July 2017) to study the effect of various growing environments on crop performance. Sowing at onset of monsoon provided optimal growing environment to two out of three cultivars and they produce higher which declines almost linearly with delay sowing (Fig.4.3). Cultivar GHB 744 has maximum productivity under timely sowing (at onset of monsoon) followed by GHB 558 and GHB 5383. Performance of GHB 538 was very poor for first showing might be due to poor plant stand. In late sowing (onset + 10 days) and very late sowing (onset + 20 days), productivity of GHB 538 was higher than GHB 558. In general, it seems that sowing on onset of monsoon provides favourable growing environment for pearl millet crop during its life cycle. Considering production performance of the cultivars under different growing environments, optimal weather variable ranges for different phenophases of the crop was determined (Table 4.14).

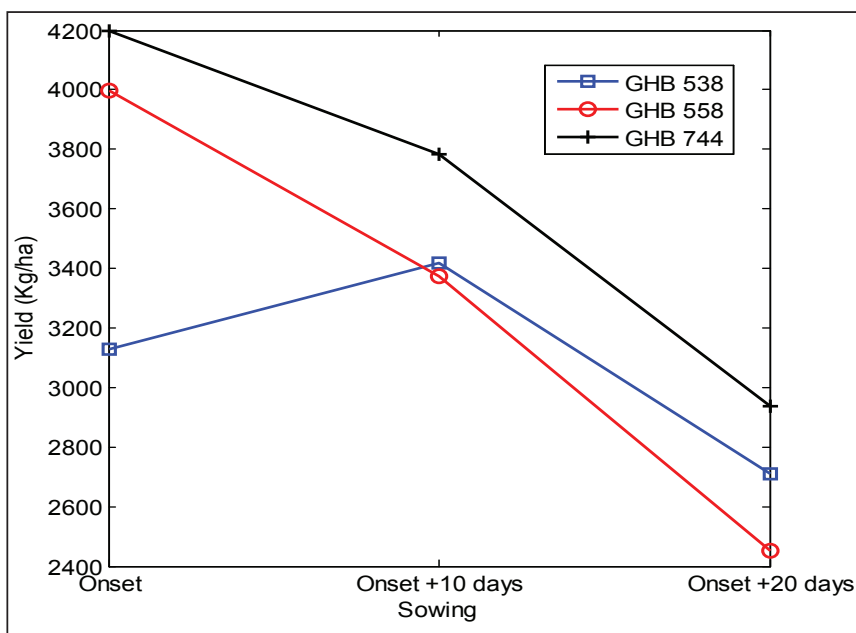


Fig. 4.3: Productivity of pearl millet cultivars during different rainfed growing environments.

Table 4.14: Optimum weather condition for different phenophases of pearl millet crop for high productivity

Phase	BSS (h)	MinT (°C)	MaxT (°C)	Rain (mm)	RHm (%)	RHe (%)
Emergence- Booting	0.0-9.7	22.8-26.6	26.0-35.1	0-85	80-100	55-100
Booting -50% Flowering	1.1-6.5	24.0-25.0	30.5-33.2	0-5	89-95	63-83
50% Flowering-100% flowering	2.1-8.7	24.0-24.5	31.0-33.0	0-8	89-93	55-70
100% flowering –Grain filling	0.0-10.0	25.0-26.0	30.2-34.4	0-4	83-100	53-85
Grain filling – Phy. maturity	0.0-9.6	23.0-26.2	30.2-35.6	0-55	85-100	56-100

Solapur

Crop-weather relationship in Pearl millet was studied under three growing environments sown on 2nd fortnight of June, 2nd fortnight of July and 2nd fortnight of August with three varieties (ICTP-8203, Mahyco hybrid and Dhanshakti) for consecutive five years (2013-2017). The pooled data (Table 4.15) indicates that *kharif* pearl millet sown in second fortnight of July (S2) produced significantly higher grain yield (1711 kg/ha) and biomass yield (3563 kg/ha) due to higher mean consumptive use of moisture (319 mm) and mean moisture use efficiency (5.2 kg/ha/mm). The highest mean values of RUE recorded by the crop sown in second fortnight of July (1.98 g / MJ) at 50 per cent flowering stage in almost all the sowing dates and genotypes. It was also revealed that with delayed sowing low mean values of RUE were recorded.

Table 4.15: Pooled grain yield (kg/ha) of *kharif* pearl millet as influenced by various sowing dates and varieties (2013-17)

Treatment	Mean grain yield (kg ha ⁻¹)	Mean fodder yield (kg ha ⁻¹)	CUM (mm)	MUE (kg/ha/mm)
Sowing dates				
S ₁ = SMW 26 (Jun 26-Jul 01)	1453.3	2641.3	303	4.8
S ₂ = SMW 30 (Jul 23-29)	1711.3	3562.6	319	5.4
S ₃ = SMW 35 (Aug 27-2 Sep)	1002.8	2232.2	285	3.5
S.E.± (Sowing dates)	159.9	307.1		
C.D. at 5 %	521.6	1001.5		
Varieties				
V ₁ = ICTP-8203	1239.8	2575.2	292	4.2
V ₂ = Mahyco hybrid	1353.2	2668.7	299	4.5
V ₃ = Dhanshakti	1574.4	3192.3	315	4.9
S.E.± (Varieties)	35.7	81.1		
C.D. at 5 %	104.2	236.7		
S.E.± (SD X V)	61.8	140.5		
C.D. at 5 %	NS	NS		

Finger millet

Bangalore

Moisture depletion pattern at different phenological phases in rainfed crop finger millet was taken up in Alfisols of Karnataka. Depletion of soil moisture from field capacity to wilting point were studied at different phenophases of the test crops and its effect on seed yield was analyzed. The percentage available soil moisture (PASM) was calculated using the following formula:

$$\text{PASM} = \{(\text{SM}_w - \text{PWP}) / (\text{FC} - \text{PWP})\} \times 100,$$

where SM_w = Weekly soil moisture (vol/vol), PWP=Permanent wilting point of the soil (vol/vol), FC= Field capacity of soil (vol/vol).

Generally majority of the rainfed crops in the semiarid tropics reach the wilting point below 33.3 per cent of PASM. Below 50 per cent to 33.3 per cent of PASM, the actual evapotranspiration by the crops is very low, and hence crops just survive but do not grow. This leads to the drastic reduction of grain or pod yield. When the PASM is below 33.3 per cent, crops start drying and withering of leaves begins, as no soil moisture is available to the crop at root zone, thereby, crops do not flower or grain formation does not takes place or grain filling and maturity are severely affected, even if the grain formation stage is reached, leading to no grain or pod yield.

For declaration of drought prone areas in India, the following PASM values may be taken as one of the criterion in addition to other mandatory criterias (rainfall deficiency, SPI, NDVI etc.) as defined in drought manual of Govt. of India. However, for declaration of drought in India, PASM value suggested is 0 to 25 (severe drought) as an impact of criteria, irrespective of the crop. This needs to be modified in the light of the below mentioned results.

Finger millet is a drought resistant staple food crop widely grown in South India, particularly in Alfisols of Karnataka. The relationship established between grain yield and PASM is depicted in Fig.4.4. The values of PASM at different phenological phases were averaged for six years, tabulated and correlations were worked out with seed yield of the crop. The results of six years (1995-2001) showed that at 58 PASM, the finger millet yield was reduced by 50 per cent (1500 kg/ha) and at 40 PASM, 25 per cent of optimum seed yield (800 kg/ha) was obtained. The interpolation of the curve depicts lower threshold of PASM as 22 per cent. In finger millet, drought classification can be made as: 20-40 PASM (severe), 40-60 PASM (Moderate), >60 PASM (no drought). Thus, the threshold value of 50 per cent may be considered to differentiate drought and non drought areas, irrespective of crop.

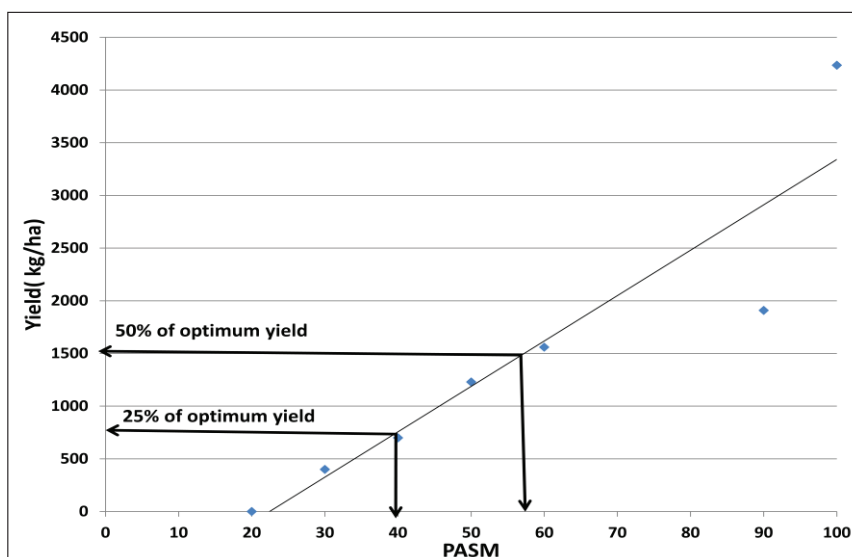


Fig. 4.4: Relationship of grain yield (kg/ha) of finger millet with PASM

Soybean

Vijayapura

A field experiment with split plot design was taken up at Dharwad during *kharif* 2016 & 2017 with three dates of sowing (22 Jun, 06 and 17 Jul) and two cultivars (JS 335, DSb 21) to study the effect of weather on phenophase development and develop predictive models for growth and development. The yield of first date of sowing is higher in both the years as compared to other dates (Table 4.16).

Table 4.16: Growing environment wise soybean yield during 2016 and 2017

Year	Yield (Kg/ha)	Tmax (°C) (whole crop period)	Tmin (°C) (whole crop period)	Seasonal temperature range (°C)
2016				
GE-1	2109	27.0 - 31.0	20.5 to 17.5	6.5 - 13.5
GE-2	1643			
GE-3	369			
2017				
GE-4	2738	27.5 - 29.0	22.0 to 20.5	5.5 - 8.5
GE-5	2200			
GE-6	2069			

The maximum temperature during vegetative stage to maturity varied between 27.5 °C and 29.0 °C during 2017, whereas during the year 2016, there was considerable variation, from 27.0 °C in vegetative stage to 31.0 °C at maturity. On the other hand, the minimum temperature was also nearly constant (22.0 °C to 20.5 °C) during crop growth period of the year 2017, compared to 20.5 °C to 17.5 °C in the year 2016. In the low yielding GE3 of 2016, the maximum temperature increased sharply while minimum temperature decreased sharply from flowering to maturity. The lower yield level in 2016 can also be attributed to lower seasonal temperature range (6.5 - 13.5 °C) as compared to 2017 (5.5 - 8.5 °C).

It is noticed that rainfall was high (more than 70 mm) in GE4 and GE5, whose yield is highest and it was almost zero in GE1 and GE6 (Fig.4.5). During 2017 the total rainfall was more or less constant in flowering and pod formation and filling stages in all the three growing environments of 2017 (about 100-130 mm), which can be considered as a favorable event of rainfall occurrence for higher yield (Fig. 4.5). On the other hand, from pod filling stage there was only marginal increase in cumulative rainfall in GE4 compared to the GE5 and GE6. This suggests that “certain” total rainfall during flowering and pod formation and filling is important to obtain high yield of soybean crop. However, further increase in rainfall from flowering to maturity did not contribute to yield in GE2 and GE3.

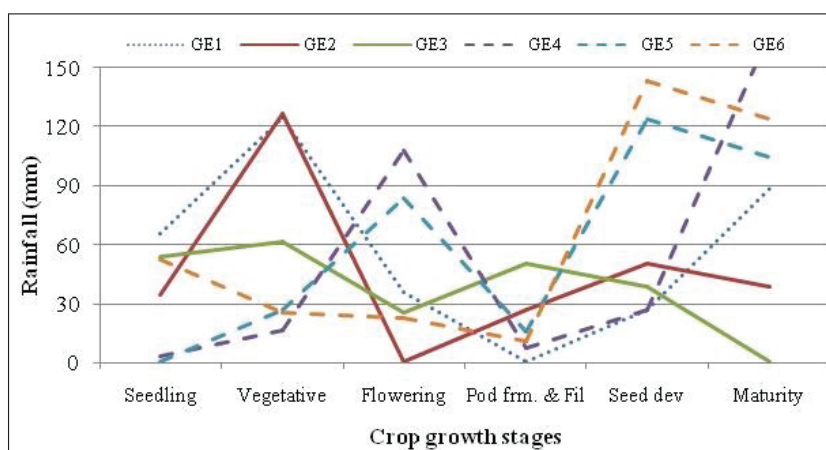


Fig. 4.5: Rainfall during the crop growth period at Vijapapura

Udaipur

Three soybean cultivars viz., JS-335, RKS-45 and RKS-18 were grown on three growing environments (sown on 21 Jun, 01 Jul, 11 Jul) to study the crop weather relationships. The highest grain yield of 1089 kg/ha was obtained under 21 Jun sown crop which was significantly superior over 1 Jul and 11 Jul sown crop varieties by 33.1 and 73.9 per cent, respectively due to more sunshine hours and higher rainfall (607 mm) during the season. The crop sown on 11 Jul though received highest rainfall of 528 mm during early vegetative phase, exposed to prolonged dry spell of 21 days after 70 DAS to harvest coinciding with the initiation of seed development caused severe yield reduction in all varieties. However, the crop sown on other dates experienced longer dry spell leading to further reduction in yield. The lowest yield (460 kg/ha) obtained in 11 Jul sown crop may be attributed to rainfall of only 159 mm during reproductive phase as compared to first two dates. Among all the three varieties, RKS-45 recorded highest grain yield under all growing environments and seed yield has positive relationship with receipt of rainfall during crop growth period (Table. 4.17).

Table 4.17: Interaction effect of growing environments and varieties on seed yield (kg/ha) of soybean

Sowing env. / varieties	JS-335 (kg/ha)	RKS-45 (kg/ha)	RKS-18 (kg/ha)	Mean (kg/ha)	Tmax (°C)	Tmin (°C)	SSH (hrs)	RF (veg. stage) (mm)	RF (Rep. stage) (mm)	Dry spell during seed dev. to maturity
21-Jun	1076	1631	561	1089	31.5	22.7	4.7	528	223	21 days
01-Jul	747	1158	549	818	30.8	22.3	4.2	415	219	29 days
11-Jul	460	915	502	626	30.7	21.9	4.3	444	159	33 days
Mean	761	1235	537							
SEm ±	27.4									
CD (P=0.05)	81.4									

Pigeon pea

Bangalore

The correlation of PASM (Per cent available soil moisture) and biomass in all sowing windows clearly showed that that PASM and seed yield have significant positive correlation. Crop yield recorded under severe drought ranged from 202.2 (8.1 % of no drought situation) to 347.8 kg/ha (18.5 % of no drought situation). PASM and seed yield relationship in Fig.4.6 (2011-2017) clearly indicated that the percent increase in yield is high with the increase in PASM as a single factor above 50 per cent PASM. Hence, any PASM < 25 will lead to crop failure. The PASM values in different stages of pigeonpea crop over all sowing windows indicated that under severe drought class (<25 PASM) during pod filling stage an average of 20 per cent of the yield was obtained, while an average of 43 per cent of the yield was obtained under severe drought during flowering stage (Fig. 4.7). Thus optimum moisture at these stages are crucial for getting potential yield of the crop. The classification for drought severity can be taken up as: 25-30 PASM (severe), 30-60 PASM (Moderate), > 60 PASM (no drought) for pigeon pea.

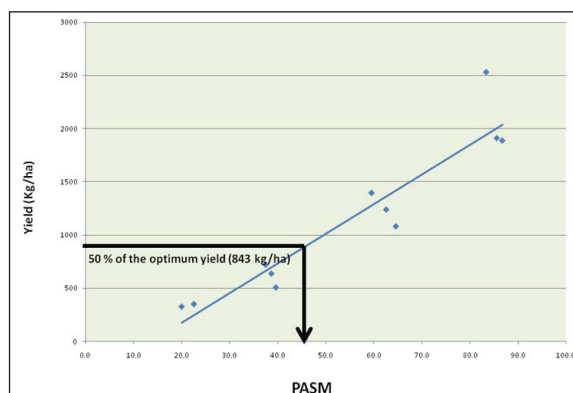


Fig. 4.6: Relationship between PASM and seed yield (kg/ha) in Pigeonpea

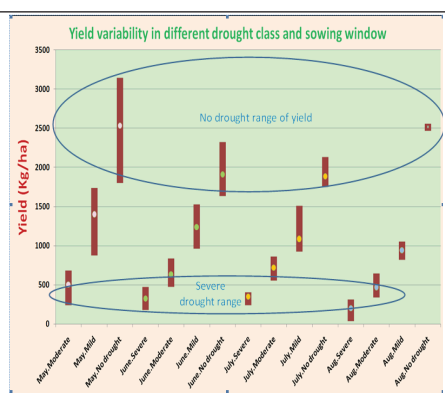


Fig. 4.7: Yield variability in different drought class and sowing windows

Greengram

Mohanpur

A field experiment was conducted to study the effect of temperature on green gram at Mohanpur under three growing environments i.e., 7 Sep (D1), 17 Sep (D2) and 28 Sep (D3) and three Varieties (Meha, PM 05, Samrat). It was observed that the crop matured 15 days earlier in case of first date of sowing (D1) compared to other dates, irrespective of variety. Irrespective of dates of sowing and variety, crops grown under D2 produced highest average yield (1720 kg/ha) followed by D3 (1657 kg/ha) and D1 (1363 kg/ha). However, Samrat is found best for cultivation in this region with an average productivity of 1653 kg/ha. Therefore, it can be concluded that last fortnight of September is the best sowing time for green gram cultivation as the crops cultivated at the 2 half of September grown under favourable mean temperature range (28–30°C) during the reproductive stage (Fig. 4.8)

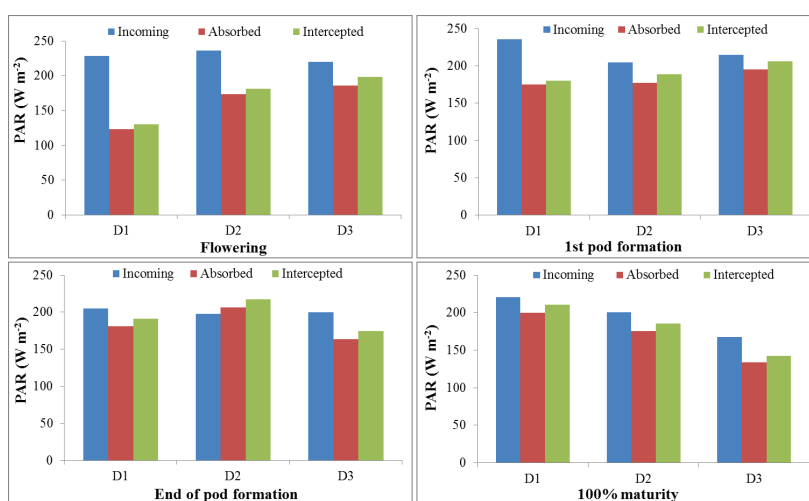


Fig. 4.8: Variation in incoming, absorbed and intercepted PAR during various phenophases of greengram

At the early phenological stages, D1 sown crops intercepted comparatively low PAR than other two sowing dates. Whereas, the absorption and interception pattern was reversed during the maturity period when D3 cultivated crops absorbed low PAR. This may be due to having lesser crop canopy under D3 sown crops compared to D1. Crops sown in D2 showed a steady interception pattern throughout its growing period and this may be the another reason for its highest yield.

Jorhat

Monitoring of crop stress was undertaken in Greengram at Jorhat centre using canopy-air temperature difference (CATD). Three varieties viz., Pratap, SGC-16 and Samrat varieties were exposed to three growing environments (sown on 5 Sep, 21 Sep and 7 Oct 2017) and periodic observations on canopy and air temperature were taken using infra-red thermometer. Late sown crop suffered from water stress during early vegetative growth, compared to early sown crops as revealed by the positive CATD values (Fig. 4.9). Stress-free days with more negative CATD values were observed during reproductive stage in all the three cultivars. In case of seed yield, crop sown on 21 Sep performed better due to lesser moisture stress during the crop growth period as compared to crop sown on 5 Sep and 7 Oct.

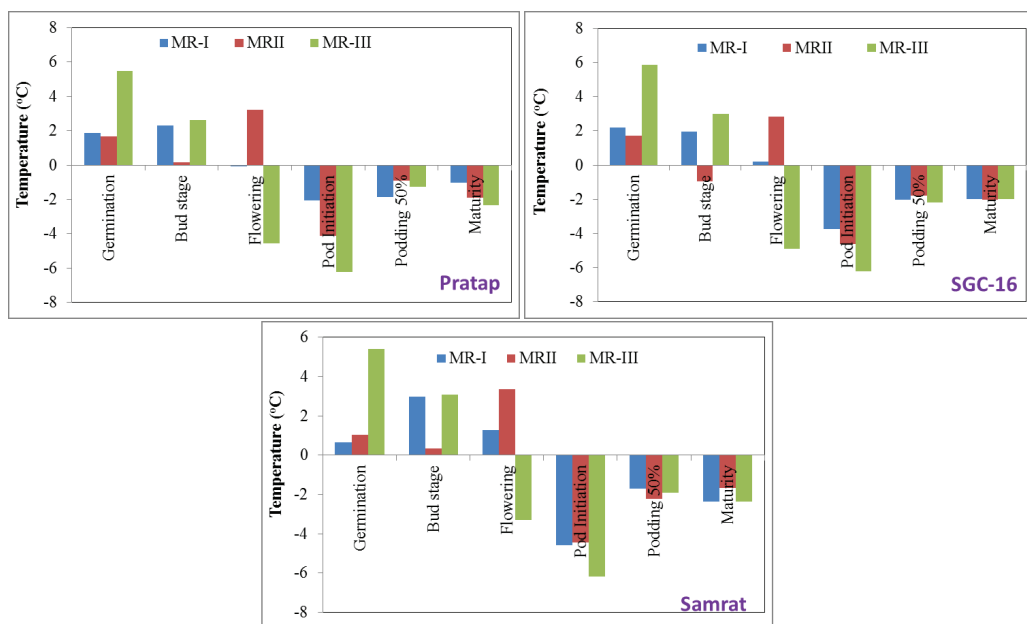


Fig. 4.9: Effect of growing environments on canopy-air temperature difference in greengram

Correlation of weather parameters with seed yield indicated significant positive correlation (0.69*, 0.76*, 0.66*) with maximum temperature during Budding, Flowering and 50% podding stages and with minimum temperature during budding and 50% podding (0.80*, 0.77*) (Table 4.18). Afternoon Relative Humidity (RH II) and Pan Evaporation during reproductive stage had also showed significant positive correlation with yield.

Table 4.18: Correlation coefficient values between yield and weather parameters at different phenophases of greengram at Jorhat

Phase	Tmax	Tmin	Tmean	RH (%)			RF	Pan E	SSH
				RH I	RH II	RHmean			
Germination	-0.74*	-0.33	-0.63	0.06	0.77*	0.48	0.83**	-0.84**	-0.89**
Budding	0.69*	0.80*	0.77*	0.43	0.88**	0.83**	0.85**	0.74*	-0.82**
Flowering	0.76*	0.70*	0.73*	-0.37	0.69*	0.72*	0.76*	0.80**	-0.45
50% Podding	0.66*	0.77*	0.76*	-0.62	0.75*	0.80**	0.77*	0.77*	-0.60
Phy. Maturity	0.72*	0.71*	0.71*	-0.56	0.70*	0.85**	0.77*	0.76*	0.03

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

Groundnut

Anantapur

Groundnut varieties K6, Kadiri Harithandra, Dharani, Anantha were grown under three growing environments (sown on 1st & 2nd FN of Jul and 1st FN of Aug). Crop sown during 2nd FN of Jul (2622 kg/ha) produced significantly higher yield compared to 1st FN of Jul (2303 kg/ha) and 1st FN of Aug (1766 kg/ha). Among four varieties, Kadiri Harithandra (2373 kg/ha) achieved significantly highest pod yield over other three varieties (Table 4.19). Dharani (2295 kg/ha) recorded higher pod yield than Anantha (2137 kg/ha) and K6 (2089 kg/ha), while Anantha and K6 varieties recorded on par pod yield. The higher yield in 27 July sown crop may be attributed to higher sunshine hours during both vegetative and reproductive stages and higher rainfall (123.6 mm) during pegging to pod development stage.

Table 4.19: Pod yield (kg/ha) as influenced by growing environments and varieties of groundnut under protective irrigation and rainfed conditions during *khari*f 2017

Treatment	Yield (kg/ha)	Vegetative stage				Reproductive stage			
		Tmax	Tmin	RF*	SSH	Tmax	Tmin	RF**	SSH
13-Jul	2303	33.9	24.5	7.5	4.3	32.5	23.9	16.6	6.1
27-Jul	2622	34.5	24.7	15.2	6.5	32.2	23.2	123.6	6.6
11-Aug	1766	32.5	24.0	11.2	4.9	32.0	22.9	43.4	5.6
CD (P=0.05)	130								

*-Rainfall during sowing to emergence; **- Rainfall during pegging to pod development

Bangalore

The PASM values in different stages of groundnut crop indicated that moderate drought (25-50 PASM) at pegging/pod formation stages, a crucial stage for yield of the crop will result in obtaining 41 per cent of yield. The PASM values of more than 50 at all phenological phases of the crop were of satisfactory ranges and they have no negative effect on crop yield. At PASM values of 38-41, per cent, the pod yield was 29 per cent (278 kg/ha) of the optimum yield (962 kg/ha under no drought). PASM and yield relationship in Fig.4.10 (based on 2011-2017 data)

indicates that the percent increase in yield was high with the increase in PASM as a single factor above 50 per cent PASM and any PASM ≤ 25 will lead to crop failure. The classification for drought severity in groundnut can be made as: 35-50 PASM (Severe), 50-70 PASM (Moderate), >70 PASM (No drought).

