AICRPAM

All India Coordinated Research Project on

Agrometeorology

Annual Report - 2011-12

ICAR

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Central Research Institute for Dryland Agriculture

(Indian Council of Agricultural Research)

Santoshnagar, Hyderabad, India.

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All India Coordinated Research Project on Agrometeorology

Annual Report - 2011 - 2012

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PREFACE

Weather and climate are the prime risk factors impacting on farming performance and its management. Variability in climate and increasing frequency of extreme weather events such as severe droughts, floods, or temperature shocks often strongly impede sustainable farming development. Increasing variability in the monsoon onset, its advancement and amount of rainfall in the recent years is creating ambiguity in the decision makers in preparation of suitable agricultural plans and placing the agricultural production and food security at stake.

In this background, the All India Coordinated Research Project on Agrometeorology (AICRPAM) has played significant role in identifying regions vulnerable to climate change, development of adaptation strategies and dissemination of weather-based agro advisories. To further strengthen the ongoing activities AICRPAM has carried out a commendable job in establishing 100 Automatic Weather Stations in KVKs spread across the country to develop and disseminate the Agromet advisories at block level. It is also executing the research on impacts of temperature and change in rainfall patterns on crops through modelling, contingency crop plans for different rainfall situations, development of weather indices at different growth stages of important crops; development of weather insurance products, decision support systems for crop management and forewarning of pests and diseases through its Network Centres located in different agroclimatic zones of the country.

The efforts of the Cooperating Centres of AICRPAM in pursuing the assigned research programs are commendable. However, much has to be done in areas of amalgamation of on-farm activities undertaken by farmers that have been directly aided by Agrometeorological systems. Associated information to develop user friendly products, and integrated approaches based on remote sensing data, GIS and modelling to assess meteorological hazards and extreme event impacts to agriculture and evaluation of potential risk useful for insurance organisations are highly desirable. There is a need for strong linkages between AICRPAM, AICRPDA and NICRA to improve the production and minimize the climate risks in dryland agriculture for sustainable production. The Annual Progress Report of 2011-12 contains results of research carried out during *Rabi* 2010-11, *Kharif* 2011and *Rabi* 2011-2012 across 25 centres in the country. I take this opportunity to congratulate the efforts made by the Agrometeorologists of all the centres and the Project Coordinator, Dr. VUM Rao and his staff at the Coordinating Unit in compilation of this valuable report.

B. Venkateswarlu

(B.VENKATESWARLU)
Director

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The sincere efforts of the Agrometeorologists of all 25 Cooperating Centres in conducting the experiments as per technical program and in bringing out useful results made it possible to compile a comprehensive report. Help rendered by my colleagues, Drs. B.Bapuji Rao, P. Vijaya Kumar, AVM Subba Rao and Rajkumar Dhakar in compiling the results of the reports is highly appreciated. My sincere appreciation to Shri IR Khandgonda and Ms. Pallavi in preparing necessary diagrams and typing the manuscript. Also the continuous support from Shri A. Mallesh Yadav is acknowledged.

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1. INTRODUCTION

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

The Technical Program for the years 2011-13 for different centres of the Project and a common core program decided for all the centres are given below with emphasis on location-specific research needs.

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
- Water balance studies, FAO CROPWAT
- Characterization of onset of monsoon and LGP
- 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 events and their impacts on agriculture including livestock, poultry and fisheves

2) Crop-Weather Relationships (All Centres)

Centre	*Kharif* Crop(s)	*Rabi* Crop(s)
Akola	Soybean	Chickpea
Anand	Groundnut	Wheat
Anantapur	Groundnut	Chickpea
Udaipur	Maize	Wheat
Bangalore	Pigeonpea, Groundnut	Mango
Bijapur	Pigeonpea	Sunflower
Bhubaneswar	Rice	——
Dapoli	Rice	Mango
Faizabad	Pigeonpea	Chickpea
Hisar	—-	Mustard, Wheat
Jabalpur	Soybean	Chickpea
Jorhat	Rice	Potato
Kanpur	Rice	Wheat
Kovilpatti	—	Blackgram, Greengram, Maize
Ludhiana	Rice	Mustard, Wheat
Mohanpur	Rice	Mustard, Potato
Palampur	Tea	Wheat
Parbhani	Cotton, Soybean	——
Raipur	Rice	Wheat
Rakh Dhiansar	Maize	Wheat
Ranchi	Rice	Wheat
Ranichauri	Finger millet	Wheat
Samastipur	Rice	Wheat, Winter Maize
Solapur	Pearlmillet	Sorghum, Chickpea
Thrissur	Coconut, Rice	Vegetables (Cauliflower)

3) Crop Growth Modeling

Compilation of phenology for every crop species, yield and soil properties etc.

