AICRPAM

All India Coordinated Research Project on AGROMETEOROLOGY

Annual Report 2014 - 15

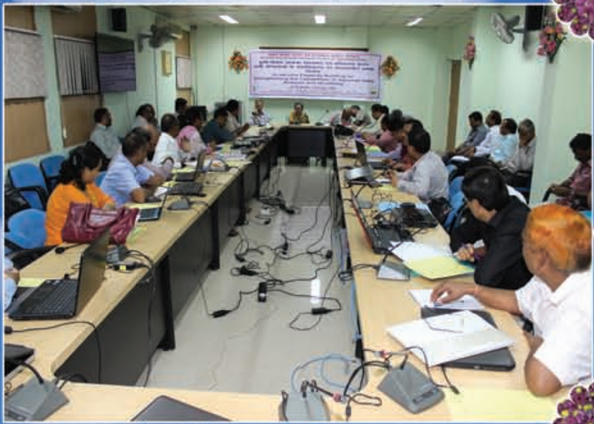
भाकृअनुप ICAR

ICAR - Central Research Institute for Dryland Agriculture

Santoshnager, Hyderabad, India

AICRPAM


अखिल भारतीय समन्वित कृषि-मौसमविज्ञान अनुसंधान परियोजना
All India Coordinated Research Project on Agrometeorology
कृषि-मौसम आंकड़ा विश्लेषण एवं प्रतिरूपण करने




All India Coordinated Research Project on Agrometeorology
In-service Capacity Building on


LAYOUT OF CSRC-KVK FARM

All India Coordinated Research Project on Agrometeorology

Annual Report - 2014-15

भाकृअनुप
ICAR

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Contents

Cooperating Centres

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2. Dr. S. N. Malleswari, Anantapur (since 19.11.2014)
3. Dr. H. R. Patel, Anand (01.04.2007 to 30.06.2015),
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9. Dr. Diwan Singh, Hisar (since 02.01.1984)
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21. Dr. R. G. Upadhyay, Ranichauri (since 2012)
22. Dr. I. B. Pandey, Samastipur (21.09.2012 to 11.08.2015) Dr. Abdu Sattar (since 12.08.2015)
23. Dr. J. D. Jadhav, Solapur (since 19.01.2010)
24. Dr. B. Ajith Kumar Pillai, Thrissur (since 02.04.2013)
25. Dr. N. S. Solanki, Udaipur (since 01.08.2000)

Preface

Weather continues to play a dominant role in agricultural production despite many technological advances made. This is particularly clear this year as unseasonal, erratic and often flash floods has lashed many parts of the country. SW monsoon season of 2015 witnessed mid-season droughts on some parts of the country, while parts of West Bengal, Rajasthan and Gujarat faced flood. Agrometeorological 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) is playing a significant role in identifying regions vulnerable to climate change, development of adaptation strategies and dissemination of micro-level agromet advisories. Along with this, AICRPAM is doing a commendable job in the manning of 100 Automatic Weather Stations in KVKs spread across the country to develop and disseminate the agromet advisories at block level. It is also undertaking research on impacts of temperature and change in rainfall patterns on crops through modeling, designing contingency crop plans for different rainfall situations, development of 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 the cooperating centres of AICRPAM in pursuing the assigned research programs are commendable. Associated information to develop user friendly products and integrated approaches to assess meteorological hazards and extreme event impacts on agriculture and evaluation of potential risks that are useful for insurance organizations are highly desirable. There is a need for strong linkages between AICRPDA, AICRPAM and NICRA to improve the production and minimize the climate risks in dryland agriculture for sustainable production. The Annual Progress Report of 2014-15 contain results of research carried out during *kharif* 2014 and *rabi* 2014-15 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. VUM Rao and his staff at the Coordinating Unit in compilation of this valuable report. I believe that the results presented in the report will be useful for several ministries for policy implementation for minimizing the effect of weather aberrations.

(Ch. Srinivasa Rao)
Director

Acknowledgement

I wish to express my sincere gratitude to Indian Council of Agricultural Research for its continuous and generous help and support during the period under study. The encouragement and guidance from Hon'ble Director General and Secretary, DARE, Dr. S. Ayyappan; Deputy Director General (NRM), Dr. A.K. Sikka is gratefully acknowledged. The help and guidance received from Dr. Ch. Srinivasa Rao, Director, CRIDA in the effective functioning of the project and in preparation of this annual report is acknowledged with sincere thanks.

The untiring efforts made by the Agrometeorologists of all 25 cooperating centres in conducting the experiments as per technical program and in bringing out meaningful results made it possible to compile a comprehensive report. Help rendered by my colleagues Drs. M.A. Sarath Chandran, B. Bapuji Rao, P. Vijaya Kumar and A.V.M. Subba Rao in compiling the results of the reports is highly appreciated. My sincere appreciation to Shri IR Khandgonda in preparing necessary diagrams of the manuscript. The continuous support received from Shri A. Mallesh Yadav and Ms. Harini is acknowledged.

(V.U.M. Rao)
Project Coordinator (Ag. Met.)

1. Introduction

The All India Coordinated Research Project on Agrometeorology (AICRPAM) was initiated by Indian Council of Agricultural Research (ICAR) in May 1983 with the establishment of Coordinating Cell at the Central Research Institute for Dryland Agriculture, Hyderabad and 12 Cooperating Centres at various State Agricultural Universities. After a detailed review and evaluation of the progress made by the project and realizing the importance of agrometeorological research support for enhancing food production, ICAR had extended the Cooperating Centres to the remaining 13 Agricultural Universities of the country w.e.f. April 1995. The network of 25 Agrometeorological Cooperating Centres 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 recently in 2011.

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 the 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 2014-16

The Technical Program for the years 2014-16 for different centres of the project and a common core program decided for all the centres with emphasis on location-specific research needs are 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 (All Centres)

Centre	*Kharif* Crop(s)	*Rabi* Crop(s)
Akola	Soybean	Chickpea
Anand	Groundnut	Wheat
Anantapur	Groundnut	Chickpea (Nandyal)
Bangalore	Pigeoan pea	Mango
Bijapur	Pigeoan pea	Soybean
Bhubaneswar	Rice	----
Chatha/Jammu	Maize	Wheat
Dapoli	Rice	Mango
Faizabad	Rice	Chickpea, Mustard
Hisar	Cluster bean/Horticulture	Mustard, Wheat
Jabalpur	Soybean	Chickpea
Jorhat	Rice	Potato
Kanpur	Rice	Wheat
Kovilpatti	--	Greengram, Maize
Ludhiana	Rice	Wheat
Mohanpur	Rice	Potato
Palampur	Tea	Wheat
Parbhani	Cotton, Soybean	----
Raipur	Rice	Wheat
Ranchi	Rice	Wheat
Ranichauri	Finger millet	Wheat
Samastipur	Rice	Wheat, Winter Maize
Solapur	Pearlmillet	Sorghum
Thrissur	Coconut, Rice	Pepper
Udaipur	Maize	Wheat

3) Crop Growth Modelling

Crop	Lead Centres	Associated Centre
Wheat	Ludhiana	Palampur, Anand, Jabalpur, Chatha/Jammu, Samastipur, Ranchi, Hisar, Kanpur, Ranichauri
Rice	CRIDA	Mohanpur, Samastipur, Dapoli, Faizabad, Thrissur, Bhubaneswar, Jorhat, Ranchi, Kanpur, Jabalpur, Raipur
Groundnut	Anand	Anantapur, Bangalore

4) Weather Effects on Pests and Diseases

Centre	Crop(s)	Pests/diseases
Anand	Mustard	Aphids
Anantapur	Groundnut	Leaf miner
Akola	Soybean	Spodoptera/Semilooper
Bangalore	Groundnut Redgram	Late leaf spot Heliothis
Bijapur	Grapes Pomegranate	Powdery mildew, Downy mildew Anthracnose, Bacterial Leaf Blight
Bhubaneswar	Rice	Sheath Blight, Blast
Chatha/Jammu	Wheat	Yellow rust
Faizabad	Chickpea	Pod borer
Jabalpur	Chickpea	Heliothis
Kovilpatti	Cotton Blackgram	Aphids, Leaf hopper Powdery mildew
Ludhiana	Cotton	Sucking pests
Mohanpur	Mustard Potato	Aphids Late blight
Palampur	Mustard Wheat	Aphids Yellow rust
Parbhani	Cotton	Mealy bug, sucking pests
Ranchi	Rice	BLB, Brown spot
Ranichauri	Apple Amaranthus	Apple scab Leaf webber
Solapur	Sunflower	Leaf eating caterpillar (Heliothis)
Raipur	Rice Chickpea	Stemborer, Leaf blast/Brown spot Heliothis
Kanpur	Rice Wheat	Blight, Stem borer Blight
Thrissur	Rice	Stemborer, Leaf roller

Centre	Crop(s)	Pests/diseases
Udaipur	Mustard	Aphids
Hisar	Mustard Wheat	Aphid Yellow rust

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

2. Weather Conditions During The Year 2014

A brief account on rainfall with its onset, withdrawal and distribution during monsoon and post monsoon seasons of the year 2014 for the country as a whole as well as at 25 centres of AICRPAM is presented hereunder:

Onset of Southwest Monsoon (June–September):

The southwest (SW) monsoon set over Kerala on 6thJune, 5 days later than its normal date of 1st June. Same day, monsoon also advanced into most parts of south Arabian Sea, some parts of Tamil Nadu, most parts of southwest Bay of Bengal and some parts of west central Bay of Bengal. Thereafter, though not rapid, it consistently advanced and by 18th June, it covered central Arabian Sea, some parts of north Arabian Sea, south Gujarat, entire Konkan & Goa, some parts of south peninsula, Odisha, Jharkhand and Bihar, entire northeastern states and most parts of Gangetic West Bengal. The Arabian Sea branch of the monsoon current was aided by the formation of a Cyclonic Storm (**Nanauk**) over the Arabian Sea. The eastward propagation of Madden Julian Oscillation (MJO) over maritime continent led to the development of convection over north Bay of Bengal and the subsequent formation of season's first low pressure area over coastal areas of Bangladesh and neighbour hood on 19th June. This aided the advance of Bay of Bengal branch of the SW monsoon over northeastern states. Subsequently it further advanced into most parts of south peninsula, east and adjoining parts of central India by 20th June.

During the last week of June, the weakening of monsoon activity caused the re-appearance of the heat wave conditions over eastern parts of peninsular India. After a hiatus of 10 days, monsoon started reviving. Subsequently, a favorable interaction of the SW monsoon current with the mid-latitude westerlies aided the advance of SW monsoon into the western Himalayan region and adjoining plains of northwest India. It advanced into entire Uttarakhand, Himachal Pradesh and Jammu & Kashmir, some more parts of Uttar Pradesh and some parts of Haryana (including Chandigarh) and Punjab on 1st July.

During the first week of July, the presence of anticyclone over the peninsular region resulted in subdued rainfall activity over parts of north, central and peninsular region. But the formation of a low pressure area over north Bay of Bengal and adjoining coastal areas of Bangladesh and Gangetic West Bengal (during 1st–7th July) and a cyclonic circulation over West Uttar Pradesh and neighbourhood (during 3rd - 6th July) caused further advance of the monsoon into some more parts of Uttar Pradesh, remaining parts of Haryana (including Delhi) and Punjab and some parts of north Rajasthan on 3rd July and subsequently into most parts of Vidarbha, remaining parts of East Madhya Pradesh and Uttar Pradesh, some parts of West Madhya Pradesh and some more parts of northeast Rajasthan on 7th July. Subsequent to the formation and west northwestward movement of a low pressure area (during 11th- 16th July), an off shore trough at mean sea level extending from Gujarat coast to Kerala coast (10th-16th July) and the cyclonic circulation extending between 3.1 & 5.8 kms above sea level (ASL) over northeast Arabian Sea during (14th-16th July) the second week, the monsoon activity revived gradually over central India and west coast thereby causing further advance of SW monsoon over remaining parts of central India and most parts of northwest India on 16th and remaining parts of north Arabian Sea, Saurashtra & Kutch, Gujarat Region and West Rajasthan and thus the entire country on 17th July, 2014.

Rainfall Distribution During Monsoon Season

The seasonal (June to September) rainfall received over 36 met sub-divisions for broad geographical regions during the 2014 SW monsoon season are given in the table 2.1 along with respective long period average (LPA) values and deviations from normal.

Table 2.1: IMD Sub-divisional rainfall during monsoon season (June–September)–2014

S. No.	Centre	Actual	Normal	Excess or deficit (mm)	Deviation (%)
1	Andaman & Nicobar Islands	1618.6	1682.5	-64	-4
2	Arunachal Pradesh	1747.6	1768.0	-20	-1
3	Assam & Meghalaya	1635.1	1792.8	-158	-9
4	Naga., Mani., Mizo. & Tripura	1118.8	1496.9	-378	-25
5	Sub-Himalayan W. B & Sikkim	1864.5	2006.2	-142	-7
6	Gangetic West Bengal	1001.1	1167.9	-167	-14
7	Orissa	1256.9	1149.9	107	9
8	Jharkhand	930.1	1091.9	-162	-15
9	Bihar	849.3	1027.6	-178	-17
10	East Uttar Pradesh	518.1	897.6	-380	-42
11	West Uttar Pradesh	340.3	769.4	-429	-56
12	Uttarakhand	897.6	1229.1	-332	-27
13	Haryana, Chandigarh & Delhi	203.2	466.3	-263	-56
14	Punjab	243.9	491.9	-248	-50
15	Himachal Pradesh	521.8	825.3	-304	-37
16	Jammu & Kashmir	651.1	534.6	117	22
17	West Rajasthan	262.8	263.2	0	0
18	East Rajasthan	618.6	615.8	3	0
19	West Madhya Pradesh	771.5	876.1	-105	-12
20	East Madhya Pradesh	746.6	1051.2	-305	-29
21	Gujarat Region	777.0	901	-124	-14
22	Saurashtra, Kutch & Diu	454.7	473.5	-19	-4

23	Konkan & Goa	2752.8	2914.3	-162	-6
24	Madhya Maharashtra	675.0	729.3	-54	-7
25	Marathwada	398.8	682.9	-284	-42
26	Vidarbha	817.6	954.6	-137	-14
27	Chhattisgarh	1104.3	1147.3	-43	-4
28	Coastal Andhra Pradesh	448.7	581.1	-132	-23
29	Telangana	498.5	755.2	-257	-34
30	Rayalaseema	308.6	398.3	-90	-23
31	Tamil Nadu & Pondicherry	315.2	317.2	-2	-1
32	Coastal Karnataka	3122.7	3083.8	39	1
33	North Interior Karnataka	483.3	506	-23	-4
34	South Interior Karnataka	795.2	660	135	20
35	Kerala	2163.0	2039.6	123	6
36	Lakshadweep	955.3	998.5	-43	-4

The seasonal rainfall from 1st June to 30th September 2014 was normal in 23 sub-divisions (67% of the total area of the country) and deficient in 12 sub-divisions (30% of the total area of the country). Only one subdivision (South Interior Karnataka) constituting 3% of the total area of the country received excess rainfall. Out of the 12 deficient sub-divisions, six sub-divisions were from north India, two from central India, one from northeast India and three from south Peninsula.

On a monthly basis, the distribution of rainfall, in June, except for five sub-divisions (Sub-Himalayan West Bengal, Assam & Meghalaya, Rayalaseema, Tamil Nadu and Andaman & Nicobar Islands), which received normal rainfall, all the other sub-divisions (31 out of 36) received deficient (20 sub-divisions) or scanty (11 sub-divisions) rainfall. In July, majority of the sub-divisions from central India and west peninsula received excess (Three sub-divisions) or normal rainfall (17 sub-divisions). The excess rainfall sub-divisions are Konkan & Goa, South Interior Karnataka and Odisha. Out of the 16 remaining sub-divisions, 15 sub-divisions received deficient rainfall, majority of which are from northwest and northeast India, region close to Himalayas and interior & southeast Peninsula. However, one subdivision (Lakshadweep) received scanty rainfall.

In August, majority of the sub-divisions from Peninsula, east and northeast India received normal/excess rainfall. On the other hand, majority of the sub-divisions from northwest India and neighboring central India received deficient/scanty rainfall. During August, eight sub-divisions received excess rainfall, 13 sub-divisions received normal rainfall, 12 sub-divisions received deficient and 3 sub-divisions received scanty rainfall. The excess sub-divisions were Lakshadweep, Kerala, Tamil Nadu and Pondicherry, South Interior and North Interior Karnataka, Coastal Karnataka, Madhya

Maharashtra, and Arunachal Pradesh. The three scantly rainfall sub-divisions were neighboring sub-divisions from north India (Punjab, Haryana, Chandigarh & Delhi and West Uttar Pradesh).

In September, the rainfall activity over many parts of the country showed significant increase and nine sub-divisions from northwest, west coast, northeast and east central India received excess rainfall. On the other hand, 13 sub-divisions mainly from north India along the plains of Himalayan region and north peninsula received deficient rainfall. The remaining 14 sub-divisions received normal rainfall.

From the monthly distribution, it can be seen that all the sub-divisions have received deficient/scantly monthly rainfall during at least one of the four months. Similarly, in every month, at least 13 out of the 36 sub-divisions have received deficient/scantly rainfall with highest number of sub-divisions (31) received deficient/scanty rainfall during June. Four sub-divisions (*i.e.* Himachal Pradesh, West Uttar Pradesh, East Uttar Pradesh and Telangana) were deficient/scantly during all the four months of the season.

Withdrawal of Southwest Monsoon

The weather over the western parts of Rajasthan remained mainly dry from 17th Sept. A change in the lower tropospheric circulation pattern over the region from cyclonic to anti cyclonic during 16th - 17th Sept. also made conditions favorable for the withdrawal of SW monsoon from the region. Subsequently, withdrawal of monsoon from northwestern parts of the country commenced on 23rd Sept. It withdrew from some parts of West Rajasthan and Kutch on 23rd Sept. and from some parts of Punjab, Haryana and Gujarat region, some more parts of Kutch area and remaining parts of West Rajasthan on 26th. On 28th Sept, it further withdrew from remaining parts of Punjab, Haryana, Chandigarh & Delhi and East Rajasthan; some parts of Jammu & Kashmir, Himachal Pradesh, East Uttar Pradesh, Madhya Pradesh and Saurashtra; most parts of West Uttar Pradesh and some more parts of Gujarat Region, Kutch and north Arabian Sea. As on 30th September, the withdrawal line passed through Jammu, Una, Bareilly, Kanpur, Nowgong, Ujjain, Vadodara, Porbandar, Lat. 22 °N/ Long. 65 °E and Lat. 22 °N / Long. 60 °E.

Incessant rainfall associated with the monsoon low pressure systems and active monsoon conditions in the presence of strong cross equatorial flow, often caused flood situations over various areas during different parts of the season. During the first half of the season, incessant heavy rains and floods over Odisha, Chhattisgarh, Madhya Pradesh, Uttar Pradesh and Assam & Meghalaya were observed in associated with the formation and the movement of monsoon low pressure systems over north Bay of Bengal. During the second half, the floods and associated huge casualty and damage occurred over Jammu & Kashmir during 1st week of Sept., which resulted from the interaction between a monsoon low and a trough in the westerlies. Uttar Pradesh and

Bihar experienced flood like situation due to heavy rainfall in the catchment areas of Nepal and release of water in Barrages. The formation of low pressure systems caused flooding in Odisha and Rajasthan whereas, the eastern end of monsoon trough passing through northeastern states and trough in mid-latitude westerlies led to extremely heavy rains and thus floods in Assam & Meghalaya and Arunachal Pradesh during the second half of season. Apart from these, some other sub-divisions/states which experienced flood situations are Jharkhand, Gujarat, Konkan & Goa, Andhra Pradesh, Karnataka and Kerala.

Post-Monsoon (October-December) 2014

In the sub division wise Post-Monsoon (October–December) season rainfall, it is noticed that rainfall was excess in two sub-divisions, *viz.* East Uttar Pradesh and East Madhya Pradesh, normal rainfall in 10 sub-divisions, *viz.* Uttarakhand, Chhattisgarh, Konkan & Goa, North Interior Karnataka, South Interior Karnataka, Coastal Karnataka, Kerala, Tamil Nadu & Pondicherry, Lakshadweep and Andaman & Nicobar Islands and 13 sub-divisions *viz.,* Jammu & Kashmir, Himachal Pradesh, Haryana, Chandigarh & Delhi, Punjab, West Uttar Pradesh, West Madhya Pradesh, Bihar, Jharkhand, Odisha, Madhya Maharashtra, Rayalaseema, Telangana and Coastal Andhra Pradesh received deficit rainfall and scanty/no rain in 11 sub-divisions.

During the year, two out of 25 centers of the AICRPAM, *viz.,* Bijapur and Udaipur received excess rainfall and remaining 17 centers received normal rainfall and remaining 6 centers received either deficit or scanty rainfall (Table 2.2).

Table 2.2: Annual rainfall received at AICRPAM centers during 2014

S.No.	Center	Actual	Normal	Departure (%)
1	Akola	661.3	813.0	-19
2	Anand	998.4	853.0	17
3	Anantapur	375.2	432.0	-13
4	Bangalore	994.5	917.0	8
5	Bhubaneswar	1521.4	1548.0	-2
6	Bijapur	736.8	594.0	24
7	Chatha/Jammu	1152.7	1124.0	3
8	Dapoli	3370.2	3529.0	-4
9	Faizabad	638.0	1001.0	-36
10	Hisar	427.3	456.0	-6
11	Jabalpur	1040.8	1395.0	-25
12	Jorhat	1676.9	2148.0	-22
13	Kanpur	662.9	8834.0	-92
14	Kovilpatti	666.8	723.0	-8
15	Ludhiana	610.4	733.0	-17
16	Mohanpur	1436.6	1607.0	-11
17	Palampur	1902.2	2320.0	-18
18	Parbhani	569.7	963.0	-41
19	Raipur	1253.2	1399.0	-10
20	Ranchi	854.7	1270.0	-33
21	Ranichauri	1367.8	1270.0	8
22	Samastipur	1166.3	1235.0	-6
23	Solapur	609.1	721.0	-16
24	Thrissur	2631.1	2782.0	-5
25	Udaipur	738.8	601.0	23

3. Agroclimatic Characterization

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

Akola

Long term changes in rainfall pattern and its distribution was analysed by estimating seasonality index (SI). SI measures the spread and steadiness of the rainfall during the wet season. Theoretically, the SI can vary from zero (if all the months have equal rainfall) to 1.83 (if the entire rainfall occurs in one month). District-wise monthly rainfall data from 1901-2013 of 11 districts of Vidarbha region was used for the study. Table 3.1 shows the different class limits of SI and representative rainfall regimes and the results of the trend analysis of rainfall is given in table 3.2

Table 3.1: Seasonality Index classes and the associated rainfall regimes

Rainfall regime	Seasonality Index (SI)
Very equable	≤ 0.19
Equable but with a definite wetter season	0.20 -0.39
Rather seasonal with a short drier season	0.40 – 0.59
Seasonal	0.60 – 0.79
Markedly seasonal with a long drier season	0.80 – 0.99
Most rain in 3 months or less	1.00 -1.19
Extreme, almost all rain in 1- 2 months	≥ 1.20

Table 3.2: Trends in distribution of rainfall for different districts of Vidarbha

District	Jan	Feb	Mar	Apr	May	Jun	Jly	Aug	Sep	Oct	Nov	Dec	Ann	Win	Pre-Mon	Mon	Post-Mon
Akola	-0.04	-0.08*	0.05	-0.04*	-0.01	0.10	-0.11	0.75***	-0.10	0.26**	-0.05	-0.08*	0.67	-0.11*	0.14	0.64	0.14
Amravati	-0.06	-0.11	0.04	-0.03*	-0.06*	-0.10	-0.17	0.81**	-0.27	0.09	-0.07	-0.04*	0.02	-0.17**	-0.06*	0.28	-0.03
Buldhana	-0.09**	-0.08**	0.03	-0.07***	-0.08**	-0.19	-0.14	0.66***	-0.31	0.17	-0.08	-0.09**	-0.27	-0.17***	-0.12***	0.05	0.00
Washim	-0.02	-0.09**	0.02	-0.05*	-0.09	0.18	0.03	0.53	-0.23	0.24	-0.09	-0.05	0.39	-0.11**	-0.11*	0.51	0.11
Yavatmal	0.01	-0.14***	-0.02	-0.11***	-0.05	0.04	-0.18	0.53*	-0.51*	0.24*	-0.04	-0.03	-0.25	-0.13***	-0.17**	-0.12	0.17
Wardha	0.04	-0.11*	-0.03	-0.04	-0.04	-0.30	-0.38	0.44*	-0.43	0.11	-0.02	-0.01	-0.71	-0.07	-0.05	-0.67	0.08
Nagpur	0.06	-0.13	-0.01	-0.07	-0.06	-0.28	0.00	0.10	-0.35	0.05	0.01	-0.01*	-0.70	-0.07	-0.14	-0.53	0.04
Bhandara	0.06	-0.16	-0.03	-0.09	0.01	-0.32	-0.75*	-0.56	-0.34	0.04	0.03	0.00	-2.05***	-0.10	-0.10	-1.98***	0.07
Chandr.	0.04	-0.16	-0.03	-0.06	0.00	-0.03	-0.53	0.50*	-0.44	0.16	-0.04	0.01*	-0.59	-0.13	-0.09	-0.50	0.12
Gondia	0.06	-0.15	0.02	-0.03	-0.02	-0.10	0.02	0.00	-0.06	-0.07	-0.05	-0.01	-0.40	-0.09	-0.03	-0.15	-0.13
Gadchi-roli	0.04	-0.14	-0.02	-0.05	-0.03	0.37	-0.11	0.92**	-0.32	0.14	-0.05	0.00	0.76	-0.10	-0.09	0.87	0.09

*(*Sig(0.1), **Sig(0.05), ***Sig(0.01) + Increasing trend, -Decreasing trend)*

Significant decreasing trends in monthly rainfall were observed during February (Yavatmal, Washim, Buldhana districts) and April (Yavatmal and Buldhana districts). On the other hand, significant increasing trend was observed during August (Akola, Amaravati and Buldhana districts). On seasonal basis, Yavatmal, Washim, Buldhana and Amaravati districts showed significant decreasing trend during winter and pre-monsoon seasons. During monsoon season, only Bhandara district showed significant decreasing trend.

SI was computed for four different time periods, *viz.*, 1901-1930, 1931-1960, 1961-1990 and 1991-2013 and the results are given in table 3.3.

Table 3.3: Change in the SI values in 113 years and during the period 1901-30, 1931-60, 1961-90 and 1991-2013

District	SI trend (1901-2013)	Seasonality Index value					
		1901-2013	1901-1930	1931-1960	1961-1990	1991-2013	Change (1901-1930 to 1991-2013)
Akola	1.305	1.057	1.060	1.039	1.071	1.061	0.002
Amravati	2.010**	1.076	1.053	1.055	1.109	1.092	0.039
Buldhana	2.650***	1.044	1.028	1.027	1.061	1.069	0.041
Washim	1.737*	1.068	1.050	1.060	1.098	1.061	0.011
Yavatmal	0.759	1.064	1.056	1.066	1.061	1.077	0.020
Wardha	-0.211	1.068	1.064	1.082	1.049	1.077	0.013
Nagpur	0.372	1.074	1.078	1.062	1.062	1.102	0.024
Bhandara	-0.891	1.119	1.124	1.117	1.118	1.118	-0.005
Chandrapur	-0.201	1.106	1.097	1.113	1.103	1.110	0.013
Gondia	0.429	1.133	1.115	1.128	1.142	1.151	0.037
Gadchiroli	0.270	1.125	1.110	1.133	1.121	1.138	0.027
Mean	--	1.085	1.076	1.080	1.090	1.096	0.020

*(*Sig(0.1), **Sig(0.05), ***Sig(0.01) + Increasing trend, -Decreasing trend)*

Across the Vidarbha districts, the SI value ranged between 1.044 to 1.133 (avg. 1.085) during 1901-2013, 1.028 to 1.115 (avg.1.076) during 1901-1930, 1.027 to 1.133 (avg.1.080) during 1931-1960, 1.049 to 1.142 (avg.1.090) during 1961-1990 and 1.061 to 1.151 (avg.1.096) during 1991-2013 period, indicating most of the rain occurred in three months period or less. Observed shift towards greater SI values from 1.076 (1901-30) to 1.080 (1931-60) to 1.090 (1961-1990) to 1.096 (1991-2013) indicates shifting of rainfall distribution to lesser seasonal period. The change in SI value between 1901-1930 period and latest by 1991-2013 period indicated positive shift of SI in most of the districts except Bhandara district. However, Mann Kendall test statistic showed significant increasing trend of SI value (1901-2013) only in Amravati, Buldhana and Washim districts. By and large, increasing trend of SI values needs consideration in agriculture and water sectors for better planning in the region.

Anand

Trend analysis was undertaken (Mann Kendall test) for identifying significant changes in maximum temperature (Tmax), minimum temperature (Tmin) and rainfall on annual, monsoon, post - monsoon, summer and winter season for four locations, *viz.*, Anand & Vadodara (representing middle Gujarat), Rajkot & Junagadh (representing Saurashtra). The results are given in table 3.4.

Table 3.4 : Trend analysis of weather parameters

Station	Season	Parameters	1961-1990		1991-2013	
			Slope	Significance	Slope	Significance
Anand	Annual	Tmax	0.034	*	0.007	NS
		Tmin	0.035	**	0.039	**
	Post monsoon	Tmax	0.050	*	0.013	NS
	Summer	Tmax	0.013	NS	0.050	*
		Tmin	0.021	NS	0.056	**
Vadodara	Annual	Tmin	0.038	**	0.056	NS
	Monsoon	Tmin	0.026	**	0.127	*
	Summer	Tmin	0.028	NS	0.107	*
	Winter	Tmin	0.049	*	0.038	NS
Rajkot	Annual	Rainfall	-2.286	NS	31.800	**
	Monsoon	Tmin	0.033	**	0.014	NS
		Rainfall	-2.993	NS	35.142	**
Junagadh	Annual	Tmin	0.025	*	0.065	NS
	Monsoon	Tmin	0.019	*	0.018	NS
	Post monsoon	Tmin	0.024	NS	0.092	*
	Summer	Tmin	0.025	NS	0.066	**
	Winter	Tmin	0.009	NS	0.114	**
		Rainfall	0.000	NS	0.000	*

*(*Significant at 95% level, **Significant at 99% level)*

Significant positive trend in maximum temperature on annual basis and during post-monsoon season (1961-90) was observed at Anand. During summer, both Tmax and Tmin showed significant positive trend during 1991-2013. At Vadodara, Tmin showed significant positive trend on annual basis as well as monsoon and winter seasons during 1960-90, whereas similar trend was noticed in Tmin during 1991-2013 during monsoon season and winter. Annual and monsoon rainfall showed significant positive trends at

Rajkot during 1991-2013, whereas Tmin showed similar trend during 1961-90 period in monsoon season. At Junagadh, Tmin showed significant positive trend on annual basis and monsoon months during 1961-90. Similar trend was observed in Tmin during post-monsoon, summer and winter season and in winter rainfall during 1991-2013.

Bangalore

Using 43 years weekly rainfall data (1972-2014), the probability of week being wet [P (W)] or dry [P (D)] was worked out. A week that gets rainfall of 10 mm or more is considered as wet week. Using the initial probabilities, the conditional probabilities of wet week followed by wet week P(W/W), wet week followed by dry week P(W/D), dry week followed by wet week P(D/W) and dry week followed by dry week P(D/D) are worked out.

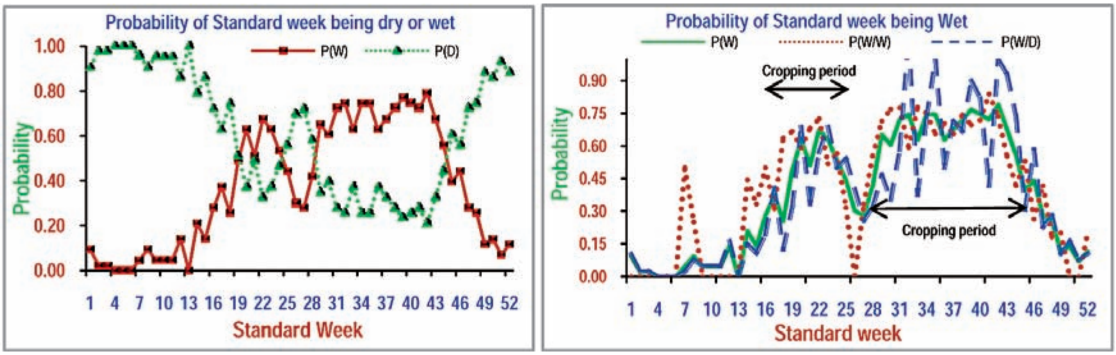


Fig. 3.1: Initial and conditional probabilities for wet/dry weeks at UAS, Bangalore.