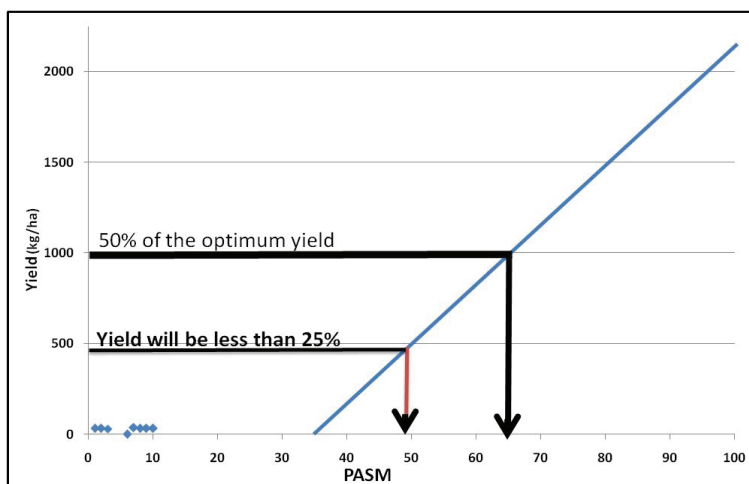


Fig. 4.10: Relationship of groundnut yield (kg/ha) and PASM

Sorghum

Kovilpatti

Four sorghum varieties K 12, K 8, CSV 20, RSV 1006 (Phule Revathi) were grown with three growing environments viz., 39 SMW-25 Sep (D1), 41 SMW-09 Oct, 43 SMW-23 Oct) to study the effect of varied time of sowing on crop weather relationships. Sowing during 39th and 41st standard week registered significantly increased grain yield (1463 and 1478 kg/ha) (Table 4.20). The higher yield in the first two dates of sowing may be attributed to higher rainfall and optimum sunshine duration during both vegetative and reproductive stages.

Table 4.20: Influence of sowing windows on yield of sorghum under rainfed condition during 2017-18

Treatments	Grain yield	Stover yield	Tmax (°C)	Tmin (°C)	SSH (hrs)	Rainfall (mm)	Tmax (°C)	Tmin (°C)	SSH (hrs)	Rainfall (mm)
Date of sowing	(kg/ha)		Vegetative stage				Reproductive stage			
D ₁ : 39 th SMW	1463	10788	33.3	23.5	4.2	400	32.1	20.3	6.8	22.5
D ₂ : 41 st SMW	1478	10713	33.3	23.5	4.2	400	32.1	20.3	6.8	22.5
D ₃ : 43 rd SMW	1160	9288	32.7	23.2	5.6	330	32.4	19.9	7.0	1.9
SEd	109	514								
CD (5 %)	304	1426								

Sunflower

Solapur

Crop weather relationship studies in sunflower was undertaken during 2013-2017 by sowing three cultivars (Bhanu, MSFH-17 and Phule Bhaskar) under three growing environments viz., 2nd fortnight of Jun (D1), 2nd fortnight of Jul (D2) and 2nd fortnight of Aug (D3). The five years data were considered for pooled analysis. The crop sown in second fortnight of Jul (D2) produced significantly highest grain yield (1708.2 kg/ha). However, among the genotypes Phule Bhaskar produced significantly higher grain yield (1446.8 kg/ha) than the other two cultivars. *Kharif* sunflower sown in second fortnight of July (S2) recorded higher mean consumptive use of moisture (320 mm) and mean moisture use efficiency (5.3 kg/ha/mm) number of days to attain physiological maturity (92 days), total dry matter (400.8 g/m²) and LAI (0.95). A linear relationship between CUM and grain yield with higher correlation coefficient of 0.87 was obtained (Fig. 4.11). Further, a significant positive linear relationship of yield with RUE and a curvilinear relationship with maximum temperature was obtained (Fig.4.11). From these relations, it can be inferred that, CUM of 350 mm and maximum temperature of around 32-33 °C are optimum limits for obtaining highest yields.

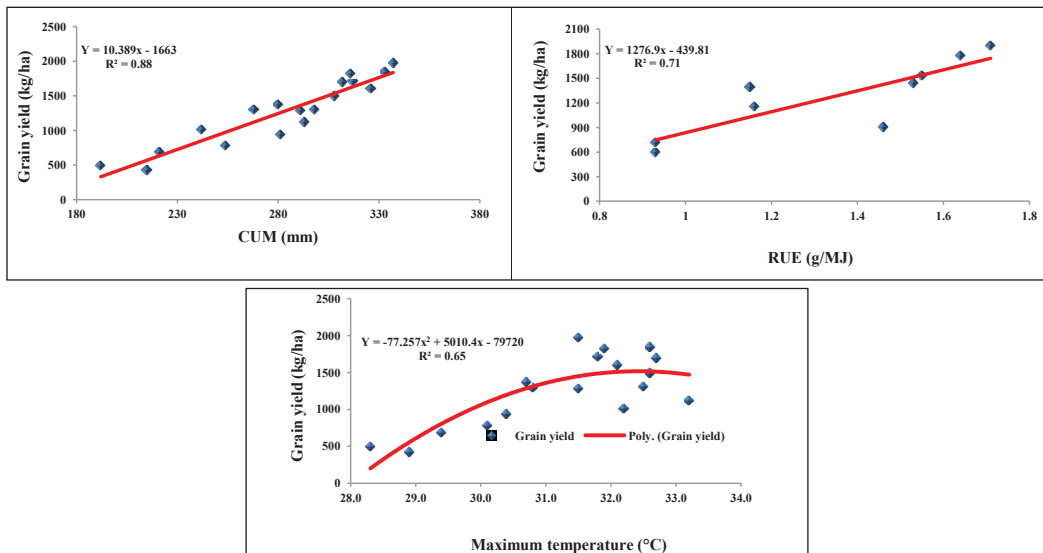


Fig.4.11: Relationship between CUM, RUE and maximum temperature in Sunflower

Rabi 2017

Wheat

Ludhiana

The historical (1971-2015) wheat productivity of Ludhiana district was used for detrending of wheat productivity. Between 1970-71 and 2011-12, the wheat yield has increased by 3279 to 5375 kg/ha and maximum and minimum temperatures have increased by 0.02 and 0.05 °C per

year, respectively resulting in a change of maximum and minimum temperature from 24.1-25.0 °C and 8.8-11.2 °C, respectively. Out of the detrended productivity data of 45 years, the 12 years of highest detrended productivity (>5500 kg/ha) were selected for further analysis. The ranges were calculated starting from 45th SMW upto 15th SMW, as these weeks cover the period of normal date of sowing upto harvest of wheat crop and the temperature outside these weeks had little effect on wheat productivity. The upper and lower limits were in close aggreement (Fig.4.12) with the actual maximum and minimum temperature during the years 2015-16 (low productivity year) and 2016-17 (high productivity year).

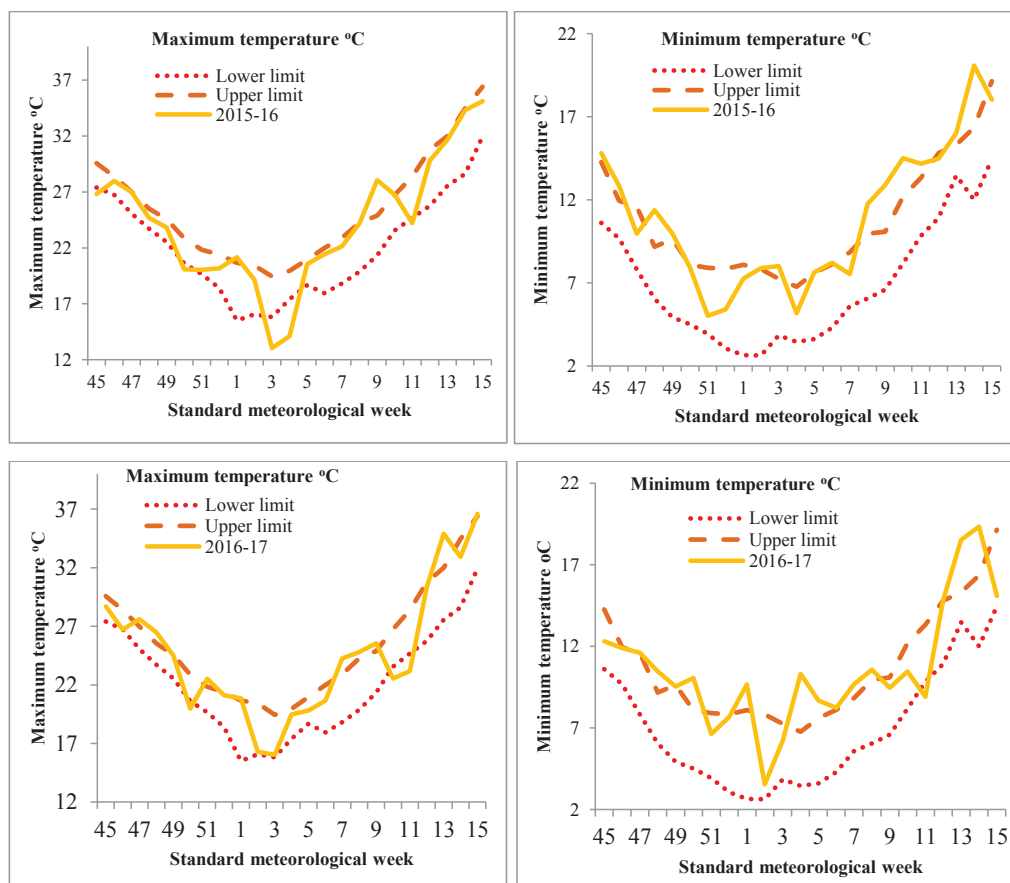


Fig 4.12: Comparison of actual temperatures (2015-16, lower productivity year; 2016-17, higher productivity year) with the range of temperatures (high and low productivity years) in Ludhiana district of Punjab

Palampur

Wheat cultivars HD-2967 (V1), HS-490 (V2) and VL-907 (V3) were grown under four growing environments viz., Nov 5 (D1), Nov 20 (D2), Dec 5 (D3), and Dec 20 (D4) to study crop weather relationships in wheat under irrigated condition. The 05 Nov (D1) and 05 Dec (D3) sown crop produced higher and on par yield (2500 and 2580 kg/ha, respectively) where as fourth date (20

Dec) gave lowest yield (1820 kg/ha). The lower yield may be attributed to higher temperatures during T-H and H-GF phases (Table 4.21).

Table 4.21: Effect of various growing environments on yield of wheat cultivars during 2017-18 at Palampur.

Date of sowing	Yield (Kg/ha)	Tmax (°C)					Tmin (°C)				
		S-E	E-T	T-H	H-GF	GF-M	S-E	E-T	T-H	H-GF	GF-M
05 Nov.	2500	23.4	19.7	18.9	23.6	26.3	10.1	7.3	6.1	10.7	14.0
20 Nov.	1970	20.1	18.4	20.4	26.2	26.0	5.8	5.7	7.5	12.2	14.3
05 Dec.	2580	18.9	18.3	20.7	26.7	26.9	8.7	4.9	8.0	13.7	15.3
20 Dec.	1820	18.4	18.0	23.3	25.8	27.7	5.1	4.7	10.3	14.4	16.0

E-Emergence, T-Tillering, H-Heading, GF-Grain Formation, M-Maturity

SASE analysis was also carried out to identify critical stages and critical weather parameters for wheat by pooling data (2010-11 to 2015-16) of five wheat cultivars viz., HS-490, VL-892, VL-829, VL-804 & VL-907 and over four dates of sowing viz., 5 Nov, 20 Nov, 5 Dec and 20 Dec. The yield and phenophase-wise weather parameters were fitted and it was ascertained that, in wheat, tillering to heading (T to H) and heading to grain filling (H to G) phases where highly sensitive to raising temperatures. Further, the negative impact of rising Tmin during T to H & H to G was found higher (169-207 kg/ha/°C) than that of Tmax (134-157 kg/ha/°C) (Table 4.22). The analysis further suggest that for obtaining >40 q/ha yield for irrigated wheat, the maximum and minimum temperatures, 15.5-20.7°C and 4.2-9.4 °C during T to H and 20.5-25.9 °C and 7.9-13.8 °C during H to G were found to be ideal. With delay in sowing the rising maximum and minimum temperatures decreased the yield (Table 4.23). These limits were tested during 2017-18 for varieties HS-490 & VL-907 and were found to be in agreement with the identified thresholds. It can be seen that the 1.5°C higher maximum temperature and 3.0°C higher minimum temperature during T to H and 0.5°C higher maximum temperature and 1.0°C higher minimum temperature during H to G caused 20q reduction in the yield in irrigated wheat.

Table 4.22: Ideal temperature during critical phenophases of irrigated wheat (varieties HS-490 & VL-907)

			Tillering - Heading (T to H)	Heading - Grain filling (H to G)
Temperature (°C)	Ideal temperature for >40 q/ha yield	Max	15.5-20.7 (18.1)	20.5-25.9 (23.2)
		Min	4.2-9.4 (6.8)	7.9-13.8 (10.8)
	for yield of >20 q/ha (as in 2017-18)	Max	11.2-28.0 (19.5)	19.0-28.5 (23.7)
		Min	1.3-19.0 (10.1)	7.0-17.0 (12.0)

Table 4.23: Simple regression model for wheat yield using different parameters at different phenological phases of five cultivars

Weather Parameters	Statistics	S-E (GS5)	E-T (GS 14)	T-H (GS21, G31 & GS 60)	H-G (GS73 & GS 83)	G-M (GS 91)
Maximum Temperature	Intercept	1955.29731	1669.88171	5962.03531	6289.52204	6218.68261
	Linear	56.83806	82.37128	-157.25435	-134.13020	-112.71243
	t-value	1.21	1.42	-2.78	-2.94	-1.75
	Pr > t	0.2286	0.1598	0.0064	0.0041	0.0838
	Adj. R ²	0.0042	0.0090	0.0571	0.0642	0.0181
	Pr > F	0.2286	0.1598	0.0064	0.0041	0.0838
Minimum Temperature	Intercept	2801.55124	2811.06627	4260.25855	5567.33564	4522.70438
	Linear	40.76875	56.00266	-168.81245	-207.07498	-93.94383
	t-value	0.84	0.60	-2.51	-3.87	-1.44
	Pr > t	0.4029	0.5474	0.0137	0.0002	0.1538
	Adj. R ²	-0.0027	-0.0058	0.0454	0.1120	0.0095
	Pr > F	0.4029	0.5474	0.0137	0.0002	0.1538

Ranichauri

An experiment was conducted in a randomized block design (RBD) having treatment combinations of three growing environments (30 Oct, 20 Nov, 05 Dec 2017) and three varieties *i.e.* VL-892, UP-2572 and HD-2967 laid under three replications. Grains/panicle was not influenced significantly by sowing dates and varieties. Sowing on second date significantly resulted in higher grain and stover yields as compared to first and third sowing dates (Table 4.24). Influence of varieties were found to be non significant for grain yield, though higher grain yield was observed in VL-892. The reason for higher yield in the 15 Nov sown crop could have been the higher plant population (218 per m²) under this sowing compared to other dates of sowing due to higher thermal regime (maximum and minimum temperature) prevailed in 31st Oct to 15th Nov sown crops.

Table 4.24: Wheat yield of wheat cultivars as influenced by sowing dates and varieties during *rabi* 2017-18 at Ranichauri

Treatments	Plant population (/m ²)	Grain Yield (kg/ha)	Weather during vegetative stage				Weather during reproductive stage			
Sowing Dates			Tmax (°C)	Tmin (°C)	RF (mm)	SSH (hrs)	Tmax (°C)	Tmin (°C)	RF (mm)	SSH (hrs)
31 Oct.	200	1193	16.4	4.6	79.2	7.3	21.7	9.4	123.3	8.4
15 Nov.	218	1597	16.1	4.2	79.2	7.2	21.9	9.7	123.3	8.4
30 Nov.	165	725	16.0	4.1	79.0	7.2	21.9	9.7	123.3	8.4
SEm ±		81								
CD (P=0.05)		245								

Kanpur

Wheat cultivars HD-2733, K-307, K-9107 and HD-2967 were grown under three growing environments, viz., 15 Nov., 30 Nov, and 15 Dec during *rabi* 2017-18. It was observed that lower maximum and minimum temperature during reproductive stages was more congenial for mineralization of nutrients in soil and nutrients uptake which might be responsible for higher yield (5060 kg/ha) in 15 Nov. sowing as compared to gradually delayed sowing of 30 Nov. (4290 kg/ha) and 15th Dec. (3670 kg/ha) (Table 4.25). Higher yield in case of 15 Nov sowing can be attributed to higher growing degree days (1641.2 °C-days) and heat use efficiency (7.98 kg/ha/°Cday) as compared to 30 Nov. and 15 Dec. sowing.

Table 4.25: Yield and HUE as influenced by different sowing environments during 2017-18 at Kanpur

Treatment	Yield (kg/ha)	GDD (°C-days)	HUE (kg/ha/°Cday)	Tmax (°C)	Tmin (°C)	SSH (hrs)	Tmax (°C)	Tmin (°C)	SSH (hrs)
Dates of sowing				Vegetative stage			Reproductive stage		
15 Nov.	5060	1641.2	7.98	23.8	8.3	3.9	27.7	11.6	7.6
30 Nov.	4290	1565.8	7.57	23.4	8.2	5.2	30.2	13.6	7.9
15 Dec.	3670	1512.9	7.33	22.7	8.3	5.0	32.9	15.6	8.3

Weather parameters during various crop growth phases showed positive relationships of temperature (Max., min. and soil temperature) during vegetative phase (emergence to tillering) with the grain yield. Temperature (Tmax, Tmin and STmean) at all stages during reproductive period (Jointing to maturity) showed highly negative relationship with grain yield. However, the duration of vegetative and reproductive phases, respectively had negative and positive correlations with grain yield (Table 4.26).

Table 4.26: Correlation coefficients between grain yield and phenophase-wise weather parameters of wheat during 2017-18 at Kanpur

Dates of Sowing	Growth stages	Weather parameters			
		Tmax (°C)	Tmin (°C)	ST _{mean} (5 cm)	Duration
Grain yield	Emergence	0.89	0.89	0.87	-0.78
	CRI	0.84	0.36	0.77	-0.76
	Tillering	0.54	0.84	0.83	-0.68
	Jointing	-0.87	-0.76	-0.80	-0.17
	Panicle Ini.	-0.78	-0.85	-0.84	-0.06
	Flowering	-0.80	-0.88	-0.83	0.34
	Anthesis	-0.83	-0.87	-0.87	0.53
	Milking	-0.88	-0.83	-0.84	0.70
	Dough	-0.89	-0.83	-0.88	0.73
	Maturity	-0.88	-0.85	-0.87	0.78

Jammu

Crop-weather relationship studies were conducted in wheat with cultivars HD 2967, Raj-3077 and RSP-561 under four growing environments (05, 20 Nov and 05, 20 Dec 2017). Late sown crop (20 Dec) required less days for reproductive stages, which is due to abrupt rise in temperature. RUE reached maximum in the crop at 110 days after sowing and thereafter showed decreasing trend under all the dates of sowing. The crop sown on 05 Nov registered highest RUE ($1.64 \text{ g MJ}^{-1} \text{ m}^{-2}$) followed by 1.26, 1.01 and $0.84 \text{ g MJ}^{-1} \text{ m}^{-2}$ for 20 Nov, 05 Dec and 20 Dec sown crops, respectively. Among the varieties HD-2967 showed highest RUE ($1.25 \text{ g MJ}^{-1} \text{ m}^{-2}$) at all intervals of after sowing followed by RSP-561 ($1.14 \text{ g MJ}^{-1} \text{ m}^{-2}$) and Raj-3077 ($1.11 \text{ g MJ}^{-1} \text{ m}^{-2}$). The higher RUE registered by the variety HD-2967 was reflected in its higher yield. Grain yield found at par for 5 Nov (39.31 q ha^{-1}) and 20 Nov (37.54 q ha^{-1}) sown crop (Table 4.27.).

Table 4.27: Effect of sowing environments and variety on yield and yield attributing characters of wheat crop during *rabi* 2017 -18.

Treatments	Grain yield (kg/ha)	Harvest Index	Days taken for phenophases		Cumulative rainfall (mm)		RUE (g/MJ/m^2)
			Sowing to Heading	Heading to Phy. maturity	Heading	Physiological maturity	
D ₁ (05 Nov)	3931	29.84	122	46	143.0	218.1	1.64
D ₂ (20 Nov)	3754	30.1	123	34	168.8	223.8	1.26
D ₃ (05 Dec)	3436	30.98	111	37	169.0	251.9	1.01
D ₄ (20 Dec)	3085	33.64	103	33	74.4	173.2	0.84
SE(m)	87	0.25					
CD at 5%	250	NS					
V ₁ (HD-2967)	3785	31.01					1.25
V ₂ (Raj-3077)	3282	29.43					1.11
V ₃ (RSP-561)	3588	30.93					1.14
SE(m)	22	0.22					
CD at 5%	89	NS					

Barley

Hisar

Four Barley cultivars namely BH 393, BH 902, BH 946, BH 885 were grown under four growing environments. viz., 1st week of Nov (D1), 2nd week of Nov and 1st week of Dec (D3) and 2nd week of Dec (D4) to study crop weather relationships. The D1 sown barley crop had higher thermal use efficiency (HUE) i.e. 0.80, 0.73 and $0.66 \text{ g/m}^2/^\circ\text{C-day}$ at 105, 120 DAS and physiological maturity followed by the HUE at vegetative stages under D2, D3 and D4 (Table 4.28). The HUE was observed highest at 105 DAS in all sowing environment and varieties. Among the sowing dates, D1 was superior in RUE throughout the crop period followed by D2, D3 and D4. The RUE was observed highest at 105 DAS in all sowing environment and varieties due to higher biomass accumulation at this stage.

The barley yield was highest for 03 Nov sown crop (5900 kg/ha) followed by the yield of 5300, 4810 and 3620 kg/ha under 18 Nov, 03 Dec and 19 Dec sown crops, respectively. The highest yield in 03 Nov crop may be attributed to higher radiation utilization and optimum use of thermal energy during the crop period.

Table 4.28: Effect of growing environments and varieties on yield attributes and yields of Barley

Treatments	Seed yield	HI %	Heat use efficiency		Radiation use efficiency		AGDD
	(kg/ha)		(g/m ² °C day)		(g/MJ)		
			60 DAS	Phy. Mat.	60 DAS	Phy.Mat.	°C day
D ₁ - 3 Nov.	5900	45.1	0.29	0.66	0.9	1.51	1508
D ₂ - 18 Nov.	5300	43.9	0.35	0.63	0.75	1.3	1529
D ₃ - 3 Dec.	4810	41.7	0.37	0.59	0.72	1.24	1644
D ₄ - 19 Dec.	3620	32.2	0.38	0.53	0.62	1.14	1720
SEm ±	130	0.9	0.01	0.01	0.01	0.01	6.7
CD at 5%	470	3.3	0.02	0.01	0.03	0.01	23.5

Rabi maize

Samastipur

To study the crop weather relationship, three maize cultivars viz., Shaktiman-4, Shaktiman-5 and X3522 were grown under four growing environments (01, 10, 20 and 30 Nov 2017). Grain yield showed negative correlation with maximum temperature, minimum temperature and mean temperatures during germination to knee high stage. Maximum temperature during tasseling to silking and silking to milking showed significantly positive correlations with grain yield having correlation coefficients of 0.65* and 0.58*, respectively (Table 4.29). On the other hand, minimum temperature had significant positive correlation ($r=0.72$) during milking to dough stage. The correlation coefficient between daily mean temperature and grain yield was 0.59* during tasseling to silking stage. Hence, as far as the impact of temperature on grain yield is concerned, it was observed that maximum temperature during tasseling to silking and silking to maturity played an important role in deciding the grain yield. On the other hand, minimum temperature during germination to knee high ($r=-0.60^*$) and milking to dough ($r=0.72^{**}$) had significant higher impact on grain yield.

The effect of temperature was more pronounced and adverse during germination to knee high stage while during knee high to tasseling stage is insignificant and positive. The crop sown on 30 Nov recorded the highest heat use efficiency (HUE) of 4.68 Kg ha⁻¹ °C-day⁻¹ followed by 10 Nov sown crop (Table 4.xx). Among the varieties, X3522 recorded the highest HUE (4.72 Kg ha⁻¹ °C-day⁻¹) and the lowest HUE was associated with the variety Shaktiman 4.

Table 4.29: Maize yield as influenced by various growing environments; Correlation coefficients of max, min and mean temperature during different phenophases with grain yield

Dates of sowing	Maize Yield (kg/ha)	HUE Kg ha ⁻¹ °Cday ⁻¹	Phenophases	Tmax (°C)	Tmin (°C)	Tmean (°C)
01 Nov	5154	3.25	P1 (Germination to knee high)	-0.56	-0.60*	-0.58*
10 Nov	6848	4.12	P2 (Knee high to tasseling)	0.39	0.36	0.38
20 Nov	7446	4.68	P3 (Tasseling to silking)	0.65*	0.38	0.59*
30 Nov	6732	4.17	P4 (Silking to milking)	0.58*	0.39	0.48
CD (P=0.05)	970		P5 (Milking to dough)	0.31	0.72**	0.49
Shakti-man-4	5654	3.53	P6 (Dough to maturity)	0	0.30	0.10
Shakti-man-5	6453	4.00				
X3522	7679	4.72				
CD (P=0.05)	850					

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

Mustard

Anand

Crop weather relationship studies in mustard were taken up by conducting a field experiment involving four growing environments (10, 20, 30 Oct and 10 Nov) and three varieties (Bio-902, GM-3, GDM-4) to explore favourable weather conditions and develop predictive models for mustard. Significantly highest seed yield (2526 kg/ha) and harvest index (24.9 %) were recorded in the crop sown on 10 October (Table 4.30).

Sowing at 10 Oct provides favourable growing environment to all the three cultivars and they produce higher yield which declines linearly with delay in sowing. Considering production performance of the cultivars under different growing environments, optimal weather variable ranges during different phenophases of the crop for achieving higher productivity were determined and given in Table 4.30.