Crop	Lead Centres	Associated Centre
Wheat	Ludhiana	Palampur, Anand, Jabalpur, Rakh Dhiansar, Samastipur, Ranchi, Hisar, Kanpur, Ranichauri
Rice	Raipur	Mohanpur, Samastipur, Dapoli, Faizabad, Trissur, Bhubaneswar, Jorhat, Ranchi, Kanpur, Jabalpur
Groundnut	Anand	Anantapur, Bangalore

4) Weather Effects on Pests and Diseases

Centre	Crop(s)	Pests/diseases
Anand	Mustard	Aphids, Sawfly, Powdery Mildew, Rust
Anantapur	Groundnut	Leaf miner
Akola	Soybean	Spodoptera
Bangalore	Groundnut	Late leaf spot
	Redgram	Heliothis
Bijapur	Grapes Pomegranate	Powdery mildew, Downy mildew, Anthracnose, Bacterial Leaf Blight
Bhubaneswar	Rice	Blight, BPH
Faizabad	Pigeonpea	Pod borer
Jabalpur	Chickpea	Heliothis
Kovilpatti	Cotton Blackgram	Aphids, Mealy bug Powdery mildew
Ludhiana	Rice Cotton	Stem borer Sucking pests
Mohanpur	Mustard Potato	Aphids, Alternaria blight Early blight
Palampur	Rice Mustard	Blast Aphids
Parbhani	Cotton	Mealy bug, Pink boll warm
Ranchi	Rice	BLB, Stem borer, Blast
Ranichauri	Apple Amaranthus	Apple scab Leaf webber
Solapur	Sunflower	Leaf eating caterpiller
Raipur	Rice	Stemborer, Leaf blast

Centre	Crop(s)	Pests/diseases
Kanpur	Rice	Blight, Stem borer
	Wheat	Rust
Thrissur	Vegetables	Leaf spot
Udaipur	Mustard	Aphids
Hisar	Cotton	Leaf curl virus
	Wheat	Karnal Bunt
Rakh Dhiansar	Mustard	Aphids

5) Agromet Advisory Services (All Centres)

- Monitoring of crop and weather situation, twice in a week and its updation on website
- Development of contingency plans for aberrant weather situations
- 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 2011

A brief account on the rainfall with its onset, withdrawal and distribution during monsoon and post monsoon seasons of the year 2011 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 monsoon onset over Andaman Sea out delayed by about 10 days than its normal date (20th May). However, it set over Kerala 3 days prior to its normal date (1st June). Monsoon further advanced rapidly and covered entire Kerala, Tamil Nadu and Goa, most parts of Karnataka and some parts of south Andhra Pradesh by 5th June. However, during 6th – 10th June, there was a short pause in the further advance of monsoon along the west coast. Though there had been certain periods of subdued rainfall activity during the season in different spatial and temporal scales, there were no all India break monsoon conditions during this year.

The eastern branch of monsoon advanced over northeastern states, with a delay of nearly 5 days. Subsequently, there had been a rather steady advance during 15th – 26th June over the northwest Bay of Bengal and its gradual west-northwestward movement. This synoptic situation caused the monsoon to cover most parts of the country except western parts of Rajasthan and north Gujarat state. The southwest monsoon covered the entire country by 9th July, 6 days earlier than its normal date of 15th July.