Probability of wet week followed by wet week (more than 0.5) during 18th to 24th week of the pre monsoon season indicates that there exists higher chances of getting adequate amount of moisture to the crop growth during this period in most of the years. This indicates that a short duration crop can be grown. As 28th to 45th week has continuous higher probability of wet week followed by wet week, indicating that main crop of the year can be grown so that there exists adequate supply of moisture to the crop growth during this period in most of the years. Therefore, this period is identified as the crop growing period, *i.e.*, the crop sown during 28th to 31st week would not suffer from any moisture stress. The drop in conditional probability of P (W/W) below 70 per cent during 32nd, 35th to 37th week would provide congenial conditions to take up inter-cultivation and other operations. The crop sown during 29-31st week, may reach the maximum growth or grand growth period during 38th to 44th week, and during this stage crop requires highest amount of water, which is available during the period (Fig. 3.1).

Kovilpatti

Length of growing period (LGP) and rainy days were calculated for high rainfall zone of Tamil Nadu and the results are presented in table 3.5.

Table 3.5: LGP and rainy days analysis for high rainfall zone of Tamil Nadu

S. No.	Place	Rainfall (mm)					Annual rainy days	Growing period (weeks)
		Annual	Winter	Summer	SWM	NEM		
1.	Anaikidangu	1367.5	36.42	260.27	498.91	571.97	64.31	34
2.	Balamore	1710.7	42.51	266.66	822.72	578.88	104.62	32
3.	Boothapondi	1088.4	36.8	219.81	380.45	451.37	62.72	35
4.	Chitrar	2012.7	146.71	475.04	847.58	543.38	95.07	36
5.	Eraniel	1189.6	37.2	271.2	419.4	461.8	61.2	33
6.	Kalikesam	1768.8	53.19	336.48	799.11	580.05	86.28	35
7.	Kaliyal	1330.2	37.2	250.0	546.2	496.8	68.5	33
8.	Kallar	1949.0	53.26	344.81	834.01	716.93	97.67	35
9.	Kannikmar	1242.1	36.27	250.91	415.54	539.39	71.88	33
10.	Keeripari	1810.8	56.39	325.71	787.18	641.52	94.62	34
11.	Kulachal	921.1	13.1	181.5	354.4	372.1	52.3	29
12.	Kulasekaram	1031.1	33.73	208.17	394.53	394.65	69.38	32
13.	Kutriar	1808.2	44.94	294.94	846.35	622.01	89.7	34
14.	Kuzhithurai	1149.5	14.9	249.0	473.6	412	66.3	33
15.	Manalodai	1760.9	54.55	360.53	730.56	615.32	86.86	34
16.	Marudham-parai	2987.1	82.7	591.3	1280.6	1032.6	98.1	35
17.	Mecode	1419.9	36.85	298.24	557.67	527.16	73.03	34
18.	Mukkadal	1146.3	31.61	249.63	414.84	450.22	70.34	34
19.	Mulagu-mode	1410.3	36.8	288.0	559.5	525.9	67.8	33
20.	Mylar	2529.4	61.84	482.94	1121.06	863.59	101.69	36
21.	Nagerkovil	1050.5	25.44	237.7	324.82	462.42	59.79	34
22.	Parliyar	1825.5	54.77	353.13	751.71	665.98	89.59	35
23.	Puthandam	1427.0	40.0	320.6	539.48	526.95	77.55	34
24	Sivalogam	1560.0	44.5	326.5	614.6	574.4	82.2	35
25	Surulodu	1641.4	38.36	359.74	627.66	615.67	85.93	34
26	Thirparappu	1522.2	40.2	333.6	600.6	547.8	61.0	35
27	Thucklay	1303	41.7	277.0	460.5	523.9	68.4	34
	Average	**1554.2**	**45.6**	**311.6**	**629.8**	**567.2**	**78.0**	**33.9**

The average annual rainfall of the zone is 1554 mm, which is received in 78 rainy days. The mean LGP of this region is 34 weeks. Lower annual rainfall of 921 mm was recorded at Kulachal whereas, higher annual rainfall of 2987 mm was received at Marudhamparai

(Table 3.6). Marudhamparai receives higher rainfall (1280 mm) whereas Nagerkovil observes with lesser rainfall (325 mm) during SW monsoon season. The length of growing period ranges from 29 to 36 weeks with the average of 34 weeks. Lowest LGP of 29 weeks was observed in Kulachal whereas highest LGP of 36 weeks was observed in Chittar and Mylar.

Ludhiana

The impact of projected climate change on weather parameters was simulated using PRECIS model for Ludhiana. The baseline (1961-1990) and projected (2020-2100) meteorological data for Ludhiana was downscaled. The daily data for maximum temperature, minimum temperature and rainfall for the baseline period (1961-1990) and projected data for A1B scenario for mid century (2020-2050) and for A1B, A2 and B2 scenarios for the end of 21st century (2070-2100) was downscaled using this model and the results are presented in table 3.6.

Table 3.6: Changes in temperature and rainfall on annual and seasonal basis for the mid and end century for different scenarios and their deviation from baseline period for Ludhiana

Time period	Baseline (1961-1990)	Mid century (2020-2050)	End century (2070-2100)		
		A1B	A1B	A2	B2
		Maximum temperature (°C)			
Annual	29.8	32.7 (+2.9)*	35.6 (+5.8)	35.2 (+5.4)	32.9 (+3.1)
Kharif	35.1	37.3 (+2.2)	40.4 (+5.3)	38.0 (+2.9)	36.4 (+1.3)
Rabi	24.5	28.0 (+3.5)	30.9 (+6.4)	32.4 (+7.9)	29.3 (+4.8)
		Minimum temperature (°C)			
Annual	16.0	20.9 (+4.9)*	23.4 (+7.4)	22.5 (+6.5)	21.0 (+5.0)
Kharif	22.6	30.0 (+7.4)	32.7 +10.1)	31.6 (+9.0)	30.2 (+7.6)
Rabi	9.3	11.6 (+2.3)	14.0 (+4.7)	13.4 (+4.1)	11.6 (+2.3)
		Rainfall (mm)			
Annual	741	1075 (+334)*	1204 (+463)	1066(+325)	1131(+390)
Kharif	614	912 (+298)	1027 (+413)	995(+381)	1035 (+421)
Rabi	128	165 (+37)	172 (+44)	72 (-56)	98 (-30)

(*Figures in parenthesis indicate the change in °C for temperature and in mm for rainfall from the baseline period)

The temperature projections for the 21st century based on the PRECIS model represent a strong warming over the 21st century. The differences in maximum temperature, minimum temperature and rainfall for the years 2020-2050 and 2070-2100 from baseline period 1961-1999 in the PRECIS projections, averaged over the central region of Punjab are given in Table 3.6. Increase in Tmax was found to be more during *rabi*, compared to *kharif* for mid century under A1B scenario. Similar was the trend for end century with

A1B, A2 and B2 scenarios. The reverse was observed in the case of Tmin, where *kharif* showed more increase compared to *rabi*. Rainfall also showed similar trends of Tmin, where *kharif* showed more increase in rainfall during mid and end century. Interestingly, rainfall under end century showed decreasing trend under A2 and B2 scenarios.

Mohanpur

Effect of El Nino on annual and monsoon rainfall and crop yields was assessed. Weather (1970-2014) and yield data (Jute and rice) of Nadia district was used for the study. It has been observed that during years 1998 and 1994, strong El Niño conditions coincided with low monsoon-rainfall. During 1995 and 2010 which are moderate EL Nino-years the annual rainfall was less than normal (Fig. 3.2 (a) & (b)).

A B

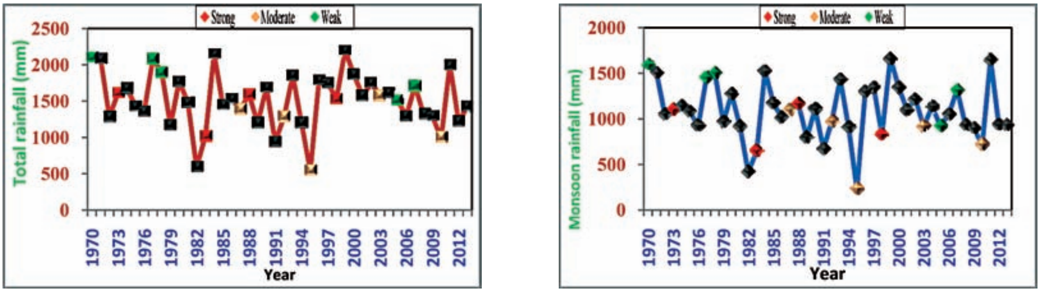


Fig. 3.2(a) : Impact of El Nino on (A) annual rainfall and (B) SW monsoon rainfall

Effect of El Nino on rice and jute production was studied out for Nadia district and the results are presented in figure (3.2a&b). No significant trend has been observed due to El Nino effect.

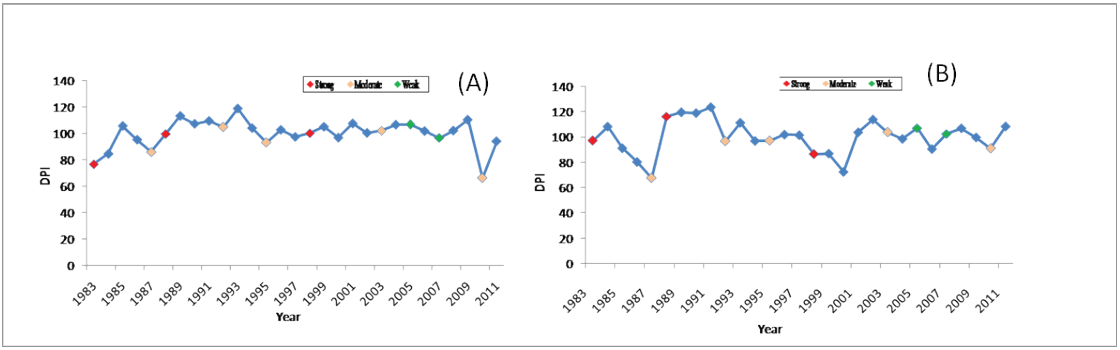


Fig. 3.2 (b) : Impact of El Nino on (A) jute production and (B) rice production in Nadia district, West Bengal.

Thus it can be concluded that moderate and strong El Nino years affect the rainfall situation in southern West Bengal, but as the amount of seasonal rainfall of the region is very high (more than 1000 mm), no significant effect on yield has been noticed in jute and rice.

Palampur

Trends in extreme weather events in Palampur were analysed. The events considered were hail, dew days and snowfall days. The results are presented in Fig. 3.3 (A,B,C).

A B

C

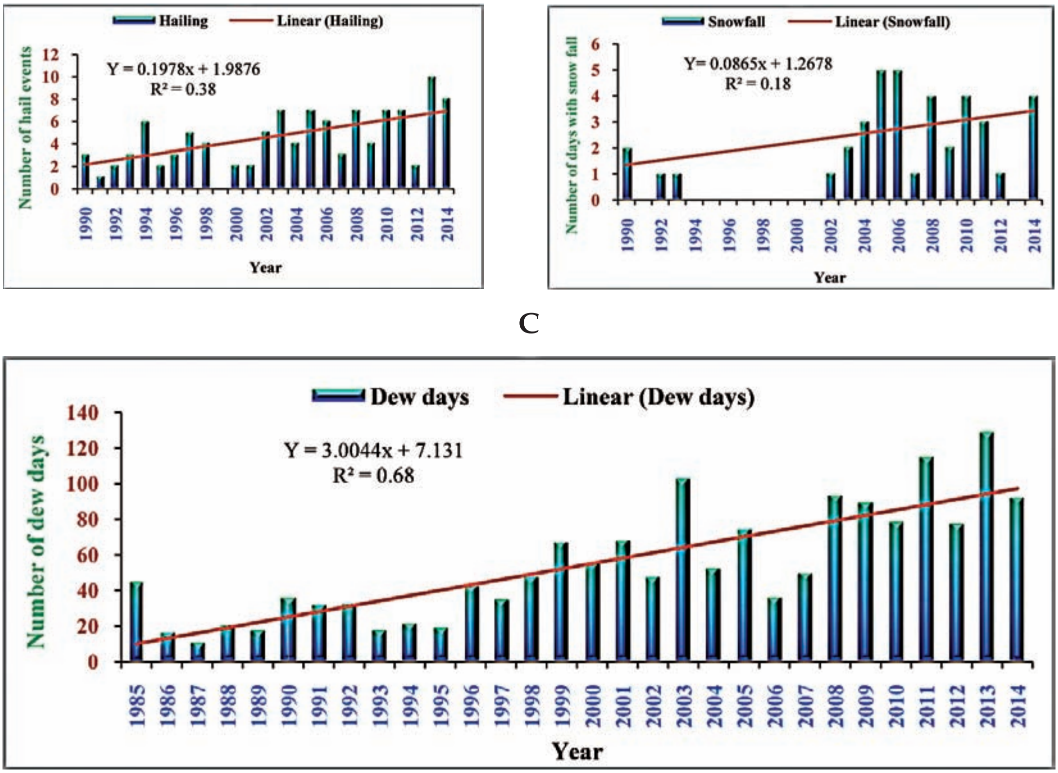


Fig. 3.3: Increasing trend in (A) hail events (B) snow days and (C) dew days at Palampur

Number of hail events (since 1990) and dew days (since 1985) are on rise as evident from fig. 3.3 (a) at Palampur *i.e.*, in mid hills region of Himachal Pradesh. It is also noticed that the dew days are increasing at the rate of 3 days per year at this station.

Raipur

Impact of El Nino on annual rainfall, SW monsoon rainfall and total crop production in the Chhattisgarh state was studied. Crop statistics and weather data for the period 1971-2012 were used for the analysis. The years were classified under weak, moderate and strong El Nino classes based on the criteria given by NOAA Oceanic Nino Index (ONI) and the details are given in table 3.7.

Table 3.7: Classification of years based on El Nino intensity

El Nino intensity	Years
Weak	1951,1963,1968,1969, 1976, 1977, 2004, 2006
Moderate	1986,1987,1994, 2002
Strong	1957,1965.1972,1982,1991,1997, 2009

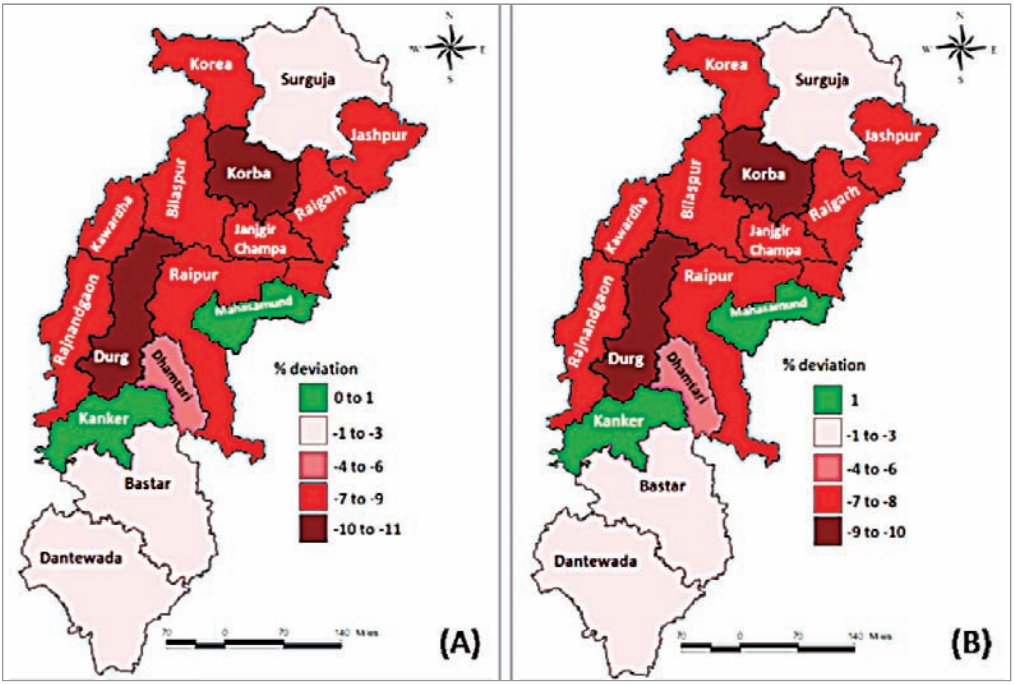


Fig. 3.4: Per cent change in (A) SWM rainfall (B) annual rainfall during El Nino years and normal years in Chhattisgarh

Change in either south-western rainfall and or annual rainfall during El Niño years (Fig. 3.4 (A) and (B) remained almost same. For all the districts during El Niño years, there is decrease in rainfall and deviation is on negative side. However, in two districts Mahasamund and Kanker a positive deviation of rainfall is noticed.

Table 3.8: Effect of different intensities of El Niño (strong, moderate, weak) on area, production and productivity of major food grain crops in Chhattisgarh state

Strong El Niño years						
Year	Area ('000 ha)	% change compared to average area	Production ('000 tons)	% change compared to average production	Yield (Kg/ha)	% change compared to average yield
1972	3606	-23	2552	-42	708	-23
1982	3704	-21	2703	-38	730	-20
1991	5271	13	5101	17	968	6
1997	4435	-5	3656	-16	824	-10

2009	4860	4	4900	12	1008	10
Average	**4375**	**-6**	**3782**	**-13**	**848**	**-8**
Moderate El Niño years						
Year	**Area ('000 ha)**	**% change compared to average area**	**Production ('000 tons)**	**% change compared to average production**	**Yield (Kg/ha)**	**% change compared to average yield**
1986	5203	11	3895	-11	749	-18
1987	5247	12	4020	-8	766	-16
1994	4199	-10	5380	23	1281	40
2002	5030	8	3275	-25	651	-29
Average	**4920**	**5**	**4142**	**-5**	**862**	**-6**
Weak El Niño years						
Year	**Area ('000 ha)**	**% change compared to average area**	**Production ('000 tons)**	**% change compared to average production**	**Yield (Kg/ha)**	**% change compared to average yield**
1976	3495	-25	2177	-50	623	-32
1977	5116	10	3927	-10	768	-16
2004	5129	10	5023	15	979	7
2006	5056	8	5805	33	1148	25
Average	**4699**	**1**	**4233**	**-3**	**880**	**-4**
All El Niño years						
Year	**Area ('000 ha)**	**% change compared to average area**	**Production ('000 tons)**	**% change compared to average production**	**Yield (Kg/ha)**	**% change compared to average yield**
1972	3606	-23	2552	-42	708	-23
1982	3704	-21	2703	-38	730	-20
1991	5271	13	5101	17	968	6
1997	4435	-5	3656	-16	824	-10
2009	4860	4	4900	12	1008	10
1986	5203	11	3895	-11	749	-18
1987	5247	12	4020	-8	766	-16
1994	4199	-10	5380	23	1281	40
2002	5030	8	3275	-25	651	-29
1976	3495	-25	2177	-50	623	-32
1977	5116	10	3927	-10	768	-16
2004	5129	10	5023	15	979	7
2006	5056	8	5805	33	1148	25
Average	**4642**	**-1**	**4032**	**-8**	**862**	**-6**

It can be observed that during the 5 strong El Niño years as recorded in the history, combined production of pulses and cereals declined by about 13 per cent on an average while average yield has declined by about 8 per cent.The effect was also noticed on crop acreage as it decreased by 6 per cent. The most severe effect in this category is noticed in 1972 when a decline of about 42 per cent in production and 23 per cent in yield was observed. It can be inferred from the analysis that there can be a decline in acreage under cereals and pulses about 1 per cent in El Niño years and production loss in cereals and pulses group has been about 8 per cent while productivity loss has been about 6 per cent. Year to year variation in food grains production has also been given in Table 3.8 with respective intensities of El Niño.

Ranchi

Meteorological droughts of various intensities *viz.*, mild, moderate and severe over 56 years (1956-2011) at Palamau district was analyzed using Weather Cock v.15 software.

Table 3.9: Meteorological droughts at Ranchi

Type of Drought	No. of Years	Per centage
Mild	16	29
Moderate	15	27
Severe	1	2
No drought	24	43

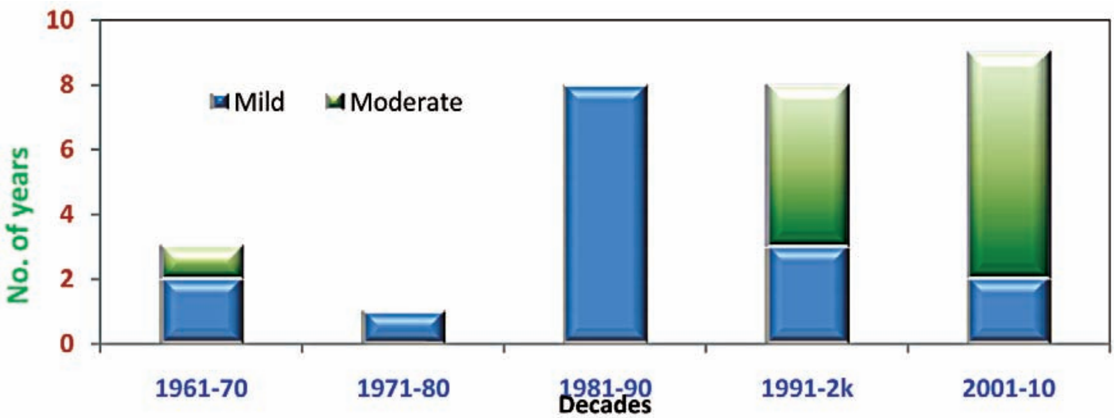


Fig. 3.5: Number of drought years and drought intensity over the decades

The analysis indicated that Palamau region experienced 32 drought years out of which 16 were mild, 15 moderate and one severe accounting for 29%, 27% and 2%, respectively (Table 3.9). Increase in number of drought years and drought intensity over the decades is depicted through fig. 3.5. Frequency of mild drought was more during 1961-1990. However, the subsequent decades 1991-2000 and 2001-2010 registered higher intensity of moderate droughts. There were 8 mild droughts during the decade 1981-90 whereas the decade 1990-2000 had 5 moderate droughts. The recent decade, 2001-2010, experienced maximum number of drought years (9) of which seven were moderate.

The occurrence of agricultural drought was also estimated using Weather Cock v.15 software. Percentage of years experiencing agricultural drought was 50% at Palamau which were most frequently observed in early (23-26 standard meteorological week (SMW)) as well as late (37-40 SMW) stages of *kharif* crops at the seedling and reproductive stages of rice crop, respectively. In recent decade (2001-10) there were eight agricultural drought years affecting rice production in this region (table 3.10). Two consecutive years of drought in 2009 and 2010 restricted the rice crop coverage in this area by covering only 16 and 7.7 per cent of target area under rice cultivation, respectively. At the same time, maize and pulses crops achieved the target area by covering 83 and 75 per cent during 2009 and 87 and 52 per cent during 2010, respectively. Less variation in crop coverage under maize and pulses crops during drought years indicates greater perspective of these crops in future for food security.

Table 3.10: Agricultural drought during *kharif* season at Palamau region, Jharkhand

Year	Week	Year	Week	Year	Week	Year	Week
1956	24 - 27	1980	37 - 41	1991	25 - 28	2001	36 - 39
1957	30 - 34	1981	39 - 42	1992	22 - 27	2002	38 - 41
	36 - 42	1982	24 - 29		30 - 33	2003	22 - 25
1958	22 - 27		38 - 42		37 - 42	2004	22 - 25
1965	22 - 26	1983	31 - 34	1995	22 - 28	2005	37 - 42
1966	35 - 42	1984	37 - 41	1996	36 - 42	2008	39 - 42
1976	22 - 25	1988	33 - 36	1997	36 - 40	2009	30 - 33
1979	22 - 25			2000	39 - 42	2010	22 - 25
						2011	33 - 36

4. Crop Weather Relationships

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

Kharif 2014

Rice

Faizabad

Cultivars Sarjoo 52, Narendra Sona and Swarna were grown under three growing environments (sown on 5, 20 July and 4 August, 2014) to study the crop weather relationships in rice. Heat use and radiation use efficiencies were assured.

Heat Use Efficiency

Data pertaining to heat use efficiency (HUE) of rice at various phenophases as influenced by dates of transplanting and genotypes are given in Table 4.1. Results revealed that July 5th transplanting recorded higher HUE at all the phenophases followed by July 20th and lowest in Aug 4th transplanting. Among the genotypes, Sarjoo-52 showed relatively higher HUE over Narendra Sona at all the stages.

Table 4.1: HUE (g/m^2/ ^{0}days) of rice at different phenophases as affected by various treatments

Treatments	Phenophases						
	Tillering	Vegetative	PI	50% flowering	Milk	Dough	Maturity
Growing Environment							
July 5	0.47	0.48	0.45	0.66	055	0.54	0.55
July 20	0.36	0.36	0.41	0.66	0.53	0.57	0.52
Aug 4	0.32	0.33	0.40	0.62	0.55	0.54	0.50
Varieties:							
Sarjoo-52	0.46	0.46	0.46	0.72	0.55	0.56	0.54
Narendra Sona	0.40	0.30	0.43	0.66	0.53	0.53	0.53
Swarna	0.45	0.41	0.43	0.63	0.51	0.50	0.57

Table 4.2: Radiation Use Efficiency (g/MJ) of rice as affected by various treatments

Days After Transplant

Treatments	15	30	45	60	75	90	AH
Growing Environment							
July5	1.6	2.1	2.7	2.1	2.4	2.6	2.4
July 20	1.2	1.2	2.1	2.6	2.2	2.3	2.2
Aug. 4	1.8	1.2	2.5	2.2	2.7	2.6	2.1
Varieties:							
Sarjoo-52	1.5	1.7	2.0	2.4	2.4	2.6	2.2
Narendra Sona	1.3	1.2	2.4	2.7	2.9	2.2	2.5
Swarna	1.8	1.4	2.6	2.3	2.3	2.6	2.7

Higher cumulative APAR were recorded under July 5th transplanting followed by July 20th at all the stages. However, lowest APAR were recorded under Aug 4th transplanting. It ranged from 406 MJ/m^2 to 664 MJ/m^2 from transplanting to maturity in varying transplanting treatments. Among the genotypes, Sarjoo-52 gave higher value of cumulative APAR and RUE over Narendra Sona. Highest radiation use efficiency (RUE) was recorded by crop sown on July 5. Among varieties, Swarna showed higher RUE (Table 4.2).

Kanpur

To study crop weather relations in paddy, 4 varieties, *viz;* NDR-359 (V1), CSR-27 (V2), Sarjoo-52 (V3) and Swarna (V4) were exposed to three growing environments (sown on 13, 23 July and 2 August 2014-D1, D2 and D3, respectively). Dry matter accumulation as influenced by growing degree days (GDD) was studied and HUE in different environments are presented in table 4.3.

Table 4.3: Dry matter accumulation and HUE as influenced by different transplanting date of paddy cultivars during *kharif* 2014 at Kanpur

Treatment	Dry matter (kg/ha)	GDD ($^{\circ}$days)	HUE (g/m^2/^{0} day)
D_1V_1	11983	2800.6	0.43
D_1V_2	10742	2619.7	0.41
D_1V_3	11174	2750.6	0.41
D_1V_4	11078	3024.1	0.37
D_2V_1	11474	2668.6	0.43
D_2V_2	10259	2467.1	0.42
D_2V_3	10647	2601.1	0.41
D_2V_4	10275	2892.8	0.36

D_3V_1	10035	2516.4	0.40
D_3V_2	9214	2372.5	0.39
D_3V_3	9531	2485	0.38
D_3V_4	5939	2664.2	0.22
Mean for date of transplanting			
D_1	11244.3	2798.8	0.40
D_2	10663.8	2657.4	0.40
D_3	8679.8	2509.5	0.35
Mean for Variety			
V_1	11164.0	2661.9	0.42
V_2	10071.7	2486.4	0.40
V_3	10450.7	2612.2	0.40
V_4	9097.3	2860.4	0.31

Dry matter was found higher in crop sown on 13 July. A progressive decrease in total dry matter per hectare was observed with subsequent sowing. Reason could be exploitation of weather and soil moisture at important growth stages by early sown crop and higher leaf area index which might have provided more photosynthetic area. First sown crop also recorded higher GDD (2798.8 ^{0}days) and HUE (0.40 g/m^2/^{0}day). Among the varieties, NDR-359 recorded highest 0.42 g/m^2/^{0}day followed by CSR-27 which achieved 0.40 g/m^2/^{0}day.

Ludhiana

Effect of microclimate modification on rice yield and yield contributing attributes were studied (Table 4.4). Cultivar PR-118 was transplanted on 2nd July, 2014. Split plot design was followed with five levels of shade [no shade, 50% shade during 0-30 days after transplanting (DAT), 50% shade during 30-60 DAT, 60-90 DAT, 90 DAT-harvest].

Table 4.4: Effect of shade on yield and yield attributes in rice at Ludhiana

Treatments	**Actual value under no shade**	**Per cent change as compared to no shade**			
		Shade (0-30) DAT	**Shade (30-60) DAT**	**Shade (60-90) DAT**	**Shade (90-harvest) DAT**
No. of effective tillers/m^2					
Nitrogen levels					
N_0-100% normal application	313.0	-20.1	23.4	26.2	-15.9

N_1- 100% normal application+3% urea spray during stress	492.8	-17.4	-22.3	-21.5	-12.0
Panicle wt. /m^2					
N_0-100% normal application	4375.6	-4.2	-9.9	-8.2	-8.9
N_1- 100% normal application+3% urea spray during stress	6719.9	-3.6	-10.6	-9.7	-5.1
1000- grain wt.					
N_0-100% normal application	17.4	-2.9	-11.5	-5.7	-6.8
N_1- 100% normal application+3% urea spray during stress	18.2	-3.3	-6.6	-4.3	-5.5
Grain yield (q/h)					
N_0-100% normal application	60.3	-4.3	-7.9	-2.7	-6.6
N_1- 100% normal application+3% urea spray during stress	60.9	-4.1	-4.8	-2.5	-5.7
Biomass yield (q/h)					
N_0-100% normal application	183.4	-2.3	-3.5	-1.9	-2.6
N_1- 100% normal application+3% urea spray during stress	192.6	-2.2	-1.4	-0.9	-2.5
Harvest index (%)					
N_0-100% normal application	32.9	-2.2	-5.1	-0.9	-4.5
N_1- 100% normal application+3% urea spray during stress	31.6	-1.9	-3.6	-1.6	-3.3

Compared to the crop grown without shade, yield was found to be decreasing in all other treatments. Maximum reduction in yield was observed when shade imposed during 30-60 DAT when nitrogen was 100% normally applied. Harvest index, biomass, 1000 grain weight and panicle weight/m^2 also showed similar response.

Raipur

Cultivars Swarna (with two levels of fertilization, *viz.,* 100:60:40 and 60:40:40 kg $N:P_2O_5:K_2O$/ha) was grown under three growing environments (sown on 15, 25 June and 5 July) and its effect on heat and radiation use efficiencies were assessed. HUE of different rice varieties as affected by growing environments has been presented in table 4.5(a). It can be observed that highest HUE is observed for Mahamaya and MTU-1010, Swarna being at par in both the fertilizer doses. Lowest value is noticed in for Karma Mahsuri. Highest HUE is found in crop sown on 5 July, followed by 25 June, however the difference is negligible.

Table 4.5 (a): Heat use efficiency (g/m^2/^{o}day) of rice varieties as influenced by different growing environments

Varieties	15 June sown	25 June sown	5 July sown	Mean
Swarna 100:60:40	0.35	0.41	0.38	**0.38**
Swarna 60:40:40	0.35	0.39	0.40	**0.38**
Mahamaya	0.38	0.44	0.43	**0.42**
MTU1010	0.32	0.41	0.41	**0.38**
Karma Mahsuri	0.32	0.37	0.38	**0.36**
Mean	**0.35**	**0.41**	**0.41**	

RUE value was highest in Mahamaya followed by MTU-1010 (Table 4.5(b)). Under second date of sowing (25 June), RUE value is significantly high.

Table 4.5 (b): Radiation use efficiency (g/m^2/MJ) of rice varieties as influenced by different sowing dates.

Varieties	D1	D2	D3	Mean
Swarna 100:60:40	0.96	1.09	0.97	**1.01**
Swarna 60:40:40	0.96	1.04	1.03	**1.01**
Mahamaya	1.08	1.21	1.13	**1.14**
MTU1010	0.89	1.17	1.10	**1.05**
Karma Mahsuri	0.87	1.00	0.96	**0.94**
Mean	**0.97**	**1.13**	**1.05**	

Ranchi

Cultivars Sahbhagi, Naveen and Swarna were exposed to three growing environments (sown on 8, 18 and 28 June, 2014) to explore the crop weather relationships. Different energy conversion efficiencies *viz.*, heat, water and RUE in rice were studied in these varieties by exposing them to varied environmental conditions. The comparison made among different varieties and sowing dates revealed that the crop sown on 18th June registered higher efficiency values than the crop planted later (Table 4.6). The rice variety Naveen was found to be comparatively more efficient in resource capturing. Rice cv. Swarna was the poorest among the varieties tested in harnessing the natural resources as revealed by its low HUE, RUE and water use efficiency (WUE).