Table 4.30: Yield as influenced by different sowing environment and variety; Optimum weather condition for different phenophases of mustard for high productivity (2017-18)

Treatment	Seed yield (kg ha ⁻¹)	HI (%)	Optimum weather condition for higher productivity					
			Phenophases	SSH (hr)	Tmin (°C)	Tmax (°C)	RHm (%)	RHe (%)
10-Oct	2526	25	Emerg. – Early veg.	8.8-10.0	14.8-15.7	33.6-35.0	75-92	28-32
20-Oct	2092	21	Early veg. - Flower ini.	0.0-9.8	11.1-17.5	24.2-35.2	69-100	25-98
30-Oct	1751	21	Flower ini. – Pod ini.	0-5.6.0	14.2-17.2	18.2-32.0	81-96	43-82
10-Nov	1402	15	Pod ini. – Seed dev.	0.7-9.7	9.0-16.5	25.2-29.0	53-95	25-56
S.Em.±	83.9	0.7	Seed dev. – Phy. Mat.	0.8-9.9	6.7-16.5	26.2-34.8	63-95	23-50
C.D. at 5%	268.1	2.4						
C. V. %	15	13						

Faizabad

Three varieties of mustard (Narendra Ageti Rai-4, NDRS-2001-1 and NDR-8501) were exposed to three different sets of weather conditions by sowing them on four dates (Oct 31, Nov 15, Nov 30) to study the crop weather relations. Data pertaining to yield as affected by crop growing environments have been presented in Table 4.31. Perusal of data showed that different crop growing environments influenced the yield significantly. Maximum yield was recorded in the crop sown on 31 Oct. which was significantly superior over the yield obtained in 15 Nov and 30 Nov. The higher yield may be attributed due to favourable maximum and minimum temperature (28.0-29.9 and 12.2-12.3 °C, respectively) and higher sunshine hour both during vegetative and reproductive stages. The maximum HUE requirement from sowing to maturity was recorded (0.64 g/m²/°days) at growing environment 31 Oct sown crop, while minimum HUE from sowing to maturity 0.54 was observed under growing environment of 30 Nov sown crop.

Table 4. 31: Yield and HUE of mustard as affected by growing environment

Treatments	Seed yield (kg /ha)	Harvest index (%)	HUE (g m ⁻² °C-day)	Avg. Tmax (°C) during		Avg. Tmin (°C) during		Avg. SSH (hrs) during	
				Veg.	Rep.	Veg.	Rep.	Veg.	Rep.
31 Oct.	1960	22.4	0.64	28.0	29.9	12.2	12.3	5.1	7.3
15 Nov.	1770	22.2	0.62	25.4	28.6	10.7	11.1	2.0	6.5
30 Nov.	1560	21.3	0.54	24.6	27.8	8.2	9.5	1.9	4.1
SEm±	334	0.44							
CD at 5%	98	NS							

Udaipur

To study the crop weather relationship in mustard, five cultivars Bio-902, Giriraj, RH-0749, NRC HB-101, NRC DR-2 were grown on four growing environments (sown on 01 Oct, 16 Oct,

1 Nov and 16 Nov 2017). Delayed sowing was exposed to higher temperatures from green seed stage to physiological maturity in all varieties. Later two sowing dates (D_3 and D_4) experienced mean temperature of 23-24 °C during brown seed stage to physiological maturity as against the 17-22 °C under D_1 and D_2 sowing dates in all varieties. The crop sown on 01 Oct availed maximum SSH during the same period. Higher seed yield of mustard was recorded when mean temperature at sowing ranges from 25.7 to 27.0 °C where as lower sowing temperature drastically reduced the crop yield (Fig.4.13)

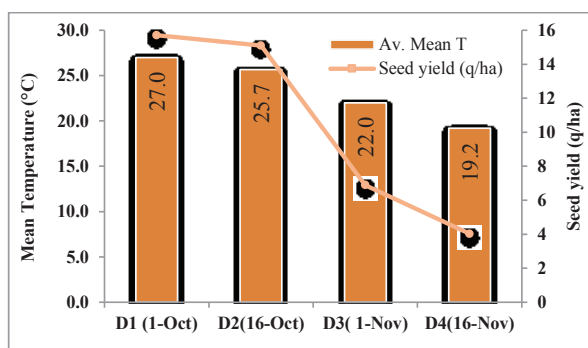


Fig. 4.13: Mean sowing temperature (°C) and seed yield of mustard under different sowing environments

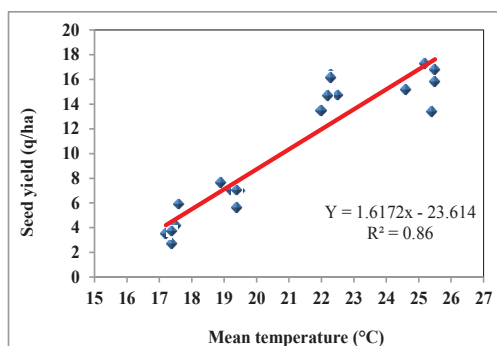


Fig. 4.14: Seed yield of mustard as influenced by mean temperature during vegetative phase

The seed yield increases significantly with increase in mean temperature during vegetative period (Fig. 4.14). The unit increase in mean temperature during vegetative period increases seed yield of mustard by 1.6 q/ha.

Palampur

Identification of critical stages and critical weather parameters influencing yield of five gobhi sarson varieties (HPN-1, HPN-3, HYOLA-401, ONK-1 and GSL-1) over all the four dates of sowing viz., 10 Oct, 20 Oct, 30 Oct and 10 Nov from a pooled data of three years was accomplished through SASE analysis. It was found that, higher rainfall during sowing to emergence (GF 1) had significant positive impact on yield (Table 4.32). Higher maximum temperature during emergence to first flower (GF 2) was positively correlated to yield. Higher maximum and minimum temperature during both first flower to 50% flowering (GF 3) and 50% flowering to 90% pod formation (GF 4) showed significantly negative relationship. Though rainfall during both these phases had a positive influence, rainfall during 90% pod formation to physiological maturity (GF 5) phase had a negative influence on seed yield. In all the cultivars, the negative impact of rising minimum temperature during FL to 90P is higher (150-222 kg/ha/°C) than that of maximum temperature (75-127 kg/ha/°C).

Table 4.32: Simple regression model for mustard yield using different weather parameters at different phenological phases of five cultivars

Parameter	Statistics	S-E (GF 1)	E-FL (GF 2)	FL-50%F (GF 3)	50%F-90%P (GF 4)	90%P-PM (GF 5)
Maximum Temperature	Intercept	88.56019	-896.35689	3584.62337	3008.29628	808.06108
	Linear	59.08125	127.15842	-126.95683	-74.61309	26.49966
	t-value	1.66	2.79	-3.37	-2.88	1.39
	Pr > t	0.1008	0.0064	0.0011	0.0049	0.1669
	Adj. R ²	0.0191	0.0702	0.1032	0.0752	0.0104
	Pr > F	0.1008	0.0064	0.0011	0.0049	0.1669
Minimum Temperature	Intercept	1187.96743	1405.62377	2740.30576	2802.91324	1175.38055
	Linear	26.67064	8.38198	-221.94801	-149.88396	21.80033
	t-value	0.90	0.14	-6.01	-3.59	0.50
	Pr > t	0.3707	0.8867	<.0001	0.0005	0.6179
	Adj. R ²	-0.0021	-0.0110	0.2807	0.1165	-0.0084
	Pr > F	0.3707	0.8867	<.0001	0.0005	0.6179
Rainfall (mm)	Intercept	1368.26223	1796.04168	1188.49251	1256.91970	1789.54206
	Linear	10.74641	-2.50350	2.64923	1.46129	-5.34083
	t-value	3.23	-4.62	2.73	2.62	-4.12
	Pr > t	0.0017	<.0001	0.0077	0.0103	<.0001
	Adj. R ²	0.0947	0.1842	0.0669	0.0612	0.1505
	Pr > F	0.0017	<.0001	0.0077	0.0103	<.0001

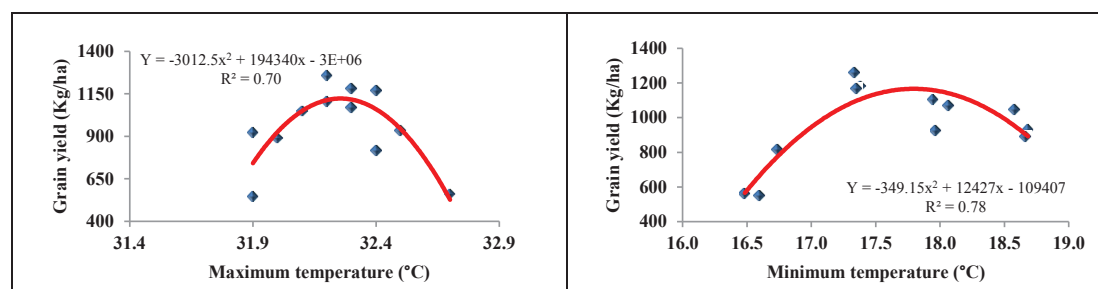
Rabi sorghum

Solapur

Field experiments were conducted during *rabi* season of 2013-14 to 2017-18 using four growing environments [36 SMW (S1), 38 SMW (S2), 40 SMW (S3) and 42 SMW (S4)] and three sorghum cultivars M-35-1, Mauli and Yashoda. Among all the sowing dates the crop sown at SMW 40 (01-07 Oct) has produced maximum grain yield (1204 kg/ha). Among the varieties, M-35-1 produced significantly higher grain yield (1057 kg/ha). The mean CUM and MUE recorded by sorghum crop were 211 mm and 4.5 kg/ha/mm, respectively (Table 4.33). The highest CUM was recorded by S1 sown crop (233 mm) and the highest MUE was recorded by S3 sown crop (5.8 kg/ha/mm). This indicated that S3 sown crop (Chitra Nakshttras) utilized moisture more efficiently than other dates of sowing. Among the varieties, M-35-1 recorded maximum mean CUM (220 mm) and MUE (4.8 ha⁻¹mm) than other varieties. RUE from different treatments are presented in Table 4.xx. Relationship of grain yield with maximum and minimum temperature (Fig. 4.15) indicated that, yield increased up to threshold maximum and minimum temperature of 32.0 and 17.5 °C, respectively and decreased with temperature above these threshold limits.

Table 4.33: Consumptive Use of Moisture (CUM) and Moisture Use Efficiency (MUE) as influenced by growing environments in *rabi* sorghum (2013-14 to 2017-18)

Sowing	CUM				MUE (kg/ha/mm)			
Time	M-35-1	Mauli	Yashoda	Mean	M-35-1	Mauli	Yashoda	Mean
S ₁	231	229	239	233	4.5	4.1	3.7	4.1
S ₂	225	205	234	221	4.9	5.2	4.0	4.7
S ₃	229	185	216	210	5.5	6.4	5.4	5.8
S ₄	195	160	181	179	4.2	3.4	3.1	3.6
Mean	220	195	218	211	4.8	4.8	4.0	4.5

**Fig. 4.15:** Relationship of grain yield of *rabi* Sorghum with CUM, RUE, maximum and minimum temperature at Solapur

Chickpea

Anantapur

Effect of weather on three cultivars of chickpea (JG 11, NBeG 3, NBeG 49) was evaluated by growing them under three sowing dates (sown on 25 Oct, 5 Nov, 25 Nov 2017). Seed yield of chickpea varieties JG 11, NBeG 3 and NBeG 49 was not significantly influenced by sowing environments. The crop sown during 1st FN of November has recorded higher seed yield of (1312 kg/ha) followed by 2nd FN of October (1166 kg/ha) and 2nd FN of November (1140 kg/ha). Among the three varieties, JG 11 (1270 kg/ha) and NBeG 3 (1217 kg/ha) have recorded on par and achieved significantly higher yield over NBeG 49 (1130 kg/ha). The higher yield in 05 Nov sown crop can be attributed to higher daily thermal range of 18.4 °C during pod development to maturity compared to 25 oct (16.9 °C) and 25 Nov (16.8 °C) sown crops (Table 4.34). The optimum maximum temperature (31.3-32.7 °C) and minimum temperature (20.9-15.3 °C) during flowering to maturity were favourable for obtaining higher yield in 05 Nov sown crop. The total GDD requirement of D1 and D3 sown crop was higher than the D2 crop, whereas the yield was maximum in D2 crop. This reveals that the maximum number of degree days (°C-day) was used for development of vegetative phase rather than reproductive.

Table 4.34: Seed yield (kg/ha) as influenced by growing environments and varieties of chickpea during *rabi* 2017-18

Seed yield (kg/ha)					50% F - PD		PD - M		S - M	F - M	
DOS	JG 11	NBeG 3	NBEG 49	Mean	DTR (°C)	SSH (hr)	DTR (°C)	SSH (hr)	GDD (°C-day)	Tmax °C	Tmin °C
25 Oct.	1302	1160	1035	1166	13.4	7.3	16.9	8.0	583	32.3-32.4	15.4-14.8
05 Nov.	1350	1351	1234	1312	14.6	7.7	18.4	8.0	462	31.3-32.7	20.9-15.3
25 Nov.	1158	1141	1122	1140	16.6	8.2	16.8	8.5	513	33.5-33.9	16.7-16.3
Mean	1270	1217	1130								
	D	V	DxV	VxD							
CD	NS	90	NS	NS							

DTR- Daily Temperature Range, F-Flowering, PD-Pod development, S-Sowing, M-Maturity

Vijayapura

A field experiment with split plot design was taken up at Dharwad during *rabi* 2017-18 with four dates of sowing (05, 23 Oct, 02 and 10 Nov 2017) and five cultivars (JG-11, BGD-111-1, Jaki-9218, BGD-103, Vijay) to study the effect of weather on phenophase development and develop predictive models for growth and development. Due to extreme moisture stress, no yield was obtained on 02 and 10 November sown crops. From Table 4.35 it was observed that the mean yield of all varieties was 672.8 kg/ha in first growing environment and 259.7 kg/ha in the second growing environment with a reduction of 413.1 kg/ha, showing comparative yield loss by 61 percent. The data indicates that BGD-111-1 is better compared to other varieties in terms of both higher yields under both favourable and unfavourable conditions during 2017-18.

Table 4.35: Yield differences in Chickpea varieties (kg/ha) (2017-18)

Variety	GE1	GE2	Mean	Deviation (GE2-GE1)	Percent deviation
JG-11	691.1	317.8	504	-373.2	-54
BGD-111-1	858.7	368.9	614	-489.8	-57
Jaki-9218	594.5	256.9	426	-337.7	-57
BGD-103	686.0	165.1	426	-520.8	-76
Vijay	533.5	189.5	362	-344.0	-64
Mean	672.8	259.7	466	-413.1	-61

From Fig. 4.16 it was noticed that there was as much as 135 mm rainfall during germination and seedling stages of GE1, whereas there was no rainfall during GE2. It is further noticed that in GE2, the Chickpea crop experienced all sorts of consequent adverse events, like lower morning and afternoon relative humidity, and higher duration of insolation during these two initial stages of crop growth. Thus, GE2 could not recover from moisture stress in the germination stage in view of no rainfall thereafter, with only about 20 mm during flowering stage. However, the

variety BDG-111-1 could withstand the initial stress conditions in terms of both soil moisture stress due to low rainfall and atmospheric moisture in terms of low vapour pressure and relative humidity.

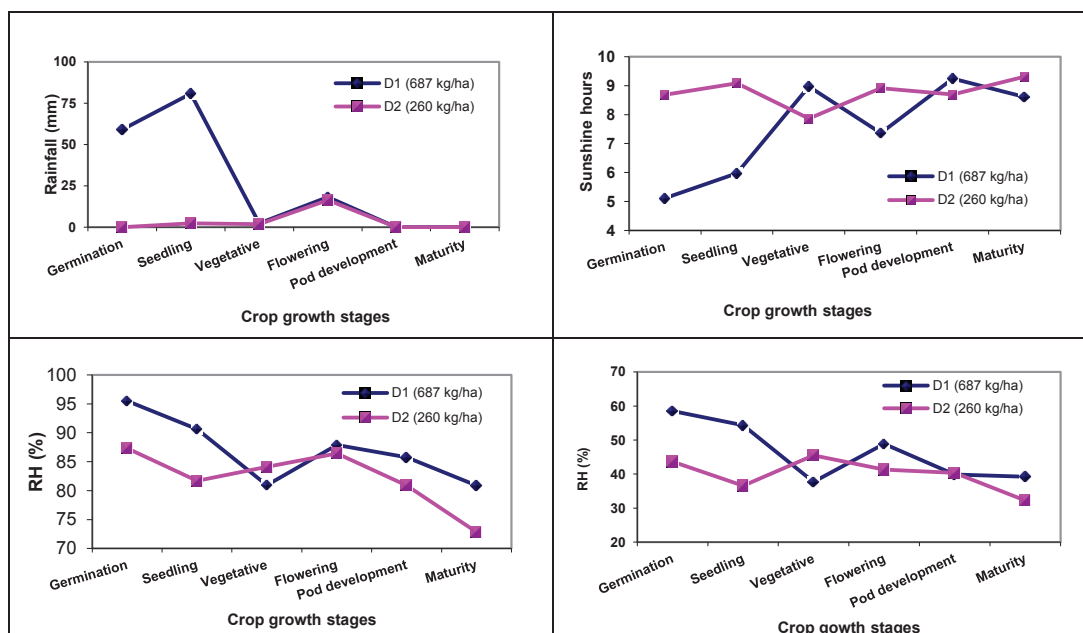


Fig. 4.16: Stage-wise stagewise rainfall, daily SSH, morning and afternoon RH under different growing environments (2017-18)

Ranchi

A field experiemnt in factorial RBD was conducted during *rabi* 2017-18 (main plot: three dates of sowing (10 Nov, 25 Nov, 10 Dec); Sub-plot: three chickpea cultivars (JG 14, GNG 1581, Birsa Chana 3). Late sown crop varieties (10 Dec) were exposed to comparatively higher average maximum (27.6 °C) and minimum (10.5 °C) air temperatures during each stage of the growing period than the timely sown crop varieties. The quantum of radiation measured during different stages showed that total amounts of radiation during the crop periods of D1, D2 and D3 were 1795, 1877 and 1871 MJ m⁻², respectively. Total sunshine hours has been found considerably higher (254 hrs) for early sown crops than normal (248 hrs) and late sown (221 hrs) crops during reproductive stage. The higher amounts of radiation as well as sunshine hours available for normal sown crops seem to have positive impact on crop yield. Average performance of chickpea sown by 10th Nov (Early) was significantly higher (21.6 q/ha) than crop sown on 25 Nov (12.2 q/ha) and 10 Dec. (12.4 q/ha) during 2017-18. Among the varieties, higher yield was recorded by Birsa Chana 3 (16.64 q/ha) with 56 % harvest index followed by GNG 1581 (15.02 q/ha) and JG 14 (14.55q/ha). Heat and radiation use efficiencies in terms of yield of chickpea showed early sown crop registering higher heat and radiation use efficiency compared to the late sown crop (Table 4.36).

Table 4.36: Yield and yield attributes of chickpea under different sowing dates .

Treatments	TDM (q/ha)	Yield (q/ha)	HI (%)	Tmax (°C)	Tmin (°C)	RF (mm)	Cum. SSH (hr)	Total Radiation (MJ m ⁻²)	HUE kg/ha/°C-day	RUE kg/ha/MJ
10-Nov	34.44	21.6	63	25.1	7.1	6.2	254	1795	1.5	1.2
25-Nov	23.16	12.2	53	27.0	8.5	4.2	248	1877	0.9	0.6
10-Dec	27.77	12.4	45	27.6	10.5	4.2	221	1871	0.8	0.7
S Em	2.04	1.16	1							
C D at 5%	6.13*	3.4*	4*							
JG 14	28.72	14.55	51							
GNG 1581	27.77	15.02	53							
Birsa Chana3	28.88	16.64	56							
S Em	2.04	1.16	1.2							
C D at 5%	NS	NS	NS							
Interaction										
S Em	3.54	2	2.1							
C D at 5%	NS	NS	6.4*							

Raipur

An experiment was carried out to study the effect of different growing environments (sown on 10 Nov, 25 Nov, 10 Dec) on growth, development and yield of chickpea cultivars (Vaibhav, JG 14 and JG16). The crop yield was at par in both 10 and 25 Nov sown crops and lowest in the 10 Dec sowing (Table 4.37). The higher yields in the first and second dates of sowing may be attributed to lower maximum (28.9-29.8 °C) and minimum (8.2-12.5 °C) temperature during the crop growth period compared to the third date.

Table 4.37: Yield and yield attribute of chickpea varieties as influenced by different growing environments during *rabi* 2017-18

Growing environment	Grain Yield (Kg/ha)	Stover yield (kg/ha)	Harvest index (%)	Tmax (°C)	Tmin (°C)	SSH (hr)	RF (mm)
D ₁ (10 Nov.)	1803	2002	47.4	28.9	12.5	8.0	17.4
D ₂ (25 Nov.)	1942	1828	51.7	29.8	8.2	8.2	16.4
D ₃ (10 Dec.)	1241	1243	50.2	30.8	14.4	14.4	17.6
SEm ±	73.8	110.5	1.16				
CD(p=0.05)	221.2	331.2	NS				
Varieties							
V ₁ Vaibhav	1596.8	1702.9	48.5				
V ₂ JG-14 (ZC)	1465.2	1490.6	49.9				
V ₃ JG-16	1924.5	1880.3	50.9				
SEm ±	73.8	110.49	1.16				
CD (p=0.05)	221.2	331.2	NS				
SEm ± (DxV)	127.8	191.37	2.0				
CD(p=0.05)	NS	NS	NS				

D₁-10/11/2017, D₂- 25/11/17, D₃- 10/12/2017, V₁-Vaibhav, V₂- JG-14, V₃- JG-16

Potato

Hisar

Effect of dates of sowing and cultivars on the radiation balance, phenological development of potato was studied under four dates of sowing (8 Oct (D₁), 22 Oct (D₂), 5 Nov (D₃), 22 Nov (D₄)) and three cultivars (Kufri Bahar, Kufri Pushkar, Kufri Surya). The D₂ sown crop recorded highest number of tubers per plant (14.0), whereas the lowest (9.9) by the delayed sown crop (D₄). The crop sown on D₂ recorded highest harvest index (HI) followed by D₁, D₃ and D₄ (Table 4.38). The highest tuber yield (29658.6 kg/ha) was obtained by D₂ crop followed by D₁, D₃ and D₄, which recorded 25216, 22801 and 18416 kg/ha, respectively. Among the varieties, K. Pushkar (V₂) produced highest tuber yield (28263 kg/ha) followed by K. Bahar (V₁) (25997 kg/ha) and K. Surya (V₃) (17808 kg/ha). Intercepted radiation in potato plants was increased gradually from emergence to tuber bulking among all the treatments. Among the dates of sowing, early sown crop was attained higher radiation and heat units. During the cropping season, the yield was significantly correlated with maximum and minimum temperature (P1-P3 and P1-PM) and sunshine hours (P4-P5).

Table 4.38: Potato yield attributes and yield at different growing environment and cultivars

Dates of sowing	Tubers /plant	Tuber yield	HI	Int. Rad./ (MJ/m ² /day) (°C day)		Growing Degree Days	Correlation between weather and yield				
							Tmax	Tmin		SSH	
		(kg/ha)	(%)	IT	PM	PM	P1-P3	P1-PM	P1-P3	P1-PM	P4-P5
D ₁	13.1	25216	63.3	173.4	277	1251.5	0.665*	0.546*	0.723*	0.611*	-0.822*
D ₂	14.0	29659	70.4	175.2	347	1165.0					
D ₃	10.6	22801	59.5	149.9	206	871.5					
D ₄	9.9	18416	53.6	114.0	129	666.9					
CD at 5%	1.02	1582	4.76	19.7	41.8	54.8					
Varieties							P1-P3, Emergence to tuber initiation; P1-PM, Emergence to physiological maturity; P4-P5, Tuber bulking to physiological maturity *-Significant at 5% level of probability				
V ₁	12.3	25997	65.6	139.4	222	984.9					
V ₂	14.2	28263	66.8	186	317	1107.5					
V ₃	9.2	17808	52.7	133.9	181	873.7					
CD at 5%	1.23	1285	4.79	24.1	27.2	32.1					

HI-Harvest Index; IT-Initiation of Tuber; Pm-physiological Maturity

Pooled analysis of crop weather data across multiple locations under AICRPAM

Wheat

To study the influence of weather on grain yield of wheat, the grain yield of common variety i.e., HD 2967 grown under different growing environment over three multiple locations viz., Chatha, Kanpur and Ludhiana during *rabi* 2017-18 were pooled. The yield and weather during different phenological stages identified maximum and minimum temperature during vegetative and reproductive stages as the critical weather parameters and stages showing significant influence on grain yield. Both maximum and minimum temperature during vegetative stages showed (Fig. 4.17) significant positive correlation ($R^2 = 0.47$ & 0.56 , respectively) while they showed significant negative correlation during reproductive period ($R^2 = 0.59$ & 0.38 , respectively). Unit increase in maximum and minimum temperature during vegetative stages enhance the yield by 0.314 and 0.2992 t/ha, respectively and during the reproductive period decrease the yield by 0.2204 and 0.2299 t/ha, respectively. The decrease in yield during reproductive stage may be attributed to enhanced respirational losses. However, the positive impact of higher temperature during vegetative stage may be attributed to increased ET and increased translocation of photosynthates/nutrients.