Rainfall distribution during monsoon season

The southwest monsoon season (June to September) rainfall of 2011 for the country as a whole and the four broad geographical regions are as follows:

Region	Actual (mm)	Long Period Average (LPA) (mm)	Actual % of LPA	Coefficient of Variation (CV) % of LPA
All- India	899.9	887.5	101	10.7
Northwest (NW) India	654.8	615.0	107	18.9
Central India	1073.6	975.5	110	15.0
South Peninsula	715.2	715.5	100	15.3
Northeast (NE) India	1233.6	1438.3	86	12.6

The southwest monsoon season (June to September) rainfall over the country as a whole was 101% of LPA. Seasonal rainfall over NE India was 14% below its LPA. Seasonal rainfall over south Peninsula was normal. However, the seasonal rainfall over Central India and NW India were 10% and 7% above their LPA values, respectively.

The table 2.1 shows that cumulative season rainfall from 1st June to 30th September 2011 was excess in 7 meteorological subdivisions (21% of the total area of the country), normal in 26 meteorological subdivisions (71% of the total area of the country) and deficient in 3 meteorological subdivisions (8% of the total area of the country). Three subdivisions (Arunachal Pradesh, Assam & Meghalaya, and NMMT) from the eastern part of the country recorded deficient rainfall.

Table 2.1: IMD Sub-divisional rainfall (mm) during monsoon season (June – September) – 2011

S. No.	Centre	Actual	Normal	Excess or deficit	Deviation (%)
1	Andaman & Nicobar Islands	2300.4	1682.5	618	37
2	Arunachal Pradesh	1342.7	1768.0	-425	-24
3	Assam & Meghalaya	1226.9	1792.8	-566	-32
4	Naga, Mani, Mizo, Tripura	1087.9	1496.9	-409	-27
5	Sub-Hima. West Bengal	1865.1	2006.2	-141	-7
6	Gangetic West Bengal	1394.7	1167.9	227	19
7	Orissa	1099.9	1149.9	-50	-4
8	Bihar Plateau (Jharkhand)	1101.5	1091.9	10	1
9	Bihar Plains	1057.6	1027.6	30	3
10	East Uttar Pradesh	820.2	897.6	-77	-9
11	Plains of West Uttar Pradesh	724.0	769.4	-45	-6
12	Uttaranchal	1454.3	1229.1	225	18
13	Haryana, Chandigarh & Delhi	379.2	466.3	-87	-19
14	Punjab	459.3	491.9	-33	-7
15	Himachal Pradesh	732.5	825.3	-93	-11
16	Jammu & Kashmir	520.9	534.6	-14	-3
17	West Rajasthan	401.2	263.2	138	52
18	East Rajasthan	828.6	615.8	213	35

S. No.	Centre	Actual	Normal	Excess or deficit	Deviation (%)
19	West Madhya Pradesh	1079.1	876.1	203	23
20	East Madhya Pradesh	1221.4	1051.2	170	16
21	Gujarat (Daman Dadar & N. Haveli)	901.3	901.0	0	0
22	Saurashtra & Kutch	719.4	473.5	246	52
23	Konkan & Goa	3716.3	2914.3	802	28
24	Madhya Maharashtra	761.1	729.3	32	4
25	Marathwada	632.8	682.9	-50	-7
26	Vidarbha	897.5	954.6	-57	-6
27	Chhattisgarh	1220.4	1147.3	73	6
28	Coastal Andhra Pradesh	665.5	755.2	-90	-12
29	Telangana	537.8	581.1	-43	-7
30	Rayalaseema	379.1	398.3	-19	-5
31	Tamil Nadu & Pondicherry	298.9	317.2	-18	-6
32	Coastal Karnataka	3775.9	3083.8	692	22
33	North int. Karnataka	440.1	506.0	-66	-13
34	South int. Karnataka	640.2	660.0	-20	-3
35	Kerala	2215.1	2039.6	176	9
36	Lakshadweep	1014.1	998.5	16	2

From monthly distribution, the rainfall during June to September except July was above the normal LPA. In June, excess rainfall was observed over two subdivisions from Maharashtra (Konkan & Goa and Marathawada) and many subdivisions of northern and west coast of the country. However, deficit rainfall was observed over 5 subdivisions from the eastern part of the south Peninsula, Kerala, Lakshadweep, North eastern India and scanty rainfall was observed over 2 sub-divisions of Gujarat state. Rainfall activity picked up in August. In August, except for 4 sub-divisions from northeast India and 2 sub-divisions (West UP, Haryana, Chandigarh & Delhi) from north India, the remaining sub-divisions received normal or excess rainfall (14 normal and 16 excess). In September, excess rainfall was observed over subdivisions along the west coast, island subdivisions and many subdivisions from northwest India and east part of the central India. Most of the remaining subdivisions from south Peninsula, northeast India (3 subdivisions) and north India (2 subdivisions) received deficient or scanty rainfall. Thus, rainfall over north east India was deficient throughout the season.