Table 4.6: Heat, Water and Radiation Use Efficiency of rice varieties under sowing dates.

Treatments	Heat use efficiency ($kgha^{-1}/ {}^{0}C$ day)	Water use efficiency ($kgha^{-1}/cm$)	Radiation use efficiency (g/MJ)	Yield(q/ha)
Sowing date				
08 June	1.5	61.2	1.3	34.54
18 June	1.7	60.9	1.5	36.72
28 June	1.6	54.1	1.3	32.87
Variety				
Sahbhagi	1.6	50.3	1.4	33.94
Naveen	1.8	65.6	1.5	38.48
Swarna	1.4	60.2	1.1	31.70

Samastipur

Cultivars RAU-3055, Rajendra Bhagwati, Saroj and Swarna were grown under four growing environments (sown on 31 may, 15, 30 June and 16 July, 2014). Effect of growing environments on phenology, thermal requirement and grain yield were studied and the results are presented in table 4.7.

Table 4.7: Effect of sowing dates on growth, yield attributes and grain yield of rice varieties

Treatment	Tillers/hill	Panicle length (cm)	Grains Panicle	Grain yield (q/ha)	HUE (kg/ha °C)
Sowing dates					
31 May 14	7.9	23.3	106.5	39.5	1.3
15 June 14	8.9	22.6	110.9	42.1	1.4
30 June 14	8.6	21.7	102.8	35.6	1.2
16 July 14	6.7	20.2	96.4	26.7	0.8
CD (P=0.05)	NS	1.9	13.6	1.8	-
RAU 3055	8.6	23.4	106.3	35.1	1.2
Rajendra Bhagawati	9.1	22.7	112.5	37.1	1.3
Saroj	8.2	22.5	96.3	33.2	1.2
Swarna	9.4	22.1	113.7	38.3	1.2
CD (P=0.05)	NS	NS	NS	1.8	_

The thermal period and heat unit requirement of rice varieties varied significantly among the sowing dates. Except dough stage, the thermal period required for different phenophases *i.e.* boot stage, 50 per cent ear head emergence, milk stage and maturity reduced significantly when seeding was delayed beyond 31st May. The crop sown earlier on 31st May accumulated maximum heat unit for these phenophases while the lowest heat unit accumulation for these phenophases was associated with 16th July sown crop.

Number of tillers/hill, panicle length and grains/panicle varied significantly among the sowing dates. The crop sown on 15th June recorded higher number of tillers/hill and number of grains/panicle while higher panicle length was associated with 31st May sown crop. Lower value of these yield indices were recorded under 16th July sown crop.

Grain yield showed significant variation among the sowing dates. The crop sown on 15 June recorded maximum grain yield (42.1q/ha) which was significantly higher than earlier as well as later sown crop (Table 4.7). The reduction in grain yield was of the order of 6.2% in earlier sown crop (31 May) and 15.4 and 36.7% in later sown crop on 30 June and 16 July respectively. Among the varieties, Swarna recorded higher grain yield (38.3q/ha) which was found at par with Rajendra Bhagawati and these varieties produced significantly higher grain yield than RAU 3055 and Saroj. Lowest grain yield (33.2q/ha) was recorded under Saroj. Thus it can be inferred that 15th June is the optimum for raising paddy nurseries in north-Bihar agro-ecological conditions as it recorded highest HUE. Heat-use efficiency decreased with subsequently delay in seeding time. Among the varieties, highest HUE was associated with Rajendra Bhagawati followed by Swarana.

Maize

Udaipur

Hybrids *viz.*,HQPM-1, Pratap Makka-3, Pratap-5, Pratap QPM, PEHM-2 and BIO-9637 were exposed to three growing environments [sown on 15 June, 30 June and 15 July] to study the crop weather relationship. Effect of growing environment and varieties on yield of maize was studied and the results of pooled analysis (*kharif* 2009 to 2014) is presented in table 4.8.

Table 4.8: Effect of sowing environment on grain yield of maize varieties during 2004-2014

Treatment	Grain yield (q/ha)						
	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**Mean**
Sowing environment							
15th June	34.85	39.82	48.20	41.04	41.19	53.19	43.05
30th June	30.08	33.41	35.81	55.08	50.87	48.94	42.37
15th July	26.23	23.92	29.35	37.47	43.55	40.11	33.44
SEm ±	**1.516**	**0.147**	**1.340**	**1.11**	1.31	**1.26**	**-**
CD (P = 0.05)	**4.201**	**0.462**	**4.223**	**3.49**	4.53	**4.35**	**-**

Varieties							
HQPM-1	32.15	33.70	37.94	39.45	46.68	47.05	39.49
PEHM-2	30.52	32.73	38.47	45.75	43.56	-	38.60
Pratap Makka-3*	-	-				48.95	48.95
Pratap Makka-5	-	-	-	-	37.28	49.04	43.16
Pratap QPM-1	-	-	-	-	46.70	48.26	47.48
BIO-9637	-	-	-	-	51.78	43.76	47.77
SEm ±	**1.516**	**0.194**	**0.841**	**1.16**	1.58	**1.39**	**-**
CD (P = 0.05)	**NS**	**0.565**	**NS**	**3.4**	4.52	**NS**	**-**

The results indicated that early sown crop gave higher grain yield by availing longer crop growing period as compared to successive delayed in sowings. Among different hybrids, Pratap Makka-3 and BIO-9637 and recorded highest mean yield and PEHM-2 recorded the lowest.

Pearl millet

Solapur

Crop-weather relationship studies with cultivars Shanti (V_1), Mahyco hybrid (V_2) and ICTP-8203 (V_3) were conducted during *kharif* 2010 to 2014 and the results of pooled data analysis are presented herewith. Consumptive use of soil moisture (CUM) and moisture use efficiency (MUE) were computed and the results are presented in table 4.9(a). The data on CUM and MUE indicated that the crop sown in second fortnight (FN) of June (S1) recorded highest value of CUM (303-332 mm) and MUE value (5.37-6.11 Kg ha^{-1} mm). The lowest values of CUM (272-288 mm) and MUE value, (3.24-3.94 Kg ha^{-1} mm) were recorded from second fortnight of August (S3) sown crop. Among the genotype, shanti recorded highest value of CUM and MUE than Mahyco and ICTP-8203.

Table 4.9(a): CUM and MUE as influenced by sowing time in *kharif* pearl millet (2010-14).

Treatment	GY (kg ha^{-1})	CUM (mm)	MUE (kg ha^{-1}mm)	Treatment	GY (kg ha^{-1})	CUM (mm)	MUE (kg ha^{-1} mm)
S_1V_1	1765.7	303	5.43	$\mathbf{S_2V_3}$	1783.7	308	5.21
S_1V_2	1820.6	312	5.37	$\mathbf{S_3V_1}$	699.4	272	3.24
S_1V_3	1999.3	332	6.11	$\mathbf{S_3V_2}$	863.8	281	3.75
S_2V_1	1430.9	285	4.31	$\mathbf{S_3V_3}$	911.1	288	3.94
S_2V_2	1501.1	292	4.75				

(S_1: 2nd FN of June; S_2: 2nd FN of July; S_3: 2nd FN of August)

RUE was also worked out and the results are presented in table 4.9(b).

Table 4.9 (b): Radiation use efficiency (g MJ^{-1}) as influenced by sowing dates in *kharif* pearl millet (2010-14).

Sowing	Phenological stage						
Time	Emer.	PI	Flag leaf	50 % flowering	Soft dough	Hard Dough	Phy. maturity
S_1V_1	0.13	0.25	1.48	1.93	1.8	1.44	1.65
S_1V_2	0.16	0.29	1.29	1.68	1.59	1.25	1.44
S_1V_3	0.16	0.47	1.18	1.48	1.22	1.14	1.07
S_2V_1	0.13	0.23	0.85	1.6	1.49	0.87	1.34
S_2V_2	0.16	0.28	1.43	1.72	1.73	1.45	1.58
S_2V_3	0.35	0.35	0.9	1.56	1.42	0.92	1.32
S_3V_1	0.11	0.24	0.87	0.96	1.11	0.89	1.01
S_3V_2	0.09	0.17	0.77	0.81	0.84	0.79	0.74
S_3V_3	0.09	0.11	0.65	0.74	0.59	0.67	0.49

The maximum values of leaf area index (LAI) and RUE was recorded highest at 50 per cent flowering stage in almost all the sowing dates and genotypes. This indicated that the rate of conversion of light *i.e.* photosynthetically active radiation (PAR) was considerably high at 50 per cent flowering stage, thereafter the conversion rate declined due to senescence of leaves. Among the sowing dates, maximum RUE values were higher in early sown crop than late sown crop. Further, it can be noticed that Shanti showed higher values of RUE than variety Mahyco and ICTP-8203 is converting of light into dry matter across the dates of sowings.

Pigeoan pea

Bangalore

Three varieties of pigeon pea (*viz.* TTB-7, BRG-1 and BRG-2) were sown on three different dates *viz.*, 05.06.2014, 01.07.2014 and 09.08.2014 with three different spacing (60 cm x 22.5 cm, 90 cm x 22.5 cm and 120 cm x 22.5 cm). The accumulated meteorological parameters in each stage were worked out. During this year poor crop growth was observed in crop sown on 9th August compared to others. The highest grain yield was observed in the first date of sowing (1275.2 kg ha^{-1}) followed by second and third date sown crop 990.2 kg ha^{-1} and 270.8 kg ha^{-1} respectively (Table 4.10). This is attributed to prolonged water deficit situation *i.e.* poor rainfall distribution. This might have led to the development of moisture stress during pod formation stage, which is genreally considered as a moisture sensitive stage. Among spacing, maximum grain yield of 1905.6 kg ha^{-1} and1236.7 kg ha^{-1}were observed with 60 cm x 22.5 cm of first date sown crop and 90 cm x 22.5 cm of the second date sown croprespectively.

Table 4.10: Effect of date of sowing, varieties and spacing on yield (kg/ha) of pigeon pea

Varieties	(D1) 05.06.2014				(D2) 01.07.2014				(D3) 09.08.2014			
	S 1	S2	S3	Mean	S1	S2	S3	Mean	S1	S2	S3	Mean
TTB-7 (V- 1)	398.3	1028.3	405.0	610.6	331.7	931.7	475.0	579.4	91.5	265.8	999.1	452.1
BRG-1 (V-2)	2576.7	1008.3	240.0	1275.0	2211.7	998.3	883.3	1364.4	286.5	35.1	63.5	128.4
BRG-2 (V-3)	2741.7	1638.3	1440.0	1940.0	1166.7	1393.3	520.0	1026.7	276.8	120.2	299.2	232.0
Mean	1905.6	1225.0	695.0	1275.2	1236.7	1107.8	626.1	990.2	218.3	140.3	453.9	270.8
Particulars		Spacing	Variety	Date	S*V	S*D	V*D	SVD	CV=29 %			
SEm ±		344.5	344.5	344.5	298.4	198.9	298.4	172.3				
CD (0.05 P)		1001.5	1001.5	1001.5	867.3	578.2	867.3	500.8				

(Spacing S_1: 60 cm x 22.5 cm, S_2: 90 cm x 22.5 cm, S_3: 120 cm x 22.5 cm)

Bijapur

Cultivars TS-3R, Maruti (ICP-8863) and BSMR-736 were cultivated under three growing environments (Sown on 7th, 19th July and 1st August, 2014) to study the crop weather relationships. The data on all genotypes were pooled and analyzed using scatter plots between pigeon pea yield and important parameters which showed highly significant association. To explore further, a yield strata was created with the following criteria:

- High yield stratum: Yield more than 25% of average
- Moderate yield stratum: Yield of -25% to +25% of average
- Low yield stratum: Yield less than 25% of average

Table 4.11: Variation in individual parameter of different stages among various yield strata

Item	Yield / variation	Germi-nation	Seedling		Vegetative		Flowering		Pod formation and grain filling			Physiological Maturity	
		BSS	BSS	MinT	TR	RH1	TR	RH2	MinT	RH2	RF	MaxT	TR
Mean for high yield stratum	1283	3.2	2.3	21.5	8.9	89.9	10.2	57.0	20.1	52.1	96.8	29.7	14.8
Mean for moderate yield stratum	787	3.1	4.3	21.5	9.7	88.3	11.5	49.6	16.8	44.6	36.5	29.8	16.0
Mean for low yield stratum	422	5.8	5.0	20.2	11.7	84.9	13.6	42.4	16.0	35.0	11.6	32.5	16.2
Moderate – High yield stratum	-496	-0.1	2.0	0.0	0.8	-1.6	1.2	-7.5	-3.3	-7.5	-60.2	0.0	1.2
Low – Moderate yield stratum	-365	2.7	0.7	-1.3	1.9	-3.4	2.1	-7.2	-0.8	-9.6	-24.9	2.7	0.1
Low – High yield stratum	-861	2.7	2.6	-1.2	2.8	-5.0	3.4	-14.7	-4.1	-17.1	-85.1	2.8	1.3

The variation of these parameters in moderate yield stratum from high yield stratum (moderate–high), in low yield stratum from moderate yield stratum (low–moderate) and in low yield stratum from high yield stratum were calculated (low–high), and presented in the three rows of the table (4.11)

The mean of high yield stratum is 1283 kg/ha. The mean yield of moderate yield stratum is less than this by 496 kg/ha and that of low yield stratum is 861 kg/ha. Similarly the mean yield of low yield stratum is less than moderate yield stratum by 365 kg/ha. Such calculations were performed for all the variables. It is observed from the Table, for some variables values are nearly same for moderate and high yield strata or for low and moderate yield strata, as overlapping of parameters was noticed in the graphical presentations. More sunshine by two hours per day during seedling stage and lower minimum temperature by 3.4 °C in pod formation and grain filling stage were found favorable for higher yield stratum compared to moderate stratum (Table 4.11).

Soybean

Akola

The effect of rainfall at critical stages of crop growth were studied across four different sowing environments. With later sowings (27-28-29-30 SMW) soybean crop recieived lower amount of rainfall during critical reproductive stages–pod formation to seed development which significantly lowered seed yield. The crop also received low rainfall during vegetative stage (Fig. 4.2).

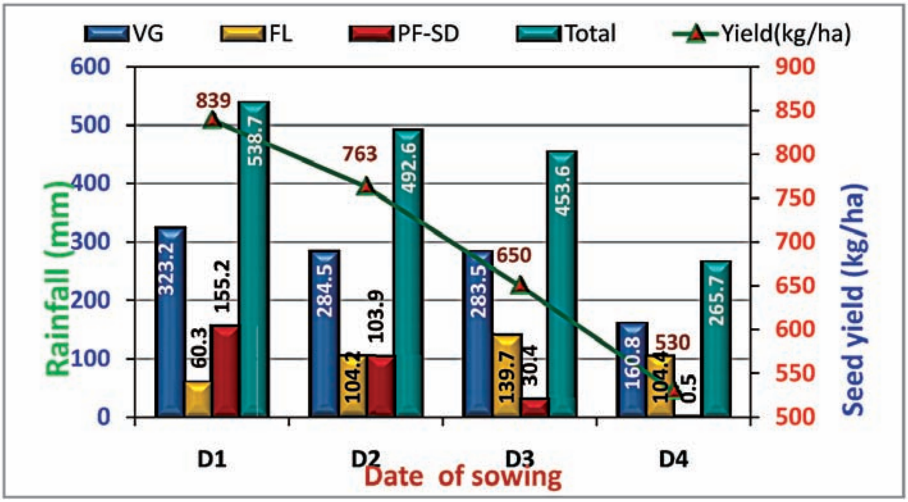


Fig. 4.2: Rainfall at critical stages and seed yield of soybean at Akola during 2014

Water use indices for different varieties and sowing times were estimated (Table 4.12).

Table 4.12: Water use indices as influenced by treatments

Treatment	Seed yield (kg ha^{-1})	Eta (mm)	Etp (mm)	WRSI (%)	WP (kg ha-mm^{-1})
Sowing time					
D_1 - 27 SMW	839	336.7	362.3	0.93	2.49
D_2 - 28 SMW	763	318.9	349.6	0.91	2.39
D_3 - 29 SMW	650	296.5	344.8	0.86	2.19
D_4 - 30 SMW	530	259.1	327.5	0.79	2.05
B. Variety					
V_1 - JS-335	700	303.2	346.0	0.88	2.31
V_2 - JS-9305	653	300.1	337.3	0.89	2.18
V_3 - TAMS-98-21	734	305.1	354.9	0.86	2.41

Actual (Eta) and potential (Etp) crop water use decreased with later sowings. Water requirement satisfaction index (WRSI), an indicator of crop performance based on the availability of water to the crop during a growing season, was more in earlier sowings indicating lesser degree of yield reduction due to water deficit. Water productivity (WP), a ratio of yield to actual crop water use, was maximum under earliest sowing (D_1- 27 SMW) and decreased with later sowings. Among the varieties, TAMS-98-21 showed higher Et_a and Et_p followed by JS-335 and JS-9305. WP was higher with TAMS-98-21 followed by JS-335 and JS-9305.

Parbhani

Six soybean cultivars (MAUS-158, 47, 81, 71, JS 93-05 and JS-335) were sown under four sowing windows (7, 14, 21 and 28 July, 2014) to study the crop weather relationships. The correlations between weather variables prevailed during different growth stages of different cultivars under different growing environments were computed and the results are presented in Table 4.13 .

Table 4.13: Correlation coefficients between seed yield and weather variables prevailed in different phenophases of soybean.

Param-eters	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
Rainfall	-0.112	0.579*	0.356	-0.722**	-0.481	-0.100	0.842**	0.551*	-0.611*
T.max	0.640**	-0.776**	-0.807**	0.474	0.051	0.787**	-0.306	-0.778**	-0.499
T.min	0.838**	0.696**	-0.469	-0.119	0.627**	0.586*	0.356	0.792**	-0.062
BSS	0.136	-0.866**	-0.323	0.687**	0.650**	0.697**	-0.776**	-0.610*	-0.620*

(* = Significant at 5 % ** = Significant at 1%)

P_1-Sowing to seedling, P_2-Seedling to branching, P_3-Branching to flowering, P_4 Flowering to pod formation, P_5-Pod formation to grain formation, P_6-Seed formation to pod development, P_7-Pod development to pod containing full grain size; P_8-Pod containing full grain size to dough stage; P_9-Dough stage to maturity.

The analysis indicated that during flowering stage to pod formation stage (P_5), minimum temperature and bright sunshine showed significant positive association where as rainfall showed negative association. In case of grain formation stage (P_6) maximum temperature, minimum temperature and BSS showed significant positive association. During grain development stage (P_8) rainfall, minimum temperature showed highly significant positive association whereas as maximum temperature and bright sunshine hours showed negative association.

Sunflower

Solapur

Cultivars Bhanu (V1), MSFH-17 (V2), Pule Raviraj (V3) were grown under three growing environnements [Sown during 2nd FN of June (S_1), 2nd FN of July (S_2) and 2nd FN of August (S_3)]. The CUM and MUE estimated indicate that the crop sown in second fortnight of June (S_1) recorded highest value of CUM (342 mm) and MUE valueof 5.48 Kg ha^{-1} mm. The lowest values of CUM (290 mm) and MUE (2.06 Kg ha^{-1} mm) were recorded in second fortnight of August (S_3) sown crop. Among the genotypes, Phule Raviraj recorded highest CUM and MUE than other varieties (Table-4.14).

Table 4.14: CUM and MUE as influenced by different treatments in *Kharif* sunflower(2010-14)

Treatment	GY (kg ha^{-1})	CUM (mm)	MUE (kg ha^{-1} mm)	Treatment	GY (kg ha^{-1})	CUM (mm)	MUE (kg ha^{-1} mm)
$S_1V_1T_1$	2205	312	4.2	$S_2V_2T_2$	1890	319	3.89
$S_1V_1T_2$	1731	306	3.36	$S_2V_3T_1$	2545	322	5.45
$S_1V_2T_1$	2550	323	4.64	$S_2V_3T_2$	2233	337	4.67
$S_1V_2T_2$	2458	310	4.83	$S_3V_1T_1$	1089	293	3.26
$S_1V_3T_1$	2764	342	5.48	$S_3V_1T_2$	454	290	2.06
S_1V3T_2	2648	337	4.68	$S_3V_2T_1$	1295	324	3.63
$S_2V_1T_1$	2029	325	4.10	$S_3V_2T_2$	673	295	2.77
$S_2V_1T_2$	1852	297	3.29	$S_3V_3T_1$	1660	306	4.53
$S_2V_2T_1$	2107	323	5.02	$S_3V_3T_2$	962	295	3.45

The maximum values of LAI and RUE were recorded at 50 per cent flowering stage in all sowing dates and genotypes. This indicates that the rate of conversion of light *i.e.* photo synthetically active radiation (PAR) was considerably high at 50 per cent flowering stage, thereafter the conversion rate was less due to leaf senescence. Among the sowing dates, RUE values were higher in early sown crop than late sown crop. Further, it is seen that Phule Raviraj showed high values of RUE than other varieties in all the dates of sowing (Table 4.15).

Table 4.15: Radiation use efficiency (g MJ $^{-1}$) as influenced by sowing dates in sunflower (*Kharif* 2010-14)

Sowing	Growth Stage					
Date	4 Leaf	Button	50% flow.	Soft Dough	Hard Dough	Phy. Maturity
S_1V_1	0.12	0.59	1.68	1.42	1.34	0.38
S_1V_2	0.13	0.63	1.79	1.47	1.38	0.56
S_1V_3	0.14	0.69	1.86	1.55	1.40	0.61
S_2V_1	0.11	0.52	1.31	0.94	0.93	0.39
S_2V_2	0.09	0.55	1.30	0.96	0.85	0.49
S_2V_3	0.12	0.61	1.70	1.01	0.81	0.55
S_3V_1	0.05	0.48	1.08	0.81	0.72	0.48
S_3V_2	0.09	0.51	1.08	0.84	0.71	0.51
S_3V_3	0.11	0.55	1.61	0.88	0.80	0.55

Cotton

Parbhani

Cultivars Ajit-155, Rasi-2 and Mallika were raised under four growing environments to explore the crop weather relationships. The correlations between cotton yield and weather that prevailed during crop growing season are presented in table 4.16.

Table 4.16: Correlation co-efficient exhibited by weather parameters prevailed in different phenophases with cotton yield (2014-15).

Parameters	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9
Rainfall	0.582*	-0.579*	0.657**	-0.369	0.118	0.419	-0.542*	0.501	-0.403
T.max	0.598*	0.474	-0.575*	0.446	0.420	-0.471	0.356	-0.092	0.473
T.min	0.616*	0.582*	-0.649**	0.563*	-0.582*	0.257	-0.427	0.558*	-0.350
BSS hrs/day	0.581*	-0.338	0.550*	0.491	0.071	-0.529*	0.641**	-0.537*	0.355

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

(P_1 = Sowing to emergence, P_2 = Emergence to seedling, P_3 = Seedling to square formation, P_4 = Square formation to flowering, P_5 = Flowering to boll setting, P_6 = Boll setting to boll bursting, P_7 = Boll bursting to 1st picking, P_8 = 1st picking to 2nd picking, P_9 = 2nd picking to 3rd picking)

The most critical growth stages influencing cotton yield are square formation to flowering (P_4), flowering to boll setting (P_5) and boll setting to boll bursting (P_6). The data revealed that during early stage *i.e.*, seedling to square formation stage (P_3) the weather parameters *viz;* rainfall and bright sunshine hours showed significant positive relationship with cotton yield while maximum and minimum temperature showed negative relationship with cotton yield. During square formation to flowering stage (P_4), only minimum temperature showed positive association. At flowering to boll setting also, minimum temperature showed negative association. At boll setting to boll bursting stage, BSS showed significant negative relationship and during final growth stage *i.e.*, boll bursting to picking stage of crop, minimum temperature, BSS showed positive significant correlation with cotton yield.

Groundnut

Anand

Three cultivars (M-335, GG-20 and GG-5) were raised under three growing environments (sown on 18th July, 2nd August and 17th August) for exploring the crop weather relationships.

The relationship between water use efficiency and pod yield of groundnut was also worked out (Fig. 4.3). Under rainfed farming, WUE of groundnut was about 61%.

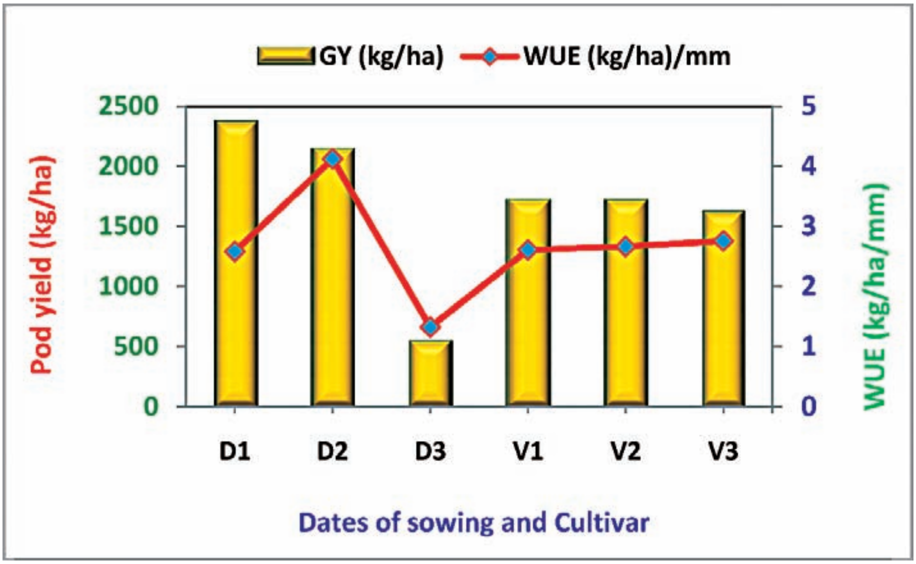


Fig. 4.3: Relationship between water use efficiency and pod yield of groundnut at Anand

Crop sown on 2 Aug recorded highest WUE (3 kg/ha/mm), whereas late sown (D_3) had lowest (1kg/ha/mm). Amongst different cultivars, they had almost similar WUE (3 kg/ha/mm). Under rainfed farming of groundnut, WUE totally depends on rainfall distribution.

The favourable range of various weather parameters under different phenophases were found out based on correlation studies using pooled data of 2009-2012 and the results are presented in table 4.17.

Table 4.17: Favourable weather range for higher production (2009-2012)

Weather Parameter	Pod Ini		Seed Sett		Pod Mat	
	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit
EP(mm)	2	4	3	4	3	4
BSS (hr)	2	4	3	3	3	6
RF (mm)	50	166	35	205	54	273
Tmax(^{0}C)	31	32	31	33	31	32
RH_1(%)	92	97	95	98	94	98
RH_2(%)	71	81	77	84	67	80
RHmean (%)	83	89	86	91	80	89
VP_1(mm of HG)	24	26	25	26	23	25
VP_2(mm of HG)	24	26	25	26	23	26
VPmean(mm of HG)	24	26	25	26	23	25

Anantapur

Vemana, K6 and Anantha (K1271) cultivars were grown under rainfed and irrigated conditions in three growing environments [sown on 10 (D1), 30 July (D2) and 9 August (D3) 2014] to study the crop weather relationships. The crop sown during 2nd fortnight of July has recorded highest yield (607 kg/ha) for rainfed crop, while crop sown on first fortnight of August recorded highest yield for irrigated crop (767 kg/ha) (Table 4.18). The yield of Vemana (588 kg/ha), K6 (632 kg/ha) and Anantha (629 kg/ha) varieties sown in different dates of sowing was also on par. The crop sown during 1st fortnight of July accumulated 2021 growing degree days, 2nd fortnight of July sown crop accumulated 1888 GDD and 1st fortnight of August sown crop accumulated 1937 GDD.

Table 4.18: Effect of irrigation, growing environments and cultivars on pod yield and accumulated GDD of groundnut at Anantapur.

Treatment	Pod yield (kg/ha)			
	D1	**D2**	**D3**	**Mean**
Rainfed	471	607	446	508
Irrigated	665	744	767	725
Mean AGDD (°days)	2021	1888	1937	
	Vemana	**K6**	**Anantha**	**Mean**
Rainfed	493	522	510	508
Irrigated	683	745	749	725

Bangalore

Groundnut cultivars C-2, JL-24 and TMV-2 were grown under two growing environments (sown on 10th July and 9th August, 2014). Effect of different growing environments and varieties on groundnut pod and haulm yield was studied and the results are presented in table 4.19.

Table 4.19: Interaction effect of different dates of sowing and varieties on groundnut pod and haulm yield (kg/ha)

Growing Environments	Pod Yield(kg/ha)			Haulm Yield(kg/ha)		
Date of sowing/ variety	D1 10.07.2014	D2 09.08.2014	Mean	D1 10.07.2014	D2 09.08.2014	Mean
V1-TMV-2	1456.4	400.8	**928.6**	600.0	2133.3	**1366.7**
V2-JL-24	1203.2	570.8	**887.0**	1416.7	2600.0	**2008.3**
V3-C-2	1815.5	663.3	**1239.4**	1591.7	2108.3	**1850.0**
Mean	**1491.7**	**545.0**	**1018.3**	1202.8	2280.6	**1741.7**
Particulars	**SEm±**	**CD (0.05 P)**	**CV (%)**	**SEm±**	**CD (0.05 P)**	**CV (%)**
Variety	56.1	169.0		160.6	484.1	
Date of sowing	45.8	138.0	15.6	131.1	395.2	26.1
V*D	79.3	239.0		227.1	NS	

The groundnut sown on 10th July has given the higher mean pod yield of 1491.7 kg/ha compared to that crop sown on 09.08.2014 which recorded low yield of 545kg/ha. Among varieties C-2 has given higher yield of 1239 kg/ha followed by TMV-2 and JL-24 were recorded 929 kg/ha and 887 kg/ha respectively. The low yield of groundnut in second sown crop was mainly due to prolonged drought spell at growth stage and water stress in the pod development and maturity stage. Crop water balance was worked out using FAO model (Fig. 4.4 (a) & (b))

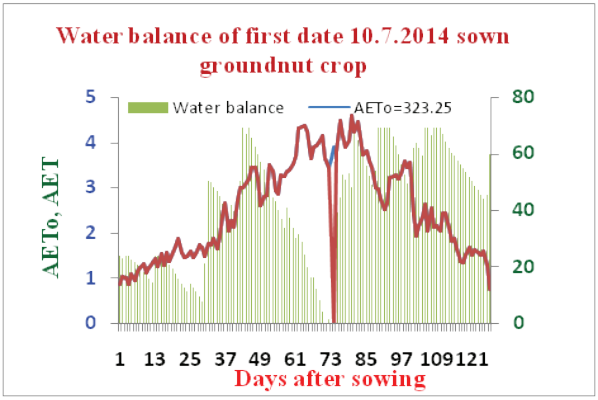


Fig. 4.4 (a): Crop water balance for groundnut sown on 10-7-2014 in Bangalore

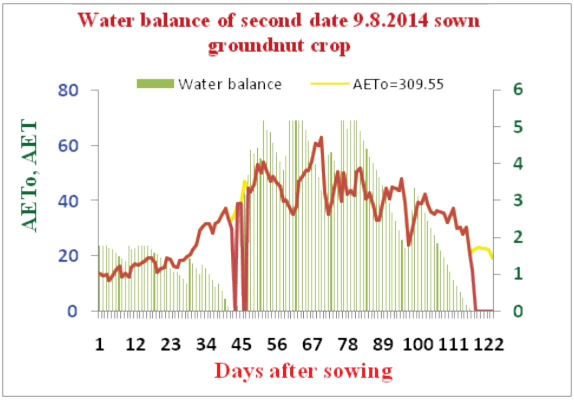


Fig. 4.4 (b): Crop water balance for groundnut sown on 9-8-2014 in Bangalore

The actual water required for the crop sown on 10thJuly is about 323.25 mm and water available was only 317.54 mm. For the late sown crop *i.e.* although the water requirement was 309.55 mm but the available water was only 292.72 mm. There was inadequate soil moisture during pod development and maturity that has led to a decline in pod yield (Table 4.19). Hence the 2nd date sown groundnut yields were drastically reduced.

Rabi 2014-15

Wheat

Hisar

Wheat cultivar WH-1105 was exposed to four growing environments (sown on 5, 20 Nov and 5, 20 Dec 2014) and four irrigation regimes (I_1: irrigation at CRI, I_2: CRI+heading, I_3: CRI+jointing+milk, I_4: CRI+jointing+anthesis+dough) to study the influence of growing environments and water use on RUE at various phenological stages of crop. The RUE under different growing environments and irrigation level at various phenophases were computed with dry matter accumulation and intercepted PAR and illustrated in table 4.20.