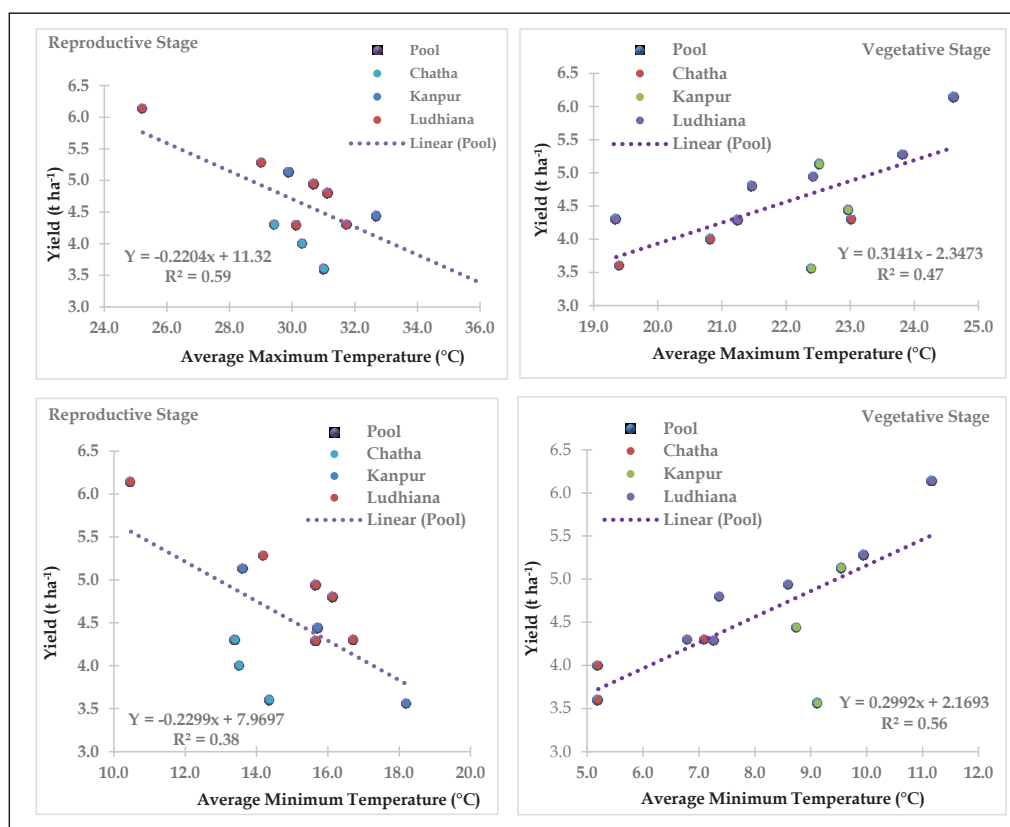


Fig. 4.17: Relationship between temperature (maximum and minimum) and wheat yield (HD-2967) during vegetative and reproductive stages

Soybean

The relationship between seed yield of soybean (JS-335) grown at Akola, Bijapur and Udaipur during *kharif* 2017 under various growing environments and the phenological stage-wise weather parameters revealed that soybean yield responded negatively ($R^2=0.81$) to the increase in maximum temperature (28.0-34.5°C) during pod formation to maturity stage (Fig. 4.18). This may be due to acceleration of crop senescence during seed filling which reduces seed yield. Secondly, small increases in crop evapotranspiration arising from increased maximum temperatures reduce the availability of soil moisture later in the season, and can induce significant yield losses from water shortage during grain filling. However, the trend in response of yield to total rainfall (0.0-160.0mm) during the same period was positive ($R^2=0.80$, Fig. 4.18). This increase may be attributed to favourable soil moisture conditions as rainfall has a large impact on yields. It is also to be noted that along with the trend, there is a large variation in yield of two stations which may be due to variable soil and temperature driven physiological processes of the crops.

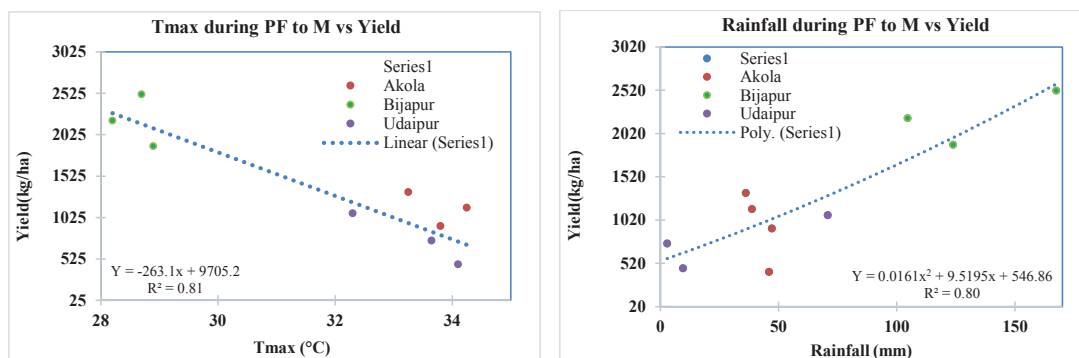


Fig. 4.18: Relationship between maximum temperature and rainfall with soybean yield (JS-335) during pod formation to maturity stage

Chickpea

The experimental data of chickpea (JG-14) grown at Raipur, ranchi and Jabalpur during *rabi* 2017-18 under various growing environments, was pooled to workout the relationship between seed yield of chickpea and weather during different phenological stages. The significant negative relation ($R^2=0.44$) between yield and average minimum temperature during the above mentioned critical stage (Fig. 4.19) revealed that, yield decreases by 0.06 t/ha with each 1°C increase in minimum temperature in the range of 8.2-19.2 °C during the pod formation to maturity stage. This may be due to acceleration of crop senescence during seed filling which reduces seed yield as chickpea is grown under rainfed conditions with residual soil moisture. Secondly, small increases in crop evapotranspiration arising from increased maximum temperatures reduce the availability of soil moisture later in the season, and can induce significant yield losses from water shortage during grain filling.

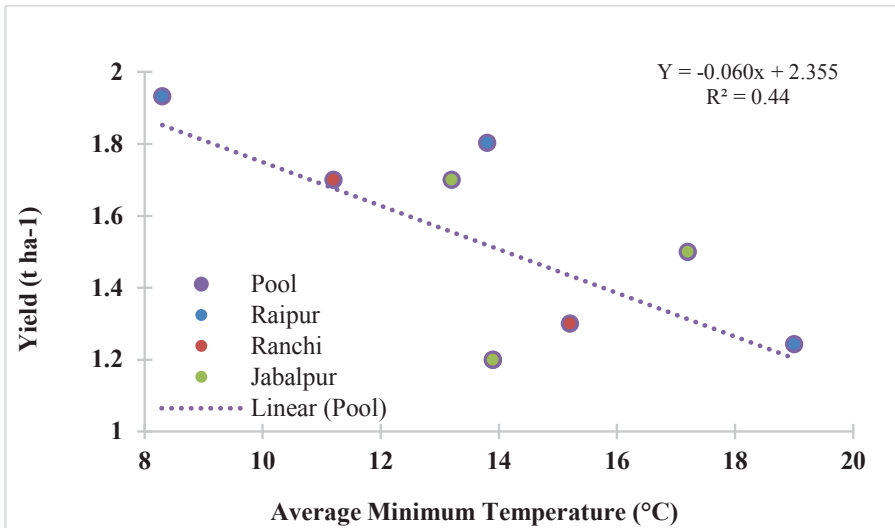


Fig. 4.19: Relationship between minimum temperature and chickpea yield (JG-14) during pod formation to maturity stage

Rice

The multi locational experimental data of rice (MTU 1010) pooled from Jabalpur, Raipur and Ranchi during *Kharif* 2017 under various growing environments revealed that with increase in average maximum temperature during reproductive stage in the range 29.7-32.4 °C, the rice yield has decreased significantly ($R^2=0.69$) (Fig. 4.20). Every degree increase in maximum temperature caused 1.07 t/ha reduction in yield. The decrease in yield may be attributed to effect of higher temperature on anthesis, pollen sterility, higher evapotranspiration etc.

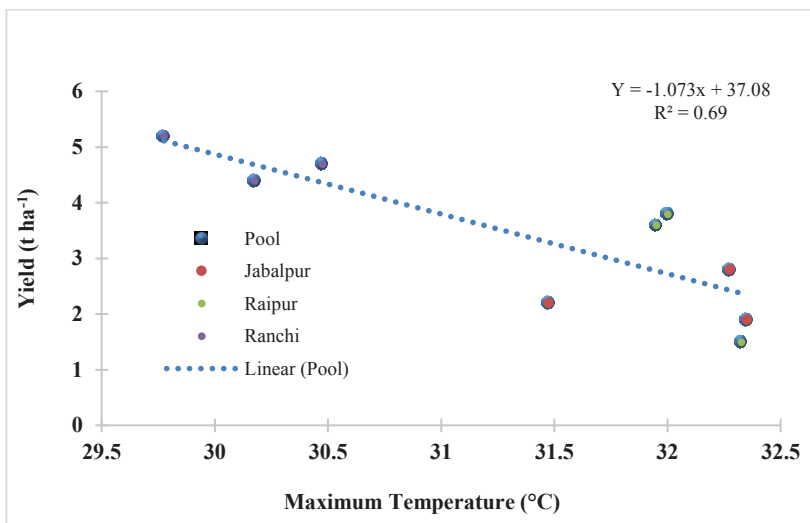


Fig. 4.20: Relationship between maximum temperature and rice yield (MTU 1010) during reproductive stage

Similarly, experimental data of Rice (Swarna) pooled from Jorhat, Mohanpur and Bhubaneswar during *kharif* 2017 was pooled under various growing environments revealed that with increase in either maximum or minimum temperature during panicle initiation to flowering stage, in the range of 31.8-36.9°C and 12.0-28.2°C, the rice yield has decreased significantly ($R^2=0.56, 0.72$) (Fig. 4.21). Every degree increase in maximum and minimum temperature caused 0.18 and 0.06 t/ha yield reduction. However, increase in total rainfall during tillering to panicle initiation also reduced the grain yield significantly ($R^2=0.62$). Every 100mm increase in rainfall could reduce the grain yield by 0.14 t/ha.

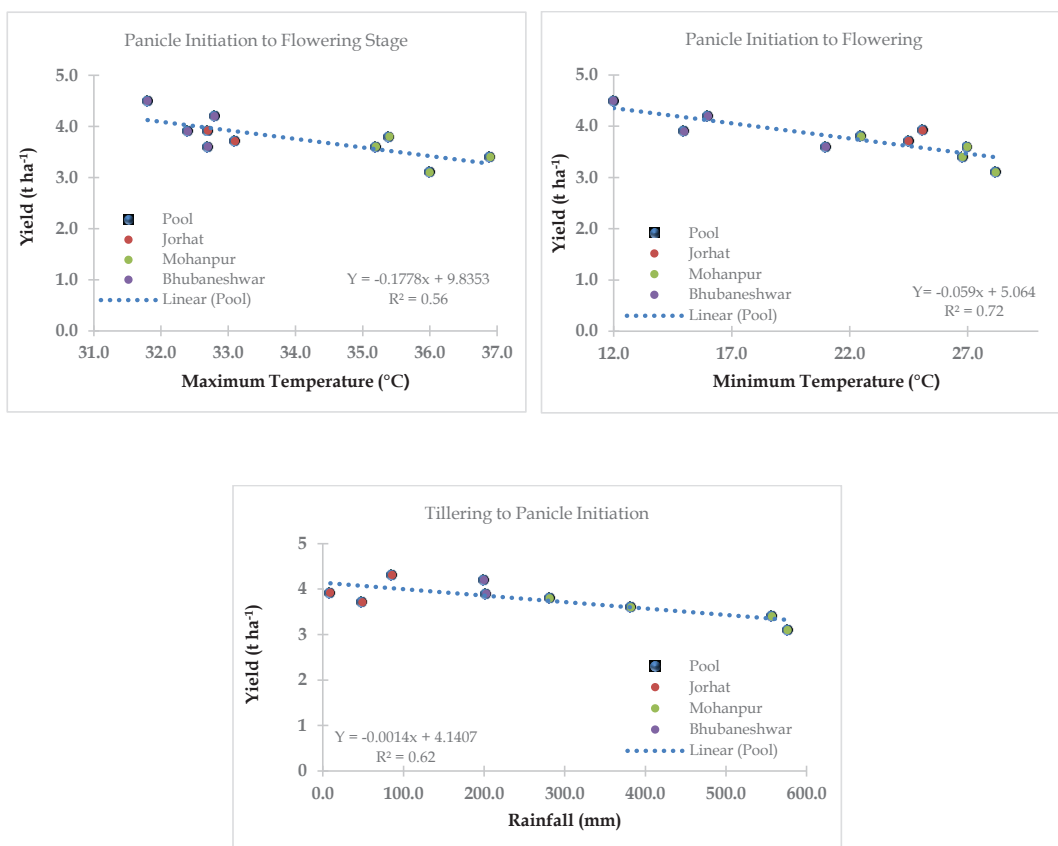


Fig. 4.21: Relationship between maximum temperature, minimum temperature and rainfall with rice yield (Swarna)

5. Crop Growth Modeling

Anand

Calibration of CERES-millet model

Crop simulation DSSAT 4.6 CERES-millet model was calibrated using the experimental data of three cultivars (GHB 338 (V1), GHB 558 (V2) and GHB 744 (V3) of pearl millet sown on 7th July 2017 under middle Gujarat agro-climatic condition (Table 5.1).

Table 5.1: Genetic coefficients of three varieties of Pearl millet. GHB 338, GHB 558 and GHB 744 required for CERES-Millet (DSSAT v.4.6) model.

NAME	Description	GHB 338	GHB 558	GHB 744
P1	Thermal time from seedling emergence to the end of juvenile phase (expressed in degree days above a base temperature of 10 °C) during which the plant is not responsive to changes in photoperiod	98.0	105.0	101.0
P2O	Critical photoperiod or the longest day length (in hours) at which development occurs at a maximum rate. At values greater than P2O, the rate of development is reduced.	12.0	12.0	12.0
P2R	Extent to which phasic development leading to panicle initiation (expressed in degree days) is delayed for each hour increase in photoperiod above P2O.	480.0	490.0	485.0
P5	Thermal time (degree days above a base temperature of 10 °C) from beginning of grain filling (3-4 days after flowering) to physiological maturity.	289.0	288.0	285.0
G1	Scaler for relative leaf size.	0.50	0.50	0.50
G4	Scaler for partitioning of assimilates to the panicle (head).	11.30	13.50	13.80
PHINT	Phylochron interval; the interval in thermal time (degree days) between successive leaf tip appearances.	43.0	43.0	43.0

Validation of CERES-millet (DSSAT4.6) model:

CERES-millet model was validated with the help of growth and yield data of three cultivars of pearl millet (GHB 338, GHB 558 and GHB 744) sown on 27 June (D1) and 17 Jul (D3) 2018. The validation statistics of the model (Table 5.2) revealed that the observed days to anthesis ranged between 45-56 days while the simulated days to anthesis ranged between 52 and 58 days. The percent of error in simulating the anthesis varied from -3.6 to 15.6 %. In case of days to maturity, observed days ranged from 86 to 89 and simulated days ranged from 88 to 101, with a percentage of error varying from 0.0 to 17.4 days. Observed and simulated peak LAI varied between 3.85 to 4.46 and 2.9 to 4.1, respectively. Observed grain yield ranged from 2451 to 4200 kg ha⁻¹ while simulated yield varied from 2744 to 4211 kg ha⁻¹, with an error percentage of

1.6 to 14.5. Observed straw yield varied from 6145 to 8768 kg ha⁻¹ and simulated straw yield were from 5321 to 7866 kg ha⁻¹ with error percentage in the range of -13.4 to 1.5 %. Total dry matter, observed below and simulated varied between 9417 to 12767 kg ha⁻¹ and 8065 to 12036 kg ha⁻¹, respectively with error percentage ranging from -9.4 to -1.32 %. The scatter plot with 1:1 line between observed and simulated values of days to anthesis, days to maturity, maximum LAI, grain yield, straw yield and total biomass (Fig 5.1) showed the following observations.

- Both days to anthesis and maturity are poorly simulated and they are mostly overestimated.
- Maximum leaf area index was under-estimated by the model for all three genotypes grown under two different growing environments.
- The grain yield simulated by the model was slightly higher than the observed. Simulation was close to the actual yield values.
- Simulated straw yield was slightly lower than the observed.

Table 5.2: Observed, simulated and percentage deviation values of days for anthesis physiological maturity, LAI, grain yield, straw yield and total above ground biomass in different environments and varieties of *khari* pearl millet.

Treatment	Anthesis (Days)			Maturity (Days)			LAI			Grain yield (kg/ha)			Straw yield (kg/ha)			Total above ground biomass (kg/ha)		
	Obs	Sim	Dev. (%)	Obs	Sim	Dev. (%)	Obs	Sim	Dev. (%)	Obs	Sim	Dev. (%)	Obs	Sim	Dev. (%)	Obs	Sim	Dev. (%)
D ₁ V ₁	52	58	11.54	86	96	11.63	3.85	3.5	-9.09	3129	3422	9.36	6663	6241	-6.34	9793	9663	-1.32
D ₁ V ₂	45	52	15.56	86	101	17.44	4.46	3.5	-21.52	3999	4211	5.29	8768	7825	-10.76	12767	12036	-5.73
D ₁ V ₃	48	52	8.33	88	98	11.36	4.20	2.9	-30.95	4200	4166	-0.80	8539	7866	-7.89	12739	12032	-5.55
D ₃ V ₁	53	53	0.00	88	90	2.27	4.39	4.1	-6.61	2709	3101	14.45	6707	6124	-8.69	9417	9225	-2.03
D ₃ V ₂	54	53	-1.85	89	90	1.12	4.45	3.9	-12.36	2451	2744	11.97	6145	5321	-13.40	8595	8065	-6.17
D ₃ V ₃	56	54	-3.57	88	88	0	4.04	3.9	-3.47	2936	2889	-1.59	6773	5911	-12.73	9708	8800	-9.36

- The model slightly underestimated the biomass production in most cases of all the treatments.
- The model requires further improvement by incorporating the second and third year experimental data in the coming years

Bhubaneswar

Calibration of CERES-Rice model (DSSAT 4.6)

The CERES-Rice model was calibrated for rice variety “Pratibha” sown under four transplanting dates viz., 2 July (D1), 16 July (D2), 1 August (D3) and 20 August (D4) at Bhubaneswar center. The simulations of days to panicle initiation, anthesis & maturity and yield were showing close agreement with observed data with better values of indices of agreement (Table 5.3), whereas model overestimated the LAI (Fig 5.2).

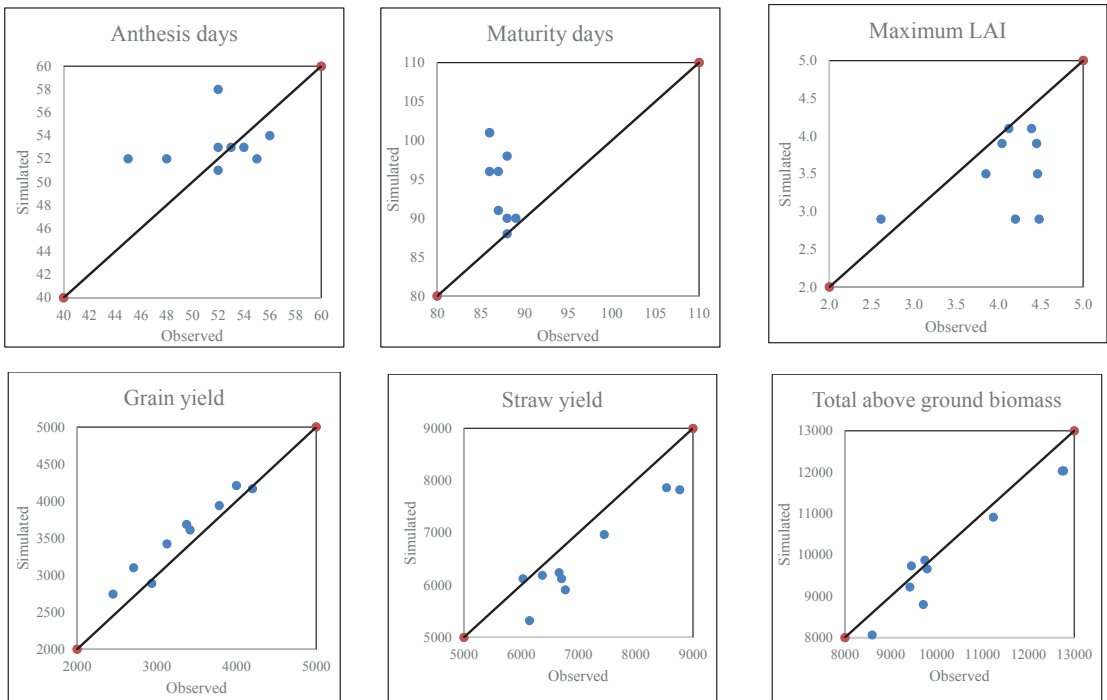


Fig 5.1: Observed vs simulated growth and yield variables of pearl millet (2017) at Anand

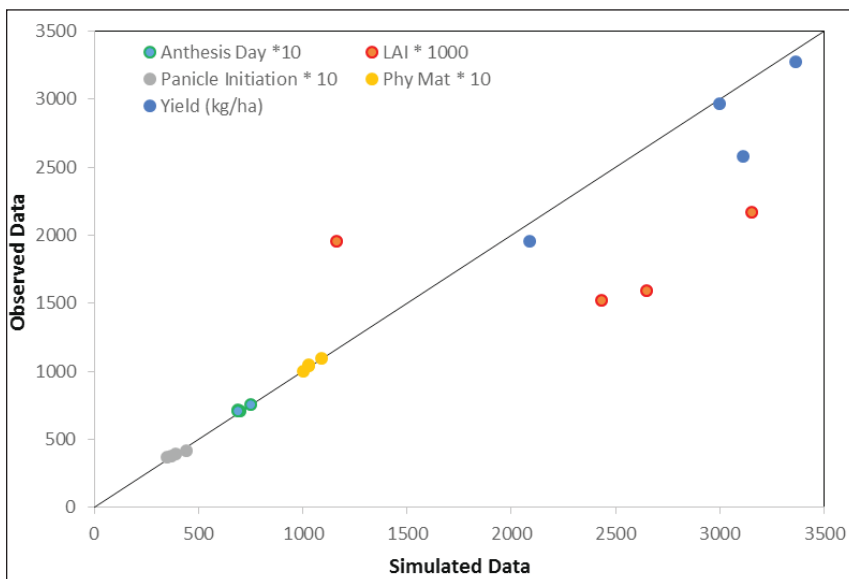


Fig 5.2: Simulated Vs observed physiological parameters

Table 5.3: Simulated vs observed physiological parameters and their statistical significance

Variable	Observed	Simulated	RMSE	D-Index
Panicle Initiation day (dap)	39	39	1.50	0.92
Anthesis day (dap)	73	71	1.94	0.84
Physiological maturity day (dap)	105	104	1.22	0.97
Yield at harvest maturity (kg [dm]/ha)	2694	2891	277.45	0.92
Leaf area index, maximum	1.81	2.35	0.94	0.35

Ludhiana

Nitrogen management in wheat for reducing the harmful effects of high temperature during reproductive stages

The CERES-Wheat model, available in the DSSAT v 4.5 software package was used for the study. In the present study, the normal (long term average) temperature data was used for simulation of wheat yield under normal conditions. An increase in temperature by 3°C (both in maximum and minimum) was imposed as heat stress during 16th February to 15th March corresponding to most sensitive phase ‘reproductive phase’ of wheat growth. Different nitrogen management options were tried to reduce the harmful effect of high temperature on wheat productivity (Table 5.4). The results indicated that:

- Wheat grain yield obtained under normal temperature and with recommended dose and time of N application was 4.13 t/ha and it decreased to 3.70 t/ha (10.41%) in response to heat stress. While using recommended quantity of N, in three and four splits of N application led to reduction in wheat productivity, irrespective of the time of application and growing conditions.
- Application of 125% of recommended N in two and three [0, 30 and 60 days after sowing (DAS)] splits led to an increase in wheat productivity by 3.63 and 1.94%, respectively, under normal temperature conditions. It also helped in reducing the harmful effects of heat stress as the yield reduction was 7.02 and 8.72% with two and three splits, respectively, as compared to the recommended practice having yield reduction of 10.41%.
- Application of equal splits of 150% of recommended N at 0, 60 DAS; 0, 30, 60 DAS; 0, 30, 124 DAS (applied before stress); 0, 30, 138 DAS (applied mid way of stress) and 0, 30, 60, 90 DAS led to an increase in wheat productivity by 4.36, 4.12, 0.48 and 0.48% under normal temperature conditions. These treatments also helped in increasing wheat productivity under stress conditions. Under heat stress conditions the maximum wheat productivity of 3.87 t/ha was observed with application of 150% of recommended N at 0 and 30 DAS. The reduction in wheat productivity due to heat stress in this treatment was minimum (6.30%).
- The harmful effects of heat stress during reproductive stage on wheat productivity can be reduced by additional application of nitrogen. The best treatment in terms of reducing the harmful effects of heat stress during reproductive phase of wheat growth was to apply 150% (156 kg/ha) of recommended N in two equal splits at 0 and 30 DAS.