From all India cumulative weekly rainfall anomaly distribution, it was noticed that anomalies were negative from the second week of July to fourth week of August, while positive in the last week of August and remained so till the end of the season.

Flood Situations

Part of the states which faced flood situations were West Bengal, Bihar, Kerala, Karnataka, Himachal Pradesh, Madhya Pradesh, Rajasthan, Gujarat, Jammu & Kashmir, Maharashtra, Goa, Assam, Andhra Pradesh, Uttarakhand, Chhattisgarh and Orissa.

Withdrawal of Monsoon

Analogous to last three years, there was delay in the withdrawal of southwest monsoon during 2011 also. The withdrawal from west Rajasthan started on 23rd September (a delay of more than 3 weeks). Subsequently, it withdrew from most parts of northwest India and some parts of west Uttar Pradesh on 26th September and from most parts of Uttar Pradesh, some parts of Madhya Pradesh and some more parts of Gujarat state on 28th September. On 30th Sept. it further withdrew from some more parts of Uttar Pradesh and Madhya Pradesh. Finally, it withdrew from the entire country on 24th October, 2011

Post-Monsoon (October- December) 2011

In the sub-divisionalwise Post- Monsoon (October – December) season rainfall, it is noticed that rainfall was excess in 1 sub-division, *viz.* Tamil Nadu & Pondicherry, normal in 6 sub-divisions *viz.* Konkan & Goa, Coastal Karnataka, Rayalaseema, South Interior Karnataka, Kerala and Lakshadweep; deficit in 5 sub-divisions *viz.,* Jammu & Kashmir, Madhya Maharashtra, North Interior Karnataka, Coastal Andhra Pradesh and Andaman & Nicobar Island and 24 sub-divisions received either scanty/ no rain.

During the year, 3 out of 25 centers of the All India Coordinated Research Project on Agrometeorology, viz., Akola, Kovilpatti and Parbhani received deficit rainfall; 11 centers viz., Dapoli, Faizabad, Hisar, Ludhiana, Mohanpur, Palampur, Ranchi, Ranichauri, Raipur, Thrissur and Udaipur received excess rainfall and remaining 11 centers received normal rainfall (Table 2.2).

Table 2.2: Annual rainfall (mm) at AICRPAM centers during 2011

S.No.	Center	Actual	Normal	% Departure
1	Akola	516	813	-37
2	Anand	878	853	3
3	Anantapur	466	514	-9
4	Bangalore	809	925	-13
5	Bhubaneswar	1373	1498	-8
6	Bijapur	564	594	-5
7	Dapoli	4932	3529	40
8	Faizabad	1198	1002	20
9	Hisar	528	451	17
10	Jabalpur	1858	1209	54
11	Jorhat	1979	2148	-8
12	Kanpur	846	879	-4
13	Kovilpatti	466	752	-38
14	Ludhiana	1284	733	75
15	Mohanpur	2001	1665	20
16	Palampur	2503	1498	67
17	Parbhani	678	963	-30
18	Ranchi	2457	1458	69
19	Ranichauri	1506	1232	22
20	Raipur	1468	1150	28
21	Rakh Dhiansar	1153	1114	4
22	Samastipur	1428	1235	16
23	Solapur	762	723	5
24	Thrissur	3462	2822	23
25	Udaipur	952	601	58