Table 4.20: Effect of different treatments on radiation use efficiency (g/MJ) during different growth stages in wheat

Growing Environments	CRI	TL	JT	BT	HD	AN	ML	DS	P.M.
D_1	0.08	0.13	0.34	0.64	0.79	0.91	1.13	1.18	1.10
D_2	0.08	0.14	0.35	0.70	0.76	0.91	1.10	1.09	1.01
D_3	0.12	0.18	0.39	0.63	0.75	0.83	0.96	1.00	0.99
D_4	0.17	0.17	0.33	0.57	0.62	0.66	0.84	0.94	0.95
Mean	0.11	0.16	0.35	0.63	0.73	0.83	1.00	1.05	1.01
S.D. (±)	0.04	0.03	0.03	0.05	0.08	0.12	0.13	0.11	0.06

C.V. (%)	36.0	18.0	0.07	0.08	0.10	0.14	0.13	0.10	0.06
Irrigation levels									
I_1	0.08	0.10	0.32	0.65	0.82	1.01	1.28	1.25	1.34
I_2	0.08	0.14	0.36	0.70	0.83	0.94	1.20	1.17	1.20
I_3	0.12	0.19	0.38	0.65	0.80	0.89	1.09	1.08	1.06
I_4	0.15	0.21	0.34	0.59	0.70	0.75	0.93	0.94	1.01
Mean	0.11	0.16	0.35	0.65	0.78	0.90	1.12	1.11	1.15
S.D.(±)	0.04	0.05	0.03	0.05	0.06	0.11	0.15	0.13	0.15
C.V. (%)	34.0	30.0	7.0	7.0	7.0	12.0	13.0	12.0	13.0

Under different growing environments, the early sown crop showed more efficient in radiation use at reproductive stages as compared to delayed sowing and vice versa at vegetative stage. In case of irrigation levels, RUE was found to be low under poorly irrigated crop at early stages, while at later stages, reverse condition prevailed due to differences in intercepted PAR.

Jammu

Cultivars HD-2967, Raj-3077 and RSP-561 were grown under four sowing environments (sown on 29 Oct, 12, 26 Nov and 10 Dec 2014) to study its effect on water use efficiency. The results of the study are given in table 4.21.

Table 4.21: ET and WUE of winter wheat under the different crop growing environments

Treatment	Grain Yield (kg ha^{-1})	ET (mm)	WUE (kg ha^{-1} mm^{-1})
Crop growing environments			
29-10-2014	2120	139.92	15.10
12-11-2014	2240	195.74	11.44
26-11-2014	1994	149.82	13.32
10-12-2014	1642	154.21	10.64
Varieties			
HD-2967	1915	159.41	12.04
Raj-3077	2228	160.61	14.07
RSP-561	1848	159.88	11.77

The results indicated that ET of wheat increased with delay in sowing. ET at second, third and fourth date of sowing increased by about 55.8, 9.9 and 14.3 mm as compared to early sown crop, respectively. However, ET in 3rd crop growing and 4th crop growing environments didn't increase substanstially comapared to recorded in 2nd crop growing, because of heavy rains during the months of Feb., March and April, which caused water logged conditions in the field. The increase in water use efficiency was associated with an increase in grain yield of wheat crop. WUE was highest (15.1 kgha^{-}

[1]mm[-1]) in 1st crop growing environment and lowest in crop sown on 10 Dec. As far as variety is concerned, Raj 3077 showed high WUE followed by HD 2967. The least WUE was observed in RSP-561.

Ludhiana

The wheat data collected during *rabi* 2009-10 to *rabi* 2012-13 for four cultivars namely PBW-550, DBW-17, PBW-343 and PBW 621 were analyzed for the major growth stages to find the range of meteorological parameters favourable for high wheat yield. The results of the analysis are presented in table 4.22.

Table 4.22: Range of meteorological parameters favourable for high wheat yield (*rabi* 2009-10 to 2012-13).

Crop stage	Durtaion (Days)	Temperature (°C)		Relative humidity (%)		Sunshine hours (Hr)	Rainfall (mm)
		Maximum	Minimum	Maximum	Minimum		
CRI stage	25-35	21-29	6-13	90-98	36-54	4.5-7.5	4.0-19.0
Tillering stage	30-35	20-29	7-16	90-97	36-57	4.0-7.2	4.0-24.0
Booting stage	10-17	18-28	6-9	92-97	50-60	4.5-6.5	15.0-115.0
Anthesis stage	7-15	19-22	7-10	93-96	50-60	4.5-6.5	40.0-142.0
Milking stage	15-30	20-24	7-9	94-96	47-60	4.7-6.5	40-142.0
Hard dough stage	7-15	20-25	8-12	90-95	45-55	5.0-7.0	40.0-142.0
Physiological maturity stage	5-10	22-24	8-10	85-95	45-55	5.5-7.0	4.0-16.0

Palampur

Optimum temperatures for highest wheat productivity were characterized using five seasons experimental data (2010-11 to 2014-15). The exercise was carried out for both rainfed and irrigated crop and the results are presented in table 4.23.

Table 4.23: Optimum temperature for highest productivity during past five years during vegetative and reproductive phases in wheat.

Year	Temperature	Irrigated condition		Rain fed condition	
		Vegetative	Reproductive	Vegetative	Reproductive
2010-11	Maximum	19.1	22.8	18.6	23.1
	Minimum	6.0	11.0	5.6	11.3

2011-12	Maximum	19.6	26.2	18.7	25.6
	Minimum	7.6	13.6	7.0	13.1
2012-13	Maximum	17.4	24.8	17.6	24.3
	Minimum	5.5	12.3	6.0	12.0
2013-14	Maximum	16.9	21.0	16.3	21.5
	Minimum	4.8	9.6	4.7	10.0
2014-15	Maximum	17.1	21.9	16.8	25.4
	Minimum	4.8	11.4	4.7	14.2

Under rainfed conditions, the maximum temperature during vegetative phase did not exceed 18.7 °C and minimum above 7 °C but during reproductive phase maximum temperature exceeded the earlier established optimum limit of maximum (23.4) and minimum (10.9) temperature by 2.2 and 3.3 °C. The higher phasic temperatures as mentioned above coincided with year with lowest productivity during *rabi* 2011-12.

Kanpur

Seven cultivars (CG-1006, HI-1544, Ratan, Kanchan, CG-1013, GW-273, HD-2967) were exposed to three growing environments (sown on 25 Nov, 10 and 25 Dec, 2014). Heat and radiation use efficiencies were worked out. HUE of different varieties is shown in Table 4.24 (a). It can be observed that Kanchan variety is having the highest HUE among the 7 wheat varieties tested and it is followed by GW-273 variety. However, the highest HUE is observed under 10 December sowing, however crop sown on 25 Nov and 10 Dec were at par.

Table 4.24 (a): Heat use efficiency (g/m^2/^{o}day) of wheat varieties as influenced by different growing environments.

Varieties	D1-25 Nov.	D2-10 Dec.	D3-25 Dec.	MEAN
CG 1006	0.31	0.36	0.33	0.33
HI1544 (zonal check)	0.39	0.41	0.35	0.38
Ratan (State check)	0.36	0.38	0.34	0.36
Kanchan	0.42	0.47	0.40	0.43
CG1013	0.40	0.38	0.36	0.38
GW273	0.45	0.40	0.38	0.41
HD2967 (National check)	0.30	0.27	0.27	0.28
Mean	**0.37**	**0.38**	**0.35**	

RUE of seven varieties were worked out for the purpose of selecting the best three for further experimentation. As shown in Table 4.24 (b), interestingly the national check

HD-2967 variety, exhibited poor RUE. Highest value of RUE is found with Kanchan variety followed by GW-273.

Table 4.24 (b): Radiation use efficiency (g/m^2/Mj) of wheat varieties as influenced by different growing environments.

Varieties	D1 (25 Nov.)	D2 (10 Dec.)	D3 (25 Dec.)	MEAN
CG 1006	0.76	0.93	0.89	**0.86**
HI1544	0.97	1.07	0.95	**1.00**
Ratan	0.89	0.99	0.92	**0.93**
Kanchan	1.05	1.20	1.07	**1.10**
CG1013	0.98	0.99	0.98	**0.98**
GW273	1.12	1.03	1.02	**1.06**
HD2967	0.80	0.73	0.77	**0.77**
Mean	**0.94**	**0.99**	**0.94**	

Ranchi

Cultivars HUW-468, K-9107 and Birsa Genhu-3 were sown under three dates of sowing (20 Nov, 5 and 20 Dec) to study the crop weather relationship. Heat and radiation use efficiencies were studied and the results are presented in table 4.25.

Table 4.25: HUE and RUE of wheat cultivars under different growing environments at Ranchi.

Sowing Date	Variety	HUE (kg/ha°days)	RUE (kg/ha/MJ)	Yield (kg/ha)
20th Nov	HUW 468	3.2	2.3	4603
	K9107	2.5	1.8	3980
	BG 3	3.0	2.4	4991
5th Dec	HUW 468	2.9	2.2	4378
	K9107	2.2	1.7	3573
	BG 3	2.7	1.8	4240
20th Dec	HUW 468	2.7	2.1	4069
	K9107	2.1	1.8	3479
	BG 3	2.3	1.8	3565

The results indicated that early sown crop registered higher heat and radiation use efficiencies compared to the late sown crop. Among varieties, HUW-468 achieved highest HUE (3.2 kg/ha ^{o}days) whereas BG 3 recorded highest RUE (2.4 kg/ha/MJ). The higher heat and radiation use efficiencies in case of early sowing and HU-468 were also reflected in their higher yields.

Comparison between mean temperature and average yield of K 9107 (*rabi* 2007-08 to 2013-14) with that of *rabi* 2014-15 crop performance (table 4.26) showed that normal (20^{th} Nov), mod. normal (5^{th} Dec) and late (20^{th} Dec) sown wheat crops experienced optimum range of maximum temperature, but all were exposed to higher minimum temperature as compared to their optimum minimum temperature ranges during each reproductive stage *i.e.* from anthesis to maturity stage and yielded less than 4 t/ha. Minimum temperature was 2.4 to 6.5 ^{0}C higher over optimum range during reproductive stage and maximum differences were found during anthesis to milking stage (4.3 to 6.5 ^{0}C) for all the three sowing dates crops resulted into decrease in yield of K 9107 by 11-13%.

Table 4.26: Long term analysis of temperature vs. yield with current year (Var. K 9107)

Stages	**Tmax (°C)**			**Optimum range (°C) (Yield >4t/ha)**
	20^{th} Nov	5^{th} Dec	20^{th} Dec	
Vegetative	21.7	21.9	22.3	22.5 - 24.5
Boot-Anthesis	25.9	28.8	27.3	21 - 27.5
Anthesis-Milk	27.4	26.8	29.4	23.5 - 29.5
Milk-maturity	29.0	31.2	32.3	30 - 32.5
	Tmin (°C)			
Vegetative	5.9	7.0	8.3	7- 8
Boot-Anthesis	11.9	14.8	15.8	7.5 - 11.5
Anthesis-Milk	14.3	16.5	15.6	7 - 10.0
Milk-maturity	15.9	17.8	19.2	11.5 - 13.5
Yield (t/ha)	**5.4**	**4.7**	**3.8**	

Samastipur

Cultivars RW-3711, HD-2824 and HD-2733 were grown under five growing environments (sown on 15, 25 Nov, 5, 15 and 25 Dec 2014) to study the crop weather relationships. Effect of growing environment on grain yield and HUE was explored and the results are presented in table 4.27.

Table 4.27: Effect of seeding dates on growth, yield attributes and grain yield of wheat varieties.

Treatment	**Grain yield (q/ha)**	**HUE (kg/ha °C)**
Sowing dates		
15.11 14	32.7	1.6
25.11.14	35.7	2.0
5.12 14	33.5	1.9

15.12 14	24.5	1.4
25.12.14	18.4	1.2
CD (P=0.05)	1.4	--
Varieties		
RW3711	27.0	1.5
HD2824	28.5	1.6
HD2733	31.4	1.7
CD (P=0.05)	1.1	--

Crop sown on 25th November sown crop recorded significantly higher grain yield (35.7 q/ha) than earlier as well as later sown crop. The reduction in grain yield was recorded to the tune of 8.4 % in earlier sown crop on 15th November and 6.2, 31.4 and 48.5 % in later sown crop on 5, 15 and 25 December sown crop, respectively.

Grain yield also varied significantly among the varieties. Wheat variety, HD 2733 produced significantly higher grain yield (31.4 q/ha) than HD 2824 and 3711. Similarly, HD 2824 also significantly surpassed over RW 3711.

Crop sown on 25th November recorded maximum HUE than earlier as well as late sown crops. Hence, 25th November was found optimum seeding time for wheat under agro ecology conditions of North Bihar. Among the varieties, HD 2733 recoded highest HUE followed by HD 2824. Hence, this varietyis more suitable for this region.

Udaipur

Cultivars HI-1544 (V_1), MP-1203 (V_2), Raj-4037 (V_3), Raj-4238 (V_4) and HD-2967(V_5) were grown under four growing environments [sown on 5 Nov (D1), 20 Nov (D2), 5 Dec (D3) and 20 Dec (D4) 2014]. Effect of mean temperature during critical growth stages of the crop on yield was assessed and the results are presented in fig. 4.5 a,b,c.

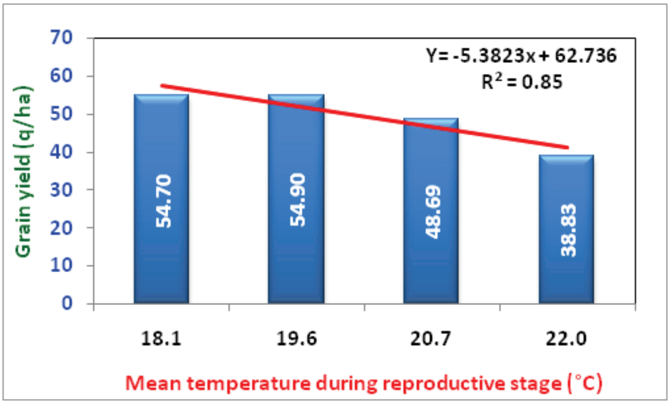


Fig. 4.5a: Effect of mean temperature during reproductive period on grain yield of wheat var Raj-4037 (mean of 8 years from 2007-08 to 2014-15)

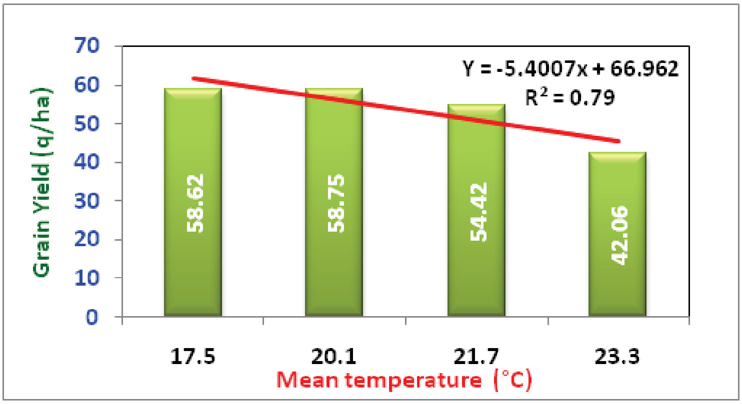


Fig. 4.5b: Effect of mean temperature during reproductive period on grain yield of wheat var HI1544 (mean of5 years from 2010-11 to 2014-15)

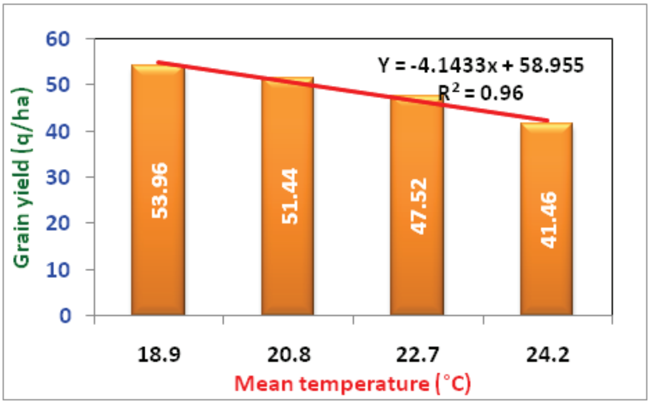


Fig. 4.5c: Effect of mean temperature during reproductive period on grain yield of wheat var MP-1203 (mean of 5 years2010-11 to 2014-15)

Higher mean temperature of (16.4 to 17.9 °C) during tillering to heading was observed under 5th December and 20th December sown crop in all varieties. Early sowing exposed the crop to mean temperature around 15 °C during this stage. However, large variations in mean temperature during heading to milking stage and milking to dough stage was recorded in different sowings. It was also noted that the early sown crop (5th November and 20th November) experienced lower mean temperature as compared to delayed sowing *i.e.* 5th December and 20th December in all varieties. Similarly, first two dates of sowing also experienced lower mean temperature during milking to dough stage as compared to later sowing dates.

On the basis of pooled data for 4 years from 2011-12 to 2014-15, it was observed that the mean temperature of 15.2 to 18.2 ^{0}C and 19.6 to 20.5 ^{0}C during heading to milking stage and during milking to dough stage, respectively found conducive for getting higher grain yield of wheat variety Raj-4037. Data further revealed that later sown wheat (5th and 20th December) experienced higher mean temperature during milking to maturity and heading to maturity stage in all varieties as compared to early sown crop (5th and 20th November). Hence, period between heading to dough stage is more sensitive to higher mean temperature which resulted into reduction in grain yield when sowing were delayed in all varieties.

Raj-4037 gave higher grain yield when the mean temperature ranged from 18.1 to 19.6 °C during reproductive phase. Similarly variety HI-1544 and MP-1203 also performed better in terms of grain yield when the mean temperature during reproductive phase is ranged from 17.5 to 20.1°C and 18.9 to 20.8 °C, respectively.

Chickpea

Akola

Heat use efficiency, with respect to seed yield and biomass production (seed+straw) under different dates of sowing was estimated. Crop sown on 41 and 42 SMW showed maximum HUE in terms of seed (0.30 kg ha^{-1} °C day^{-1}) In terms of biomass yield it was maximum (0.83 kg ha^{-1} °C day^{-1}) under 42nd SMW (16 October) sowing followed by 41 and 40 SMW sowings. October 1st sowing (40 SMW) recorded minimum HUE in terms of seed yield (0.24 kg ha^{-1} °C day^{-1}). Amongst the varieties, HUE with respect to seed yield (0.30 kg ha^{-1} °C day^{-1}) was higher in JAKI-9218(V_1) and for biomass production it was maximum with Vijay (0.80 kg ha^{-1} °C day^{-1}). Chaffa 816 (V_2) recorded the minimum HUE in terms of seed yield (0.26 kg ha^{-1} °C day^{-1}) (table 4.28).

Table 4.28: Heat use efficiency of chickpea varieties in terms of seed and biomass production (kg ha^{-1} °C day^{-1}) under different dates of sowing.

Varieties	Sowing date			
	D_1 - 40 MW (02.10.14)	D_2 - 41 MW (09.10.14)	D_3 - 42 MW (16.10.14)	Mean
V_1 - JAKI-9218	0.26	0.32	0.33	0.30
	0.65	0.72	0.86	0.74

V_2 – CHAFFA 816	0.22	0.26	0.29	0.26
	0.71	0.74	0.75	0.73
V_3 – VIJAY	0.23	0.31	0.29	0.28
	0.73	0.79	0.87	0.80
Mean	0.24	0.30	0.30	
	0.69	0.75	0.83	

Faizabad

Chickpea cultivars Radhey, Pusa-362 and Uday were grown under three growing environments (sown on 25 Oct, 4, 14 Nov 2014) to explore the crop weather relationship. Heat and radiation use efficiencies were worked out. RUE increased progressively till 90 days after sowing and thereafter gradually declined under different treatments. Chickpea sown on Oct 25th recorded highest RUE at all the stages followed by Nov 4th sown and lowest RUE was recorded in crop sown on Nov 14th.

Variation on RUE was noted for different varieties as given in table 4.29. Highest RUE was recorded for Radhey followed by Pusa 362 at all the stages of crop growth, while the lowest RUE was recorded in Uday.

Table 4.29: Radiation use efficiency (g/MJ) of chickpea as affected by various treatments

	Days after sowing							
Treatment	**30**	**45**	**60**	**75**	**90**	**105**	**120**	**135**
Sowing dates								
Oct. 25	1.2	1.17	1.26	1.27	1.64	1.55	1.48	1.33
Nov. 4	0.95	1.15	1.17	1.25	1.52	1.47	1.37	1.25
Nov. 14	0.90	1.10	1.11	1.21	1.47	1.35	1.35	1.21
Varieties								
Radhey	0.99	1.13	1.23	1.27	1.57	1.38	1.26	1.27
Pusa 362	0.97	1.11	1.17	1.25	1.51	1.35	1.24	1.23
Uday	0.95	1.07	1.14	1.21	1.43	1.32	1.25	1.21

Jabalpur

Cultivars JGK-1, -3 (Kabuli type), JG-315, -11, -322, and -74 (Desi type) and JGG-1 (Gulabi type) were grown under three growing environments (sown on 14, 22 Nov and 10 Dec 2014) to study the effect of weather parameters on yield. Correlations were worked out between chickpea grain yield and weather parameters at different phenological stages using Pearson's correlation coefficient with SPSS software and the results are presented in table 4.30.

Table 4.30: Pearson's correlation coefficient between seed yield and weather parameters at different phenological stages in chickpea.

Phenological stages	Tmax	Tmin	Tmean	GDD	HTU	PTU	SSH	RHm	RHe	Winds	Eva	RF	RD
Branching	.823**	.770**	.808**	0.193	.453*	0.174	.770**	-.784**	-.807**	-.742**	.804**	-.811**	-.811**
Flowering	.711**	-0.16	.573**	0.289	.516*	0.205	.740**	-.587**	-.750**	-.772**	.680**	-.766**	-.711**
Podding	.754**	0.263	.698**	.705**	.698**	.685**	.650**	-.757**	-.755**	-.605**	.603**	-0.362	-0.366
Maturity	.754**	0.263	.698**	.705**	.698**	.685**	.650**	-.757**	-.755**	-.605**	.603**	-0.362	-0.366

(**Correlation is significant at the 0.01 level {2-tailed})

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

Evaporation, sunshine hours, maximum temperature and mean temperature had a positive correlation with seed yield among all phenological stages in chickpea. On the other hand, wind speed, morning and evening relative humidities had negative correlation with grain yield at all the stages. Heavy and continuous rainfall during branching and flowering stages is not good for getting high seed yield. Intermittent rainfall with cloud free period would be congenial for better chickpea yield at Jabalpur.

Solapur

Cultivars Vijay (V_1) and Dig Vijay (V_2) were grown under four crop growing environments [sown on 38 SMW (S_1), 40 (S_2) , 42 (S_3) and 44 (S_4)] to study the crop weather relationship. Consumptive Use of Moisture (CUM) and Moisture Use Efficiency (MUE), as influenced by different growing environments were studied and the results are presented in table 4.31.

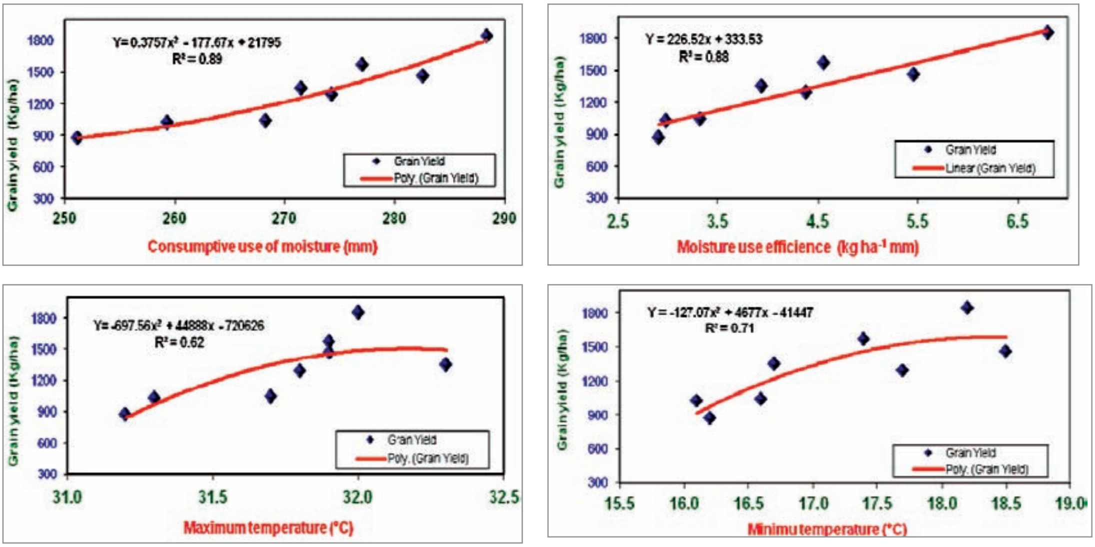
Table 4.31: CUM and MUE as influenced in chickpea (2010-11 to 2014-15)

Treatment	CUM (mm)	MUE (kg ha^{-1} mm)	Treatment	CUM(mm)	MUE (kg ha^{-1} mm)
S_1V_1	282.6	5.82	**S_3V_1**	268.3	3.39
S_1V_2	288.4	6.94	**S_3V_2**	271.5	4.02
S_2V_1	274.3	4.46	**S_4V_1**	251.2	2.98
S_2V_2	277.1	4.68	**S_4V_2**	259.3	3.12

The average CUM (288.4 mm) was recorded higher by the S_1 sown crop (MW 38) and MUE (6.94 kg ha^{-1} mm) was recorded higher by the S_1 sown crop (MW 38). Among the varieties, Dig Vijay recorded highest average value of CUM and MUE. This might be due to more days required for Dig Vijay variety for growth and development.

The relationship of MUE, maximum and minimum temperature with pod yield in chickpea was also assessed (Fig. 4.6)

A B



C D

Fig. 4.6: Relationship of grain yield with (A) MUE (B) CUM (C) Tmax and (D) Tmin in Chickpea at Solapur

The CUM during total growth period of chickpea showed a polynomial relationship with grain yield. The CUM of 275 mm was found to be optimum for getting higher grain yield and thereafter there was decrease in yield. The correlation between MUE and chickpea yield showed a linear relationship. Tmax during total growth period of chick pea showed a polynomial relationship with grain yield. The yield decreased when Tmax increased above 31.8 °C. Tmin during total growth period of chickpea also showed a polynomial relationship with grain yield. A Tmin of 17.5 °C was found to be optimum for getting higher grain yield and thereafter there was a decline in chickpea yields.

Mustard

Faizabad

Thermal use efficiency (TUE) of three cultivars (Varuna, NDRS-2001 and NDR-8501) grown under three growing environments (sown on 30th Oct, 14, 29th Nov, 2014) were computed. The maximum TUE requirement from sowing to maturity was recorded (0.67) at growing in crop sown on 30th Oct. while minimum TUE from sowing to maturity (0.56) was observed in 29th Nov sown crop. Varieties showed marked influence on the TUEat all the phenophases. TUEranged from 0.53 to 0.67, across the varieties. Maximum seasonal TUE(0.67) were recorded in NDR-8501 while minimum seasonal TUEwas noticed in Varuna variety (0.53) from (table 4.32).

Table 4.32: Thermal use efficiency (g/m^2/^{o}days) of mustard as affected by growing environment and varieties.

Treatments	Thermal use efficiency (g/m^{-2}/^{o}days)						
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	At harvest
Growing Environment							
30 Oct.	0.13	0.18	0.22	0.43	0.55	0.63	0.67
14 Nov.	0.11	0.16	0.20	0.37	0.50	0.54	0.60
29 Nov.	0.11	0.15	0.19	0.36	0.47	0.59	0.56
Varieties							
Varuna	0.12	0.16	0.21	0.40	0.52	0.56	0.62
NDRS-2001-1	0.10	0.14	0.18	0.34	0.44	0.48	0.53
NDR- 8501	0.13	0.18	0.22	0.43	0.56	0.60	0.67

Hisar

Brassica spp. cultivars Laxmi, RH-0749, Kranti, RH-406 and RH-30 were grown under three growing conditions (sown on 25th Oct, 5th & 15th Nov, 2014) to study the crop weather relationships. RUE (Table 4.33) and energy balance were worked out for different growth stages of the crop.

Table 4.33: Radiation use efficiency of *Brassica* cultivars at various phenophases under different growing environments during *rabi 2014-15.*

Date of sowing	Emergence	5th leafstage	First flower	50% flower	Pod initiation	Seed development	PM
25 Oct	2.82	1.94	2.04	2.37	2.39	2.26	2.20
5 Nov	1.33	1.62	1.19	2.09	1.97	1.85	1.98
15Nov	0.61	0.86	0.74	1.18	3.89	2.49	1.84
Mean	1.59	1.47	1.32	1.88	2.75	2.20	2.01
SD (±)	1.13	0.56	0.66	0.62	1.01	0.33	0.18
CV (%)	0.71	0.38	0.50	0.33	0.37	0.15	0.09
Laxmi	1.46	1.41	1.24	1.93	2.49	2.27	2.04
RH0749	1.74	1.61	1.61	2.28	2.88	2.65	2.47
Kranti	1.37	1.32	0.97	1.59	2.24	1.77	1.67
RH0406	1.41	1.41	1.21	1.79	2.35	2.09	2.02
RH30	1.40	1.37	1.27	1.68	2.38	1.98	1.90
Mean	1.48	1.43	1.26	1.85	2.47	2.15	2.02
SD (±)	0.15	0.11	0.23	0.27	0.25	0.33	0.29
CV (%)	0.10	0.08	0.18	0.15	0.10	0.15	0.14

The proportion of intercepted PAR differed because of differential crop cover owing to variation in LAI and varying levels of biomass production in different treatments, implying that RUE also differed. Among varieties, RH 0749 recorded highest RUE followed by Laxmi at all stages of crop growth. The highest RUE in the earlier sown crop was due to the maximum PAR absorption and dry matter production, both of which decreased subsequently with the delayed sowing.

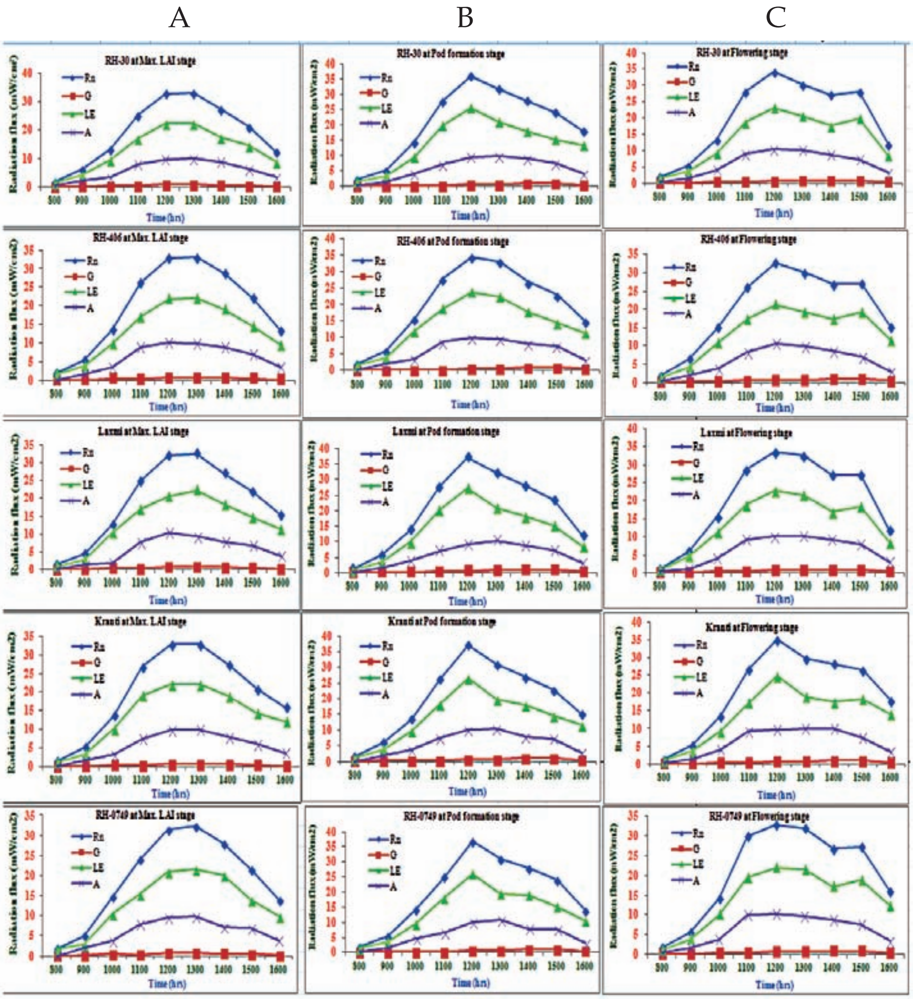


Fig. 4.7: Energy balance components at (A) max LAI stage, (B) flowering and (C) pod formation stage in different mustard varieties during *rabi* 2014-15 at Hisar.