Table 5.4 : Effect of heat stress and different N management practices on grain yield of wheat and its deviation from control using CERES Wheat model

Treatments	Grain yield (t/ha)		Deviation (%) of grain yield from control	
	Normal temperature	Heat stress	Normal temperature	Heat stress
Recommended N (125 kg/ha)				
Control, Two equal splits (0, 30 DAS)	4.13	3.70	-	-10.41
Three equal splits (0, 30, 60 DAS)	4.08	3.66	-1.21	-11.38
Three equal splits (0, 30, 124 DAS (applied before stress))	3.83	3.45	-7.26	-16.46
Three equal splits (0, 30, 138 DAS (applied mid way of stress))	3.83	3.45	-7.26	-16.46
Four equal splits (0, 30, 60, 90 DAS)	3.99	3.55	-3.39	-14.04
125% of recommended N (156 kg/ha)				
Two equal splits (0, 30 DAS)	4.28	3.84	3.63	-7.02
Three equal splits (0, 30, 60 DAS)	4.21	3.77	1.94	-8.72
Three equal splits (0, 30, 124 DAS (applied before stress))	4.00	3.59	-3.15	-13.08
Three equal splits (0, 30, 138 DAS (applied mid way of stress))	4.00	3.59	-3.15	-13.08
Four equal splits (0, 30, 60, 90 DAS)	4.24	3.80	2.66	-7.99
150% of recommended N (188 kg/ha)				
Two equal splits (0, 30 DAS)	4.31	3.87	4.36	-6.30
Three equal splits (0, 30, 60 DAS)	4.30	3.85	4.12	-6.78
Three equal splits (0, 30, 124 DAS (applied before stress))	4.15	3.71	0.48	-10.17
Three equal splits (0, 30, 138 DAS (applied mid way of stress))	4.15	3.71	0.48	-10.17
Four equal splits (0, 30, 60, 90 DAS)	4.28	3.84	3.63	-7.02

Mohanpur

A study was conducted on Satabdi variety with all standard recommended practices to find out the likely attainable yields under four RCP scenarios in future. The Intergovernmental Panel for Climate Change (IPCC) in preparing the Assessment Report -5 (AR5), used a new set of scenarios that substituted the Special Report on Emissions Scenarios (SRES) used in two earlier reports. The new scenarios are called as Representative Concentration Pathways (RCPs) consisting of four scenarios: RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5. The four scenarios portray four possible future climates, depending on how much amount of greenhouse gases are released in the upcoming years. The names reflected by a possible range of radiative forcing values by the year 2100 relative to pre-industrial values. A glimpse of all the RCPs is furnished in Table 5.5. The DSSAT model was employed to evaluate the rice productivity during 2025,

2050, 2075 and 2095 periods and compared with the current productivity level. The results showed that, under RCP 2.6 scenario, rice production showed likely decrease (-10% to -4%) in 2025 to 2050 (Fig 5.3a). However, there is a chance of increase (16% to 20%) in productivity from 2075 onwards. The trend is fully reversed under RCP4.5, where gain in productivity may be seen during 2025 and likely decreasing trend thereafter (Fig 5.3b). In the next two scenarios, no significant/continuous trend was observed. Yield gains are only expected during 2050 and 2075 under RCP 6.0 and RCP 8.5, respectively (Fig 5.3c and 5.3d). Irrespective of the dates of transplanting and time periods, yield losses would be the predominant phenomena under both these scenarios. If the transplanting window is considered, then first fortnight of July is recommended for transplanting operations followed by middle of June transplanting time. Crops transplanted towards the end of July are expected to produce higher yields compared to the current scenario.

Table 5.5: A glimpse of four RCP's

RCP	Description	Emission	Consistent with
2.6	Peak in radiative forcing at $\sim 3 \text{ Wm}^{-2}$ ($\sim 490 \text{ ppm CO}_2 \text{ eq}$) before 2100 and then decline	Low	Methane emission reduced by 40 per cent. Use of croplands increase due to bio-energy production. Declining use of oil.
4.5	Stabilization without overshoot pathway at 4.5 Wm^{-2} ($\sim 650 \text{ ppm CO}_2 \text{ eq}$) at stabilization after 2100	Intermediate	Stable methane emission Decreasing use of croplands and grasslands.
6	Stabilization without overshoot pathway at 6 Wm^{-2} ($\sim 850 \text{ ppm CO}_2 \text{ eq}$) at stabilization after 2100	Intermediate	Stable methane emission. Increasing use of croplands and declining use of drylands. Heavy reliance on fossil fuels.
8.5	Radiative forcing pathway leading to 8.5 Wm^{-2} ($\sim 1370 \text{ ppm CO}_2 \text{ eq}$) by 2100	High	Rapid increase in methane emission. Increased use of croplands and grasslands. Heavy reliance on fossil fuels.

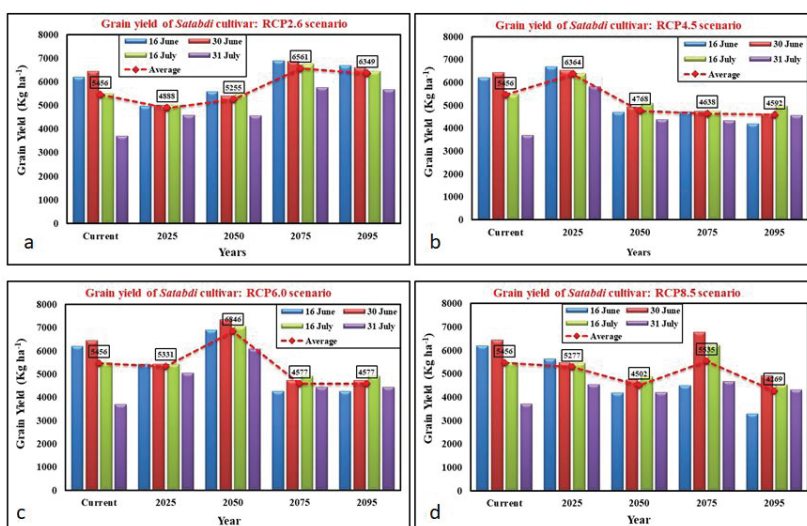


Fig. 5.3: Projection of future yield scenario of Kharif rice (*Satabdi* variety) for 2025, 2050, 2075 and 2095 under four RCP scenarios (a. RCP2.6; b. RCP4.5; c. RCP6.0; d. R-CP8.5)

Parbhani

Cotton

Experimental field data of cotton (cv Ajeet-155) under four dates of sowing viz. 25th SMW, 26th SMW, 27th SMW and 28th SMW was collected and compiled in a minimum data set format for the last 3 years 2015, 2016 and 2017. DSSAT cotton model was calibrated with first two years of data and validated with 2017 data at Parbhani. The summarized results are presented below;

The absolute error between observed and simulated phenology of cotton crop was 4 to 10 days and absolute error between observed and simulated yields of cotton (Table 5.6) was higher in D₁ (25th SMW) and less in D₂ (26th SMW). But in case of crop sown on 26th SMW was 1st boll and 90 % boll opening stages were simulated within the reasonable limits.

Table 5.6: Simulated vs Observed phenology and yield of cotton under two growing environments (25th and 26th SMW)

Date of sowing	Phenophases	Observed	Simulated	Error (%)
25 th SMW	Flowering	53	44	17
	1st boll	57	54	5.3
	90% boll opening	131	139	-6.1
	Yield	1306	1002	23.3
26 th SMW	Flowering	55	45	20
	1st boll	59	55	6.7
	90% boll opening	134	142	-5.9
	Yield	920	1026	-11.5

Jorhat

Rice

Calibration and validation of CERES-Rice of DSSAT (Cv. Swarna Mahsuri)

Field experiments on Rice crop “cv. Swarna Mahsuri” were conducted during 2011-2017, at Jorhat center. For calibration and validation of CERES-Rice model for Swarna Mahsuri variety of rice, three transplanting windows were selected for transplanting of rice and they were on the 3rd week of June, 2nd week of July and 1st week of August with near about 15 days interval between each transplanting. Recommended doses of fertilizer for Upper Brahmaputra Valley (UBV) agroclimatic zone were followed. The genetic coefficients of rice cv. Swarna Mahsuri were generated (2011-2015) using inbuilt ‘Genotype Coefficient Calculator’ and RMSE and D-stat analysis were done to test the levels of agreement between observed and simulated values during the calibration runs.

The CERES-Rice model calibration (2011-15) and validation (2016-17) results along with the genotype coefficients developed for rice cv. Swarna Mahsuri are presented in Table 5.7 and 5.8. The observed and simulated values for anthesis, maturity and grain yield under calibration runs exhibited a very good agreement with acceptable D-stat values, which are above 0.5. During

model validation, percent difference between observed and simulated grain yields were 7.5, 6.5 and 8.9 %, for dates of transplanting viz. D1 (3rd week of June), D2 (2nd week of July) and D3 (1st week of August), respectively. Similarly, days for anthesis and maturity also showed close agreement between observed and simulated values. The calibration and validation results suggest suitability of the model for further yield projections.

Table 5.7: Calibration (2011-15) and validation (2016-17) results for rice cv Swarna Mahsuri at Jorhat

Variable	Observed	Simulated	RMSE	D-stat
Calibration (2011-15)				
Anthesis day	122	123	3.3	0.90
Grain yield (kg ha ⁻¹)	3758	3926	1549.1	0.52
Maturity day	164	150	19.1	0.51
Validation (2016-17)				
D1* (3rd week of June)				
Anthesis day	127	123		
Grain yield (kg ha ⁻¹)	2652	2452		
Maturity day	152	165		
D2 (2nd week of July)				
Anthesis day	119	121		
Grain yield (kg ha ⁻¹)	4321	4042		
Maturity day	161	158		
D3 (1st week of August)				
Anthesis day	113	117		
Grain yield (kg ha ⁻¹)	3231	3520		
Maturity day	135	141		

*D1 (3rd week of June), D2 (2nd week of July) and D3 (1st week of August) are the dates of transplanting

Table 5.8: Genotype coefficients for rice cv. Swarna Mahsuri at Jorhat

Genetic Coefficient	Description	Values
P1	Growing degree day (GDD) for the basic vegetative phase (°C day)	759.2
P20	Critical day length (h)	325.1
P2R	Photoperiod sensitivity coefficient (°C day)	274.3
P5	GDD from the beginning of grain filling to physiol. maturity (°C day)	10.9
G1	Potential spikelet number coefficient	36.9
G2	Single grain weight (g)	0.26
G3	Tillering coefficient	1
G4	Temperature tolerance	1

Faizabad

Rice

Field experiments were conducted at Faizabad centre and minimum data sets were generated for three rice varieties viz. NDR-359, Sarjoo-52, Swarna under three growing environments or transplanting dates during 2014 and 2015. The DSSAT 4.5 Rice model was calibrated for these three rice varieties using the data of the years 2014 and 2015 (Table 5.9) and validated with observed value of *kharif* rice 2016. The summarized results are presented in Table 5.10. RMSE was found to be high under 5th July transplanted crop compared to other crop environments (15 July and 25 July) with respect to the developmental stages and yield.

Genetic coefficients generated

Table 5.9: Genetic coefficient determined under different rice varieties

Variety Name	P ₁	P ₂ R	P ₅	P ₂ O	G ₁	G ₂	G ₃	G ₄
NDR-359	850	180	180	10.9	34.5	.0280	1	0.90
Sarjoo-52	955	160	200	10.5	39	.0290	1	0.85
Swarna	1100	190	260	10.2	48	.0300	1	0.85

Table 5.10: Validation of CERES-rice model in simulating different phenological stages and yield of rice cultivars under different growing environments

Crop growth parameters	Cultivars	Growing environment								
		5 th July			15 th July			25 th July		
		O	S	E%	O	S	E%	O	S	E%
Days to panicle initiation	NDR-359	59	58	1.69	56	57	-1.8	58	56	3.45
	Sajoo-52	60	61	-1.7	60	59	1.7	59	60	-1.69
	Swarna	64	63	1.6	61	60	1.64	66	67	-1.52
Days to anthesis	NDR-359	90	92	-2.22	90	91	-1.1	88	89	-1.14
	Sajoo-52	94	95	-1.1	89	92	-3.4	93	94	-1.08
	Swarna	97	96	1	95	96	-1.05	94	97	-3.19
Days to Maturity	NDR-359	114	112	1.75	108	106	1.9	115	117	-1.74
	Sajoo-52	115	114	0.9	113	115	-1.8	118	118	0
	Swarna	122	119	2.5	124	125	-0.81	121	123	-1.65
Grain Yield (kg ha ⁻¹)	NDR-359	3690	4014	-8.78	3492	4030	-15.4	3893	4061	-4.32
	Sajoo-52	4282	4758	-11.1	4389	4694	-6.9	4592	4666	-1.61
	Swarna	3070	3391	-10.5	2957	3129	-5.82	2655	2658	-0.11

O- Observed, S-Simulated and E-Error

6. Weather Effects on Pest and Diseases

Anantapur

Pigeonpea

Relationship between weather and incidence of spotted pod borer (*Maruca vitrata*) in Pigeonpea was established under both rainfed and protective irrigation. Incidence of spotted pod borer was first observed on 25.10.17 in the (first fortnight) of July sown crop followed by 2nd FN of June (01.11.17), 2nd FN of July (09.11.17) and 1st FN of August (10.11.17) sown Pigeonpea. During the crop growing period, incidence period of spotted pod borer was observed for 8 weeks in all the sowing environments, irrespective of the date of sowing. Peak incidence of spotted pod borer was noticed between 06.11.17 to 22.12.17 across all the sowing environments, both under rainfed and protective irrigation conditions. Higher incidence of the pest (> 5 webs/m² and > 3 live larvae/m²) was observed for longer period of 6 weeks in 2nd FN of June and 1st FN of July sown crop, followed by 3 weeks in 2nd FN of July and 1st FN of August sown crop. Highest no. of webs/m² and live larvae/m² (11&9) was recorded at 147 DAS in 2nd FN of June sown crop, at 119 DAS in 1st FN of July (8.6 & 5.6), at 112 DAS in 2nd FN of July (10.5 & 10.6) and at 112 DAS in 1st FN of August (9.6 & 5.8) sown crop. The correlation analysis indicated significant negative correlation of both no. of webs per m² and live larvae per m² with minimum temperature, maximum temperature, afternoon relative humidity, rainfall, wind speed and evaporation and significant positive correlation with bright sunshine hours recorded during previous 7 day lag period.

Table 6.1: Correlation coefficients between webs & Live larvae per m² in Pigeonpea and weather parameters

Weather parameters	Webs/m ²	Live Larvae/m ²
Tmax (°C)	- 0.287 **	- 0.203**
Tmin (°C)	- 0.443 **	- 0.343 **
RH 1 (%)	0.052	0.057
RH 2 (%)	- 0.267 **	- 0.215 **
WS (kmph)	- 0.305 **	- 0.276 **
Rainfall (mm)	- 0.358 **	- 0.315 **
SSH (hrs)	0.191 **	0.165 *
EVP (mm)	- 0.392 **	- 0.342 **

* Significant at P=0.05, ** Significant at P = 0.01 ; N = 19

Dynamic relationship between Leaf miner and weather in groundnut

Historical data on leaf miner in groundnut was collected over 2012-2017. The results of the experiments conducted under AICRPAM revealed that the no. of webs per m² shown positive

significant correlation with sunshine hours, rain free days and negative significant correlation with minimum temperature, afternoon relative humidity, wind speed and rainfall received during the previous 7 days. It was observed that the first incidence of leaf miner started when the prevailing maximum temperature is in the range of 32.0-35.6 °C. The no. of webs did not cross 10/m² when maximum temperature is in between 31.0-34.3 °C. Decrease in the minimum temperature by 1.0-1.7 °C after the no. of webs reached 10/m² also lead to further multiplication of the leaf miner. Peak leaf miner incidence was observed when the sunshine hours per day reached 7.3. (>200 webs/m²). Less than 10 mm rainfall during the previous 7 days and dry spell has lead to multiplication of the leaf miner. The no. of webs/m² were less than 50, if the mean rainfall received during the week ranged from 12.7 – 29.6 mm and incidence increased to >200 webs/m² with decrease in rainfall to 6.4 mm.

Palampur

Rice

Analysis of weather data in relation to rice blast

Historical weather data for the past 33 years (1984 to 2014, 2016 & 2017) for rice growing period was segregated into blast years and non blast years at Palampur center. further weather parameters particularly Rainfall, max and min temperatures and relative humidity were identified during blast and non blast years (Table 6.2)

Table 6.2: Weather parameters during disease incidence period (25th July- 5th Aug)

Particulars	Years	Tmax (°C)	Tmin (°C)	Tmean (°C)	Rainfall (mm)	Rainy days	Days RH ≥ 90%	Days with minimum temperature ≤ 20 °C
Blast years	1984, 1986, 1992	25.0	19.1	22.1	331	11	9	10
Non blast years	1985, 1987-1991, 1993-2014, 2016 and 2017	26.1	20.0	23.1	298	10	7	7

Further, weather during one week before disease incidence phase was identified. The average maximum and mean temperature one week before disease incidence of blast years was 24.5 and 21.8 °C i.e., 1.8 and 1.2 °C lower than the non-blast years (Table 6.3). But during 2016 and 2017 it was observed that maximum temperature, minimum temperature and mean temperature were higher than non blast years. These conditions reduced the rice blast disease during 2016 and 2017.

Table 6.3: Weather parameters during one week before disease incidence phase

Particulars	Temperature (°C) during one week before disease incidence phase		
	Maximum	Minimum	Mean
Blast years	24.5	19.1	21.8
Non blast years	26.3	19.7	23.0
2016	26.6	18.2	22.4
2017	27.8	20.0	23.9

This indicates that the blast disease of rice appears during tillering stage of the crop when the temperatures are lower one week before of disease incidence period. But if the temperatures are higher by 1-2 °C then there is little incidence and no further progress in the disease.

Mustard aphid prediction thumb rule

The weather sequence of temperature & rainfall during 1st and 2nd fortnight of February determined the aphid population in mustard (Table 6.4). In first sequence, if during first fortnight of February, temperature are higher (≥ 12.5 °C) and rainfall is low (≤ 14.0 mm) and reverse happens in second fortnight of February, lower population build up takes place. In second sequence if opposite happens, lot of population built up takes place. These sequences were tested during 2017-18 and were found to be correct. It can be seen that the weather (temperature and rainfall) and aphid population followed sequence II and accordingly higher population build up was obtained. This thumb rule is potentially useful hence being used for advising the farmers.

Table 6.4: Effect of temperature & rainfall of 1st and 2nd fortnight of February on mustard aphid

Sequence	Weather	February		Mustard Population
		1 st Fortnight	2 nd Fortnight	
I	Temperature (°C)	High (13.5)	Low (10.1)	Lower (dislodging effect of rain)
	Rainfall (mm)	Low (30.6)	High (110.8)	
II	Temperature (°C)	Low (9.4) 11.6	High (12.5) 14.6	Higher (higher temp & low rainfall favourable)
	Rainfall (mm)	High (65.5) 42.8	Low (14.0) 4.6	

Raipur

Rice

Incidence of BPH and leaf folder

There is a close relationship between plant diseases and weather. Viral and bacterial diseases are more weather dependent than insects due to the fact that viral and bacterial pathogens remain at fixed locations consistently exposed to a particular type of weather for a sufficiently long period. Insects however are mobile and move from place to place at different times and hence are less affected by the changing weather. It is certain that common diseases are dependent on weather compared to insects, however the spread of certain pests is directly weather dependent. The insect population collected through light trap was used to check the pest weather relationship. Trapped of insects has been shown in rice crop for the *kharif* 2017 (Table 6.5).

Graphical representation has been shown for weather parameters and YSB/ Leaf folder (Fig. 6.1) and BPH (Fig. 6.2), respectively. It has been found that the said insects were more in the 37-46 SMW (Sep.10-Nov 18). During this period crop was at reproductive stage and reaching physiological maturity. Initial moderate rainfall, intermittent rains and maximum temperature of around 30-33 °C and minimum temperature of around 20-25 °C are generally favouring

outbreak of YSB. There were sharp increase in YSB collection from 38 SMW (Sept 17-23) and further upto 48 SMW (Nov 26-28). The crop stages during the peak infestations was from milking to grain filling stage. Morning relative humidity is more than 90 per cent and evening relative humidity of minimum 50 per cent is maintained, that generally is very much conducive environment for YSB.

It is clear from Fig. 5 that Yellow stem Borer and Leaf Folder population generally reach a peak in second fortnight of October to first fortnight of November. During this period generally there is a decrease in temperature, cessation of rainfall and decrease in Evening relative humidity. These are the conditions generally favourable for the development of YSB and leaf folder.

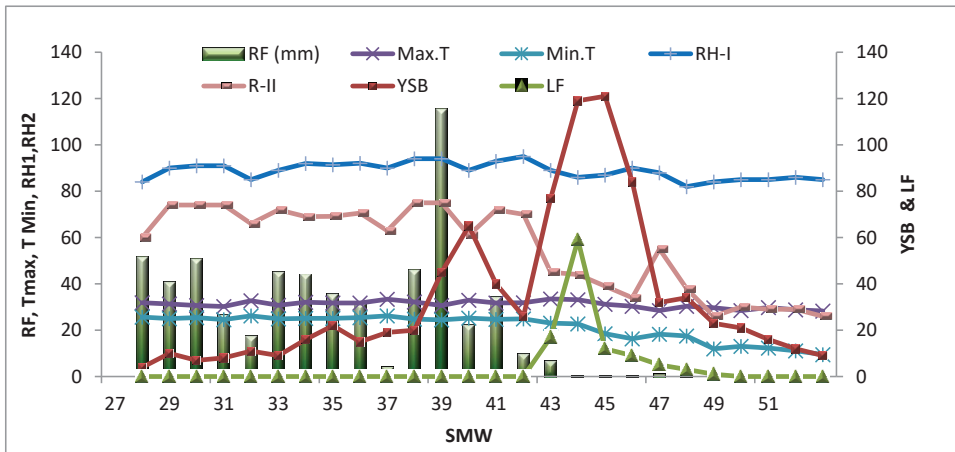


Fig. 6.1: Weather parameters and yellow stem borer population and leaf folder during *kharif* 2017

Weather parameters and development of brown plant hopper are shown in Fig. 6. The peak intensity of BPH is in between end October to first fortnight of November month. Therefore medium to late duration varieties of rice are likely to be more affected by this pest. Forewarning models can help the farmers in its control measures and minimizing the severe economic losses caused.

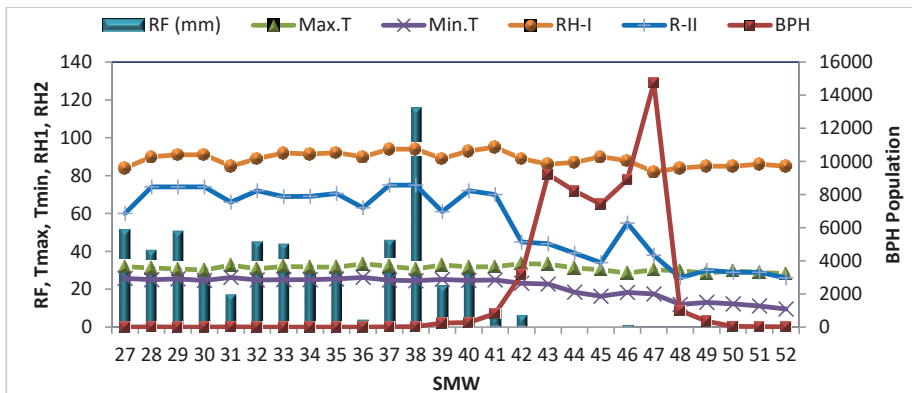


Fig. 6.2: Weather parameters and Brown Plant Hopper during *kharif* 2017

Forewarning models

In this analysis, correlation coefficients between BPH and leaf folder population with individual meteorological parameters for the corresponding and each of the four previous weeks have been worked out. Pest forewarning models developed by using the light trap data and selected significant meteorological parameters

Table 6.5: Week based significant Forecasting equation for BPH

SMW	Equation/Model	R ²	Correlation coefficient
34	$Y_{34} = 275.24 + (-2.934) \times \text{RH-I (3 week lag)}$	0.42	-0.65*
41	$Y_{41} = -48957 + 2036.13 \times \text{Min temp. (4 week lag)}$	0.41	0.64**
	$Y_{41} = 3246.36 + (-408.67) \times \text{SSH (3 week lag)}$	0.40	-0.63**
42	$Y_{42} = -12804.9 - 1529.6 \times \text{(1 week lag SSH)}$	0.53	-0.71**

Table 6.6: Week based significant Forecasting equation for Leaf folder (LF)

W.No.	Equation / Model	(R ²)	Correlation coefficient
34	$Y_{34} = 372.84 + (-4.011) \times \text{RH-I (Current week)}$	0.50	-0.702*
35	$Y_{35} = 573.56 + (-6.154) \times \text{RH-I (1 week lag)}$	0.48	-0.702**
36	$Y_{36} = 466.69 + (-4.993) \times \text{RH-I (2 week lag)}$	0.54	-0.70**
38	$Y_{38} = 1974.5 + (-21.179) \times \text{RH-I (4 week lag)}$	0.42	-0.65**
46	$Y_{46} = -184.02 + 10.84 \times \text{(3 wk lag Tmin)}$	0.72	0.84*
47	$Y_{47} = 16.133 + 18.369 \times \text{RF (2 week lag)}$	0.57	0.76**

Yellow stem Borer

Forewarning of YSB in rice with a lead time of two weeks is possible. Maximum temperature of around 33 °C and minimum temperature of around 25°C are generally favouring outbreak of YSB. The crop stages during the peak infestations was from milking to grain filling stage. Morning relative humidity is more than 90 per cent and evening relative humidity of minimum 50 per cent is maintained, that generally is very much conducive environment for YSB.

Table 6.8: Thumb Rules of Weather for Infestation of YSB in Rice (1998-2015)

Weather parameters	Threshold Limits	During Standard Met Weeks
Tmax	30 to 33 °C	37
Tmin	Around 25 °C	37
RH	More than 85%	37

The multiple regression equations were developed between YSB and significant weather parameters obtained by step wise regression are presented below:

$$Y_{28} = -0.18 + 3.31 \times \text{SSH (1 week lag)} \quad (R^2 = 0.23^*)$$

Y = Yellow stem borer population during the second week of July (28 SMW)

$$Y_{29} = -54.58 + 1.88 \times \text{SH (1 Week lag)} + 0.36 \times \text{RH-I (2 week lag)} +$$

$$Y_{30} = -175.24 + 1.98 \times \text{RH-I (1 week lag)} \quad (R^2 = 0.36^{**})$$

$$Y_{32} = -94.98 + 1.19 \times \text{RH-I (4 week lag)} \quad (R^2 = 0.24^*)$$

$$Y_{33} = 10.30 + 0.13 \times \text{Rain (2 week lag)} \quad (R^2 = 0.51^{**})$$

$$Y_{34} = 8.28 + 0.06 \times \text{Rain (3 week lag)} \quad (R^2 = 0.55^{**})$$

$$Y_{35} = 140.86 + 0.46 \times \text{Rain (4 week lag)} - 1.85 \times \text{RH-II (1 week lag)} \quad (R^2 = 0.37^{**})$$

$$Y_{36} = 208.19 - 2.34 \times \text{RH-II (1 week lag)} \quad (R^2 = 0.42^{**})$$

$$Y_{37} = -63.77 + 0.51 \times \text{RH-I (2 week lag)} + 19.74 \times \text{SSH (2 week lag)} \quad (R^2 = 0.55^{**})$$

$$Y_{38} = -602.08 + 27.94 \times \text{Tmax (1 week lag)} - 2.22 \times \text{RH-II (2 week lag)} \quad (R^2 = 0.71^{**})$$

Y = yellow stem borer population during the corresponding week .

Jabalpur

Chickpea

Association of Weather parameters and larval population (%) of *Helicoverpa armigera*

Weather insect-pest relationship between *Helicoverpa armigera* (Gram pod borer) and weather parameters in chickpea species sown on different dates were analysed and presented.

(a) Early sown chickpea

Larval population of *Helicoverpa armigera* showed increase in numbers when maximum temperature goes beyond 25 °C, minimum temperature goes beyond 10 °C sunshine hours > 8 hours, morning relative humidity > 80 % and evening of more than 25% percent caused an increase in larval population (Fig 6.3).

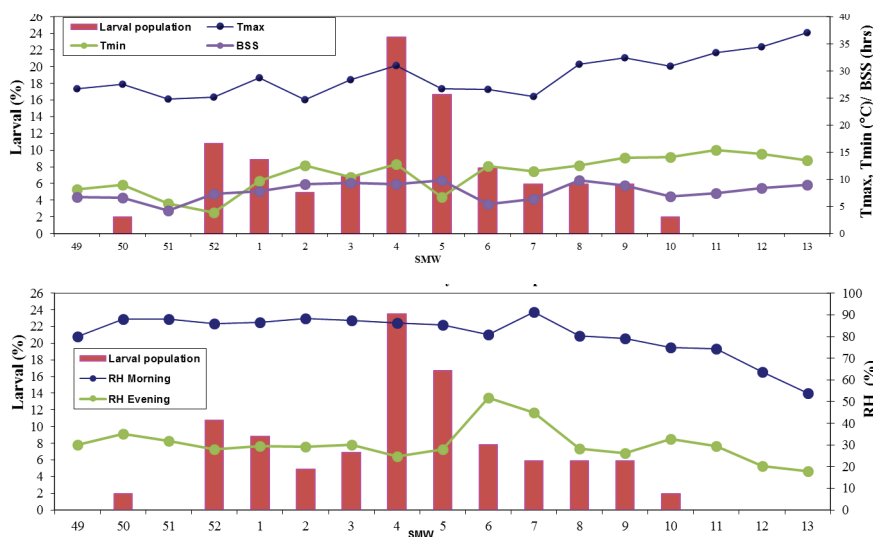


Fig. 6.3 . Effect of Weather Parameters on Larval Population (%) in early sown Chickpea

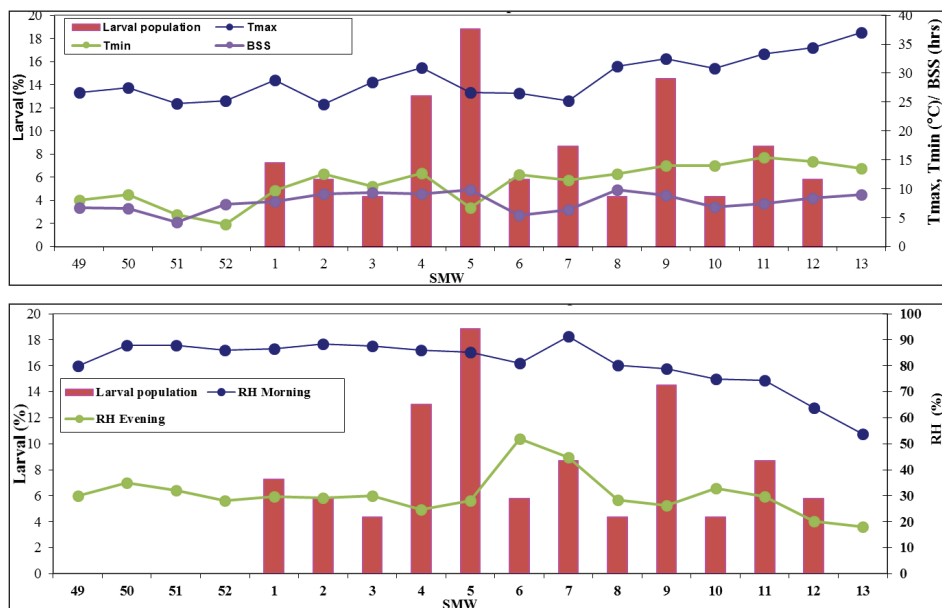


Fig. 6.4: Effect of Weather Parameters on Larval Population (%) in normal sown Chickpea.

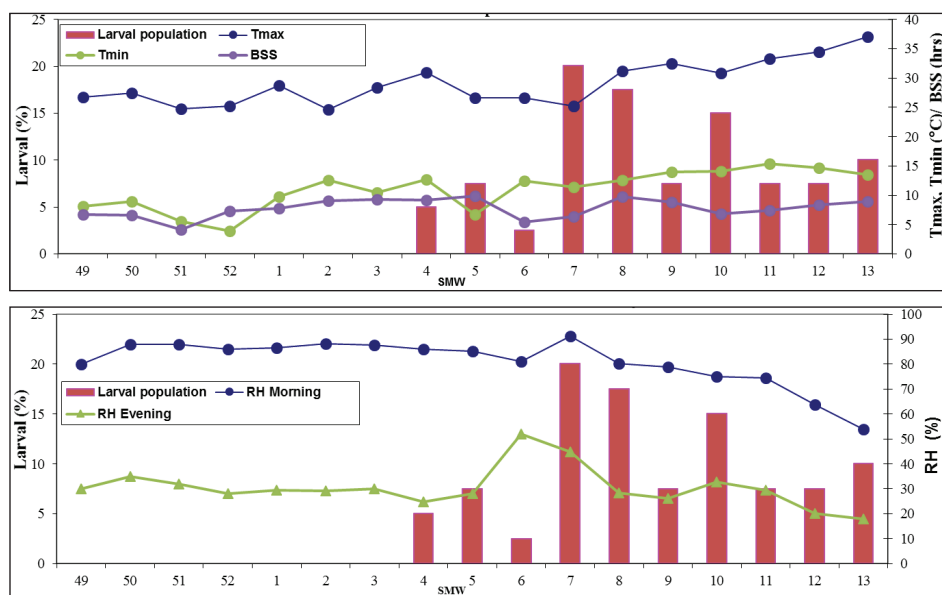


Fig. 6.5: Effect of Weather Parameters on Larval Population (%) in late sown Chickpea

(b) Normal sown chickpea

Larval population increase when maximum temperature goes beyond 25 °C, minimum temperature >10 °C, sunshine hours > 8 hours, relative humidity of morning and evening > 80 % and 28 %, respectively (Fig 6.4).

(c) Late sown chickpea

Larval population increase under the conditions of maximum temperature $> 25^{\circ}\text{C}$, minimum temperature $> 10^{\circ}\text{C}$, sunshine hours > 6 hours, relative humidity of morning and evening $> 80\%$ and 28% , respectively (Fig 6.5).

Anand

Mustard

Aphid index under different sowing environments

The mean aphid index (0-5 Scale) of mustard under different growing environment is presented in Fig 6.6. Maximum aphid index recorded in D_4 sowing followed by D_2 , D_3 and D_1 sowing. Least affected plants with lower aphid intensity were observed in D_1 sowing.

All the data of aphid index of flowering to seed development phase and seed yield recorded in four sowings during fifteen years are depicted in Fig 6.7. Aphid occurrences observed during flowering to seed development phase is associated with prevailing of high humidity condition for 2-3 days. Seed yields of mustard were found higher (≥ 1500 kg/ha) when aphid intensities were lower than 1.7. When aphid intensity increases more than 1.5 during flowering to seed development phase, the seed yield of mustard started to decreases. From this study, it is shown that sowing on 10th October and 20th October found most appropriate for achieving highest productivity and for escaping high aphid intensity problem in mustard.

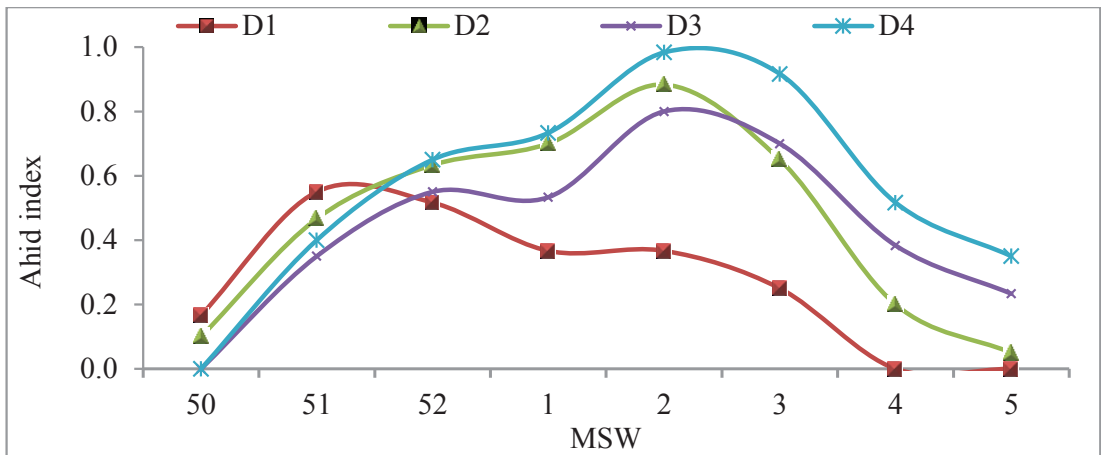


Fig. 6.6: Mean aphid index as prevailed under different dates of sowing (2017-18)

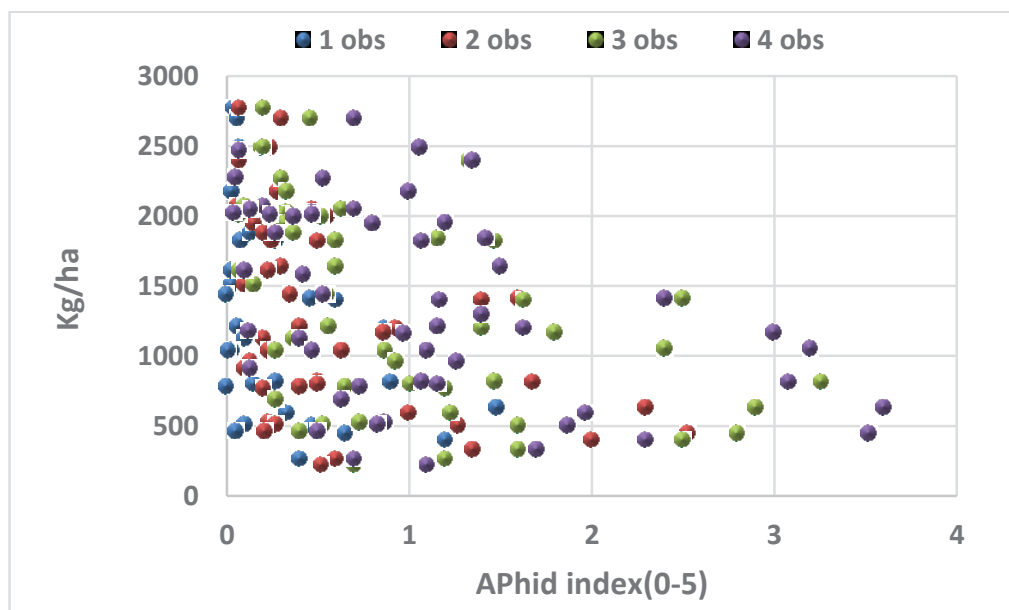


Fig. 6.7: Yield in relation to Aphid intensity at different observations during flowering to seed development

Bangalore

Pigeon Pea

Pod borer incidence recorded from 2005 to 2016 was grouped for different sowing windows and analyzed

Pest infestation in different varieties and Sowing dates

Two way ANOVA indicated that May month sown pigeon pea is least affected while the infestation was found significantly high in June sown pigeon pea (Table 6.8). However, among the varieties pod borer incidence was numerically higher in case of TTB-7 followed by BRG-1 and Hy.-3C interestingly spacing has no influence on the infestation percent (Table 6.9). In variety TTB-7 pod borer infestation was observed to be increasing with spacing but in other varieties, spacing has not shown any effect on infestation.

Table 6.8: Month wise pest infestation counts under different varieties of Pigeonpea

Month/ Variety	TTB-7.pb	Hy.-3C.pb	BRG-1.pb	Average
May	14.2	13.1	11.4	12.9
June	23.2	24.1	25.3	24.2
July	20.0	18.0	18.2	18.8
August	20.0	17.5	20.4	19.3
Average	19.4	17.9	18.5	18.6
ANOVA-F	Months	36.498**	Verities	0.823 ^{NS}

Table 6.9: Month wise pest infestation counts with different spacing options under different varieties of Pigeonpea

Spacing/Variety	TTB-7.pb	Hy.-3C.pb	BRG-1.pb	Average
60	15.6	17.9	16.9	16.8
90	19.0	18.7	19.7	19.1
120	23.8	17.3	19.0	20.0
Grand Total	19.4	17.9	18.5	18.6
ANOVA-F	Spacing	1.485 ^{NS}	Verities	0.749 ^{NS}

Bhubaneswar

Rice

A study was carried out to assess the effect of weather on population built up of two insects viz. White Backed Plant Hopper (WBPH) and Brown Plant Hopper (BPH) in aromatic rice under staggered planting was studied at Bhubaneswar centre.

BPH

The BPH population was found positively correlated with rainfall. The infestation was aggravated with the weekly cumulative rainfall up to 165 mm. However, the highest population was found under the conditions of weekly cumulative rainfall of 80 to 110 mm, maximum temperature (32-34 °C), minimum temperature (25-27 °C), high morning relative humidity 91-95% and evening relative humidity 75-80 % (Fig 6.8).

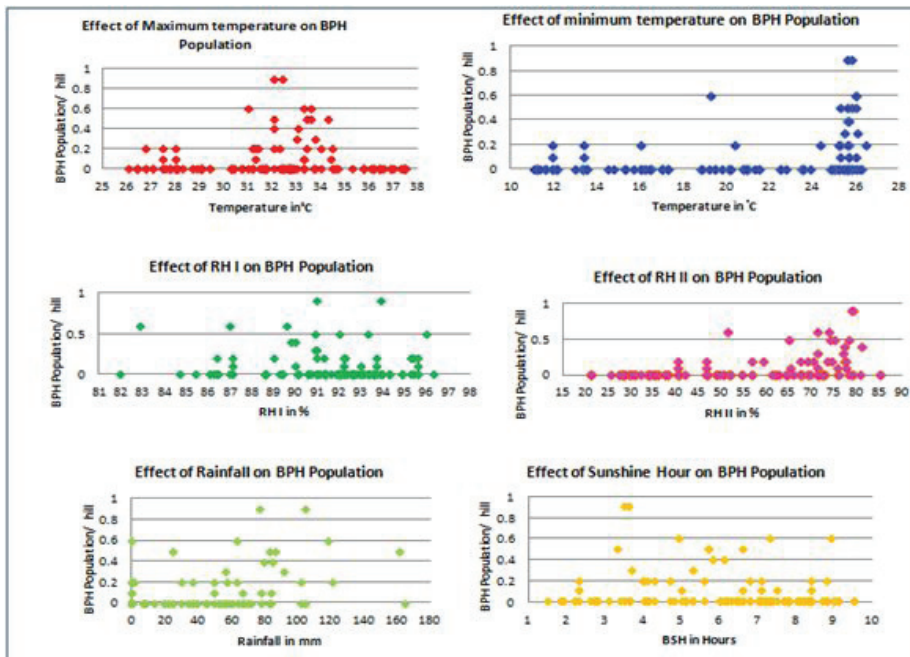


Fig. 6.8: Favorable weather parameters for BPH infestation

The correlation between BPH Population and different weather parameters revealed significant correlation only in two dates of planting viz., 1st August and 16th November out of 12 planting dates. The BPH infestation was found positively correlated with rainfall with $r = 0.55$ in 1st August and $r=0.78$ in 16th November planting dates. Under 16th September planting, BPH population was negatively correlated with morning relative humidity ($r=-0.69$) and in 16th November planting it was positively correlated with afternoon relative humidity ($r=0.58$).

WBPH

The WBPH infestation was observed in most of the planting dates starting from 1st date (16th July) to 11th date of planting (16th December). However, the infestation of WBPH was first observed in 2nd week of August (SMW 33) and continued up to second week of January (SMW 1). Though the population of WBPH was built up from August to January, but the highest occurrence was observed during second week of November in 1st August planting and second peak occurrence was observed during 3rd week of September in 1st September planting of the crop.

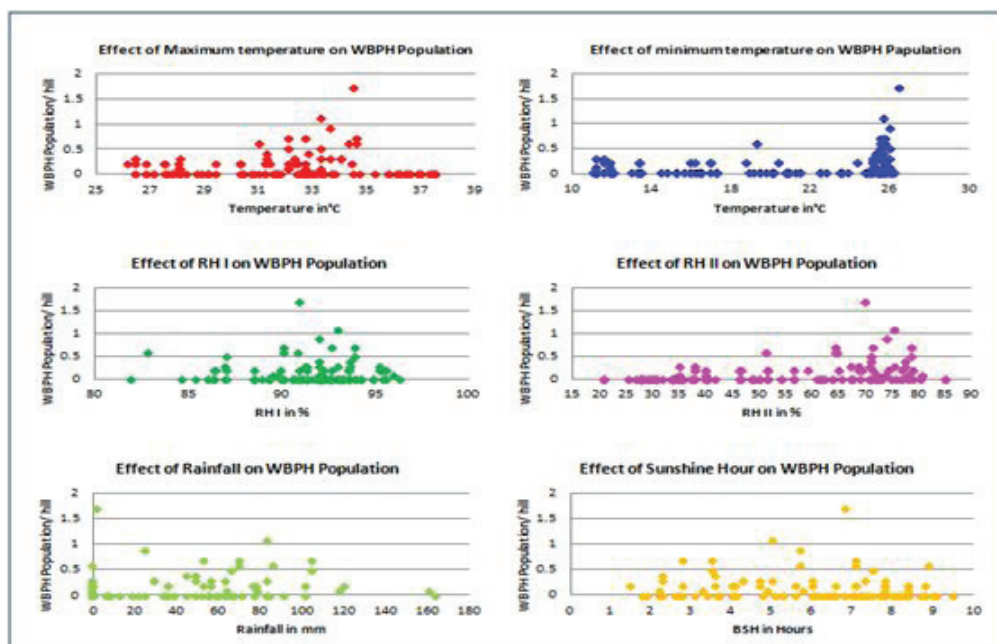


Fig. 6.9: Effect of weather parameters on WBPH infestation.

The WBPH infestation was found to be correlated positively with both maximum temperature and minimum temperature and sunshine hours with r value of 0.56, 0.67 and 0.51 respectively, during 1st August planting date. In 16th August date of planting WBPH was positively correlated with minimum temperature with the r value of 0.52. In 1st September date of planting, WBPH was positively correlated with minimum temperature, evening relative humidity and rainfall with r values of 0.53, 0.58, 0.61 respectively. In 16th September date of planting WBPH was negatively correlated ($r=-0.69$) with morning relative humidity. In 1st November and 1st December dates of plantings, WBPH was negatively correlated with maximum temperature (r value-0.46). In 1st

December date of transplanting, WBPH was positively correlated with evening relative humidity ($r=0.74$) and rainfall ($r=0.48$) respectively. In 16th November date of transplanting, WBPH was positively correlated with evening relative humidity with r value of 0.67 at 1% significance.

Ludhiana

Cotton

Formulation of weather based thumb rules for predicting incidence of whitefly in cotton

The whitefly population data (2004 to 2015) was collected from the selected farmer's field in the Bathinda and Faridkot districts of the state. The population count of cotton whitefly adults were made from three fully formed leaves in the upper canopy of 10 plants/plot selected at random at weekly intervals starting from 25 Standard Meteorological Week (SMW) (18-24 June) upto 42 SMW (15-21 October). The corresponding meteorological data with respect to maximum and minimum temperature, maximum and minimum relative humidity (RH) and rainfall were collected for the corresponding standard meteorological weeks from the meteorological observatories situated at the regional research stations (Bathinda and Faridkot) of the Punjab Agricultural University.

The whitefly count and meteorological data were analyzed to work out the favourable limits of the meteorological parameters conducive for the build up of the whitefly population. To correlate the whitefly population with a combined index of both temperature and humidity, a temperature and humidity index (THI) was computed as ratio of mean temperature and humidity. The analysis of the data revealed that whitefly population flourishes when the maximum temperature is within 32-37 °C and minimum temperature is within 21-29 °C coupled with a humid weather; i.e., maximum RH within the range of 73-90% and minimum RH within the range of 38-74%. Temperature humidity index (THI) of 0.35-0.55, was identified is favourable for incidence and build up of whitefly population. Rainfall in light showers helps the whitefly growth, but a heavy downpour of >35mm washes down the whitefly, thereby acting as a natural control of the pest.

Validation of weather based Expert System for predicting incidence of whitefly in cotton

Weather based Decision Support System for predicting the incidence of whitefly in cotton is being prepared. The initial system has been built and the validation of the system by the real time datasets during 2016 has been done. The Decision Support System for Whitefly in Cotton was validated using the actual whitefly data recorded at Abohar, Bathinda and Faridkot during 2016 and 2017. The DSS successfully predicted the incidence of whitefly in cotton and the success rate during 2016 and 2017 was 78.94 and 73.68 % (Abohar), 94.73 and 84.21 % (Bathinda) and 84.21 and 89.47 % (Faridkot), respectively. The average success rate during two years was 84.20 %.

Vijayapura

Grapes

The data on anthracnose, downy mildew and powdery mildew diseases on untreated vines of grape variety, "Thomson Seedless" were collected at weekly interval from HRS Tidagundi. The data was collected from uncontrolled treatment of various chemical testing experiments

conducted from 2012-13 to 2015-16. The disease data i.e. the progressive disease index(PDI) of each disease at each week are presented graphically. Pooled data of all the four years are presented for individual grape diseases, namely, Anthracnose, powdery mildew and downy mildew (Fig 6.10)

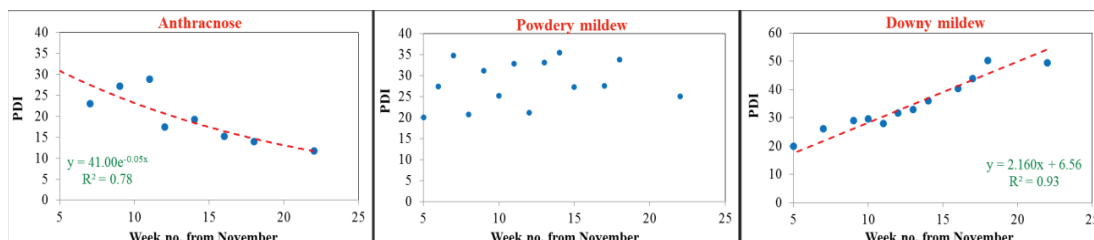


Fig. 6.10: Progress of grape diseases – pooled data of four years

Anthracnose disease decreased from SMW 49 onwards, whereas Downy mildew disease increased during the same period. No clear trend for powdery mildew disease was observed. The relationship between PDI of each disease and weather parameters of current and previous week, i.e., Zero weeks lead time and One-week lead time respectively. Role of temperature on anthracnose disease is noticed for both one week lead time and current week (Table 6.10). From the analysis it was concluded that for forecasting anthracnose disease one week ahead, maximum temperature, morning relative humidity and afternoon humidity need to be considered, which can be used for preparedness for spray schedule. On the other hand, minimum temperature in the current week has to be taken as guide in advising for implementation of the spray schedule for anthracnose disease. In case of both downy mildew and powdery mildew diseases, the values of correlation coefficient are not very high.

Table 6.10: Correlation coefficient between weather variable and incidence of grape diseases

Disease	Lead time (Weeks)	TMax	TMin	DTR	RH1	RH2	RH1-RH2	BSS
Anthracnose	1	-0.81	-0.68	-0.02	0.86	0.81	0.70	-0.52
Anthracnose	0	-0.79	-0.82	0.41	0.50	0.20	0.62	-0.11
Downy mildew	1	-0.19	-0.33	0.25	0.36	0.22	0.38	-0.10
Downy mildew	0	-0.15	-0.02	-0.21	0.42	0.25	0.41	-0.55
Powdery mildew	1	0.34	0.29	0.01	-0.10	-0.15	-0.01	-0.26
Powdery mildew	0	0.12	-0.34	0.56	0.20	-0.03	0.33	0.30

Significant thermal response is noticed in case of Powdery mildew disease. Maximum temperature is seen as the main parameter which has to be considered for forecast at one week lead time for purpose of preparedness, and minimum temperature and/or temperature range at current week for actual implementation. In case of downy mildew, the current week sunshine hours showed highest negative association, but non-significant.

Faizabad

Chickpea

Pod borer is an important major insect pest of Chickpea grown in *rabi* season. An experiment was conducted at Faizabad centre to study the crop-weather pest relationship in Chickpea. The crop was weekly monitored for incidence of pod borer C.O. *Helicoverpa armigera* from November to pod maturity stage. Weather data was collected from the Agromet. Observatory. The infestation of larval population of pod borer were recorded weekly in 5 plants of each plots and finally averaged to get weekly larval population dynamics of pod borer per plant. Data revealed that its appearance was noticed from January onwards till the pod maturity. Maximum occurrence of the pest was noticed during reproductive phase of growth. It was observed that maximum temperature and Evening Relative Humidity are the two weather parameters correlated with the increasing pest population.