Diurnal observations of energy balance at maximum LAI stage, flowering and pod formation stage over mustard varieties *viz.,* Kranti, RH-30, RH-406, RH 0749 and Laxmi were recorded in crops sown on 25th Oct together with observations over the bare field (Fig. 4.7). In general, around 25 to 85 per cent of Rn was used in cropped field as LE at different phenophases. Values of LE varied with the crop growth stages. The maximum values of LE were recorded at maximum leaf area index stage as compared to flowering and pod formation stage mainly due to variation in accumulation of biomass as well as LAI. Among the varieties, RH 0749 used higher fraction of LE in Rn as compared to other varieties.

Palampur

Threshold temperatures during vegetative, reproductive and physiological maturity of gobi sarson to achieve various yield targets were worked out and the results are presented in table 4.34 .

Table 4.34: Optimum temperature for different phenophases in mustard

Temperature	Vegetative phase	Reproductive phase	Maturity
Yield (>2 t/ha)			
Maximum (°C)	20.3-24.4 (22.4)	18.7-18.8 (18.8)	28.1-29.3 (28.7)
Minimum (°C)	7.3-9.3 (8.3)	6.0-6.1 (6.0)	14.2-15.0 (14.6)
Yield (1– 2 t/ha)			
Maximum (°C)	17.0 – 24.4 (19.6)	15.8 – 21.2 (18.2)	22.0 – 29.7 (25.5)
Minimum (°C)	5.3 – 12.1 (7.3)	5.3 – 10.8 (7.8)	8.9 – 16.6 (13.5)
Maximum (°C) 2014-15	8.5-24.5 (18.5)	10.5-24.0 (17.5)	17.7-30.0 (23.6)
Minimum (°C) 2014-15	0.0-14.0 (6.4)	3.5-13.4 (7.8)	6.0-20.5 (12.5)
Yield (<1 t/ha)			
Maximum (°C)	18.9-20.9 (19.9)	15.0-20.9 (19.3)	22.8-24.8 (23.6)
Minimum (°C)	7.0-8.1 (7.4)	4.8-8.8 (7.6)	10.9-12.5 (11.6)

The maximum and minimum temperatures were within the limit of the temperature identified as optimum for 1-2 t/ha yield. The lower temperature during the vegetative phase seems to be the constraint for growth and development and consequently leads to lower productivity in the mid hills of Himachal Pradesh. Maximum temperature in the range of 20.3-24.4 °C and minimum temperature 7.3-9.3 °C at vegetative phase seems to be optimum for higher productivity in gobi sarson.

Green gram

Kovilpatti

Cultivar CO-6 was grown under three growing environments (sown on 24th Sept, 8th and 21st Oct) to study the crop weather relationships. Growing degree days required and accumulated HTU were estimated during the crop growth. Among different sowing windows, pre monsoon sown crop (39th SMW) recorded higher AGDD. The higher GDD was registered in the pod development and vegetative phase of the crop (Fig. 4.8). The crop required 1387 AGDD for producing 850 kg of seed yield in green gram.

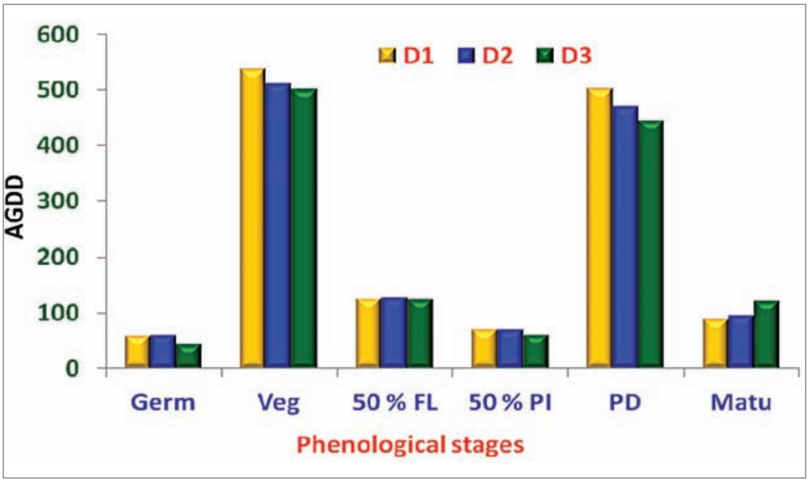


Fig. 4.8: Thermal requirment of greengram cv CO-6 for attaing different phenophases.

Rabi Sorghum

Solapur

Cultivars M-35-1, Mauli and Yeshoda were exposed to four growing environments [sown on 36 (S_1), 38 (S_2) , 40 (S_3) and 42 SMW (S_4)] to explore the crop weather relationship. Influence of different growing environments on CUM and MUE was studied and the results are presented in table 4.35. The analysis was done using pooled data of *rabi* 2010-11 to 2014-15.

Table 4.35: CUM and MUE as influenced by sowing time in *rabi* sorghum (2010-11 to 2014-15)

Sowing	CUM (mm)				MUE (kg ha^{-1} mm)			
Time	M 35-1	MAULI	VASUDHA	Mean	M35-1	MAULI	VASUDHA	Mean
S_1	363	334	374	**357**	3.22	2.97	1.98	**2.72**
S_2	342	316	351	**336**	3.49	2.84	2.12	**2.82**
S_3	318	296	327	**314**	3.94	3.11	2.36	**3.14**
S_4	286	274	292	**284**	2.42	2.41	2.79	**2.54**
Mean	**327**	**305**	**336**	**323**	**3.27**	**2.83**	**2.31**	**2.80**

The mean CUM and MUE recorded was 336 mm and 2.80 kg ha^{-1}mm respectively. The highest CUM was recorded by crop sown on 36 SMW (357 mm); however the highest MUE was recorded by 40 SMW sown crop (3.14 kg ha^{-1}mm). This indicated that crop sown on 40 SMW utilized moisture more efficiently than other dates of sowing. Among the variety, Vasudha recorded maximum mean CUM 374 mm and highest MUE was recorded by M-35-1 variety *i.e.* 3.94 kg ha^{-1}mm^{-1}.

Step-wise multiple regression of various weather parameters with yield of *rabi* sorghum (2010-11 to 2014-15) was attempted and the results are presented in table 4.36. The relations proposed are based on seasonal average values. However, stage specific parameters are needed for better performance.

Table 4.36: Stepwise multiple regression of different weather parameters with yield of *rabi* Sorghum (2010-11 to 2014-15).

Sr. No.	Weather parameter	Regression coefficient	R^2
1	Intercept	-27672.4	0.72
2	Maximum Temperature (T_{max})	717.9	
3	Minimum Temperature (T_{min})	-838.3	
4	Relative Humidity (RH-1)	263.9	

T_{max} = Max. Temperature, T_{min} = Min. Temperature, RH-1=Relative Humidity

The performance of the multiple regression yield prediction model was tested and is given in table 4.37

Yield= -27672.4 + (717.9×T_{max}) + (-838.3×T_{min})+ (263.9×RH-1)

Table 4.37: Observed and predicted yield by using linear regression equation

Treatment	Actual Yield	Predicted Yield	Deviation/ Residuals	Standardized residual
Main treatment – Sowing time				
S_1 = MW 36 (Sept.03-09)	917.6	903.5	14.1	0.8
S_2 = MW 38 (Sept.17-23)	1084.1	1154.6	-70.5	-0.9
S_3 = MW 40 (Oct. 01-07)	1250.2	1225.7	24.6	1.0
S_4 = MW 42 (Oct.15-21)	725.8	793.3	-67.5	-0.8
Sub treatment – variety				
V_1 = Maldandi	1153.6	1154.2	-0.6	-0.7
V_2 = Mauli	931.9	878.3	53.6	1.1
V_3 = Yashoda	897.6	890.3	7.3	-0.4

(Standard Residual > 3 is outlayer)

Potato

Jorhat

Cultivars Kufri Jyoti, Kufri Pokhraj and Kufri Himawali were grown under three growing environments (sown on 22nd Nov, 6th and 23rd Dec, 2014). Tuber yield of potato was correlated with mean phasic meteorological parameters (Table 4.38). It could be noticed from the table that, the minimum temperature had relatively higher correlation with yield in all the crop stages .

Table 4.38: Correlation coefficient between tuber yield and mean meteorological parameters

Growth stages	Tmax	Tmin	ET	Mean RH	Mean VP	BSS	EVP
Stolon formation	0.326	0.819	0.217	0.001	0.123	0.028	0.124
tuber formation	0.428	0.846	0.534	0.017	0.011	0.053	0.121
Tuber development	0.261	0.821	0.789	0.125	0.076	0.213	0.213
Maturity	0.321	0.730	0.321	0.032	0.153	0.396	0.012

Mohanpur

The surface energy balance component over potato field was determined using aerodynamic resistance method. Potato cultivars Jyoti, Chandramukhi and Surya were cultivated under three growing environments (sown on 17th Nov, 1 and 15th Dec, 2014). Data on temperature, humidity and wind speed at two different heights were collected at seven days interval covering different crop growth stages on diurnal basis. Simultaneously, soil heat flux, plant height and LAI were also measured. The diurnal and seasonal variations of constants related to momentum and flux transfer were studied along with sensible, soil and latent heat fluxes.

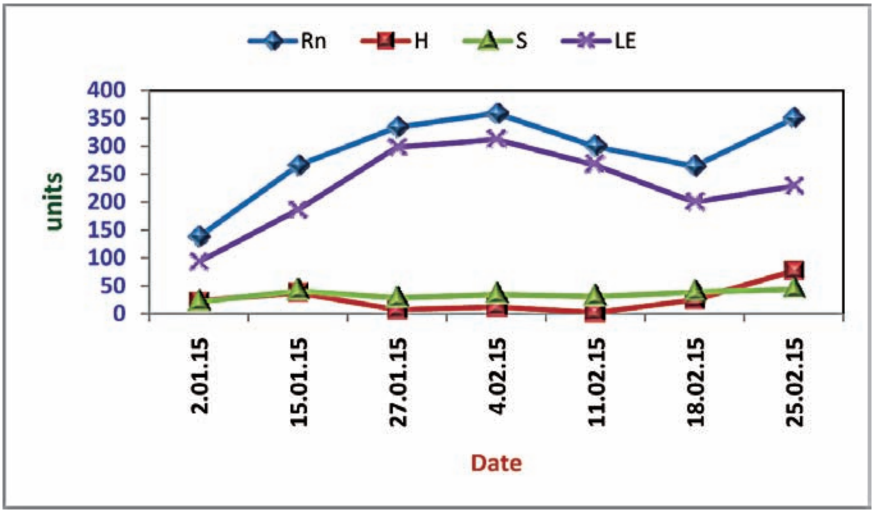


Fig. 4.10: Variation of energy balance components over potato field at Mohanpur

It has been observed that sensible heat flux varied between 1.87 W m^{-2} to 7.7 W m^{-2} on daily basis (Fig. 4.10). On the other hand, the variation of soil heat flux was not so large throughout the growing season. The latent energy was lower during initial crop growth stage and first leaf drying stage. During these two stages, irrigation was not given and the moisture condition of the field was reflacted in LE values. At 50% leaf senescence stage, the net radiation was higher (350 W m^{-2}), hence relatively higher LE was observed at this stage although the field condition was dry. The estimation of latent energy flux thus help in scheduling irrigation to a crop like potato.

5. Crop Growth Modelling

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

Kharif 2014

Akola

Soybean

CROPGRO-Soybean simulation model (DSSAT v 4.5) was evaluated with 3 years experimental data from 2011-2013 at Akola for three different varieties *viz.* JS-335, JS-9305 and TAMS 98-21 raised under four different environments. Input data for different soil physical constraints and chemical parameters for different properties were standardized.

Soil Physical constants:

Depth (cm)	LL ($cm^3 cm^{-3}$)	DUL ($cm^3 cm^{-3}$)	SATW ($cm^3 cm^{-3}$)	Bulk density ($Mg\ cm^{-3}$)
5	0.232	0.391	0.498	1.34
10	0.244	0.397	0.504	1.35
15	0.244	0.397	0.504	1.35
30	0.247	0.408	0.514	1.37
60	0.247	0.408	0.514	1.37
90	0.226	0.368	0.440	1.36

Soil Chemical analysis:

Soil depth (cm)	pH	E.C. ($dS\ m^{-1}$)	Organic carbon (%)	Available nutrients ($kg\ ha^{-1}$)		
				N	P_2O_5	K_2O
0-15	8.0	0.31	0.68	214.0	21.8	354.9
15-30	8.0	0.28	0.55	205.0	20.7	348.0

The genetic coefficients for Soybean varieties *viz.*JS-335, JS 9305 and TAMS 98-21 were estimated using the GLUE coefficient estimator embedded in the DSSAT v 4.5 model and calibrated to predict phenology, LAI, seed yield and straw yield accurately.

- The model predicted the seed yield reliably in JS-335 and TAMS-9821. Straw yield was overestimated to a greater degree in JS-335 and to a lesser degree in JS-9305 and TAMS 98-21.

- Sensitivity analysis was carried out with CROPGRO-Soybean simulation model by environmental modification by upscaling and downscaling maximum temperature (± 1 to 5 °C), minimum temperature (± 1 to 5 °C) and concentration of carbon dioxide (+100, +200 and +300 ppm).
- The enhanced maximum and minimum temperatures gradually reduced the yield by 5.2 to 65.9% under 27 SMW sowing (D_1). The magnitude of yield reduction was to a greater degree with delayed sowing (30 SMW) which recorded a reduction in yield from 8.4 to 86.3% with up scaling of temperatures from 1 °C to 5 °C. Reduced maximum and minimum temperatures gradually increased the yield from 4.3 to 7.8% across different sowings. The magnitude of yield reduction was to a lesser degree as compared to the increased temperature effects. CO_2 concentration raised from 100 ppm to 300 ppm, over the base value (330 ppm) increased seed yield by 16.5 to 38.6% per cent under 27 SMW sowing. Similarly increase of yield from 12.8 to 30.4% was observed under 30 SMW sowing.
- Elevated CO_2 concentration by 100 ppm coupled with elevated maximum temperature level by 1, 2 and 3 °C decreased the yield level from 3.2 to 28.4% under 1 °C, by 14.3 to 38.9% under 2 °C and from 22.6 to 50.8% under 3 °C.

Anand

Groundnut

Three years experimental data on phenology, yield and yield attributing characters for three groundnut cultivars *viz.* M-335, GG-20 and GG-5 were collected and PNUTGRO DSSAT model was calibrated and validated at Anand. Days to anthesis was under estimated by the model for cv. GG-20, while pod yield was over estimated for all the cultivars. Index of agreement varied from 0.55, 0.55 and 0.42 for cv. M-335, GG-20 and GG-5 respectively for pod yields. Further calibration of the model is required by collecting and incorporating more field information into the model.

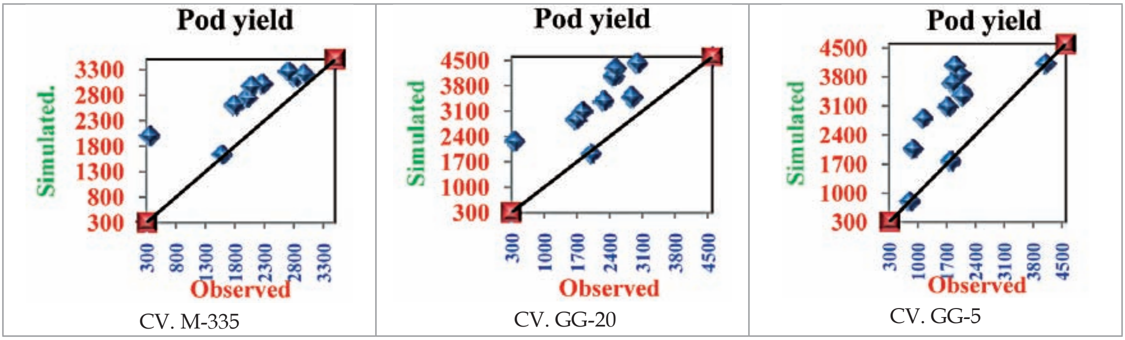


Fig. 5.1: Observed Vs simulated pod yield of groundnut cultivars at Anand

Faizabad

Rice

Crop data of rice variety Sarjoo-52 were collected for four years (2009-12) from Kumarganj under three environments. Soil profile data and weather data files were prepared. Gencalc module was used in DSSAT model and calibrated the genetic coefficients. DSSAT Rice model was calibrated for the phenology and yield. The genetic coefficients that were generated and the summarized results are tabulated below.

Genotype	P1	P2R	P5	P2O	G1	G2	G3	G4
Sarjoo-52	750	160	460	12.0	48.0	0.200	1.00	1.00

	RMSE	D-Index	Observation
Anthesis	4.8	0.56	12
Yield	1129.8	0.46	12
maturity	5.0	0.52	12

Model has underpredicted days taken to anthesis. The RMSE and D-index values showed poor agreement with observed, may due to large variation in data collected under three varied environments. Further, refinement of model is needed by incorporating more inputs.

Jorhat

Rice

Data on sali rice variety Mahsuri were collected for five years (2010 to 2014) from the experimental fields of Jorhat center under three environments. Soil profile data and weather data files were prepared and incorporated for the respective years. Gencalc module was used in DSSAT model to generate genetic coefficients for the variety Mahsuri. DSSAT Rice model was calibrated for the phenology (anthesis and maturity) and yield. The genetic coefficients generated and the summarized results are tabulated below.

P1	P20	P2R	P5	G1	G2	G3	G4
763.1	314.9	150.7	10.6	35.4	.025	1	1

Variable Name	Observed	Simulated	RMSE	D-stat
Anthesis day	122	122	3.416	0.918
Maturity Yield (Kg/ha)	3463	2830	1508.4	0.572
Maturity day	162	147	20.86	0.501

From the above tables it can be concluded that, there is a reasonably accurate in predicting the anthesis dates, but the maturity date and grain yields were under predicted. Thus calibration of the model needs further improvement by generating more information on soil and crop parameters.

Ludhiana

Future climate change scenarios generated by PRECIS model were incorporated in the InfoCrop model. The scenario data consists of baseline weather data (1961-90), A1B scenario for middle (2020-2050) and future (2070-2100), A2 scenario for future (2070-2100) and B2 (2070-2100) future scenarios were used to simulate impacts on rice and maize crops.The results of the study are presented in tables.

Rice

The grain yield of rice is projected to decrease under A1B scenario for the period 2020-2050 from the baseline by 3.6 to 19.8% under maximum temperature change scenario, by 2.7 to 5.5% under minimum temperature change scenarios and by 8.0 to 26.0% under both maximum and minimum temperature change scenarios. However, for Nawanshahar rice yields for the period 2020-50 are projected to increase under maximum and minimum temperature and their interaction change scenarios.

For the period 2070-2100, grain yield of rice in Punjab under maximum temperature change scenarios is projected to decrease from baseline under A1B scenario at all locations except Nawanshahar; under A2 scenario at only Bathinda; and under B2 scenario at all locations except Nawanshahar. Under the minimum temperature change scenarios and the maximum X minimum temperature interaction change scenarios the grain yield of rice for the period 2070-2100 is projected to decrease from baseline at all the locations in Punjab state under A1B, A2 and B2 scenarios of climate change.

Table 5.1: Impact on grain yield of rice at different locations in Punjab under projected climate change scenarios using InfoCrop model.

Station	2020-50	2070-2100		
	A1B	A1B	A2	B2
Maximum Temperature change				
Ludhiana	-3.6 to 2.3	-3.6 to-2.0	0.4 to 2.4	-0.7 to 0.2
Amritsar	-19.8 to -13.4	-8.3 to- 0.8	8.2 to 11.0	-0.5 to 0.0
Bathinda	-13.1 to -11.7	-15.3 to- 10.1	-6.9 to- 3.7	-0.5 to 0.0
Nawanshahar	9.7 to 11.3	9.3 to 9.4	3.1 to 7.0	8.0 to 8.4
Minimum Temperature change				
Ludhiana	-5.0 to -4.7	-5.0 to -4.7	-4.1 to- 1.9	-2.9 to -2.3
Amritsar	-4.2 to-3.7	-4.0 to-3.7	-3.6 to -1.9	-1.6 to 1.4
Bathinda	-5.5 to- 4.8	-4.8 to -4.6	-5.9 to -1.2	0.8 to 1.0
Nawanshahar	-2.7 to- 2.4	-3.3 to- 2.4	-2.4 to- 1.5	-3.2 to -1.1
Maximum X Minimum Temperature Interaction change				
Ludhiana	-12.3 to- 8.0	-2.0 to 0.3	-15.7 to -12.2	-0.5 to 0.0

Amritsar	-21.6 to-17.4	-3.4 to-2.6	-26.8 to- 23.6	-9.4 to 1.4
Bathinda	-26.0 to -23.7	-13.1 to 0.8	-39.1 to -25.4	-24.3 to 0.1
Nawanshahar	-12.0 to 7.8	-1.8 to 0.5	9.5 to 10.8	-3.8 to 0.5

Maize

Grain yield of maize is projected to decrease under A1B scenario for the period 2020-2050 from the baseline by 4.5 to 24.5% under maximum temperature change scenario, by 0.8 to 11.1% under minimum temperature change scenario and by 4.1 to 19.1% under both maximum and minimum temperature change scenarios. However, for Nawanshahar, maize yield for the period 2020-50 are projected to increase under maximum temperature change and maximum and minimum temperature interaction change scenarios.

For the period 2070-2100, grain yield of maize in Punjab under maximum temperature change scenarios is projected to decrease from baseline under A1B scenario at all locations; under A2 scenario at all locations except Nawanshahar; and under B2 scenarios at all locations except Amritsar and Nawanshahar. Under minimum temperature change scenarios and maximum X minimum temperature interaction change scenarios, grain yield of maize for the period 2070-2100 is projected to decrease from baseline in Punjab state at all the locations under A1B, A2 and B2 scenarios of climate change.

Table 5.2: Impact on grain yield of maize at different locations in Punjab under projected climate change scenarios using InfoCrop model

Station	2020-50	2070-2100		
	A1B	A1B	A2	B2
Maximum Temperature change				
Ludhiana	-8.3 to -8.2	-8.3 to -6.5	-1.6 to 1.2	-8.1 to- 0.7
Amritsar	-5.6 to- 4.5	-5.3 to- 1.0	-4.5 to- 4.0	0.0 to 3.7
Bathinda	-24.5 to- 20.6	-14.5 to -14.0	-11.4 to -3.9	-5.2 to 0.0
Nawanshahar	9.5 to 15.9	-10.8 to 9.1	7.3 to 13.6	-0.6 to- 0.3
Minimum Temperature change				
Ludhiana	-11.1 to- 11.0	-11.1 to- 11.0	-11.2 to- 5.9	-4.4 to -3.8
Amritsar	-8.1 to -7.9	-8.1 to- 8.0	-8.2 to- 8.1	-0.5 to 3.4
Bathinda	-7.0 to- 1.9	-7.0 to- 1.9	-7.3 to- 1.8	-22.1 to- 0.7
Nawanshahar	-8.4 to- 0.8	-1.8 to -0.8	-3.2 to -0.8	-1.9 to -1.1
Maximum X Minimum Temperature Interaction change				

Ludhiana	-8.3 to- 5.0	-4.2 to- 4.1	-8.1 to- 5.1	-8.6 to -7.3
Amritsar	-5.6 to- 4.1	-3.6 to 0.9	-12.6 to -6.1	-6.1 to- 0.5
Bathinda	-19.1 to- 14.5	-5.7 to- 0.5	-15.1 to -14.3	-7.0 to- 3.3
Nawanshahar	0.3 to 7.5	-0.5 to 1.2	6.7 to 6.8	-1.6 to 1.4

Mohanpur

Rice

DSSAT model was used to simulate the elevated temperature conditions and their impacts on the yield of wet season rice at Mohanpur. Three years (2010-2012) experimental data of popular rice cultivar cv. IET 4786 (locally known as Shatabdi) transplanted in six different environments were collected on phenological characteristics, thermal time requirements for different phenophases, yield and yield attributes. This data set (along with soil, weather and crop management data) were used to develop the genetic coefficient of cv. IET 4786 and then DSSAT model was validated for Kalyani region of Nadia district. Two elevated thermal situation were considered as follows:

i) Increase of 1˚C temperature (both maximum and minimum temperature)

ii) Increase of 2˚C temperature (both maximum and minimum temperature)

The results showed that the R^2 value between observed yield DSSAT predicted is 0.89, which is significant at 5% level. The RMSE value is also considerably low; which indicates that DSSAT could predict the yield of cv. IET 4786 reasonably well. However, the simulated maturity period is not well matched with the observed maturity period (Table 5.3).

Increase of 1°C temperature (both maximum and minimum temperature) resulted 5.69% yield decrease compared to the average yield of 2010-2012; while 2 °C temperature reduced the yield by 12.54% (Table 5.4). During the end of juvenile to grain filling stages of crop, the elevated temperature causes a decrease of LAI (Fig. 5.2). The maturity period is also reduced. This may be one of a reason for the yield reduction of the cultivar.

Table 5.3: Simulated and observed yield and maturity period of wet-season rice for different sowing dates

Treatments (DOT)	Yield (Kg ha^{-1})		Maturity period (days)	
	Observed	Simulated	Observed	Simulated
31.05.2010	4223	4301	98	97
22.06.2010	3908	4107	94	97
24.05.2011	4084	4156	101	101
23.06.2011	3943	4014	98	100

17.05.2012	4730	4372	102	99
01.06.2012	4209	4195	99	97
R^2 Value		0.89*		0.57
RMSE		174.2		2.1

*Significant at 5 % level

Table 5.4: Yield (in kg ha^{-1}) variations under elevated thermal condition for different dates of transplanting

Treatments	Observed Temperature	Observed Temperature +1ºC	Observed Temperature +2ºC
31.05.2010	4301	4084	3865
22.06.2010	4107	4053	3466
01.07.2010	4231	4001	3662
15.07.2010	4087	3896	3619
24.05.2011	4156	3869	3777
23.06.2011	4014	3855	3662
01.07.2011	4084	3614	3640
15.07.2011	4030	3893	3624
17.05.2012	4372	3990	3453
01.06.2012	4195	3890	3641
01.07.2012	4174	3955	3473
15.07.2012	3989	3811	3622
Average	4145	3909.25	3625.33
% change from NT		-5.69	-12.54

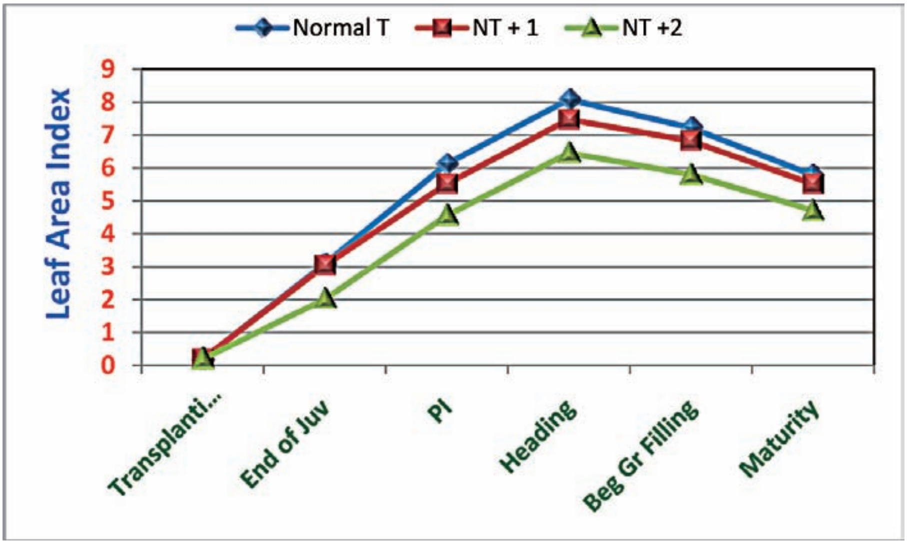


Fig. 5.2: Changes in LAI at different crop growth stages under normal temperature and elevated thermal conditions

Raipur

Rice

Crop data *viz* phenology and grain yield of rice cv. MTU-1010 was collected from the field experiment. Profile soil data and weather data for the years 2007-2014 was collected and incorporated in to the model. DSSAT rice model was calibrated and genetic coefficients were evolved using Gencalc and iteration methods and presented in table 5.5. Further, observed versus simulated grain yield and phenology for MTU-1010 were presented in the table 5.6. There is good agreement between observed and simulated phenology but the model did not perform well in predicting maturity as well as yield.

Table 5.5: Genetic coefficients calculated cv. MTU-1010

P1	P2R	P5	P2O	G1	G2	G3	G4
700.6	169.7	452.4	12.0	69.0	0.0260	1.00	1.00

Table 5.6: Observed versus simulated grain yield and phenology cv. MTU-1010

Phenophase and yield	Mean			RMSE	D-index	Total number of obs.
	Observed	Simulated	Ratio			
Anthesis day	89	87	0.98	2.121	0.8	24
Maturity yield (kg ha^{-1})	3958	4122	1.06	585.4	0.69	24
Maturity day	117	119	1.01	2.141	0.76	24

Ranchi

Rice

CERES–rice model was calibrated with experimental data for three rice cultivars (Sahbhagi, Naveen and Swarna) planted on three different dates (8th June, 18th June and 28th June). Statistical comparison between observed and simulated data (Table 5.7) showed that model under estimated days taken to anthesis for Sahbhagi (-1%) and Swarna (-4.09%) with D-index values below 0.6. Performance of model for days to anthesis was good for Naveen with a D-index value of 0.77. Days to maturity was found under estimated by the model for Sahbhagi only (- 1.47%). Grain yield was estimated reasonably well by model for all the cultivars and D -index were always greater than 0.6. Naveen variety was satisfactorily calibrated with D-Index values above 0.7. But, for remaining varieties model needs further fine tuning for more accurate prediction.

Table 5.7: Statistical estimates for the comparison of observed and simulated parameters

Variable Name/ Variety	Mean		Std.Dev.		R^2	Mean Diff.	Mean Abs.Diff.	RMSE	D-Index
	Obs	Sim	Obs	Sim					
SAHBHAGI									
Anthesis (DAS)	100	99	1.24	0.47	0.03	0	1	1.29	0.49
Yield kg/ha	3394	3475	124.1	39.71	0.55	81	112	127.12	0.64
Maturity (DAS)	136	134	3.55	2.86	0.72	-2	2	2.51	0.84
NAVEEN									
Anthesis (DAS)	104	104	3.85	1.41	0.95	0	2	2.51	0.77
Yield kg/ha	3850	3845	182.6	79.11	0.99	-5	96	103.73	0.84
Maturity (DAS)	142	142	2.82	2.05	0.64	0	2	1.73	0.86
SWARNA									
Anthesis (DAS)	122	117	0.94	1.24	0.89	-4	4	4.35	0.32
Yield kg/ha	3171	3154	182.0	204.08	0.20	-17	189	203.05	0.66
Maturity (DAS)	158	158	1.7	4.11	0.63	0	3	2.94	0.71

Thrissur

Rice

The experimental data of two rice varieties *viz.* Jyothi and Kanchana was collected and experimental files were prepared. Soil and weather data files were incorporated to the CERES-Rice model. Genetic coefficients were developed and presented in the table 5.8. Good agreement as reflected in D-index was obtained for Jyothi but model requires fine tuning in case of variety Kanchana (Table 5.9).

Table 5.8: Genetic coefficients developed for rice from the two year experiments (2013 and 2014)

Variety	P1	P2R	P5	P20	G1	G2	G3	G4
Jyothi	512.7	32.2	465.3	9.9	48.6	0.0270	1	1
Kanchana	460.7	155	458.5	12.3	51.5	0.0230	1	1

Table 5.9: Model performance during the years 2013 and 2014

Variety	Jyothi		Kanchana	
Phenology and Yield	RMSE	D-index	RMSE	D-index
Anthesis day	0.82	0.9	0.1	0.99
Maturity day	1.15	0.82	0.8	0.7
Yield kg ha^{-1}	251.7	0.8	330.4	0.7

Rabi

Ludhiana

Wheat

Future climate change scenarios generated by PRECIS model were incorporated in the InfoCrop model . The scenario data consists of baseline weather data (1961-90), A1B scenario for middle (2020-2050) and future (2070-2100), A2 scenario for future (2070-2100) and B2 for (2070-2100) future scenarios were used to simulate impacts on wheat crop. The results of the study are presented in table 5.10. The perusal of the results revealed that:

- The grain yield of wheat is projected to decrease under A1B scenario for the period 2020-2050 from the baseline by 7.8 to 11.8% under maximum temperature change scenario, by 1.8 to 8.4 % under minimum temperature change scenario and by 12.1 to 17.6% under both maximum and minimum temperature change scenarios.

For the period 2070-2100, the grain yield of wheat under maximum temperature change scenarios is projected to decrease from baseline by 5.8 to 10.4% under A1B scenario; by 1.6 to 8.7% under A2 scenario and by 0.1 to 1.0 under B2 scenarios. Under the minimum temperature change scenarios, the grain yield of wheat for the period 2070-2100 is projected to decrease from baseline by 1.8 to 8.4% under A1B scenario; by 1.4 to 7.5% under A2 scenario; and by 0.5 to 4.1 % under B2 scenarios. The grain yield of wheat for the period 2070-2100 under maximum and minimum temperature interaction change scenarios is projected to decrease from baseline by 0.5 to 7.2% under A1B scenario; by 13.6 to 22.8% under A2 scenario; and by 0.6 to 13.3% under B2 scenario.

Table 5.10: Impact on grain yield of wheat at different locations in Punjab under projected climate change scenarios using InfoCrop model

Station	2020-50	2070-2100		
	A1B	A1B	A2	B2
Maximum temperature change				
Ludhiana	-9.3 to -7.8	-7.8 to -5.8	-2.1 to -1.6	-1.0 to -0.1
Amritsar	-10.6 to -9.1	-9.0 to -6.3	-8.7 to -5.9	-1.3 to 0.0
Bathinda	-10.7 to -8.8	-9.0 to -8.7	-4.4 to -1.9	-0.4 to 0.0
Nawanshahar	-11.8 to -8.9	-10.4 to -6.5	-5.7 to -3.4	-0.3 to 1.2
Minimum temperature change				
Ludhiana	-2.0 to -1.8	-2.0 to -1.8	-2.5 to -1.4	-1.4 to -0.5

Amritsar	-8.4 to -7.4	-8.4 to -7.4	-7.5 to -5.8	-4.1 to -4.0
Bathinda	-4.6 to -4.5	-4.6 to -4.5	-5.6 to -3.7	-2.0 to -0.7
Nawanshahar	-6.7 to -3.1	-3.2 to -3.1	-3.3 to -3.1	-2.0 to -0.7
Maximum X Minimum temperature Interaction change				
Ludhiana	-13.6 to -12.1	-3.0 to -0.5	-16.3to -13.6	-7.9 to -2.4
Amritsar	-16.2 to -14.4	-6.2 to -2.7	-19.1 to -16.0	-12.6 to -4.1
Bathinda	-15.2 to -14.5	-6.5 to -0.7	-21.0 to -19.2	-13.1 to -1.8
Nawanshahar	-17.6 to -14.7	-7.2 to 0.3	-22.8 to -20.3	-13.3 to -0.6

Ranchi

Wheat

Performance of three wheat cultivars (HUW 468, K9107and Birsa Gehu 3) simulated using CERES-wheat model were compared with five years experimental data (*Rabi* 2009-10 to 2013-14) sown under three dates of sowing and results are presented in the table. The model over estimated days taken to anthesis for all the three varieties *viz*. HUW 468, K9107 and Birsa Gehu 3. Days to maturity was under estimated by model with error ranging from -1 to -4% and with D-index value of above 0.79. The model simulated the grain yields satisfactorily with D-index values above 0.7 for all cultivars (Table 5.11).

Table 5.11: Simulated and observed values of wheat crop simulated by DSSAT model

Variable Name	Mean		Std. Dev.		Mean Diff.	Mean Abs. Diff.	RMSE	d-Stat.
	Obs	Sim	Obs	Sim				
HUW 468								
Anthesis (DAS)	80	85	5.41	2.89	4	5	6.39	0.57
Yield kg/ha	5027	4761	660.01	556.93	-266	494	577.41	0.75
Maturity (DAS)	120	119	6.39	5.33	0	3	3.64	0.89
K9107								
Anthesis (DAS)	84	89	5.36	3.39	5	5	6.21	0.64
Yield kg/ha	4365	4343	569.14	471.05	-22	345	438.51	0.80
Maturity (DAS)	123	118	7.04	5.47	-6	6	6.48	0.79
BIRSA GENHU 3								
Anthesis (DAS)	81	88	5.63	3.39	7	7	8.60	0.53
Yield kg/ha	5034	5823	746.85	681.19	789	789	856.78	0.72
Maturity (DAS)	120	117	6.47	5.40	-3	4	4.28	0.87

Raipur

Wheat

Genetic coefficients were standardized for wheat cv. Kanchan for DSSAT CERES – wheat model through calibration process using observed phenology and yield data from experiments conducted at Raipur by iteration technique.

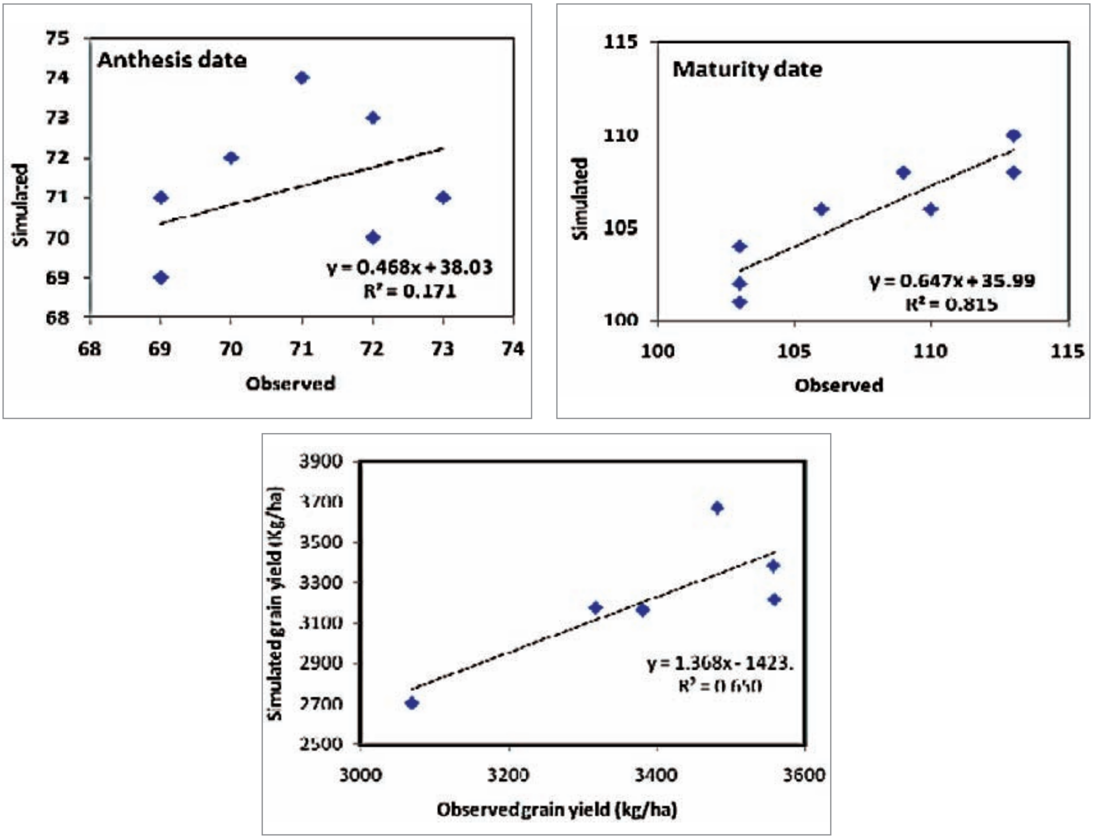
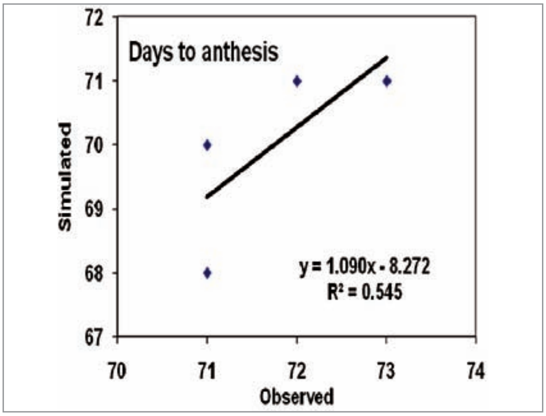


Fig. 5.3: Calibration of CERES wheat model

The model was calibrated with two years data (2011-12 and 2012-13) and validated with 2013-14 data. The model predicted very well in case of days to maturity and grain yield. But, model could not predict well the days to anthesis (Fig. 5.3). However, when the model was validated with 2013-14 data, model could predict anthesis date with 54 % accuracy and maturity date with 96% accuracy (Fig. 5.4). It is inferred from the above that, further refinement of genetic coefficients is required to improve model's performance in case of days to anthesis and grain yield.

Genetic Coefficients used for validation:

Variety	P1	P2R	P5	P20	G1	G2	G3	G4
Kanchan	399.0	150.0	329.0	11.7	61.0	0.0027	1.0	1.0



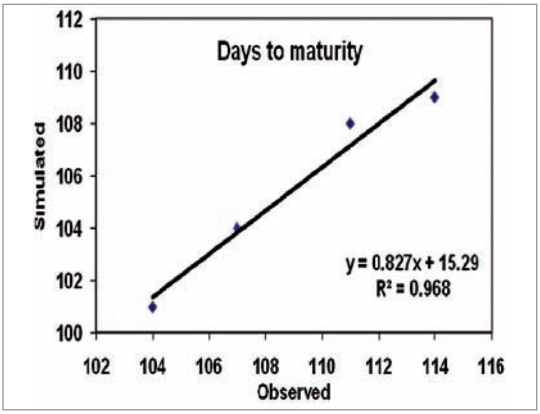


Fig. 5.4: Validation of CERES wheat model with 2013-14 experimental data

6. Effect of Weather on Pests and Diseases

Issue of forewarning on the incidence of various key pests and diseases in field/ orchard crops has considerable economic importance in view of the cost involved in their management through chemical measures. Thus, development of forewarning models for various pests and diseases with sufficient accuracy and lead time is vital. The research efforts made at various centers to develop models for various pests and diseases are presented hereunder:

Chickpea

Jabalpur

Weather-insect-pest relationship between *Helicoverpa armigera* (Gram pod borer) and weather parameters in chickpea species planted at different sown dates was attempted. Larval population was collected at metre row length five times per plot. No pesticide was applied in the experiment. The previous crop was rice and the cropping system was rice-chickpea.

During *rabi* 2014-15 season, overall population of gram pod borer was fewer as compared to 2013-14. The population dynamics were collected from 49th SMW on plot two times in a week (Tuesday and Friday) in every plot. Data was averaged week wise and the numbers of larval population on chickpea plants along with weather parameters are presented in the given table 6.1. In the field, no incidence of gram pod borer till 9th week of 2015. After then, population started increasing in numbers with the increase in meteorological week numbers with maximum population attained at the time of harvesting among all the species planted.

Association between weather parameters and larval population in *kabuli*, *desi*, and gulabi species were correlated and presented in table 6.1.

Table 6.1: Pearson's correlation coefficient between *Helicoverpa* population and weather parameters

Chickpea species	Larval population (Numbers/5m row length)										
	Tmax	Tmim	SSH	Rainfall	RHm	RHEve	Winds peed	VapM	VapE	Eva	Rainy days
Kabuli	.715**	.610**	.257	-.200	-.858**	-.434	.077	.560*	.077	.751**	-.244
Gulabi	.715**	.610**	.257	-.200	-.858**	-.434	.077	.560*	.077	.751**	-.244
Deshi	.716**	.613**	.281	-.202	-.863**	-.434	.055	.567*	.096	.750**	-.242

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

Both maximum and minimum temperatures have a positive correlation with larval population among all species planted. Similar was the result with sunshine hours. However, rainy days, rainfall, morning and evening relative humidity had negative correlation with larval population. Both temperatures, morning relative humidity and evaporation had a significant relationship (P ≥0.01) at p=0.01 level indicating relationship with these parameters influencing larval population.

Cotton

Anantapur

The relationship between weather parameters and their influence on life cycle of groundnut leaf miner was standard. Periodic incidence of leaf miner with 3–6 peaks was noticed in groundnut during 2014. Delay in the sowing from 1st FN of July to 1st FN of August increased the intensity of groundnut leaf miner. But the crop sown during 1st FN of July was subjected to longer period (8 weeks) of higher incidence (104 to 204 webs/m^2).

Correlation studies were taken up between weather parameters and number of webs per m^2 (using pooled data of *kharif* 2012-2014) and the results are presented in table 6.2.

Table 6.2: Correlation coefficients between no. of webs per m^2 and weather parameters (Pooled data of 2012 to 2014)

Lead period	Tmax (°C)	Tmin (°C)	RH1 (%)	RH2 (%)	SSH (hours)	Rainfall (mm)	Rain free days	Rainfall total (mm)	Wind spped (Kmph)	Evapor ation (mm)
3DLP	0.09	-0.07	0.08	-0.207**	-0.29**	0.33**	-0.12		-0.08	0.09
7 DPL	0.06	-0.16*	0.15*	-0.09	-0.23**	0.21**	-0.15*		-0.12	0.06
3 DLPM	0.14*	-0.15*	0.133	-0.24**	-0.31**	0.40**	-0.13	0.11	-0.04	0.14*
7 DLPM	0.10	-0.17*	0.14*	-0.23**	-0.29**	0.35**	-0.15*	0.14*	-0.12	0.10

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

The results indicated that, rainfall had significant positive correlation with pest incidence under all the lead periods. The reverse was the case with sun shine hours.

Step wise regression analysis using pooled data of 2012-14 (Table 6.3) revealed that 3 day lead period mean has shown a R^2 value of 0.27.

Table 6.3: Regression analysis 2014 and pooled data 2012 to 2014

Lead period	Step wise backward regression equation (2014)	R^2
7 DPL	Webs = 92.9+1.82Rh1-6.11WS	0.227
7 DLPM	Webs = 15.984-17.5Tmin-8.138 WS-1.295 RF-25.43 EVP	0.287
3 DLP	Webs = 168.9-6.15 WS	0.206
3 DLPM	Webs = 171.9-6.37 WS	0.209
	Step wise backward regression equation (Poolded data of 2012 to 2014)	
7 DPL	Webs = 78.8+10.92 T_{MAX} – 3.47 WS+5.75 SSH-0.93 RF-20.28 EVP	0.168
7 DLPM	Webs = 721.43+36.46 T_{MAX} – 3.35 WS+8.76 SSH – 0.85 RF +16.95 RFD-64.01 EVP	0.307
3 DLP	Webs = 184.35 + 7.2T_{MIN} -1.86 RH2-3.35WS+10.2 SSH-1.16 RF-23.64 EVP	0.223
3 DLPM	Webs = 61.98+18.42 T_{MIN}-2.93 RH2-4.35 WS+14.50 SSH-1.07 RF-35.7 EVP	0.270

Kovilpatti

A field experiment was carried out to study the influence of weather variables on aphid damage in cotton (C.V. KC-3). The crop was sown on 25th Sept, 2014 and was maintained without any plant protection measures. The aphid damage was recorded by counting number of plants infested per plot to total number of plants in the same plot. It was found that minimum temperature alone has influenced the aphid damage. The pest damage was noticed during 42nd SMW. Later the incidence increased with time due a decline in minimum temperature (Fig. 6.1).

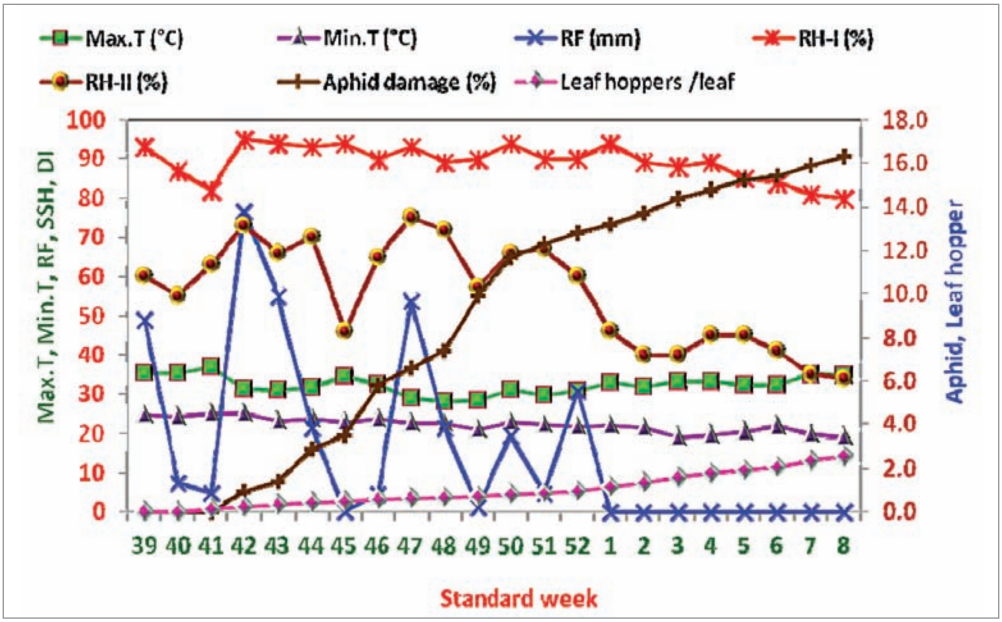


Fig. 6.1: Temporal variation in weather aphids damage and leaf hopper in cotton in relation to weather parameters

Mustard

Anand

The mean aphid index (0-5 scale) in mustard under different dates of sowing is presented in Fig. 6.2. The peak aphid intensity was observed at 4th SMW in all dates of sowing. Overall the aphid index was found higher under D_4 followed by D_3, D_2 and D_1 sowing.

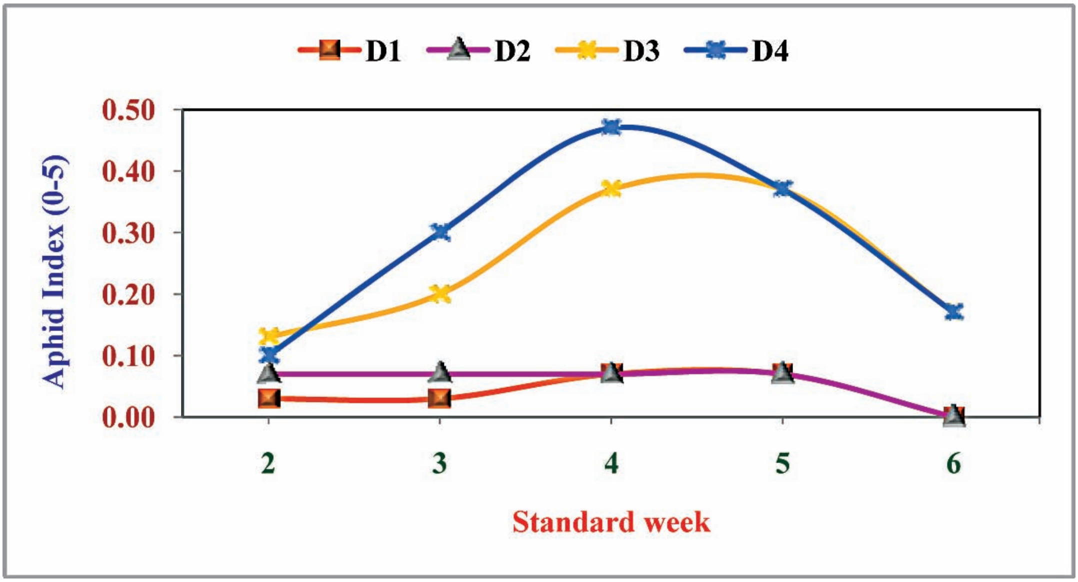


Fig. 6.2: Mean aphid index (0-5 scale) of mustard under different dates of sowing at Anand

The aphid outbreak in mustard observed during 50% flowering phase. If favourable weather range (Tmax: 28 – 33 °C, Tmin: 9 – 15 °C and Tmean: 19 – 24 °C) prevailed during 50% flowering for 3 – 5 days and aphid outbreak was observed in the succeding week. For escaping high aphid infestation, 10th to 20th October sowing was found most suitable. After 20th October sowing, favourable weather prevailed for aphid infestation and closely coincided with 50% flowering which reduced the seed yield (table 6.4).

Favourable weather range for aphid infestation during flowering period

Sr. No.	Weather parameter	Range
1	T_{max}	28 – 33 ° C
2	T_{min}	9 – 15 ° C
3	T_{mean}	19 – 24 ° C
4	T_{range}	16 – 21 ° C
5	RH_1	78 – 98 %
6	RH_2	22 – 47 %
7	RH_{mean}	50 – 67 %

Table 6.4: Correlation coefficient between peak aphid intensity and temperature

Temperature	Tmax	Tmin	Tmean
Peak aphid intensity	-0.566**	-0.579**	-0.566**

Pigeoan pea

Bangalore

Effect of different growing environments and different varieties on infestation of pod borer and fusarium wilt of Pigeoan pea was studied. Per cent pod borer damage and wilt damage noticed in the crop is given in table 6.5.

Table 6.5: Effect of date of sowing, varieties and spacing on per cent pod borer damage of redgram

Varieties	Pod borer damage (%)											
	D-1 (5.6.204)				D-2 (1.7.2014)				D-3 (9.8.2014)			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	mean
TTB-7	13.4	12.1	46.8	24.1	53.8	42.5	50.8	49.0	19.0	61.1	54.1	44.7
BRG-1	4.6	17.5	12.8	11.6	7.5	37.7	26.9	24.0	17.9	18.8	35.0	23.9
BRG-2	16.4	29.7	19.6	21.9	42.6	33.3	50.3	42.1	31.8	31.9	28.6	30.8
Mean	11.5	19.7	26.4	19.2	34.6	37.8	42.7	38.4	22.9	37.2	39.2	33.1

It was noticed that the incidence of pod borer was highest crop sown in second date (38.4%) and third sown crop (33.1%) compare to first sown crop (19.2%) and the result is shown in table-6.5.

The incidence of fusarium wilt disease at different dates of sowing, varieties and spacing of redgram is presented in table 6.6. It was observed that the incidence of wilt was highest in second sown crop (19.6%) and first sown crop (14.9%) as compared to third sown crop (9.9%).

Table 6.6: Effect of date of sowing, varieties and spacing on per cent Fusarium Wilt disease in redgram (per cent/plant)

Varieties	D1 (5.6.204)				D2 (1.7.2014)				D3 (9.8.2014)			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
TTB-7	12.5	25.9	15.7	18.0	12.7	13.2	11.2	12.4	1.3	3.2	10.3	4.9
BRG-1	10.9	17.4	14.6	14.3	9.2	15.4	37.5	20.7	2.1	17.6	10.3	10.0
BRG-2	11.1	11.4	14.3	12.3	12.8	15.8	48.8	25.8	2.9	22.2	19.1	14.7
Mean	11.5	18.3	14.9	14.9	11.6	14.8	32.5	19.6	2.1	14.3	13.2	9.9

Rice

Raipur

The insect population collected through light trap was used to study the pest weather relationship in rice crop during *kharif* 2014. Weekly mean rainfall, maximum and minimum temperature were plotted against number of different insects trapped and the results are presented in fig. 6.3.

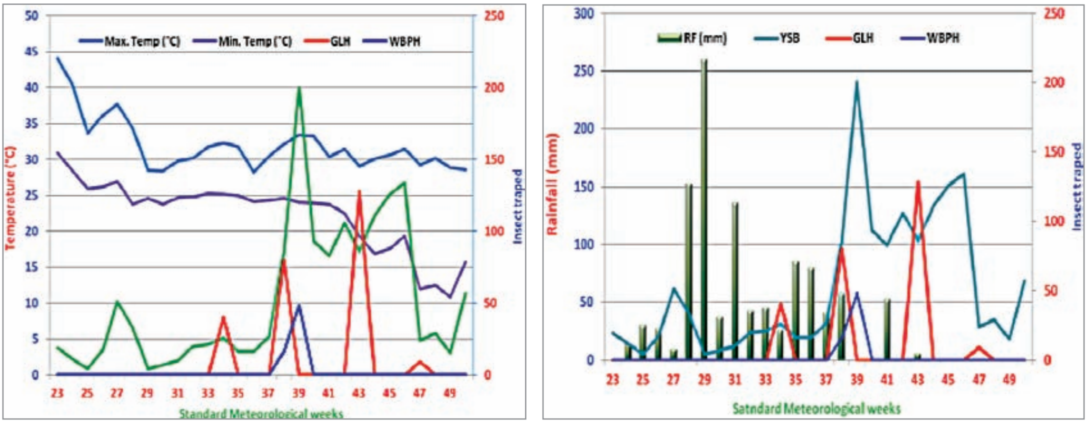


Fig. 6.3: Relationship between weekly Tmax, Tmin, rainfall and insects traped during *kharif* 2014 in rice at Raipur (GLH-Green Leaf Hopper; YSB-Yellow Stem Borer; BPH-Brown Plant Hopper)

Dry spells and associated increase in maximum tempertaure generally favoured outbreak of yellow stem borer attack in rice.

Thrissur

Leaf roller and leaf blight are the most important pest and disease of rice in Kerala during *kharif* season. Correlation studies between weather parameters one or two weeks prior to infestation and insect catch was studied and the results are presented in table 6.7.

Table 6.7: Correlation coefficients of leaf blight and leaf roller with weather elements

Parameters	Leaf blight		Leaf roller	
	1 week Before attack	2 weeks before attack	1 week before attack	2 weeks before attack
Minimum temperature	-0.162	0.205	0.13	0.116
Maximum temperature	-0.295	-.461*	-.395**	-.463**
RH1(morning)	-.387*	-0.268	-0.299*	-0.27
RH2(evening)	-0.292	-0.208	-0.278	-0.203
Sunshine hours	0.216	-0.116	-0.072	-0.166
Rainfall	-0.199	-0.088	-0.04	-0.028

From the table, it is clear that maximum temperature two weeks prior to appearance of symptoms showed significant positive correlation for leaf blight. For leaf roller, Tmax of both weeks showed significant positive correlation. Morning RH of one week prior to appearance of symptoms is the only other weather parameter which showed significant positive correlation for both leaf blight and leaf roller.

7. Research Accomplishments of Co-ordinating Unit

I. Minimum temperature trends over India and productivity of *kharif* paddy

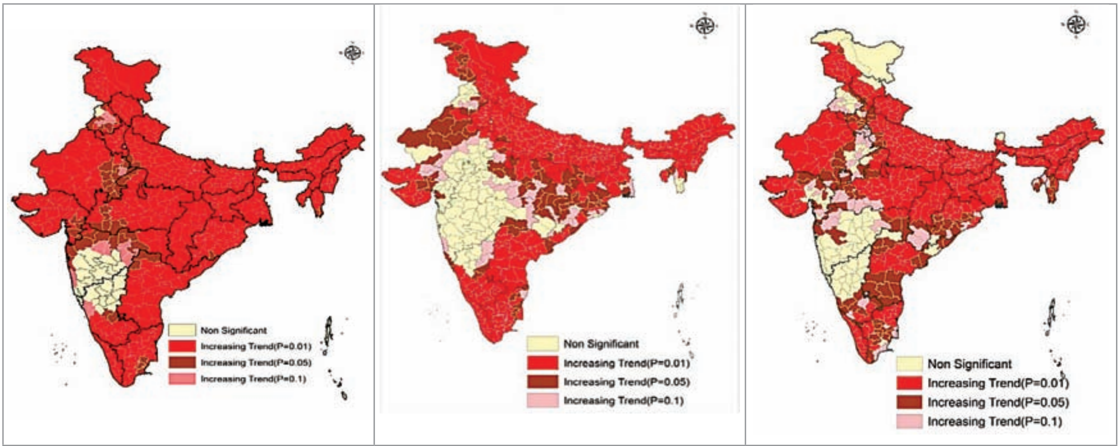
Agricultural productivity in a country is dependent on number of biophysical and socio-economic factors. Among the biophysical factors, weather has a predominant role. Apart from rainfall, the role played by temperature on agricultural production on a regional basis is gaining. We have analyzed the changes in minimum temperature considering the agricultural seasons practiced in most parts of the country at a micro level *i.e.*, district. In India, *kharif* (June-October) and *rabi* (October-March) the changes in minimum temperature over 1971 to 2009 at district level in 599 districts of India to assess its implications on future paddy yields in different agro-climatic regions of the country.

Data and Methodology

Monthly surface minimum temperature data for 0.5° grid size of Climate Research Unit (CRU), University of East Anglia, UK for the period 1971-2009 we used. Average temperature for each district was computed from grids falling within that district. Influential area of a grid was computed using Thiessen polygon method in a GIS environment. Area of different polygons falling in a district was derived in GIS environment. Monthly minimum temperature of a district was computed by using weighted average temperature, with weights proportional to area of polygons falling in a district. Minimum temperature data at district level were segregated into means for annual, *Kharif* (June to October), *Rabi* (October to March) periods. To detect warming in recent times, data were segregated into three time periods *viz.,* 1980-89, 1990-99 and 2000-2009 and then means of annual, *kharif* and *rabi* seasons were worked out. Relative change in temperature (°C) in the most recent period compared to the previous two periods was worked as the difference in temperatures between two periods. Mann-Kendall's test was used to detect any trend in the temperatures for each district. The significance in the trend is detected by two tailed test at probability levels of 0.1, 0.05 and 0.01. A district with significant increasing trend in minimum temperature was classified as slightly warm, moderately warm and strongly warm based on significance at probability levels of 0.1, 0.05 and 0.01, respectively and placed in respective clusters. Temperature values of different districts in each cluster were aggregated to arrive at the mean value of that cluster or region. Further, significance of the deviations in means of different sub periods from the long-term average was examined using Student's t test. The magnitude of changes in minimum temperatures for different time periods were determined from the slope value of a simple least square regression line with time as the independent variable.

We used historical paddy statistics to assess the association between *kharif* paddy yields and minimum temperature variations over India. Data on district-wise *kharif* paddy yields for the period 1971-2009 were sourced from Center for Monitoring Indian Economy. Since continuous yield data was not available for all districts, 355 districts for which a minimum of 12 years continuous data was available were considered. Time series yield data may feature strong trends that mask seasonal fluctuations likely to be associated with year on year variations in climate. We used a fourth-degree polynomial to de-trend the district level paddy yields. Paddy is planted from May to August and harvested between October to December and the planting time differs from region to region. The information on the region specific growing season was obtained from Rice Knowledge Management Portal. The growing season minimum temperatures were worked out for different districts by averaging the monthly temperatures. Correlations were worked out between the changes in district-wise seasonal minimum temperatures and the de-trended *kharif* paddy yields. Further, correlations were determined between monthly minimum temperatures and paddy yields to detect the most sensitive period to a change in minimum temperature in the crop's life cycle.

Our study showed that annual minimum temperatures are increasing over most parts of India @ 0.24°C 10 yr^{-1}. Large area (52.7% in *kharif*, 54.9% in *rabi*) showed strong and significant warming trend. Minimum temperatures during the *kharif* season showed strong warming trend in southern states, Gujarat, Himachal Pradesh, Indo-Gangetic Plains (IGP), northeastern region, and most parts of the Jammu & Kashmir. Minimum temperatures during *rabi* season showed strong warming over IGP, West Bengal, Northeastern states, Chhattisgarh, Rajasthan, Gujarat and eastern parts of Madhya Pradesh The magnitude of rise in seasonal mean temperatures is more during *rabi* (0.28°C 10 yr^{-1}) compared to *kharif* (0.19°C 10 yr^{-1}).



a) *kharif*	b) annual	c) *Rabi*

Fig. 1 a to c: Trends in minimum temperature over India (1971-2009) on (a) annual and during (b) *kharif* (c) *rabi* seasons.

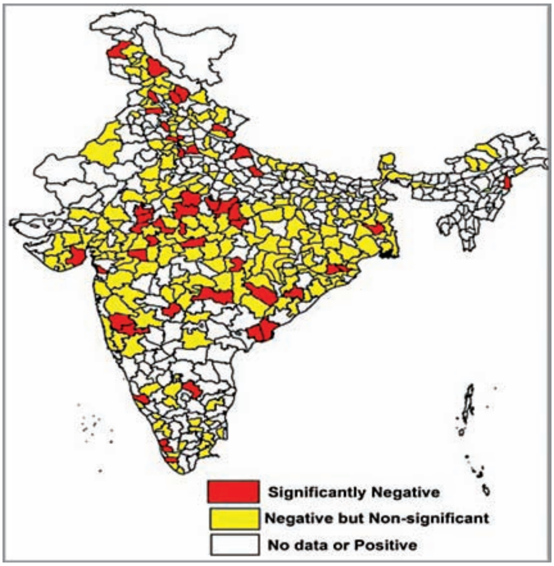


Fig. 2- Correlation between district-level seasonal minimum temperatures and *kharif* paddy yields.