Table 6.11: Effect of weather on the population dynamics of pod borer in Chickpea (averaged over 5 years)

Met. Week with date	Max. Temp. (°C)	Min. Temp. (°C)	Morning RH%	Evening RH%	Larval population per m ² or per 100 pod
45 (Nov. 5-11)	29.2	15.3	94.4	52.8	0
46 (Nov. 12-18)	29.3	13.9	91.1	42.2	0
47 (Nov. 19-25)	26.8	11.9	86.2	45.8	0
48 (Nov. 26-2)	25.9	8.1	87.4	38.5	0
49 (Dec. 3-9)	26.1	9.8	91.2	42.1	0
50 (Dec. 10-16)	25.5	10.1	94.8	47.7	0
51 (Dec. 17-23)	23.3	8.1	95.2	61.2	0
52 (Dec. 24-31)	19.4	8.4	97.1	74.1	0
1 (Jan. 1-7)	15.1	4.7	97.5	71.1	2
2 (Jan.8-14)	13.8	5.2	97.8	77.8	2
3 (Jan.15-21)	21.8	4.8	97.8	50.4	3
4 (Jan.22-28)	21.3	5.9	96.7	53.0	3
5 (Jan.29-4 Feb.)	24.3	7.2	95.0	45.1	4
6 (Feb..5-11)	24.3	8.1	86.7	34.8	4
7 (Feb.12-18)	24.7	10.7	91.7	52.7	4
8 (Feb.19-25)	28.7	11.8	88.8	43.8	5
9 (Feb.24-4 Mar.)	30.1	14.1	92.4	42.2	5
10 (Mar. 5-11)	31.1	12.3	91.0	38.5	7
11 (Mar. 12-18)	32.8	13.7	81.7	34.8	9
12 (Mar. 19-25)	34.2	14.2	83.4	25.7	9
13 (Mar. 26-31)	35.2	15.5	85.0	23.8	9
14 (Apr. 1- 7)	35.3	18.7	81.00	35.0	11

Udaipur

Mustard

Mustard crop was sown in four different environments at Udaipur centre. The aphid infestation was observed in all sowing dates with varying population at different phenological stages of mustard. The 1st appearance of aphid was noticed on 6th December, 1st January, 8th January and 12th January under 1st October, 16th October, 1st November and 16th November sowing environments, respectively. The peak infestation was observed on 23rd January under 16th November sown crop when the mean temperature and mean RH was 17.0 °C and 60.3 %, respectively and the crop was in flowering to green seed stage. Analysis of weather data showed that mean temperature 15.2 to 18.1 °C and mean RH 66.5 to 84.3% at flowering to green seed stage of mustard favoured the incidence of mustard aphid.

Table 6.12 : Crop stage and weather parameter during incidence of mustard aphid (2017-18)

Sowing environment	Incidence	Stage of crop	CC (okta)	Max T (°C)	Min T (°C)	Mean T (°C)	RH-I (%)	RH-II (%)	Mean RH (%)
Treatments		Days							
D1	6-Dec-17	67 (F)	4	24.4	11.7	18.1	90	79	84.3
D2	10-Jan-18	78 (GS)	0	26.0	6.4	16.2	93	52	72.7
D3	8-Jan-18	68(GS)	0	24.5	5.7	15.1	92	45	68.5
D4	12-Jan-18	58(F)	0	24.2	6.2	15.2	91	42	66.5

Average weather parameters before 3 days of incidence

Samastipur

Rabi Maize

Rabi Maize crop was grown in four growing environments viz. 1 November, 10 November, 20 November and 30 November during 2017-18 to study the insect pest and weather relationships. The larval counts of climbing cut worm incidence at various growth phases of *rabi* maize crop planted in different dates showed that maximum incidence of the pest occurred during tasseling stage of the crop. It was observed from the weather analysis that the maximum temperature of 28.2 to 29.1 °C and higher relative humidity of 89-91% in the morning hours and 62-65% percent in the afternoon hours were congenial for the higher infestation (Table 6.13).

Table 6.13: Population (larva/plant) of climbing cut worm incidence in *rabi* maize during 2017-18.

At Tasseling stage							
Date of sowing	SMW	Mean Insect population (larva)/plant	Max T (°C)	Min T (°C)	RH1 (%)	RH2 (%)	Rainfall (mm)
D1-1.11.17	8	2.4	28.2	13.1	91	65	0
D2-10.11.17	9	2.2	29.1	16.1	89	62	0
D3-20.11.17	12	1.6	34.0	14.8	77	48	0
D4-30.11.17	13	1.4	33.7	18.4	75	56	0

Kovilpatti

Blackgram

Experiments were conducted to study the Influence of weather parameters on incidence of powdery mildew disease in blackgram and incidence of leaf hopper in cotton under rainfed conditions at Kovilpatti centre.

Validation of statistical relationships with current year data

The black gram variety VBN 6 was selected for the validation. The receipt of Northeast monsoon rainfall was 421.4 mm with 17 rainy days and it was 6% more than normal rainfall during the crop growing period. The weather distribution during the crop period was presented in the Fig 6.11. The disease incidence was observed from 47th standard meteorological onwards. The statistical analysis correlations showed highly significant negative relationship of PDI with minimum temperature (Table 6.14) which implies that reduction in minimum temperature leads to increase in the powdery mildew disease spread in the crop and vice versa.

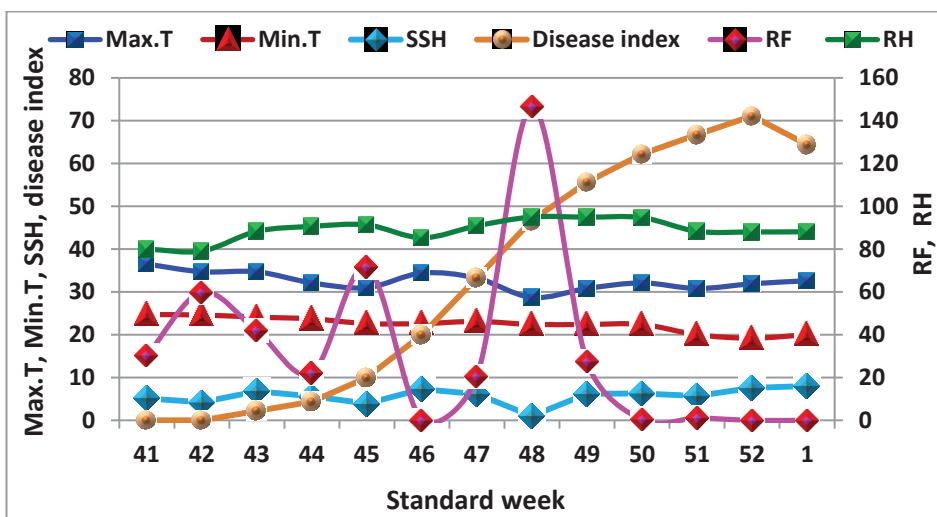


Fig 6.11: Relationship between Weather parameters and powdery mildew disease incidence in black gram crop

Table 6.14: Correlation of Disease index with different weather parameters

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

Taking minimum temperature, the most congenial weather parameter among the weather parameters tested as the predictor variable, the following estimation was developed for predicting powdery mildew disease in black gram. The equation explains nearly 76% of variability in disease incidence.

$$Y = 351.086 - 14.145 \text{ Min.T, } (R^2 = 0.759)$$

Y = Disease incidence after establishment

Influence of weather factors on aphids and leaf hopper incidence in cotton

A field experiment was carried out to study the influence of weather variables on leaf hopper population in cotton. The crop was sown on 25.09.2017. Leaf hopper population was observed in numbers per leaf at weekly intervals along with weather. Leaf hopper incidence was observed from 43rd standard week. Both wind velocity and minimum temperature had negatively influenced the leaf hopper population (Fig. 6.12). Correlation between Leaf hopper and weather parameters (Table 6.15) showed that, decrease in wind velocity and minimum temperature significantly increased the leaf hopper population. Prophylactic spray of systemic insecticide is essential for the control of this pest during reproductive stage.

Table 6.15: Correlation of leaf hopper population with weather parameters

Max.T (°C)	Min.T (°C)	SSH	WV	RH-I (%)	RF (mm)	EVP
-0.721**	-0.673**	0.047	-0.751**	0.504**	-0.125	-0.543**

The following equation taking wind velocity and Min Temperature as predictor variable explained 72% of the variation in Helicoverpa population.

$$Y = 19.3 - 1.126 \text{ WV} - 0.538 \text{ Min. T, } (R^2 = 0.72)$$

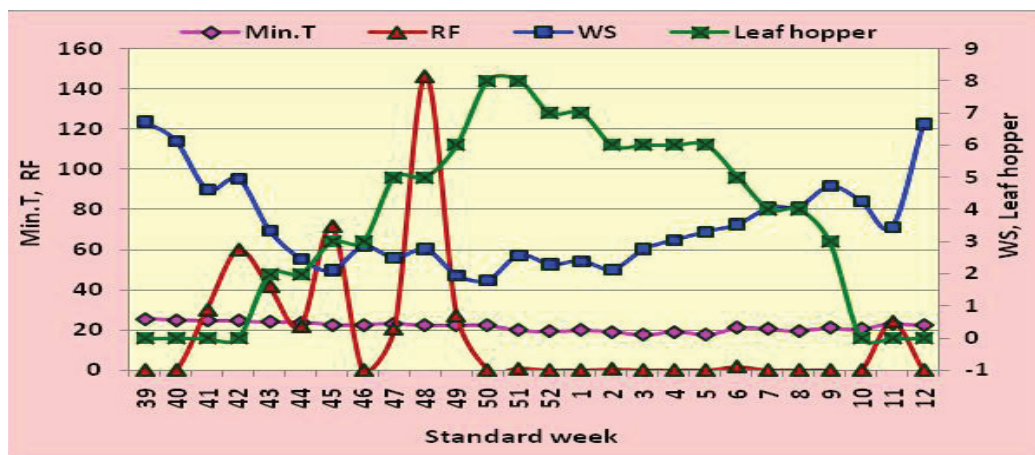


Fig. 6.12: Effect of weather factors on leaf hoppers population in cotton

Jammu

Mustard

An experiment was conducted to study the influence of weather parameters on the incidence and spread of Aphids in Gobhi sarson crop in sub tropical area of Jammu. Population build-up of aphids in gobhi sarson under different micro-climatic conditions (three sowing environments)

with three varieties GSL-1, ONK-1 and DGS-1 was studied during *Rabi* 2017-18. The correlation coefficients derived between the aphid population and different meteorological parameters preceding ten days reveals that the Maximum, Minimum and Mean temperature have significant positive relationship with aphids population, whereas, morning relative humidity is negatively correlated with aphids population (Table 6.16).

The severity of aphids attack was observed more when the maximum temperature ranged between 17.0 to 22.6 °C, minimum temperature ranged between 2.8 to 7.6 °C and maximum & minimum relative humidity ranged from 40 to 80 and 60 to 92 per cent, respectively. The aphid population peak was usually observed in the month of February and hence late sown crops, with grand growth period (start of seed development) having more leaf area experienced more aphid attacks (Fig 6.13).

Table 6.16: Correlation coefficient of aphids population with various weather parameters at different days after incidence in mustard crop during *rabi* 2017-18.

	Max.T (°C)	Min. T (°C)	Mean. T (°C)	RHm (%)	RHe (%)	RH Mean (%)	Rainfall (mm)	SSH (hr)	Thermal Relative Humidity
D 1	0.057	0.549**	0.436**	0.146	0.325**	0.334*	0.223	0.096	-0.157
D 2	0.036	0.648**	0.410**	-0.453**	0.430**	0.346*	0.031	-0.449**	-0.016
D 3	0.514**	0.546**	0.581**	-0.349*	-0.308*	-0.373*	0.293	0.263	-0.702**
D 4	0.513**	0.472**	0.671**	0.292	-0.243	-0.172	0.298	0.201	-0.606**
D 5	0.520**	0.180	0.511**	-0.175	-0.270	-0.310*	0.485**	-0.130	-0.472**
D 6	0.203	0.078	0.194	0.042	-0.101	-0.076	0.202	-0.141	-0.247
D 7	0.318*	-0.313*	0.049	0.051	-0.230	-0.182	-0.450**	0.361*	-0.145
D 8	0.199	0.063	0.194	-0.218	-0.141	-0.179	-0.462**	-0.156	-0.182
D 9	0.101	0.373*	0.326*	-0.138	0.157	0.104	-0.287	-0.037	-0.208
D 10	0.202	0.268	0.282	-0.532**	-0.120	-0.237	0.397**	-0.390**	-0.246

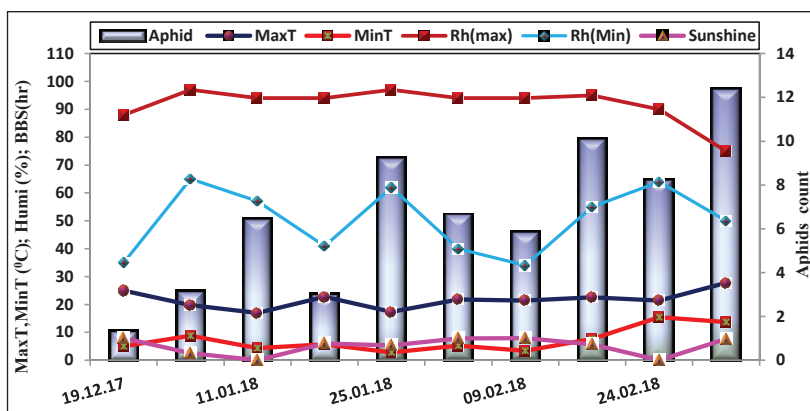


Fig 6.13: Aphid's population and weather parameters at different days after sowing in Gobhi Sarson crop during *Rabi* 2017-18.

Hisar

Cotton

A study was conducted to develop simple disease and weather relationship models for prediction of cotton leaf curl virus disease in cotton. The weekly disease incidence of cotton leaf curl virus disease in susceptible variety HS-6 was recorded under natural conditions. The disease data from 2005 to 2017 has been collected and correlated with the meteorological parameters. From the study it was observed that the optimum maximum temperature for the disease development was noted to be between 32 to 37°C, minimum temperature between 22.5 to 27 °C and relative humidity morning (RHm) 68 to 85 percent (Table 6.17). The wind speed showed a highly significant negative correlation with disease development. There was an exponential relationship between disease development and cumulative rainfall (sigmoid growth curve) i.e. the rate of disease development was initially slow till the accumulation of 100 mm rainfall and thereafter disease development increased sharply. The sunshine hours showed a linear relationship with disease indicating that the clear days favored its development.

Table 6.17: Relationship between PDI of leaf curl viruses and weather parameters

	Tmax (°C)	Tmin (°C)	AVPm (mm)	AVPe (mm)	RHm (%)	RHe (%)	WS (kmph)	SSH (hr.)	Ep (mm)	Rf (mm)	Accu. RF (mm)
Correlation	-0.57	-0.44	-0.22	-0.17	0.45	0.04	-0.64	0.17	-0.63	-0.08	0.72
Sig. (5%)	Sig	Sig	Sig	Sig	Sig	NS	Sig	Sig	Sig	NS	Sig

Stepwise multiple linear regression equations were developed to identify better models using for predicting cotton leaf curl virus above weather variables (Table 6.18).

Table 6.18: Multiple regression equation for PDI prediction (leaf curl virus disease)

Sr.	Multiple regression models	R ²
1.	$Y = -91.39 - 1.398 * T_{max} + 3.59 * BSS + 3.590 * EP - 1.956 * WS$ (2005-2015)	R ² =0.61
2.	$Y = 251.71 - 3.88 * T_{max} + 4.04 * T_{min} - 4.382 * AVPm - 5.83 * WS - 5.15 * Ep$ (2005-2016)	R ² =0.54
3.	$Y = 112.37 - 1.3799 * T_{max} + 0.080 * Accu. RF - 4.278 * WS - 1.0186 * Ep$ (2005-2017)	R ² =0.58
4.	$Y = 273.619 - 4.567 * T_{max} + 0.7927 * T_{min} - 0.8504 * RHm - 5.0406 * WS + 0.087 * Accu. RF$ (2005-2017)	R ² =0.59

Where, Tmax: Maximum temperature (°C), Tmin: Minimum temperature (°C), AVMm: actual vapour pressure morning (mm Hg), Ep: Pan Evaporation (mm), WS: Wind speed (km/hr), Accu. RF: Accumulated rainfall (mm), RHm: Relative humidity morning (%).

7. Agromet Advisory Services

Timely start of Southwest monsoon rains and their distribution governs entire gambit of the agriculture in India, which in turn affects the economy of the country. On the other hand, extreme events like heavy and unseasonal rainfall, flash 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 near real time crop management issues. A timely agromet advisory can save inputs (seeds, fertilizers, plant protection chemicals etc) as well as entire crop (especially at maturity stage). Agromet Advisory Service (AAS) is a part of extension of 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” (Fig. 7.1) 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.



Fig. 7.1: Crop weather outlook website

Apart from this, the coordinating unit at CRIDA plays a major role in issuing daily, weekly, Agromet advisories based on Extended Range Weather Forecasts, and monthly bulletins for “NITIAYOG” on status of monsoon, progress in *khari*f sowing and AAS for deficit/excess rainfall areas of the country during southwest monsoon (Fig. 7.2). 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



Fig. 7.2: Daily weather report, weekly AICRPAM / NAAS bulletins and monthly NITIYOG report

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 2018 Southwest monsoon was shared with state government authorities during interface meeting on preparedness for monsoon 2018. 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, 2018.

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, *kharif* sowings progress 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 during monsoon season.

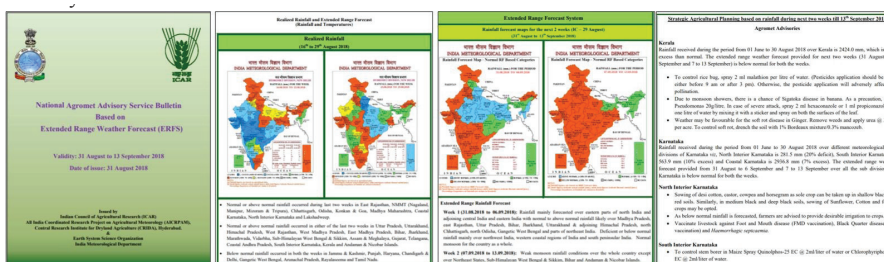


Fig. 7.3: ERFS based NAAS bulletin

1. Agroclimatic Characterization

- The concept of agroclimatic approach for determining the onset of monsoon season was developed by Anand center. Agroclimatic onset for *kharif* season progresses from South East to North West of the state during the season. South Gujarat has early onset on 8th June and it covers the entire state with its latest onset in Kutch region on 3rd July.
- Decadal distribution of Annual rainfall (1877-2017) showed a declining trend at Anantapur.
- Changes in rainfall, Length of growing period and through K-mean cluster analysis by Bangalore center established that the climate of the taluks Tiptur (Tumukur dist.) and Arasikere (Hasan Dist.) shifted from Central Dry Zone (90-150 day LGP) to Southern Dry Zone (150 to 180 day LGP) in Karnataka
- Block level annual rainfall trends were worked out over Bhadrak district of Odisha by Bhubaneswar Centre revealed decreasing trend in annual rainfall at Basudevpur ($p=0.01$ level)
- Analysis of trends in two categories of extreme events viz., 75-100 mm and >100 mm by Solapur center revealed decreasing trend in rainfall >100 mm at Ajra of Kolhapur and Patan tehsil of Satara district during southwest monsoon season.
- Dry spells analysis done at Raipur for different districts of Chhattisgarh revealed increasing trend in longest spell less than critical value at Bijapur, Janjgir-champa, Kondagaon, Korba and Sukma districts causing moisture stress in rainfed agriculture.
- Analyzing extreme weather events during 1979 to 2017 at Palampur showed increase in dew days at the rate of 3 days per year and hail events by 2 per decade.
- At Vijayapura, analysis of seasonal rainfall in covering high area districts of green gram under two different productivity levels viz., medium and low showed that lower rainfall in June and greater variability is the major reason for low productivity
- Probability of getting consecutive wet and dry spells of 10, 20, 30 mm over mid altitude intermediate zone of Jammu region showed that Jammu, Katra, Samba and Rajouri districts following same pattern with wet followed by wet week during 21 to 40th week. Whereas Bhaderwah, Banihal and Batote follow different pattern.
- Decadal means of annual and seasonal rainfall (mm) during 1971-2017 at Kanpur showed a decline in annual rainfall in all the consecutive decades.
- Increase of North East Monsoon rainfall in all blocks of Ramanathapuram district was observed by Kovilpatti center.
- At Dapoli, analysis of long term rainfall (1972-2017), showed drought years of moderate intensity in only 13% of the years. Higher single day rainfall events of >250 mm or more are experienced in 66% of the years.

- The probability analysis of occurrence of consecutive dry weeks at five locations in Upper Brahmaputra valley zone of Assam carried out at Jorhat Centre showed that the drought probability of 50% or more after 42 SMW at four locations and after 38 SMW at one location.
- The Parbhani centre worked out length of growing period of all the districts of Marathwada region. The LGP varied from 120 to 150 days across all the districts of Marathwada region.
- Samastipur centre has carried out the initial and conditional probabilities of rainfall in the districts of Samastipur and Muzaffarpur to observe highest conditional probability of > 50% for receiving wet week followed by wet week of 20 mm rainfall during 25-40 SMW in both the districts.
- The Standardized Precipitation Index (SPI) values calculated using 35 years (1983-2017) rainfall at Thrissur identified drought events (SPI < -1.0) 7, 4, 5 and 5 during southwest, northeast, winter and summer seasons respectively.
- Udaipur centre analyzed one day extreme rainfall events during last 28 years in 14 districts of Rajasthan to find out the highest frequency of occurrence of highest one day rainfall events in Sirohi district (29% of the years) followed by Bhilwara and Banswara (both in 11% of the years).
- The analysis of extreme temperature and rainfall carried out at Ludhiana centre over different locations of Punjab showed highest frequency of extreme high temperature events (>44 °C) of 432 at Bathinda and extreme low temperature (<0 °C) events of 101 at Amritsar. The extreme rainfall events of >50 mm were observed to more frequent at Ludhiana.

2. Crop Weather Relationship

Kharif 2017

Rice

- At Jorhat, reduction in grain yield with each delay in sowing w.r.t. 26 June was observed due to reduction in rainfall and temperature during reproductive period. The minimum temperature (ripening period) based predictive model was the best for prediction of grain yield with R^2 , 0.91.
- Crop sown on 5 June registered higher heat and radiation use efficiency of 2.7 kg ha⁻¹ °C-day⁻¹ and 3.0 g MJ⁻¹, respectively for the variety Sahbhagi at Ranchi. The grain yield showed negative correlation with maximum temperature at all critical stages of rice.
- Exposure of three cultivars of rice, MTU-1010, Rajeshwari and CG Sugandhit Dhan to three different growing environments at Raipur, revealed higher yield in 15 June (4019 kg ha⁻¹) and 30 Jun (3895 kg ha⁻¹) transplanted rice may be attributed to favorable maximum and minimum temperature during milking to maturity and lower yield in 01 June (2574 kg ha⁻¹) crop may be due to unseasonal heavy rainfall in the dough stage.
- In Palampur, panicle initiation did not take place in Basmati rice transplanted on July 15. The reason was ascertained by comparing with this crop grown under Jammu

conditions, where panicle initiation was observed. The maximum temperatures at Palampur lowered by 9.0-9.5 °C and 4.5-6.5 °C during sowing to emergence and emergence to Physiological maturity, respectively as compared to Jammu were understood to be the reason for non-initiation of panicles at palampur.

- At Jammu, rice yield decreased by 14.9 and 28.7 per cent with delay in sowing/transplanting by 20 and 40 days, respectively due to reduced GDD, HTU and PTU accumulated at physiological maturity with each delay in sowing.
- At Mohanpur, low sunshine hours during flowering to grain filling stage of 01 July transplanted crop reduced the crop yield (3721 kg ha⁻¹) compared to higher yield (4365 kg ha⁻¹) achieved in 16 June crop. Compared to previous years, due to higher (36-37 °C) maximum temperature, more number of chaffy grains were produced in the year 2017.
- Maximum heat units of 2215 °C-days were required by 23 SMW transplanted rice crop compared to 2163 °C-days required by 25 SMW transplanted crop at Dapoli.

Maize

- At Kanpur, June 19 sown crop (among growing environments) and cv Azad Hyb-2 (among cultivars) recorded the highest grain yield (6290 and 6470 kg ha⁻¹) and heat use efficiency (7.73 and 7.87 g m⁻² °C-day⁻¹)

Pearl millet

- Correlation between grain yield and minimum temperature was found to be significantly negative (-0.66*) and rainfall showed significantly positive correlation with yield (0.59*) at Hisar.
- Crop-weather relationship studies conducted at Anand showed that delay in sowing after onset of monsoon resulted in decline in yield almost linearly. Cultivar GHB 744 has maximum productivity under timely sowing (at onset of monsoon) followed by GHB 558 and GHB 5383.
- At Solapur, the analysis of experimental data (2013-17) reveal that pearl millet sown in second fortnight of July produced significantly higher grain yield (1711 kg ha⁻¹) and biomass yield (3563 kg ha⁻¹) due to higher mean consumptive use of moisture (319 mm), mean moisture use efficiency (5.2 kg ha⁻¹ mm⁻¹) and higher RUE (1.98 g MJ⁻¹) compared to other growing environments.

Finger millet

- Based on the study of moisture depletion pattern at different phenophases and the yield collected in finger millet over six years (1995-2001) drought classification in finger millet was made as: 20-40 PASM (severe), 40-60 PASM (Moderate), > 60 PASM (no drought). The threshold value of 50 per cent may be considered to differentiate drought and non drought areas.

Soybean

- At Vijayapura, the lower yield level in 2016 (1374 kg ha⁻¹) compared to 2017 (2336 kg ha⁻¹) can be attributed to lower seasonal temperature range of 6.5-13.5 °C in 2016

as compared to 5.5-8.5 °C in 2017. It was also due to higher rainfall (> 70 mm) in two higher yield growing environments of 2017, which indicates that rainfall during flowering and pod formation and filling is important to obtain high yield of soybean.

- The highest seed yield of 1089 kg ha⁻¹ could be obtained under 21 June sown crop at Udaipur, which was significantly superior over 1 Jul and 11 July sown crop varieties by 33.1 and 73.9 per cent, respectively due to more number of sunshine hours and higher rainfall (607 mm) during the crop growing period of 21 June compared to other dates of sowing. Comparatively shorter dry spell during the reproductive phase (21 days) in case of early sowing helped in achieving higher yield than other growing environments.