Association between minimum temperature and *kharif* paddy yields

Kharif paddy yields in 268 districts across the country (57.2% of paddy growing area) were influenced by a rise in minimum temperature. The average rate of decline in paddy yields has been estimated to be 859 kg ha^{-1} in strongly warm region and 411 kg ha^{-1} in the weakly warm regions per 1 ^{o}C rise in minimum temperature. Large geographical area during *rabi* showed a statistically significant strong warming trend and the warming was more severe during the recent decade (2000-2009). It gives a signal that minimum temperature during *rabi* may rise faster than on annual basis in near future. Warming during *rabi* season has serious implications for production of *rabi* crops like wheat, mustard and chickpea in the Indo-Gangetic plains. Influence of warming on district level paddy yields clearly exhibited the sensitivity of paddy yields to temperature rise across the country.

II. Sensitivity of wheat yields to temperature in India

Wheat is the most important food crop of India during the post-rainy *i.e.*, *rabi* (November–March) season grown over 30 million ha (58% of the net cropped area during *rabi*) with a production of 94 million tons and contributing about 43% to the country's granary. With 91.3% of its area under assured irrigation in more than 200 districts that are largely (93.5%) confined to states like Uttar Pradesh, Madhya Pradesh, Punjab, Haryana, Rajasthan, Bihar, Maharashtra & Gujarat and wheat productivity had a quantum jump from 770 kg ha−1in 1950–1951 to 3140 kg ha in 2011–2012. We have examined the spatial variability and trends in temperature (maximum temperature (Tx), minimum temperature (Tn) and diurnal temperature range (Tr)) over major wheat growing districts in India. The correlation between wheat yield and temperature at the district level was analyzed.

An attempt was also made to detect the optimum and critical ranges in temperature variables during the sensitive crop growth stages which may ultimately help the planners and breeders to evolve suitable strategies. The response of wheat to the magnitude and duration of temperature extremes were also analyzed.

Data and methodology

Monthly surface temperature data of the Climate Research Unit (CRU), University of East Anglia, UK were sourced for 0.5 °C grid sizes for the period 1970-2012. Daily temperature data were sourced from NDC, IMD which is available at 1° resolution. Area weighted temperature for each wheat growing district was computed considering the number of grids falling in that district. Influential area of a grid was computed using the Thiessen polygon method in a GIS environment. Area of different polygons falling in a district was derived in GIS environment. T_x, T_n and T_r of a district was computed by using a weighted average of temperature, with weights proportional to area of polygons falling in a district. Later these data at district level were segregated into means for individual months for the period November to March, and as a seasonal mean for November to March. To detect warming in the wheat growing areas in the three temperature variables, Mann-Kendall's test, was used to detect any trend in the temperatures for each wheat growing district. The significance in the trend was detected by two tailed test at different probability levels (0.1, 0.05 and 0.01). Each district was classified as slightly warm, moderately warm and strongly warm based on the level of significance *i.e.*, 0.1, 0.05 and 0.01, respectively, and placed in respective clusters. Values of temperature variables of different districts in each cluster were aggregated to arrive at the mean value of that cluster or region. Data on district-wise wheat yields for the period 1980-2011 were sourced from Center for Monitoring Indian Economy.

The information on the region specific growing season for wheat was obtained from http://farmer.gov.in/cropstaticswheat.html. Across the regions, wheat season starts from November 1st fortnight (normal sown) to December 1st fortnight (late sown). Growing season ends by March 2nd fortnight (normal sown) to April 1st fortnight (late sown). We considered November to March as the average growing season (sowing to maturity) for wheat for our analysis domain. Then, the growing season temperatures were worked out for different districts by averaging the monthly temperatures for the period 1980-2011 matching with crop yields' datum. Pearson's correlations were calculated for the detrended yield and temperature variables. Districts were segregated into respective clusters based on the level of significance (0.05%, one-tailed) test for correlation. Further, correlations were done between monthly temperatures and wheat yields to detect the most sensitive period to a change in temperature variables in the crop's life cycle. Later we performed multiple linear regressions with 'first differences in yield' as the response variable, and the 'first differences of temperature variables' as predictor variables to determine the relative change in yield with a change in temperature variables in those clusters which are statistically significant.

Temperature changes in wheat growing regions

Our study reveals in large wheat growing areas in India, nighttime warming is occurring at a faster rate than daytime warming. Over large wheat growing areas of India, a rise in minimum temperature (T_n) is occurring at a faster rate (@ 0.32 ^oC $10yr^{-1}$) than maximum temperature (T_x) (@ 0.28 °C $10yr^{-1}$). During February, coinciding with post-anthesis period of wheat, about 79.4 % area showed significant warming in T_n (@0.37 ^oC $10yr^{-1}$) for 1970-2012 period. Indian wheat yields were observed to be prone to continual heat stress and especially to short-term temperature extremes. Wheat yields appear to be becoming more sensitive to T_n, especially during post-anthesis period. Mean wheat yields for the period 1980-2011 declined by 7% (204 kg ha^{-1}) for a 1 ^oC rise in T_n. Exposure to continual T_n exceeding 12 ^oC for 6 days and terminal heat stress with T_x exceeding 34 ^oC for 7 days during post-anthesis period are the other thermal constraints in achieving high productivity. Improved understanding from this study on the role of T_n during post-anthesis period using historical yield-temperature relationships may reduce the uncertainties in anthropogenic climate change projections further. There is a need to consider inclusion of early maturing, high yielding and heat tolerant wheat lines in the breeding program for Indian conditions. We believe that hermally sensitive areas evolved from this investigations may guide the researchers to identify such wheat lines for their adaptability in to future climates.

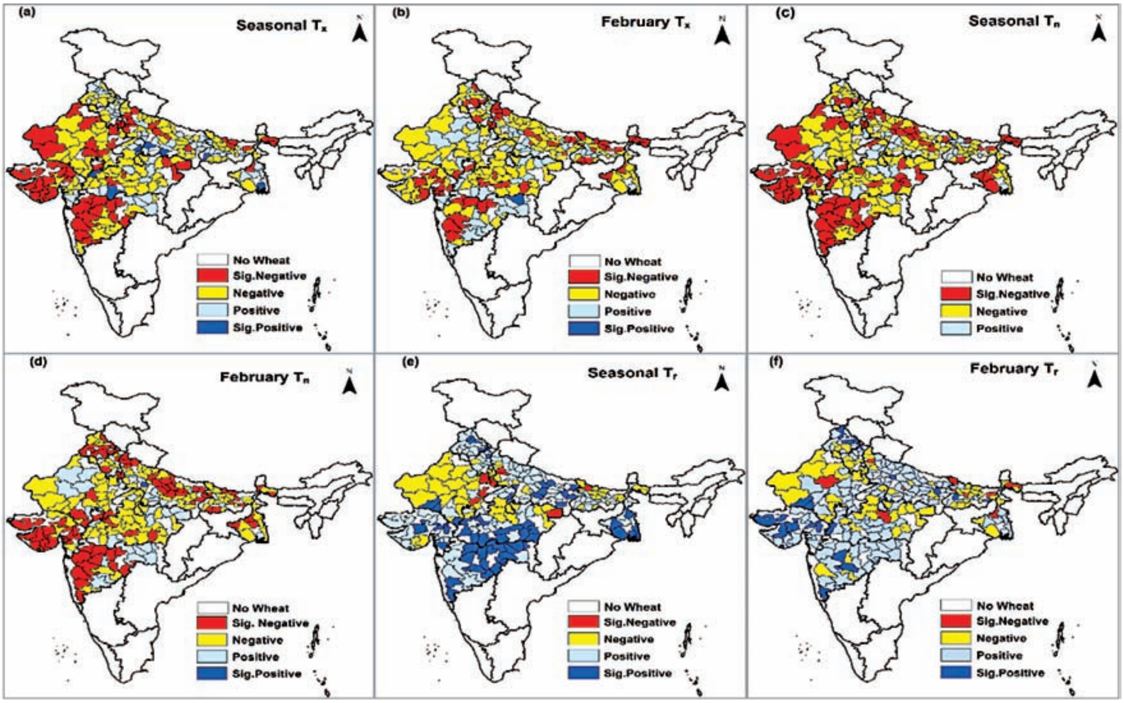


Fig. : Correlation between district wheat yields and (a) Seasonal (November-March) T_x;(b) February T_x; (c) Seasonal T_n; (d) February T_n; (e) Seasonal T_r; (f) February T_r (Un-shaded areas without district boundaries are not considered) (Shaded areas indicate either positive or negative association and un-shaded with district boundaries indicate non-significant association)

Table : Wheat growing area (%) that exhibited negative association with T_n and T_x of varying degrees

Nature of association	T_n (°C) exceeding											T_x (°C) exceeding						
	6	7	8	9	10	11	12	13	14	15	16	30	31	32	33	34	35	36
Significantly negative	2.8	3.3	7.1	9	8.2	14.2	15.6	13.6	12.8	13.1	9.8	7.1	8	5.7	5	8.1	5.5	4.3
Negative but non-significant	30.2	28.5	42.6	48.9	52.4	44.8	48.5	45.6	45.6	46.8	50	46.4	41.9	44	47.4	47.7	35.1	27
Negative (Significant + Non-significant)	33	31.8	49.7	57.9	60.6	59	64.1	59.2	58.4	59.9	59.8	53.5	49.9	49.7	52.4	55.8	40.6	31.3

Table: Wheat growing area (%) that exhibited negative association with continual exposure to $T_n > 12$ °C and $T_x > 34$ °C

Nature of association	Number of days $T_n > 12$ °C							Number of days $T_x > 34$ °C									
	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	9	10
Significantly negative	8.5	10.5	9.8	9.7	11.8	8.6	6.7	5.9	5.5	5.1	3.7	5.4	5.4	8.9	2.3	1.9	0.4
Negative but non-significant	50.8	45.1	46.1	40.1	44.9	38.4	42.1	43.4	39.6	30.4	29.6	28.9	26.8	29.3	17.6	11.6	1.7
Negative (Significant + Non-significant)	15.3	55.6	55.9	49.8	56.7	47	48.8	49.3	45.1	35.5	33.3	34.3	32.2	37.2	19.9	13.5	2.1

III. Weather indices for wheat and groundnut crops

Weather indices *viz*. triggers and exit for wheat and groundnut based on data collected at some research centres as well as major wheat and groundnut growing districts were worked out by analyzing their long-term yield data in relation to phenophase-wise weather conditions. These indices are useful in for designing district level weather insurance products for wheat and groundnut.

Wheat

Temperature thresholds at Kanpur

Critical phenological stages for heat stress, the impact of heat stress during these stages and temperature thresholds for obtaining above average, average and below average yield of wheat at Kanpur centre was worked out. Eleven years experimental data for three cultivars (HD-2285, K-8804 and K-9107) under three sowing dates at the Kanpur Centre located in the Indo-Gangetic Plains of Uttar Pradesh were used. In order to understand the relationship between yield and phenological stage-wise temperature, both simple linear regression models and second degree polynomial models were used. Among the eight phenological stages, the milk stage was identified as most sensitive for high maximum and minimum temperatures to adversely affect yield (Table 1). The rate of yield reduction with unit increase in maximum and minimum temperatures (°C) was found to be highest in K-8804 and lowest in HD-2285. The optimum ranges of maximum temperature during anthesis, milk, dough and maturity stages are 19.7-21.9, 24.2-26.5, 26.1-28.8 and 29.5-30.8 °C, respectively and those for minimum temperature are 4.3-6.2, 8.3-9.7, 11.5-12.4 and 13.0-15.1 °C, respectively. The thresholds of temperature during critical stages and quantification of heat stress on yield will be of use in devising weather-index-based crop insurance products in wheat.

Table 1. Temperatures (°C) during different phenological stages of three wheat cultivars for obtaining three different categories of yield

Yield category	Emergence	CRI	Tillering	Jointing	Anthesis	Milk	Dough	Maturity	Yield (kg/ha)
	HD-2285 Maximum temperature (°C)								
Above average	30.1	32.0	-	-	19.7	24.2	26.1	30.8	5143
Average	23.8	22.0	-	-	25.1	28.8	31.3	34.4	4522
Below average	17.6	11.9	-	-	30.5	33.4	35.6	38.3	3901
	HD-2285 Minimum temperature (°C)								
Above average	-	-	-	4.4	4.3	9.7	11.5	13.0	5143
Average	-	-	-	8.0	10.2	13.1	15.2	17.4	4522
Below average	-	-	-	11.7	14.7	17.2	19.0	21.5	3901
	K-8804 Maximum temperature (°C)								
Above average	29.0	27.9	18.5	16.2	21.5	25.6	27.9	30.3	4820
Average	23.8	22.2	21.4	22.6	25.9	29.5	32.4	35.4	4124
Below average	18.6	16.5	25.8	28.4	30.3	33.3	36.9	40.5	3428

Yield category	Emergence	CRI	Tillering	Jointing	Anthesis	Milk	Dough	Maturity	Yield (kg/ha)
	K-8804 Minimum temperature (°C)								
Above average	-	-	5.2	4.3	6.1	8.3	11.9	13.8	4820
Average	-	-	8.2	9.1	10.7	14.5	16.4	18.4	4124
Below average	-	-	10.3	12.0	15.4	17.4	19.3	23.1	3428
	K-9107 Maximum temperature (°C)								
Above average	27.5	28.4	-	14.8	21.9	26.5	28.8	29.5	4313
Average	24.8	22.2	-	23.2	26.3	30.2	33.1	36.0	3759
Below average	18.1	16.1	-	31.7	30.7	34.0	37.5	42.4	3204
	K-9107 Minimum temperature (°C)								
Above average	14.0	12.1	-	2.0	6.2	9.0	12.4	15.1	4313
Average	8.1	6.9	-	8.3	11.1	14.8	16.6	18.2	3759
Below average	2.2	1.7	-	14.6	16.0	17.8	20.7	23.8	3204

Weather indices for wheat in Haryana and Uttar Pradesh

Weather indices in wheat were developed for three districts *i.e.* Hisar, Karnal and Sirsa of Haryana and five districts of Uttar Pradesh *viz*. Faizabad, Jhansi, Kanpur, Lucknow and Varanasi (Table 2). Maximum or minimum temperature required for above average, average and below average yields were named as trigger 1, trigger 2 and exit, respectively. In Haryana, for trigger 1 maximum temperature at same critical stage (Anthesis to Dough stage) varied from 26.0 to 27.0 °C and minimum temperature varied from 9.8 to 11.3 °C, across districts Sirsa and Hisar. However, for exit both maximum and minimum temperatures varied from 27.9 to 30.1 °C and 11.3 to 14.3 °C, respectively across these districts. In Uttar Pradesh, in four out of the five districts, milk to dough stage was identified as the critical stage for temperature and for trigger 1 and exit, maximum temperature varied from 25.3 to 26.4 °C and 27.1 to 28.2 °C, respectively across the four districts. However, variation in minimum temperature for trigger 1 and exit across the districts was higher and it is 8.4 to 11.1 °C for trigger 1 and 11.1 to 13.9 °C for exit.

Table 2. Weather indices for major wheat growing districts of Haryana and Uttar Pradesh

State	District	Critical stage	MXT (°C)			MNT (°C)		
			Trigger 1	Trigger 2	Exit	Trigger 1	Trigger 2	Exit
Haryana	Hisar	Anthesis to dough	27.0	27.5	30.1	9.8	10.5	11.3
	Karnal	Ear emergence to anthesis	20.7	21.9	22.4	6.8	8.9	9.8
	Sirsa	Anthesis to dough	26.0	27.2	27.9	11.3	11.5	14.3
Uttar Pradesh	Faizabad	Milk to dough	25.8	26.5	27.1	8.4	10.4	11.1
	Jhansi	Anthesis to milk	23.4	25.0	26.0	7.1	7.4	8.9
	Kanpur	Milk to dough	25.3	25.4	27.6	9.6	11.1	12.4
	Lucknow	Milk to dough	25.5	26.3	28.2	9.1	11.1	12.5
	Varanasi	Milk to dough	26.4	26.5	27.5	11.1	12.1	13.9

Groundnut

Weather indices for research stations

Weather indices required for designing weather insurance products for groundnut were developed by analyzing long-term yield and weather conditions at three locations *viz*., Bangalore, Anand and Ludhiana.

At Bangalore, higher rainfall during pod initiation to pod filling in DH 3-30 and Robut 33-1 and during pod initiation to pod formation in TMV-2, JL-24 and K-134 was identified to be favourable for achieving higher pod yield in respective varieties (Table 3). Rainfall less than 119, 109, 156, 138 and 122 mm during this critical stage resulted in lesser than optimum yield in these varieties. At Anand, rainfall during first seed to harvest was found to be critical for obtaining higher yield and rainfall lesser than 319, 469 and 174 mm during first seed to harvest stage of varieties Robut 33-1, GG-2 and Gaug-10, respectively resulted in below optimum yield. At Ludhiana, in M-13 variety, 334 mm rainfall during complete emergence to 50% flowering was found to be critical for higher pod yield and any decrease in rainfall during this stage resulted in below optimum pod yield.

Table 3. Rainfall during critical phenological stages of different groundnut varieties for obtaining three different categories of yield at Bangalore, Anand and Ludhiana

Centre	Variety	Critical stage	Rainfall (mm)		
			Trigger 1	Trigger 2	Exit
Bangalore	DH 3-30	Pod initiation to pod filling	118.7	82.4	65.8
	Robut 33-1	Pod initiation to pod filling	108.7	71.0	10.7
	TMV-2	Pod initiation to pod formation	155.7	85.0	40.3
	JL-24	Pod initiation to pod formation	138.4	111.6	36.3
	K-134	Pod initiation to pod formation	122.3	102.4	50.8
Anand	Robut 33-1	First seed to harvest	318.8	254.9	43.7
	GG-2	First seed to harvest	469	341.8	28.9
	Gaug-10	First seed to harvest	174.3	86.9	6.9
Ludhiana	M-13	Complete emergence to 50% flowering	333.6	165.4	58.1

Another index named water requirement satisfaction index (WRSI) derived from FAO water balance model was used for identifying its limits for obtaining above average, average and below average yield in different varieties at Bangalore, Anand and Ludhiana. The relation between water requirement satisfaction index (WRSI) and yield in respect of different varieties at three locations revealed that the WRSI required for optimum pod yield ranged from 64.7 to 93.3 per cent across different crop varieties and centres (Fig 1). Yield is showing an highly significant positive relationship with WRSI and yield increases by 32 kg/ha for one per cent increase in WRSI. Decline in pod yield with respect to the number of dry spells of different durations(another index) was also studied in different varieties at all the three centres (Table 4). At Bangalore (cv. DH 3-30) and Anand (cv. Robut 33-1) two dry spells of more than 15 and 20 days, respectively caused nearly 70 per cent reduction in pod yield compared to no dry spell. At Ludhiana, M-13 variety can tolerate one spell of 15 dry days but yield was reduced by 90% with four such dry spells.

Table 4. Thresholds of dry spells affecting yield of groundnut varieties DH 3-30 at Bangalore, Robut 33-1 at Anand and M-13 at Ludhiana

Centre	Variety	Dry spells		Yield reduction (%)
		Duration	Number	
Bangalore	DH 3-30	≥ 15 days	0	-
			1	38
			2	67
Anand	Robut 33-1	≥ 20 days	0	-
			1	37
			2	69
Ludhiana	M-13	≥ 15 days	1	-
			2	46
			4	89

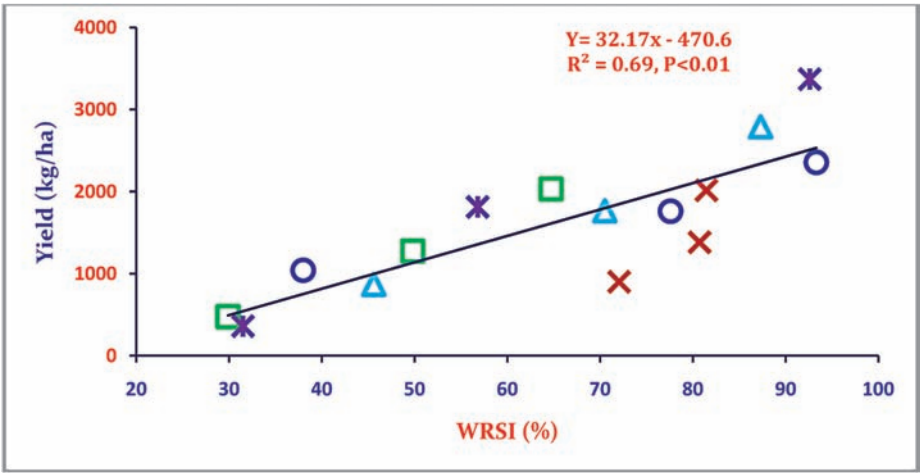


Fig. 1 Relation between WRSI and yield of different cultivars

Weather indices for groundnut growing districts

Rainfall indices in groundnut were formulated for three districts *viz*. Bangalore (rural), Dharwad and Bijapur of Karnataka and eight districts *viz*. Junagadh, Jamnagar, Rajkot, Amreli, Bhavnagar, Kutch, Sabarkanta and Banaskanta of Gujarat (Table 5). In Karnataka, critical stage for rainfall differed from district to district and as a result rainfall and rainy days for trigger 1, trigger 2 and exit differed among districts. In Gujarat, first peg to first pod was identified as the critical stage for rainfall in Rajkot, Amreli and Bhavnagar districts and rainfall in this common critical stage varied from 145 to 240, 40 to 64 and 13 to 29 mm, respectively for trigger 1, trigger 2 and exit across the three districts. At Banaskanta and Sabarkanta, 50% flowering to first peg was the critical stage and rainfall varied from 114 to 231, 78 to 110 and 1 to 17 mm for trigger 1, trigger 2 and exit, respectively at these two districts.

Table 5. Rainfall and rainy days based indices for groundnut in major groundnut growing districts of Karnataka and Gujarat

State / District	Critical stage	Rainfall (mm)		
		Trigger 1	Trigger 2	Exit
Karnataka				
Bangalore (rural)	50% Flowering to pod initiation	152 (7)	125(6)	60 (4)
Dharwad	50% Flowering to pod filling	268 (10)	171(9)	109 (7)
Bijapur	Pod initiation to pod filling	199 (9)	75(5)	64 (4)
Gujarat				
Junagadh	First seed to harvest	338 (18)	188 (12)	83 (9)
Jamnagar	50% Flowering to first pod	552 (13)	182 (9)	24 (2)
Rajkot	First peg to first pod	240 (7)	45 (4)	13 (2)
Amreli	First peg to first pod	175 (7)	40 (4)	29 (1)
Bhavnagar	First peg to first pod	145 (10)	64 (5)	21 (3)
Kutch	First pod to first seed	245 (7)	35 (2)	8 (1)
Sabarkanta	50% Flowering to first peg	231 (6)	110 (5)	1 (0)
Banaskanta	50% Flowering to first peg	114 (5)	78 (4)	17 (1)

(Values in parenthesis are rainy days)

Agroclimatic characterization

- Trend analysis of SI was carried out for four time periods (1901-1930, 1931-1960, 1961-1990 and 1991-2013) for districts of Vidarbha region using monthly rainfall data. Observed shift towards greater SI values indicateed confinement of rainfall distribution to lesser seasonal period. Mann Kendall test statistic showed significant increasing trend of SI value (1901-2013) only in Amravati, Buldhana and Washim districts.
- Significant positive trend in maximum temperature on annual basis and during post- monsoon season (1960-90) was observed at Anand. During summer, both Tmax and Tmin showed significant positive trend during 1991-2013. At Vadodara, Tmin showed significant positive trend on annual basis as well as monsoon and winter seasons during 1960-90.
- Rainfall probability analysis using 43 years' weekly rainfall data by Bangalore centere has revealed that the crop sown during 28^{th} to 31^{st} week would not suffer from any moisture stress.
- LGP was estimated for 27 locations in high rainfall zone of Tamil Nadu by Kovilpatti center. Lowest LGP of 29 weeks was observed in Kulachal whereas highest LGP of 36 weeks was observed in Chittar and Mylar.
- Impact of projected climate change on weather parameters in central Punjab was studied by downscaling baseline (1961-1990) and projected (2020-2100) meteorological data given by PRECIS model. Increase in Tmax was found to be more during *rabi*, compared to *kharif* for mid century under A1B scenarios. Rainfall and Tmin showed more increase during *rabi* in mid and end century.
- Number of hail events (since 1990) and dew days (since 1985) were found to be increasing in Palampur, Himachal Pradesh. The dew days are increasing at the rate of 3 days per year.
- The analysis of impact of El Nino on total crop production in Chhattisgarh was analyzed using crop statistics and weather data for the period 1971-2012. Five strong El Nino years were recorded during which there was a decline of average combined cereals and pulses production by 13% and the crop acreage by 6%.

Crop weather relationship

Kharif 2014

Rice

- Among three cultivars, Swarna recorded highest RUE (2.7 g/MJ) at Faizabad. On an average, the crops sown on 5^{th} July recorded highest RUE (2.4 g/MJ).
- Cultivar NDR-52 recorded the highest HUE (0.42 g/m^2/^{0}day) followed by CSR-27 (0.40 g/m2/0day) at Kanpur.

- Impact of different levels of shade on yield and yield attributes of rice was studied at Ludhiana, which revealed that maximum reduction in yield (0.8 t/ha) was observed when shade imposed during 30-60 DAT when nitrogen was 100% normally applied. Harvest index, biomass, 1000 grain weight and panicle weight/m^2 also showed similar response.
- At Raipur, cultivar Mahamaya recorded highest HUE (0.42 g/m^2/^{o}day) and RUE (1.14 (g/m^2/MJ) which was exposed to three growing environments.
- Cultivar Naveen recorded highest HUE (1.8 kgha-1/0 day), WUE (65.6 kgha^{-1}/cm) and RUE (1.5 g/MJ) compared to Sahbhagi and Swarna when grown under three growing environments at Ranchi.

Maize

- Crop sown on first fortnight of June gave higher grain yield by availing longer crop growing period as compared to successive delayed sowings at Udaipur. Among different hybrids, Pratap Makka-3 (4.9 t/ha) and BIO-9637 (4.7 t/ha) recorded highest mean yield and PEHM-2 (3.8 t/ha) recorded the lowest.

Pearl millet

- Crop sown in second fortnight of June recorded highest consumptive use of moisture (303-332 mm) and moisture use efficiency (5.37-6.11 Kg ha^{-1} mm^{-1}) at Solapur. Among cultivars, Shanti recorded highest CUM & MUE compared to Mahyco and ICTP-8203.

Pigeoan pea

- An increased duration of bright sunshine by two hours per day during seedling stage and lower minimum temperature by 3.4 ^{o}C during pod formation and grain filling stage were found favorable for obtaining higher yield at Bijapur.

Soybean

- Water productivity (WP) was found to be maximum under early sown (27 MW) crop and decreased with later sowings at Akola. Among the varieties, TAMS-98-21 recorded highest WP (2.41 kg ha^{-1}mm^{-1}).

Sunflower

- Crop sown in second fortnight of June (S1) recorded highest value of CUM (342 mm) and MUE value of 5.48 kg ha^{-1}mm^{-1}). Phule Raviraj recorded highest CUM and MUE compared to other cultivars.

Groundnut

- Crop sown on first fortnight of August recorded highest (3 kg/ha/mm) WUE, whereas late sown (second fortnight of August) had lowest (1kg/ha/mm) at Anand.
- The crop sown during 2nd fortnight of July has recorded highest yield (607 kg/ha) at Anantapur. The yield of Vemana (588 kg/ha), K–6 (632 kg/ha) and Anantha (629 kg/ha) sown in different dates of sowing was on par.

Rabi 2014-15

Wheat

- WUE was highest (15.1 kg hamm^{-1}) in 1st crop growing environment (sown on 29th Oct, 2014) and lowest in crop sown on 10th Dec. Among cultivars, Raj 3077 showed high water use efficiency followed by HD 2967.
- During reproductive phase, maximum temperature exceeded the earlier established optimum limit (for achieving highest yield) of maximum (23.4) and minimum (10.9) temperature by 2.2 and 3.3 °C, which resulted in low productivity at Palampur.
- Radiation use efficiency of seven varieties were worked out at Kanpur. National check HD-2967 exhibited poor RUE (0.77 g/m^2/MJ). Highest value of RUE was recorded with Kanchan (1.10 g/m^2/MJ) followed by GW-273.

Chickpea

- Crop sown on 41 and 42 SMW showed maximum HUE in terms of pod yield (0.30 kg ha^{-1} °C day^{-1}) at Akola. Among different cultivars, HUE with respect to seed yield (0.30 kg ha^{-1} °C day^{-1}) was higher in JAKI-9218 and for biomass production it was maximum with Vijay (0.80 kg ha^{-1} °C day^{-1}).
- The CUM of 275 mm was found to be optimum for getting higher grain yield and thereafter there was decrease in yield. The yield decreased when Tmax increased above 31.8 °C. A Tmin of 17.5 °C was found to be optimum for getting higher grain yield

Mustard

- Diurnal observations of energy balance at maximum LAI stage, flowering and pod formation stage over five mustard cultivars was studied. Among the varieties RH 0749 used higher fraction of LE in Rn as compared to other varieties.
- Maximum temperature in the range of 20.3-24.4 °C and minimum temperature 7.3-9.3 °C at vegetative phase seems to be optimum for higher productivity in gobi sarson at Palampur.

Crop growth modeling

- CROPGRO-Soybean simulation model (DSSAT v 4.5) was evaluated with 3 years experimental data from 2011-2013 at Akola for three different varieties *viz.* JS-335, JS-9305, TAMS 98-21 raised under four different environments. Elevated CO_2 concentration by 100 ppm coupled with elevated maximum temperature level by 1, 2 and 3 °C decreased the yield level from 3.2 to 28.4% under 1°C, by 14.3 to 38.9% under 2 °C and from 22.6 to 50.8% under 3 °C.
- PNUTGRO DSSAT model was calibrated and validated at Anand using three years experimental data. Days to anthesis was under estimated by the model for cv. GG-20, while pod yield was over estimated for all the cultivars. Further calibration of the model is required by collecting and incorporating more field information into the model.

- DSSAT Rice model was calibrated for the phenology and yield. The genetic coefficients were generated for Faizabad location.
- DSSAT Rice model was calibrated for the phenology (anthesis and maturity) and yield at Jorhat. The genetic coefficients generated for cultivar Mahsuri.
- Future climate change scenarios generated by PRECIS model were incorporated in the InfoCrop model by Ludhiana center. SRES scenarios were used to simulate impact of climate change on rice, maize and wheat. The grain yield of rice is projected to decrease under A1B scenario for the period 2020-2050 from the baseline by 3.6 to 19.8% under maximum temperature change scenario, by 2.7 to 5.5% under minimum temperature change scenarios and by 8.0 to 26.0% under both maximum and minimum temperature change scenarios. The grain yield of maize is projected to decrease under A1B scenario for the period 2020-2050 from the baseline by 4.5 to 24.5% under maximum temperature change scenario, by 0.8 to 11.1% under minimum temperature change scenario and by 4.1 to 19.1% under both maximum and minimum temperature change scenarios. The grain yield of wheat is projected to decrease under A1B scenario for the period 2020-2050 from the baseline by 7.8 to 11.8% under maximum temperature change scenario, by 1.8 to 8.4 % under minimum temperature change scenario and by 12.1 to 17.6% under both maximum and minimum temperature change scenarios.
- CERES–rice model was calibrated with experimental data for three rice cultivars (Sahbhagi, Naveen and Swarna) at Ranchi. Grain yield was estimated reasonably well by model for all the cultivars and D -index were always greater than 0.6.

Effect of weather on pests and diseases

Rice

- Maximum temperature two weeks prior to appearance of symptoms showed significant positive correlation for leaf blight at Thrissur. Morning RH of one week prior to appearance of symptoms is the only other weather parameter which showed significant positive correlation for both leaf blight and leaf roller.

Mustard

- A favourable weather range (Tmax: 28–33 °C, Tmin: 9–15 °C and Tmean: 19–24 °C) prevailed during 50% flowering for 3–5 days has caused aphid outbreak in the succeeding week in Mustard at Anand. For avoiding high aphid infestation 10th to 20th October sowing was found most suitable.

Pigeoan pea

- Incidence of pod borer was highest crop sown in July first fortnight (38.4%) and August first fortnight sown crop (33.1%) compared to crop sown on first fortnight of June (19.2%) at Bangalore.

9. Research Publications: 2014-15

Co-ordinating Unit

Papers in Peer Reviewed Journals

- Amrender Kumar., Chattopadhyay, C., Singh, K. N., Vennila, S and Rao, V. U. M. (2014). Trend analysis of climatic variables in Pigeoan pea growing regions in India. *Mausam*, **65**(2)**:** 161-170.
- Bapuji Rao, B., Santhibhushan Chowdary, P., Sandeep, V. M., Rao, V. U. M and Venkateswarlu, B. (2014). Rising minimum temperature trends over India in recent decades: Implications for agricultural production. *Global Planet. Change,***177**: 1-8.
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- Pasupalak, S., Rao, V. U. M., Panigrahi, G and Mukut, M. (2014). Solar Radiation

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- Patel, H. R., Lunagaria, M. M., Pandey, V., Sharma, P. K., Bapuji Rao, B and Rao, V. U. M. (2014). El Nino episodes and agricultural productivity in Gujarat. AICRPAM, AAU, Anand.
- Rajendra Prasad., Rao, V. U. M and Bapuji Rao, B. (2014). El Nino-Its impact on Rainfall and Crop Productivity: A case study for Himachal Pradesh. AICRPAM, CSKHPKV, Palampur.
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- Bapuji Rao, B., Rao, V.U.M and Subba Rao, A.V.M. (2014). El-Nino-Andhra Telangana rashtrala vyvasayarangaani prabhavitham chaiyanundha? Raythunestham, May, 41-44.

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Akola

Papers in Peer Reviewed Journals

- Maruthi Sankar, G. R., Sharma, K. L., Gabhane, V. V., Nagdeve, M. B., Osman, M., Pushpanjali., Gopinath, K. A., ReshmaShinde., Ganvir, M. M., Karunakar, A. P., Anitha Chorey., Mishra, P. K., Venkateswarlu, B., Singh, A. K., Suma Chandrika, M and Sammi Reddy, K. (2014). Effects of Long-Term Fertilizer Application and Rainfall Distribution on Cotton Productivity, Profitability, and Soil Fertility in a Semi-arid Vertisol. *Comm. Soil Sci. Plant Anal.*,**45**(3): 362-380.
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- Anil Karunakar., Nagdeve, M. B., Ganvir, M. M., Damre, P. R and Chavan, V.K. (2015). Recent trends in extreme rainfall events in Vidarbha. In: National Seminar on "Dryland Agriculture in Vidarbha: Priorities and Development Issues", March 3-4, PDKV, Akola.
- Anil Karunakar., Nagdeve, M. B., Satpute, G. U., Turkhede, A. B and Patode, R. S. (2015). Analysis of standardized precipitation index in Vidarbha zones. In: National Seminar on "Dryland Agriculture in Vidarbha: Priorities and Development Issues", March 3-4, PDKV, Akola.
- Bathkal, B. G., Nagdeve, M. B and Karunakar, A.P. (2015). Introspecting dryland farming mission project in Akola district. In: National Seminar on "Dryland Agriculture in Vidarbha: Priorities and Development Issues", March 3-4, PDKV, Akola.
- Ganvir, M. M., Nagdeve, M. B., Karunakar, A. P., Gabhane, V. V., Patode, R. S and Sakhare, S. B. (2014). Productivity and sustainability of Pearlmillet based intercropping system under dryland condition. In: International Symposium on "New-Dimensions in Agrometeorology for Sustainable Agriculture", October 16-18, GBPUA&T, Pantnagar.
- Ganvir, M. M., Nagdeve, M. B., Karunakar, A. P., Gabhane, V. V., Patode, R. S., Sakhare, S. B and Vandana Mohod. (2015). Productivity and Sustainability of Cotton Based Intercropping System in different row proportions under Dryland Condition in Maharashtra. In: Second International Conference on "Bio-Resource and Stress Management", January 7-10, PJTSAU & ANGRAU, Hyderabad.
- Ganvir, M. M., Nagdeve, M. B., Karunakar, A. P., Gabhane, V. V., Patode, R .S., Sakhare, S. B., Vandana Mohod., Nagdeote, V. G and Damre, P. R. (2015).

Sustainability of cotton based intercropping system under dryland condition in Vidarbha region of Maharashtra. In: National Seminar on "Dryland Agriculture in Vidarbha: Priorities and Development Issues", March 3-4, PDKV, Akola.

- Jadhao, D. K., Goud, V. V., Anil Karunakar., Wadaskar, R. M andPatil, A. N. (2015).Crop-weather relationship of chickpea at different sowing date under irrigated condition. In: National Seminar on "Dryland Agriculture in Vidarbha: Priorities and Development Issues", March 3-4, PDKV, Akola.
- Turkhede, A. B., Nagdeve, M. B., Gabhane, V. V., Anil Karunakar., Ganvir, M. M and Damre, P. R. (2015). Productivity of soybean + Pigeoan pea intercropping system under dryland condition. In: National Seminar on "Dryland Agriculture in Vidarbha: Priorities and Development Issues", March 3-4, PDKV, Akola.
- Turkhede, A. B., Nagdeve, M. B., Gabhane, V. V., Ganvir, M. M., Karunakar, A. P., Mali, R. S and Nandapure, S. P. (2015). Response of cotton productivity to land configuration and nutrient module under dryland condition. In: National Seminar on "Dryland Agriculture in Vidarbha: Priorities and Development Issues", March 3-4, PDKV, Akola.

Anand

Papers in Peer Reviewed Journals

- Choudhary, D., Patel, H. R and Pandey, V. (2014). Calibration and validation of InfoCrop model v. 1.0 for yield and yield attributing characters of *rabi* maize in middle Gujarat region. *Ann. Biol.,* **30**(4):658-660.
- Choudhary, D., Patel, H. R and Pandey, V. (2014). Calibration and validation of InfoCrop model v.1.0 for yield and yield attributing characters of *kharif* maize in middle Gujarat region. *Trends Biosci.,* **7**(13):1528-1530.
- Choudhary, D., Patel, H. R and Pandey, V. (2015). Evaluation of adaptation strategies under A2 climate change scenario using InfoCrop model for *kharif* maize in middle Gujarat region. *J. Agrometeorol.,* **17**(1):98-101.
- Lunagaria, M. M., Patel, H. R andPandey, V. (2015). Evaluation and calibration of noninvasive leaf chlorophyll meters in wheat. J. Agrometeorol.,17(1):51-54.
- Mishra, S. K., Shekh, A. M., Pandey, V., Yadav, S. B and Patel, H. R. (2015). Sensitivity analysis of four wheat cultivars to varying photoperiod and temperature at different phonological stages using WOFOST model. *J. Agrometeorol.,* **17**(1):74-79.

Popular Articles Authored/Co-authored in Press and Magazines.

- Patel H.R., Lunagria M.M., Karande B.I., Yadav S.B., Shah A.V. and Pandey V. (2014). Badalati abohavanaa sanrdbhmaa Gujaratni bhavi krushi tasir. Krishigovidya, February, 5-9.

- Patel H.R., Lunagria M.M., Karande B.I., Yadav S.B., Shah A.V. and Pandey V. (2014). Badalati abohavanaa sanrdbhmaa Gujaratni bhavi krushi tasir. Gujarat Samachar Krishi Vishva Ltd, March, 3.
- Patel H.R., Lunagria M.M. and Pandey V. (2014). Elnino prabhavit gujaratano varasad ane krishi utpaadan. Krishigovidya, August,5-6.
- Patel H.R., Lunagria M.M. and Pandey V. (2014). Elnino prabhavit gujaratano varasad ane krishi utpaadan. Krishijivan August,11-12.
- Technical & Research Bulletins Edited/Co-edited.
- Patel H.R., Sharma P.K., Chaudhari N.J. and Pandey V. (2014). "Farmers perceptions on climate change in middle Gujarat". AICRPAM, AAU, Anand.
- Patel, H. R., Lunagaria, M. M., Pandey, V., Sharma, P. K., Bapuji Rao, B and Rao, V. U. M. (2014). El Nino episodes and agricultural productivity in Gujarat. AICRPAM, AAU, Anand.

Papers Presented in National and International Symposia/Seminars.

- Chaudhary, N. J., Suthar, B. M., Patel, H. R., Pandey, V and Rao, V. U. M. (2014). Radiation and water use efficiency of wheat under various environmental conditions in middle Gujarat Agro-climatic region. In: International Symposium on "New Dimensions in Agrometeorology for Sustainable Agriculture", 16-18 October, GBPUAT, Pantnagar.
- Patel, H. R., Chaudhary, N. J., Suthar, B. M., Pandey, V., Bapuji Rao, B and Rao, V. U. M. (2014). Relationship between mustard yield and aphid infestation under varied environmental condition of middle Gujarat. In: International Symposium on "New Dimensions in Agrometeorology for Sustainable Agriculture", October 16-18, GBPUA&T, Pantnagar.
- Suthar, B. M., Chaudhary, N. J., Patel, H. R., Pandey, V and Rao, V. U. M. (2014). Rainfall variability and its impact on groundnut yield under rainfed condition of middle Gujarat. In: International Symposium on "New Dimensions in Agrometeorology for Sustainable Agriculture", October 16-18, GBPUA&T, Pantnagar.

Anantapur

Radio Talks

- Contingency crop plannining for Anantapurdistrictdue to scanty rainfall on 4th August, 2014 by Dr. S.M Malleshwari.
- Management practices for Bt cotton on 28th August, 2014 by Dr. S. M Malleshwari.

Bangalore

Papers in Peer Reviewed Journals

- Padmasri, H. S., Soumya, D. V., Rajegowda, M. B., Nagesh, L and Sridhar, D. (2014). Coconut yield as influenced by seasonal rainfall in Karnataka, Mysore *J.Agril. Sci.,* **48**(2): 230-234.
- Rajegowda, M. B., Soumya, D. V., Padmasri, H. S., Janardhana Gowda, N. A and Nagesh, L. (2014). Ragi, groundnut yield forecasting in Karnataka- Statistical Model, *J. Agrometeorol.,* **16**(2): 203-206.

Books / Book Chapters / Training Program Lecture Notes

- Rajegowda, M. B., Janardhana Gowda, N. A., Padmasri, H. S and Ravindra Babu, B. T. (2014). "Weather Based Agromet Advisory for Finger Millet (Ragi) crop in Karnataka". 1st Eds. 1-50pp. Published by University of Agricultural Sciences, GKVK, Bengalore using the funds provided under NICRA, ICAR, India.

Popular Articles Authored /Co-authored in Press and Magazines

- Rajegowda, M. B., Nagesha, L., Shridhar, D., Janardhana Gowda, N. A and Soumya, D. V.(2014). Krushi Havamana Munsoochane haagu salahaa varadhi praamukhyathegalu, Krishi Kayaka, 4(3): 6-7.
- Rajegowda, M. B., Nagesha, L., Soumya, D. V., Shridhar, D and Janardhana Gowda, N. A.(2014). Maleyaashritha susthira Krishige Agathyavaada havaamaana maahithi, Krishi Kayaka, 4(2): 17-18.
- Shridhar, D., Nagesha, L., Soumya, D. V and Rajegowda, M. B.(2014). Krishiyalla Havaamaana vignaanada praamukhyathe haagu adara vyaapthi, Krishi Kayaka, 5(1): 4-5.

Folders

- "Havaamaana vaipareethyakke paryaaya bele yojane", 2014, Dr. Janardhana Gowda, Dr. M. B. Rajegowda, D.Sridhar, L.Nagesh and Soumya, D. V.
- "Havaamana aadhaaritha bele maahithi" 2014, Dr. Janardhana gowda, Dr. M. B. Rajegowda, D.Sridhar, L.Nagesh andSoumya, D.V.

T.V. Programmes Attended

- Effect of delay monsoon and contingent plan to farmers of Karnataka- TV Programme on Chandana at 6.30 PM. By Dr. N. A. Janardhana Gowda on 21.07.2014
- Delayed monsoon Dr. N. A. Janardhana Gowda25.06.2014
- Male Bele proramme on Samaya TV- Farmers interaction between 6.0 pm to 7.0

pm. Dr. N. A. Janardhana Gowda28.07.2014

Radio Talks given through AIR

- Land preparation and paddy cultivation practices for *Kharif* season. Dr. N. A. Janardhana Gowda25.04.2014
- Ragi varieties and cultivation practices for late *kharif* season. Dr. N. A. Janardhana Gowda06.08.2014
- Varieties of Pulses, oil seeds and production technology for late *kharif* and *rabi* season. Dr. N. A. Janardhana Gowda15.09.2014

Bijapur

Papers in Peer Reviewed Journals

- Venkatesh H., Chattannavar, S.N., Rajput, R. B and Hiremath, J.R. (2015). Weather in relation to Grey Mildew disease in Cotton at Dharwad, Karnataka, *Environment & Ecology*, **33**(4A):1667-1671.

Popular Articles Authored /Co-authored in Press and Magazines

- Alagundagi, S. C., Venkatesh, H., Surakod, V. S., Shirahatti, M. S., Hundekar, S. T and Kulkarni, S. N. (2014). “ಬರ ಮತ್ತು ನೆರೆ ನಿರ್ವಹಣಾ ಕ್ರಮಗಳು”(Drought and Flood Management Practices) in Kannada language released during inaugural function of “Krishi Mela - 2014” held on 27.09.2014.
- Venkatesh, H. (2014). “ಆಲಿಕಲ್ಲು ಮಳೆ ಮತ್ತು ಉತ್ತರ ಕರ್ನಾಟಕದ ರೈತರ ತೊಂದರೆಗಳು”(Hail storm and farmers problems in north Karnataka), Krishi Munnade, 27, pp 4-6.
- Venkatesh, H and Rajput, R. B. (2014). “ಸಸ್ಯ ಸಂರಕ್ಷಣೆಯಲ್ಲಿ ಹವಾಮಾನದ ಜ್ಞಾನವಿರಬೇಕು” (Knowledge of weather is necessary for plant protection), Popular article. Krishi Munnade, 28(1), pp 10-11.
- Venkatesh, H. (2015). Why look at the sky when you have weather forecast on your palm? UAS Dharwad in the forefront of service to the farmers through farmer-friendly weather forecasts and near real-time dissemination- A Success Story. Released at the “Krishi Mela - 2014” on 28.09.2014 in the August presence of H.E. Governor of Karnataka, Shri Vajubhai Vaalal.

Technical & Research Bulletins Edited / Co-edited

- Venkatesh, H., Sajjanar, G. M., Hiremath, J. R., Rajput, R, B., Bapuji Rao, B andRao, V.U.M. (2014). Agrometeorology of *rabi* sorghum of north Karnataka. AICRPAM, UAS, Dharwad.

Chatha/Jammu

Papers Presented in National and International Symposia / Seminars

- Sharma,C., Meenakshi, G and Khushu, M.K. (2014). Phenological variation and its relation with yield in wheat cultivars under normal & late sown conditions. In: National Symposium on "Natural Resource Management for Sustainable Hill Farming System for Livelihood Security", July 23-24,SKUAST,Jammu.

Dapoli

Papers Presented in National and International Symposia / Seminars

- Chavan, V. G., Thorat, T. N., Mohite, N. C., Chavan, S. A and Rajemahadik, V. A.(2014). Crop weather association of hybrid rice var. sahyadri–2 during *kharif* season. In: National seminar on "Technologies for sustainable production through climate resilient Agriculture",August 8-9,JNKVV, Jabalpur.
- Chavan, V. G., Thorat, T. N., Thorat, S. T., Mahadkar, U. V., Rajemahadik, V. A., Chavan, S. A and Mohite, N. C. (2014). Impact of weather variables on yield of hybrid rice under different growing environments in Konkan region of Maharashtra. In: International symposium on "New Dimensions in Agrometeorology for sustainable Agriculture, October 16-18, GBPUA&T, Pantnagar.
- Fadavale, U. S., Rajemahadik, V. A., Shetye, V. N., Chavan, V. G and Mahadkar, U. V. (2015). Effect of sowing time and methods of establishment on growth and yield of niger (Guizotia abyssinica Cass.) under Konkan condition of Maharashtra. In: International conference on "Natural Resource Management for Food Security and Rural Livelihood", February 10-13,New Delhi.

Popular Articles Authored /Co-authored in Press and Magazines

- Chavanand, V. G andMahadkar, U. V. (2014). Agromet advisory on crop management in cloudy weather condition, Agro-one newspaper on Sunday, 1st April.
- Chavanand, V. G and Mahadkar, U. V. (2014). Agromet advisory on crop and livestock management, Agro-one newspaper on Sunday, 9th October.
- Chavanand, V. G and Mahadkar, U. V. (2015). Agromet advisory on crop and livestock Management, Agro-one newspaper on Sunday, 11th January.
- Chavanand, V. G and Mahadkar, U. V. (2015). Agromet advisory on crop livestock management, Agro-one newspaper on Sunday, 21st February.
- Award
- Awarded by Mumbai Varuttapatra Lekhak Sangh, Mumbai with "RATNAGIRI BHUSHAN" for Education during the year 2014-15.

Faizabad

Papers in Peer Reviewed Journals

- Kumar, A., Singh, A. K., Kumar, A., Maurya, P and Tripathi, C. K. (2015). Effect of sowing dates and varieties on growth, yield attributing character and yield on chickpea of eastern Uttar Pradesh. *Int. J. Ag. Sc.,* **6**(1): 44-52.
- Singh, P. K and Singh, A. K. (2014). Effect of sowing dates and irrigation schedules on yield and quality of Indian mustard (Brassica juncea). *J. Soil Water Conserv.,* **13**(3): 270-73.

Papers Presented in National and International Symposia / Seminars

- Kumar, A., Singh, A.K., Kumar, A., Tripathi, P., Mishra, A.N and Mishra, S.R. (2014). Identification of congenial climatic condition for optimum yield of chickpea under prevailing weather condition in eastern Uttar Pradesh. In:International symposium on "New Dimensions in Agrometeorology for sustainable Agriculture", October 16-18, GBPUA&T, Pantnagar.
- Kumar, A., Tripathi, P., Singh, K.K., Yadav, S.B., Kumar, A., Singh, A.K., Mishra, S.R and Singh, P.K. (2014). Potential production constraints of rice in eastern Uttar Pradesh under rice wheat cropping system.In: International symposium on "New Dimensions in Agrometeorology for sustainable Agriculture", October 16-18, GBPUA&T, Pantnagar.
- Kumar, N., Singh, A.K., Mishra, S.R., Singh, A., Pandey, J and Singh, G. (2014). Performance and evaluation of chickpea crop through crop simulation model DSSAT. In: International symposium on "New Dimensions in Agrometeorology for sustainable Agriculture", October 16-18, GBPUA&T, Pantnagar.
- Mishra, A., Singh, A.K., Tripathi, P., Kumar, A., Mishra, A.N and Mishra, S.R. (2014). Identification of congenial climatic condition of optimum yield of chickpea under prevailing weather condition in eastern U.P. In: International symposium on "New Dimensions in Agrometeorology for sustainable Agriculture", October 16-18, GBPUA&T, Pantnagar.
- Singh, A., Mishra. S. R., Singh. A.K., Krishna Deo and Kumar, N. (2014).Micro climatic study of Pigeoan pea (Cajanas cajan L) millap genotype under variable weather conditions. In: International symposium on "New Dimensions in Agrometeorology for sustainable Agriculture", October 16-18, GBPUA&T, Pantnagar.
- Singh, A. K and Mishra, S. R. (2014). Response of chickpea cultivation at varying soil temperature & soil moisture under different weather condition. In: International symposium on "New Dimensions in Agrometeorology for sustainable Agriculture", October 16-18, GBPUA&T, Pantnagar.

- Singh, G., Singh, A.K., Tripathi, P and Patil, S.R. (2014). Study of perception of climate awareness constraints and impact of weather forecast in Bahraich district (U.P.). In: International symposium on "New Dimensions in Agrometeorology for sustainable Agriculture", October 16-18, GBPUA&T, Pantnagar.

- Singh, S.P and Mishra, S.R. (2014). Performance and evaluation of DSSAT model of rice genotypes under different weather conditions. In: International symposium on "New Dimensions in Agrometeorology for sustainable Agriculture", October 16-18, GBPUA&T, Pantnagar.

Technical & Research Bulletins Edited / Co-edited

- Tripathi, P., Singh, A. K and Rao, V. U. M. (2014). "Compendium of perception of farmers of eastern Utter Pradesh (U.P) on climate change". AICRPAM, NDUA&T, Faizabad.

Books / Book Chapters / Training Program Lecture Notes

- Vijaya Kumar, P., Rao, V. U. M., Tripati, P and Venkateswarlu, B. (2014). The effect of rice transplanting date on rice-wheat cropping system performance in the middle IGP of India – A simulation study using APSIM. In: "". (Eds.). pp. 75-85. (Central Research Institute for Dry land Agriculture, Hyderabad)

Radio Talks

- Dr. A.K. Singh delivered T.V. talk at Doordarshan Kendra Lucknow on 27, August 2014.

- Dr. P. Tripathi delivered 2 Radio talks at Akashvani Faizabad and Gorakhpur and three T.V. talks at Lucknow and Gorakhpur Doordarsan during reporting year.

- Dr. P. Tripathi delivered T.V. talk at DoordarshanKendra Lucknow/ Gorakhpur.

Hisar

Papers Presented in National and International Symposia / Seminars

- Mohan Singh and Diwan Singh. (2014). Climatic variability over eastern Thar desert. In: National Seminaron "Reorientation of Agricultural Research to Ensure National Food Security",January 6-7, CCSHAU, Hisar.

- Surender Singh., Parvinder Kumar and Diwan Singh. (2014). Farmer's perception on regional climate change and variability: A case study form Sirsa district of Haryana. In: National Seminar on "Reorientation of Agricultural Research to Ensure National Food Security", January 6-7, CCSHAU, Hisar.

Technical & Research Bulletins Edited / Co-edited

- Diwan Singh., Singh, M., Singh, R., Singh, S andRao, V. U. M.(2014). "Climatic variabilty and its periodicity at Hisar (Haryana)".AICRPAM, CCSHAU, Hisar.
- Diwan Singh., Mehnaj, T.A.,Singh, M., Singh, S., Singh, R andRao, V. U. M.(2015). "El Nino and SW Monsoon Dynamics vis-à-vis Agricultural Productivity in Haryana, India".AICRPAM, CCSHAU, Hisar.

Radio Talks

- 'Barsat Ki Kami me *kharif* ki faislon ki dekhbhal'- Radio talk on 10 August 2014.

Kanpur

Radio / TV Talks

- T.V. talks on the topic of weather based management on *kharif*, *rabi* and zaid crops were delivered by Dr. A. P. Dubey in Akash vani, Local and National news channels by weekly or weekly.

Popular Articles Authored/Co-Authored in Press and Magazines

- डा0 अनिरुद्ध दुबे, मौसम के अनुसार माह जून मे की जाने वाली कृषि सस्य क्रियाए (मई 2014) । कृषि चिंतन, प्रसार शिक्षा एवं प्रशिक्षण ब्यूरों, कृषि विभाग 9, विश्वविद्यालय मार्ग, लखनऊ।
- डा0 अनिरुद्ध दुबे, मौसम के अनुसार माह जूलाई मे की जाने वाली कृषि सस्य क्रियाए (जून 2014) । कृषि चिंतन, प्रसार शिक्षा एवं प्रशिक्षण ब्यूरों, कृषि विभाग 9, विश्वविद्यालय मार्ग, लखनऊ। प्र0 सं0– 2–5।
- डा0 अनिरुद्ध दुबे, मौसम के अनुसार माह अगस्त मे की जाने वाली कृषि सस्य क्रियाए (जूलाई 2014)। कृषि चिंतन, प्रसार शिक्षा एवं प्रशिक्षण ब्यूरों, कृषि विभाग 9, विश्वविद्यालय मार्ग, लखनऊ। प्र0 सं0– 2–5।
- डा0 अनिरुद्ध दुबे, मौसम के अनुसार माह सितम्बर मे की जाने वाली कृषि सस्य क्रियाएं(अगस्त 2014)। कृषि चिंतन, प्रसार शिक्षा एवं प्रशिक्षण ब्यूरों, कृषि विभाग 9, विश्वविद्यालय मार्ग, लखनऊ। प्र0 सं0– 2–5।
- डा0 अनिरूद्ध दुबे, मौसम के अनुसार माह अक्टूबर मे की जाने वाली कृषि सस्य क्रियाएं(सितम्बर 2014)। कृषि चिंतन, प्रसार शिक्षा एवं प्रशिक्षण ब्यूरों, कृषि विभाग 9, विश्वविद्यालय मार्ग, लखनऊ। प्र0 सं0– 2–5।

Kovilpatti

Technical & Research Bulletins Edited / Co-edited

- Solaimalai, A., Subbulakshmi, S., Jawahar, D andRao, V.U.M. (2014). "Long term rainfall analysis for Virudhunagar district of Tamil Nadu". AICRPAM, ARS, Kovilpatti.

Ludhiana

Papers in Peer Reviewed Journals

- Gill, K. K., Ritu Babuta., Navneet Kaur., Prabhjyot Kaur and Sandhu, S. S. (2014). Thermal requirement of wheat crop in different agroclimatic regions of Punjab under climate change scenarios. *Mausam,* **65**(3):417-424

- Jalota, S. K., Vashisht, B. B., Harsimran Kaur., Samanpreet Kaur andPrabhjyotKaur. (2014). Location specific climate change scenario and its impact on rice and wheat in central Indian Punjab. *Agr. Syst.,* **131**: 77-86.

- Jupinder Kaur., Gosal, S. K and Prabhjyot Kaur. (2014). Effects of climate change on plant associated microbial communities and enzyme activities. *Afr. J.Microbiol. Res.,* **8** (33): 3087-3093.

- Prabhjyot Kaur., Ashu Bala., Sandhu, S. S and Gill, K. K. (2015). Yield gap in rice and wheat productivity in different agroclimatic zones of Punjab. *J. Agrometeorol,* **17**(1): 127-130.

Papers Presented in National and International Symposia / Seminars

- Chahal, B., Gill, K. K and Prabhjyot Kaur. (2015). Development of weather based weekly thumb rules for potential productivity of mustard crop in Punjab. In: National Symposium on "Weather and Climate Extremes", February 15-18, Chandigarh.

- Harleen Kaur and Prabhjyot Kaur. (2014). Effect of elevated temperature regimes on phenological development and heat unit requirements of rice (Oryza sativa L.) cultivars. In: International Symposium on "New-Dimensions in Agrometeorology for Sustainable Agriculture", October 16-18, GBPUA&T, Pantnagar.

- Harleen Kaur and Prabhjyot Kaur. (2015). Changes in the incidence of extreme of temperature events in Punjab – A case study. In: National Symposium on "Weather and Climate extremes", February 15-18, Chandigarh.

- Navneet Kaur., PrabhjyotKaur and Harpreet Singh. (2015). Climate change: Causes and impacts. Proceedings of the In: National Seminar on "Geospatial Technology in Natural Resource Management", March 17-18, Punjab Remote Sensing Center, Ludhiana.

- Navneet Kaur., Prabhjyot Kaur and Harpreet Singh. (2015). Projected climate change under diverse scenarios in different agroclimatic areas of Indian Punjab. In:National Symposium on "Weather and Climate extremes", 15-18 February, Chandigarh.

- PrabhjyotKaur., Sandhu, S. S., Gill, K. K and Harpreet Singh. (2015). Annual, seasonal and monthly climate variability analysis in Punjab. In: National Symposium on "Weather and Climate Extremes", 15-18 February,Chandigarh.

Books / Book chapters / Training Program Lecture Notes

- PrabhjyotKaur. (2014). "Climate Change in Punjab". 1stEds. () pp.

Mohanpur

Papers in Peer Reviewed Journals

- Banerjee, S., Mukherjee, A., Das, S and Saikia, B. (2014). Adaptation strategies to combat climate change effect on rice and mustard in eastern India. *Mitigation. Adapt. Strateg. Glob. Chang.*, DOI: 10.1007/s11027-014-9595-y.

- Saikia, B and Banerjee, S. (2014). Radiation balance and radiation pattern study over Brasicca campestris var yellow sarson in Gangetic West Bengal. *J. Agrometeorol.*,**16**(2): 178-182.

Papers Presented in National and International Symposia / Seminars

- Bairagya, M. D., Jha Chakraborty, A., Banerjee, S., Mukherjee, A and Sarkar, S. (2014). Impact of energy and water resources on yield of summer rice under varying transplanting dates in coastal West Bengal. In: International Symposium on "New Dimensions in Agrometeorology for Sustainable Agriculture",October 16-18, GBPUA&T, Pantnagar.

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Palampur

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- Rakesh Kumar., Saurabh Sharma., Ramesh, K., Vijaylata Pathania and Rajendra Prasad. (2014). Irradiance stress and plant spacing effect on growth, biomass and quality of wild marigold (*Tagetes minuta L.*) – an industrial crop in western Himalaya. *J. Essent. Oil Res.*, 348-358.

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Radio Talks / TV Interview

- Every week Agro advisory Broad casted + 2 own programme
- Regular weather forecasting on early morning and on every Wednesday at 07:30 pm in Gaonkari mandal on AIR Solapur regarding Agro-Advisory Service.

Thrissur

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- डॉ. सम्पत लाल मूंदडा, डॉ.एस. के. इन्टोदिया, डॉ. एन. एस. सोलंकी, डॉ. धर्मपाल सिंह एवं सोनतारा कलिटा 2015. लाभकारी टिकाउ खेती के मत्रं, विश्व कृषि संचार, मई–2015.
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Staff position at cooperating centers during 2014

Centre	Positions Sanctioned and Filled (F) / Vacant (V)					
	Agrometeo-rologist	Junior Agronomist	Senior Technical Assistant	Meteorological Observer	Field Assistant	Junior Clerk
Akola	F	–	–	F	F	–
Anand	F	F	V	F	F	F
Anantapur	V	F	F	F	F	F
Bangalore	F	V	F	F	F	F
Bhubanesh-war	F	–	–	V	F	–
Bijapur	F	–	–	F	V	–
Chatha/ Jammu	F	–	–	F	F	–
Dapoli	F	–	–	F	F	–
Faizabad	F	F	F	F	F	F
Hisar	V	F	V	F	F	F
Jabalpur	V	F	F	V	V	V
Jorhat	F	–	–	V	V	–
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	F	F	F	F	F	F
Ranichauri	F	V	V	V	V	V
Samastipur	F	–	–	V	F	–
Solapur	F	V	F	F	V	F
Thrissur	F	–	–	V	V	–
Udaipur	F	–	–	V	V	–
Total posts sanctioned	**25**	**12**	**12**	**25**	**25**	**12**
Total posts filled	**22**	**9**	**9**	**16**	**15**	**10**

F= Filled, V= Vacant,

All India Coordinated Research Project on Agrometeorology

Centre-wise and Head-wise RE allocation (Plan) for the year 2014-15

(in Rupees)

Sl. No	Name of the center	Pay & allow.	TA	RC	NEH	TSP (100 %)			Total ICAR Share
						Works/ Contin-gency	Equip	IT	
1	Akola	1600000	20000	100000		0	0	0	1720000
2	Anand	2180000	30000	120000		0	0	0	2330000
3	Ananta-pur	1650000	30000	120000		0	0	0	1800000
4	Banga-lore	3600000	35000	120000		0	0	0	3755000
5	Bhubane-swar	1400000	30000	120000		1550000	400000	150000	3650000
6	Bijapur	1620000	20000	120000		0	0	0	1760000
7	Chatha	1200000	30000	120000		0	0	0	1350000
8	Dapoli	1900000	25000	100000		0	0	0	2025000
9	Faizabad	2700000	50000	120000		0	0	0	2870000
10	Hisar	2000000	30000	100000		0	0	0	2130000
11	Jabalpur	1500000	30000	100000		700000	350000	100000	2780000
12	Jorhat	1800000	30000	100000	1500000	1300000	200000	200000	5130000
13	Kanpur	2000000	25000	100000		0	0	0	2125000
14	Kovil-patti	2600000	35000	100000		0	0	0	2735000
15	Ludhiana	3235000	30000	120000		0	0	0	3385000
16	Mohan-pur	2400000	30000	100000		0	0	0	2530000
17	Palam-pur	1800000	20000	100000		400000	375000	100000	2795000
18	Parbhani	1500000	25000	100000		0	0	0	1625000
19	Raipur	1800000	30000	120000		1500000	400000	100000	3950000
20	Ranchi	3200000	30000	100000		700000	0	50000	4080000
21	Ran-ichauri	200000	20000	100000		0	0	0	320000

22	Sa-mastipur	1370000	30000	100000		0	0	0	1500000
23	Solapur	2080000	40000	120000		750000		125000	3115000
24	Thrissur	1265000	25000	180000		0	0	0	1470000
25	Udaipur	2400000	20000	100000		100000	375000	75000	3070000
	Total	**490,00,000**	**7,20,000**	**27,80,000**	**15,00,000**	**70,00,000**	**21,00,000**	**9,00,000**	**640,00,000**


XIII Biennial Workshop on AICRP of Agrometeorology
5-7 NOVEMBER 2014
Organized by
Indira Gandhi Krishi Vishwavidyalaya
Krishak Nagar, Raipur (Chhattisgarh)
In Collaboration with Central Research Institute for
Dryland Agriculrure (CRIDA) Hyderabad
Dept. of Agrometeorology
College of Agriculture, IGKV Raipur
Director Research Services
IGKV Raipur

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In Collaboration w
earch Institute for Dryland
स्वर माला रायपुर
DR. S.K. PATIL
SHRI BRIJMOHAN AGRAWAL

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XIII Biennial Workshop of AICRP on Agrometeorology
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