Pigeonpea

- Based on percent available soil moisture (PASM) and seed yield relationship studies at Bangalore, classification of drought severity in Pigeonpea could be made as: 25-30 PASM (severe), 30-60 PASM (Moderate), > 60 PASM (no drought) for pigeon pea.

Greengram

- Greengram crop matured 15 days earlier in case of first date of sowing (7 Sep) compared to other dates (17 and 28 September), irrespective of varieties (Meha, PM 05, Samrat). However, in crops of all varieties D2 produced highest average yield (1720 kg ha⁻¹) followed by D3 (1657 kg ha⁻¹) and D1 (1363 kg ha⁻¹) which was due to favourable mean temperature range of 28-30 °C during the reproductive stage of 17 September sown crop.
- Crop weather relationship studies undertaken at Jorhat involving three varieties viz., Pratap, SGC-16 and Samrat varieties under three growing environments (sown on 5 September, 21 September and 7 October 2017) revealed significant positive correlation between seed yield and maximum temperature during Budding, Flowering and 50% podding stages (0.69*, 0.76*, 0.66*, respectively) as well as minimum temperature during budding and 50% podding (0.80*, 0.77*).

Groundnut

- Crop-weather relationship studies conducted at Anantapur showed that crop sown during 2nd fortnight of July produced significantly higher yield (2622 kg ha⁻¹) compared to 1st fortnight of Jul (2303 kg ha⁻¹) and 1st fortnight of Aug (1766 kg ha⁻¹). The higher yield in 27 July sown crop may be attributed to higher sunshine hours during both vegetative and reproductive stages and higher rainfall (123.6 mm) during pegging to pod development stage.
- Based on percent available soil moisture (PASM) and seed yield relationship studies at Bangalore, classification of drought severity in groundnut could be made as: 35-50 PASM (Severe), 50-70 PASM (Moderate), >70 PASM (No drought).

Sunflower

- Crop weather relationship studies in sunflower (2013-2017) at Solapur brought out that Cumulative moisture use of 350 mm and maximum temperature of around 32-33 °C are the optimum limits for obtaining highest yield.

Rabi 2017-18

Wheat

- At Ludhiana, historical (1971-2015) wheat productivity of Ludhiana district was analyzed in relation to temperature during 45th - 15th SMW for determining temperature thresholds for achieving higher and lower yields. The validation of these thresholds with the actual maximum and minimum temperature during the years 2015-16 (low productivity year) and 2016-17 (high productivity year) showed in close agreement with them.
- At Palampur, 05 November and 05 December sown crop produced higher and on par yield (2500 and 2580 kg ha⁻¹, respectively) where as late sown (20 December) crop achieved lowest yield (1820 kg ha⁻¹). The lower yield under delayed sowing compared to early sowing was due to higher temperatures during tillering to heading and heading to grain filling stages. By analyzing long-term (6 yrs) yield data for obtaining >4000 kg ha⁻¹ yield of irrigated wheat, maximum and minimum temperatures of 15.5-20.7 °C and 4.2-9.4 °C during Tillering to heading and 20.5-25.9 °C and 7.9-13.8 °C during heading to grain filling were found to be optimum at Palampur.
- The reason for achieving wheat yield at Ranichauri in the 15 Nov sown crop was identified due to higher plant population (218 per m²) compared to other dates of sowing due to higher thermal regime (maximum and minimum temperature) prevailed in 31 Oct to 15 Nov sown crops.
- Study on the effect of growing environments and wheat cultivars at Kanpur showed highly significant negative relationship between grain yield and temperature ($T_{\max}$, $T_{\min}$ and soil temp.) at all stages during reproductive period (jointing to maturity).
- Crop-weather relationship studies conducted in wheat cultivars HD 2967, Raj-3077 and RSP-561 under four growing environments showed highest RUE (1.64 g MJ⁻¹ m⁻²) in 05 November sown crop followed by 1.26, 1.01 and 0.84 g MJ⁻¹ m⁻² in 20 November, 05 December and 20 December sown crops, respectively. Among the varieties HD-2967 showed highest RUE (1.25 g MJ⁻¹ m⁻²) at all the stages of the crop, which was reflected in its higher yield (3785 kg ha⁻¹).

Barley

- The 03 November sown barley crop at Hisar had recorded highest radiation use efficiency at 60 DAS as well as heat use efficiency at physiological maturity compared to other dates of sowing which was reflected in the highest yield (5900 kg ha⁻¹) achieved by it.

Rabi maize

- Correlation studies between grain yield and weather parameters during different phenophases at Samastipur showed maximum temperature during tasseling to silking and silking to maturity played an important role by influencing the grain yield positively (0.65* and 0.58*, respectively), On the other hand, minimum temperature during germination to knee high showed significant negative effect ($r = -0.60^*$) and milking to dough had significant positive higher impact on grain yield ($r = 0.72^{**}$).

- Crop-weather relationship studies conducted at Kovilpatti showed that the 09 and 16 October sown crops recorded the higher grain yield ($4871\ 4752\ \text{kg ha}^{-1}$) and earlier sown crops (29 September and 03 October) recorded lesser yield due to receipt of less rainfall in irregular intervals.

Mustard

- Significantly highest seed yield ($2526\ \text{kg ha}^{-1}$) was recorded in the crop sown on 10 October which declined linearly with delay in sowing. Considering production performance of the cultivars under different growing environments, optimal weather variable ranges during different phenophases of the crop for achieving higher productivity were also determined.
- The significantly higher seed yield recorded in 31 October sown crop over subsequent dates (15 and 30 November) at Faizabad was related to favourable maximum and minimum temperature ($28.0\text{-}29.9\ ^\circ\text{C}$ and $12.2\text{-}12.3\ ^\circ\text{C}$, respectively) and higher sunshine hours during both vegetative and reproductive stages.
- The crop weather relationship studies in mustard at Udaipur showed highly significant positive relationship between seed yield and mean temperature during vegetative stage. The unit increase in mean temperature during vegetative period increases seed yield of mustard by $160\ \text{kg ha}^{-1}$.
- Three years' pooled data showed that higher rainfall during sowing to emergence and higher maximum temperature during emergence to first flower affected mustard yield positively at palampur. In all the cultivars, the negative impact of rising minimum temperature during flowering to 90 % pod formation is higher ($75\text{-}127\ \text{kg ha}^{-1}\ ^\circ\text{C}^{-1}$) than that of maximum temperature ($75\text{-}127\ \text{kg ha}^{-1}\ ^\circ\text{C}^{-1}$).

Rabi Sorghum

- Relationship of grain yield with maximum and minimum temperature pooled over five years' at Solapur indicated that, yield increased up to maximum and minimum temperature of 32.0 and $17.5\ ^\circ\text{C}$, respectively and decreased with temperature above these threshold limits. Among all the sowing dates the crop sown at SMW 40 (01-07 Oct) has produced maximum grain yield ($1204\ \text{kg ha}^{-1}$). Among the varieties, M-35-1 produced significantly higher grain yield ($1057\ \text{kg ha}^{-1}$).

Chickpea

- The higher yield in 05 November sown crop of chickpea at Anantapur was found to be related to higher daily thermal temperature range (DTR) of $18.4\ ^\circ\text{C}$ during pod development to maturity compared to the DTR in 25 Oct ($16.9\ ^\circ\text{C}$) and 25 Nov ($16.8\ ^\circ\text{C}$) sown crops.
- At Vijayapura, the experiment showed that the variety BGD-111-1 performed better compared to other varieties under both favourable and unfavourable conditions during 2017-18.
- Chickpea varieties sown late (10 Dec) at Ranchi were exposed to comparatively higher average maximum ($27.6\ ^\circ\text{C}$) and minimum ($10.5\ ^\circ\text{C}$) air temperatures during each stage of the growing period than the timely sown crop varieties. Total sunshine hours were also found considerably higher (254 hrs) for early sown crop (10 Nov) than normal

(248 hrs) and late sown (221 hrs) crops during reproductive stage, which was reflected positively in higher seed yield (2160 kg ha⁻¹).

- The higher yields in the 10 Nov and 25 Nov sown crops at Raipur were found to be in association with lower maximum (28.9-29.8 °C) and minimum (8.2-12.5 °C) temperature during the crop growing period compared to the third date (10 Dec).

Potato

- The correlation study between potato yield at Hisar and phenological stage-wise weather parameters indicated that yield had significant positive correlation with both maximum and minimum temperature during emergence to tuber initiation and negative correlation with sunshine hours during tuber bulking to physiological maturity.

Pooled Analysis

- **Rice** - Experimental data of a common variety of Rice (Swarna) under different growing environments pooled over Jorhat, Mohanpur and Bhubaneswar of the same agroclimatic zone during *kharif* 2017 was analyzed in relation to phenophase-wise weather parameters revealed that every degree increase in maximum and minimum temperature caused 0.18 and 0.06 t ha⁻¹ yield reduction, respectively.
- **Soybean** - Experimental data of Soybean (JS-335) grown under different growing environments at Akola, Bijapur and Udaipur during *kharif* 2017 were pooled and analyzed in relation to phenophase wise weather parameters. Soybean yield showed significant negative relationship ($R^2=0.81$) to increase in maximum temperature (28.0-34.5 °C) during pod formation to maturity stage. However, the response of yield to total rainfall (0.0-160.0 mm) during the same period was significantly positive ($R^2=0.80$).
- **Wheat** - The experimental data of Wheat variety HD 2967 grown at multiple locations viz., Chatha, Kanpur and Ludhiana during *rabi* 2017-18 was pooled and reveal that maximum and minimum temperature during vegetative and reproductive stages are the critical weather parameters and stages showing significant influence on grain yield. Unit increase in maximum and minimum temperature during vegetative stages enhanced the yield by 0.314 and 0.299 t ha⁻¹, respectively and during the reproductive period decreased the yield by 0.220 and 0.229 t ha⁻¹, respectively.
- **Chickpea** - The experimental data of chickpea (JG-14) grown at Raipur, Ranchi and Jabalpur during *rabi* 2017-18 under various growing environments, when pooled showed significant negative relation ($R^2=0.44$) between yield and average minimum temperature. Yield decreased by 0.06 t ha⁻¹ with each 1 °C increase in minimum temperature in the range of 8.2-19.2 °C during the pod formation to maturity stage.

3. Crop growth modeling

Kharif 2017

- DSSAT-Cotton model was evaluated for Ajeet-155 variety using experimental field data collected under four growing environments (sown in 25, 26, 27 and 28 SMW during 2015-17) at Parbhani. The absolute error between observed and simulated phenology by the model was 04-10 days. However, both phenology and yields simulated by model were within the reasonable limits for crop sown on 26 SMW.

- At Jorhat, the CERES-Rice model was calibrated and validated for rice cv. Swarna Mahsuri and the genotype coefficients were also developed for the same. The validated model now can be used for climate change impact assessment studies in the Upper Brahmaputra Valley (UBV) agroclimatic zone.
- DSSAT-Rice (Version 4.5) model was run with data generated from field experiments conducted at Faizabad involving three rice varieties viz. NDR-359, Sarjoo-52, Swarna during *kharif* season. The experimental data for 2014-15 and 2016 were used for calibration and validation of the model, respectively. the validated model could predict Phenology and grain yield within reasonable limits.
- At Anand, Genetic coefficients for Pearlmillet cv. GHB 338, GHB 558 and GHB 744 were developed using CERES-Millet (DSSAT v.4.6) model.
- The CERES-Rice model (DSSAT 4.6) was calibrated for rice variety “Pratibha” by Bhubaneswar center. The d-stat value close to one shows good agreement between observed and simulated values of phenology and yield of Pratibha variety.
- At Mohanpur, DSSAT 4.7 model was used for evaluate in the performance of cv Satabdi rice under different RCP scenarios (2025, 2050, 2075 and 2095) and it was found that under RCP 4.5, productivity is likely to increase during 2025 and decrease thereafter. In the next two scenarios, no significant/continuous trend was observed. Yield gain is expected during 2050 and 2075 under RCP6.0 and RCP8.5, respectively.

Rabi 2017-18

- Nitrogen management options to mitigate for heat stress in wheat using crop simulation model at Ludhiana identified the treatment of 150% of recommended in two equal splits at 0 and 30 DAS as the best practice for reducing the adverse effects on heat stress during reproductive period.

4. Crop weather and pest relationships

- The correlation analysis between incidence of spotted pod borer and weather parameters in pigeonpea indicated significant negative correlation of both number of webs per m² and live larvae per m² with minimum temperature, maximum temperature, afternoon relative humidity, rainfall, and wind speed, and significant positive correlation with bright sunshine hours recorded during previous 7-day period at Anantapur.
- At Hisar, aphid incidence was observed during flowering to seed development phase which was observed to be associated with prevailing high humidity conditions for previous 2-3 days. Sowing on 10th and 20th October was found to be most appropriate for escaping from aphid infestation of high intensity in mustard.
- At Bhubaneswar, experimental results showed that highest population of Brown Plant Hopper (BPH) was found at a weekly cumulative rainfall of 80 to 110 mm, with maximum temperature (32-34 °C), minimum temperature (25-27 °C), high morning relative humidity (91-95 %) and evening relative humidity (75-80 %)
- At Palampur the thumb rules developed earlier for blast and non-blast years were tested for the years 2016 and 2017. During the year 2017, maximum, minimum and mean temperatures were higher than these temperature limits for the blast years by 3.3, 0.9

and 2.1 °C, respectively and as a result no blast incidence occurred. Similarly, in 2016 also maximum and minimum temperatures were higher than these temperatures in blast years by 2.1 and 0.6 °C, respectively and no blast incidence occurred.

- At Raipur, forewarning models for BPH and Leaf folder populations were developed using light trap data and significant meteorological parameters identified through correlation analysis. At the same centre thumb rules for yellow stem borer were developed as Tmax (32-33 °C), Tmin (25 °C), RH (> 85 %) in 37th SMW.
- At Jabalpur, Larvae population of *Helicoverpa armigera* in chickpea was found to be increasing with maximum temperature > 25 °C, minimum temperature > 10°C, morning RH > 80 % and afternoon RH > 25 %.
- Ludhiana centre validated expert system developed for predicting incidence of white fly in cotton with the actual data collected at Abohar, Bathinda and Faridkot during 2016 and 2017. The DSS successfully predicted the incidence of white fly in cotton with a success rate of 73 to 79 % at Abohar, 84 to 95 % at Bathinda and 84 to 89 % at Faridkot during the years 2016 and 2017.
- Pod borer (*Helicoverpa armigera*) in chickpea at Faizabad was observed to be relating positively maximum temperature and afternoon relative humidity.
- Analysis of Aphids in mustard at Udaipur showed mean temperature 15.2 to 18.1 °C and mean RH 66.5 to 84.3 % at flowering to green seed stage as congenial for the incidence of mustard aphids.
- At Samasthipur analysis of cut worms incidence in *rabi* maize in relation to weather conditions showed that the maximum temperature of 28.2 to 29.1 °C and higher relative humidity of 89-91 % in the morning hours and 62-65 % percent in the afternoon hours were congenial for higher infestation of the pests.
- At Kovilpatti PDI of powdery mildew showed highly significant negative relationship with both maximum and minimum temperature.
- At Jammu severity of aphids attack in mustard was observed to be high when the maximum temperature ranged between 17.0 to 22.6 °C, minimum temperature ranged between 2.8 to 7.6 °C and maximum & minimum relative humidity ranged from 40 to 80 and 60 to 92 per cent, respectively.
- Anthracnose disease in grapes at Vijayapura center was forecasted one week ahead using maximum temperature, morning relative humidity and afternoon humidity one week prior to the incidence of the disease.

5. Agromet Advisory Services

- Udaipur center of AICRPAM has issued Agromet advisories (88) to selected farmers in selected villages during *kharif* and *rabi* seasons . One day Farmers awareness program on climate change were conducted on 11 Jan 2018.
- The Vijayapura centre has also established a Whatsapp group for interactions with farmers. Vijayapura and Bengaluru Centres of AICRPAM contributed for issuing Agromet advisory messages, which are disseminated to more than 38 lakh farmers by Karnataka State Natural Disaster Monitoring Centre in all districts of Karnataka.

9. Research Publications: 2017-18

AICRPAM Centres Publications

Akola

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Books/Book Chapter/Training Manual

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Popular Articles: 11

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Shivaramu, H.S. (2018) “Monitoring spatial and temporal climate change in Karnataka and case studies of resilient agriculture in the National seminar on “Application of Geo-Spatial Technologies and ICTs in Smart Agriculture” held at UAS, Dharwad during January 23 -24, 2018.

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Kadam, Y.E., Dakhore, K.K., Gote, G.N. and Nirwal, A.D. (2017). Relation between agrometeorological indices, crop phenology and yield of pigeon pea as influenced by different dates of sowing and varieties. In: Abstract of International Seminar on “Global Climate Change: Implication for agriculture and water sectors”, 14 - 16 December, Aurangabad, India.

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Raipur

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Ranchi

Papers in Peer Reviewed Journals

- Pragyan, K., Wadood, A., Singh, C.S. and Singh, S.K. (2017). Quantification of temperature and its effect on wheat yield in Jharkhand region. *The Bioscan.*, 12(1): 355-358.
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Samastipur

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Solapur

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- Jadhav, J.D., Shinde, V.A., Pawar, P.B., Patil, J.B. and Amrutsagar, V.M. (2018). Climate change impact on production, productivity of major *kharif* cereals in western Maharashtra. In: National Seminar on “Recent Trends in Plant Sciences and Agricultural Research”. 11-12 January, Solapur, Maharashtra. pp. 238.
- Londhe, V.M., Jadhav, J.D., Pawar, P.B., Shinde, V.A., Kolse, R.H. and Amrutsagar, V.M. (2018). Probability of rainfall in scarcity zone of Maharashtra. In: National Seminar on “Recent Trends in Plant Sciences and Agricultural Research”. 11th-12th January, Solapur, Maharashtra. pp. 244.

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- Pawar, S.M., Jadhav, J.D., Mohalkar, S.S., Patil, J.B. and Amrutsagar V.M. (2018). Soil type and rainfall based suggested cropping pattern for the districts of western Maharashtra. In: National Seminar on “Recent Trends in Plant Sciences and Agricultural Research”. 11-12 January, Solapur, Maharashtra. pp. 114.
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Books / Book chapters

- Solaimalai. A. and Jadhav, J.D. (2017) Agronomy of Forage Crops (ISBN - 978-93-86013-38-5). pp. 274.
- Dakhore, K.K., Karunakar, A.A. Jadhav, J.D., Jagtap, M.N., Pawar, P.B. and Vijaya Kumar, P. (2017). Agroclimatic Atlas of Maharashtra. 12/2017; ISBN: 978-81-933656-2-5, pp. 235.
- Gadakh, S.R., Kokate, K.D., Amrutsagar, V.M., Jadhav, J.D. and Upadhye, S.K. (2017). District Agriculture Contingency Plans for Western Maharashtra. ISBN: 978-81-933656-2-5, pp. 321.
- Shinde, V.A., Jadhav, J.D., Pawar, P.B., Upadhye, S.K., Sanglikar, R.V., India, D.V. and Amrutsagar, V.M. (2018). Abstract compendium book (ISBN-978-93-86013-62-0) of

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Akashe, V.B., Indi, D.V., Jadhav, J.D., Murumkar, D.R., Kharbade, S.B., Amrutsagar, V.M., Bavadekar, V.R., Pawar, P.B. and Shinde, S.K. (2018). Crop pests and disease forewarning models. pp. 1-59. First edited by MPKV., Rahuri, 12/2017; Wizcraft Publications and Distribution Pvt. Ltd., Solapur, Maharashtra, India., ISBN: 9789386013491.

Thrissur

Papers in Peer Reviewed Journals

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Ajithkumar, B., Vysakh, A. and Sreekala, P. P. (2017). Effect of El Nino on rainfall and thermal regime of Kerala. *Contemp. Res. India.*, 7(2): 279-285.

Vysakh, A., Ajithkumar, B. and Venkat, S. J. (2017). Effect of dates of planting on crop water requirement of rice in Kerala. *J. Agrometeorol.*, 19 (Special Issue): 51-54.

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Technical Bulletin

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Udaipur

Papers in Peer Reviewed Journals

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Sunita, K., Solanki, N.S., Dashora, L.N. and Upadhyay, B. (2017). Effect of super absorbent polymer and plant geometry on growth and productivity of maize (*Zea mays L.*). *J. Pharmacogn. Phytochem.*, 6(4): 179-181.

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Gautam, P., Dashora, L.N., Solanki, N.S., Meena, R.H. and Upadhyay, B. (2017). Effect carrier based and liquid bio fertilizers at different phosphorus levels on productivity of hybrid maize. *Int. J. Curr. Microbiol. Appl. Sci.*, 6 (12): 922-927.

Rana, M., Solanki, N.S., Chouhan, G.S., Mali, H. and Sunil, K. (2018). Alleviating the adverse effect of water stress in wheat by foliar sprays of bio-regulators. *Int. J. Curr. Microbiol. Appl. Sci.*, 7(special issue): 3345-3354.

Vijayapura

Books / Book Chapter / Training Manual

Venkatesh, H., Kulkarni, S.N., Boranayak, M.B. (2017). Havaamaana vyathirikthathey inda maleya mele parinaama. In: “Krishi Abhivruddhigey Jala Samrakshaney Matthu Sadbalak”. (Eds. I. S. Katageri, B. O. Kiran and S. H. Gotyal)

Technical Bulletin

Venkatesh, H., Kulkarni, S.N. and Hiremath, J.R. (2018). “Havaamaana Munsoochane: Krishiyallondur Hosha Aayama”. (In Kannada)

National and International Awards

Bengaluru

Dr. H.S. Shivaramu received an award- Certificate of Merit (Lucid Presentation) for paper “Trends in rainfall, LGP and drought occurrence in Karnataka, India” presented in the 3rd International conference on Dry Zone Agriculture at faculty of agriculture, University of Jaffna, Srilanka during 1st and 2nd November 2017.

Dr. H.S. Shivaramu received an award as leader under revolving fund on Seemaruba seedling production for generating net income of 23.96 lakhs on the occasion of foundation day of the university held on 04 October 2017.

Akola

Best Oral Presentation Award for Paper entitled, “Impact assessment through GIS based approach of rainwater harvesting structure on drainage line for developing groundwater regime” by Dr. Nagdeve. M. B, Patode R. S., Pande C. B., Gabhane V. V., and Karunakar A. P. in National Seminar on Recent Trends in Plant Sciences and Agricultural Research at Solapur during 11-12th January 2018.

Raipur

Second best poster award for presenting paper on “Trends of rainfall and temperature over Chhattisgarh for crop planning” by Patel, S.R., Das, G.K., Chaudhary, J.L., Puranik, H.V. and Dewangan, Y. K. at CCAW (2017) (International Seminar on Global climate change: Implications for agriculture and water sectors). CCAW (2017) held at WALMI, Aurangabad in joint co-ordination of VNM Krishi Vidyapeeth, Parbhani, MPKV, Rahuri, PDKV, Akola, DR. BSS KKV, Dapoli, WALMI, Aurangabad and JART, Pune during 14-16 December 2017.

Staff position at cooperating centers during 2017-18

(AICRP on Agrometeorology)

Centre	Positions Sanctioned and Filled (F) / Vacant (V)					
	Agrometeo- rologist	Junior Agronomist	Senior Tech- nical Assistant	Meteorological 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	F	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	F	V	V	V	V	V
Samastipur	F	—	—	V	F	—
Solapur	V	F	F	F	V	F
Thrissur	F	—	—	V	V	—
Udaipur	F	—	—	V	V	—
Post Filled	22	10	9	15	17	7
Post Sanc- tioned	25	12	12	25	25	12

Center-wise and Head-wise RE allocation (Plan): FY 2017-18

(AICRP on Agrometeorology)

(In Rupees)

S. No	CENTRE	PAY & ALLOW.	TA	RC	IT	NRC-Equip	IPR/HRD	TOTAL ICAR SHARE (75%)
1	Akola	1900000	75000	260000	6000	100000	-	2341000
2	Anand	3000000	75000	300000	6000	100000	-	3481000
3	Anantapur	3550000	75000	260000	6000	100000	-	3991000
4	Bangalore	3450000	75000	250000	6000	100000	-	3881000
5	Bubaneswar	875000	75000	250000	6000	0	-	1206000
6	Bijapur	3000000	80000	250000	6000	0	-	3336000
7	Chatha	2400000	75000	250000	6000	0	-	2731000
8	Dapoli	1000000	75000	250000	6000	0	-	1331000
9	Faizabad	2237500	75000	250000	6000	0	-	2568500
10	Hisar	1400000	75000	260000	6000	0	-	1741000
11	Jabalpur	1887500	75000	250000	6000	150000	300000	2668500
12	Jorhat	1350000	75000	250000	6000	0	-	1681000
13	Kanpur	2400000	75000	250000	6000	0	-	2731000
14	Kovilpatti	4100000	75000	260000	6000	100000	-	4541000
15	Ludhiana	6000000	75000	260000	6000	0	-	6341000
16	Mohanpur	4000000	75000	260000	6000	0	-	4341000
17	Palampur	2300000	75000	250000	6000	0	-	2631000
18	Parbhani	2200000	75000	250000	6000	0	-	2531000
19	Raipur	2040000	75000	250000	6000	0	-	2371000
20	Ranchi	3800000	75000	250000	6000	0	-	4131000
21	Ranichauri	300000	75000	250000	6000	0	-	631000
22	Samastipur	0	75000	250000	6000	0	-	331000
23	Solapur	3800000	75000	260000	6000	100000	-	4241000
24	Thrissur	1124500	75000	250000	6000	0	-	1455500
25	Udaipur	3085500	75000	250000	6000	100000	-	3516500
36	PC unit	0	0	1450000	0	0	-	1450000
	TOTAL	61200000	1880000	7820000	150000	850000	300000	72200000



**Working Group Meeting of AICRP on Agrometeorology
27-29 November 2017 at SKUAS&T-Jammu (J&K)**



All India Coordinated Research Project on Agrometeorology

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