3. AGROCLIMATIC CHARACTERIZATION

For agricultural development planning, adequate assessment of the agroclimatic resources is an essential pre-requisite. Failures or poor results of agricultural development projects may arise largely due to failure to properly assess and classify agroclimates. Agroclimatic classification is used in selecting appropriate agroclimatic boundaries between suitable, marginally suitable and unsuitable zones for each crop / variety. Thus, agroclimatic classification with sharply defined goals and based upon well chosen criteria can serve a very useful purpose. The analysis carried out by different centers on the agroclimatic characterization is reported hereunder:

AKOLA

The daily rainfall data during the southwest monsoon season for the period 1998-2011 (14 years) from 107 talukas of Vidarbha region were analyzed and the spatial distribution of normal rainfall during southwest monsoon season is depicted in fig. 3.1 The monsoonal rainfall varied from 668.1 mm in Bhuldana district on the western side to 1354.8 mm in Gadchiroli district on the eastern side, in the central parts it ranged from 911.3 to 988.5 mm. The normal monsoonal rainfall for the entire region is 993.3 mm with a standard deviation of 255.2 mm and a CV of 25%. The 10 year moving average rainfall for the period 1901-2010 (Fig. 3.2) indicated a non-distinct 10 year cyclic pattern in the rainfall and monsoon rainfall was below normal during the recent decade (2000-2010). The variability in rainfall at taluka level was found to be more on the western parts as compared to eastern parts. Analysis was also carried out to identify trends in extreme rainfall events. Mann-Kendall test was used to detect the trend in each taluka. The results revealed that (Table 3.1) by and large 67 to 88% of the talukas of the region across different categories of rainfall events did not show statistically significant trend. In the remaining talukas, more number of talukas showed significant increasing trend with respect to 25-50 mm (27) and 50-75 mm (22) single day rainfall events as compared to > 75 mm and heavy rainfall events. On the contrary, more number of talukas showed significant decreasing trend in case of heavy rainfall events and > 100 mm rainfall events (Fig. 3.3). Thus, significant change was observed in terms of increase in 25-50 and 50-75 mm rainfall events and decrease of heavy (maximum) and > 100 mm rainfall events.

Table 3.1: Trends in extreme rainfall events as per cent of total no. of talukas in Vidharbha region

Statistic	Rainfall events and number of talukas				
	25-50 mm	50-75 mm	75-100 mm	>100mm	Heavy
Non Significant	72	74	83	88	67
Sig(0.1)	07	09	06	07	10
Sig(0.01)	20	13	09	01	14
Sig(0.05)	08	10	08	09	15
+ Increasing trend	27	22	13	03	08
-Decreasing trend	08	10	10	14	31

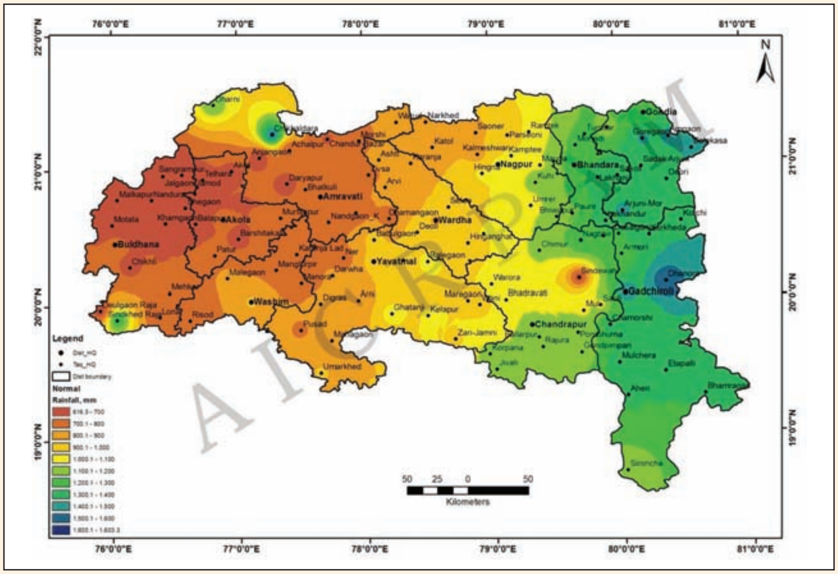


Fig.3.1: Spatial distribution of normal monsoonal rainfall over Vidarbha region

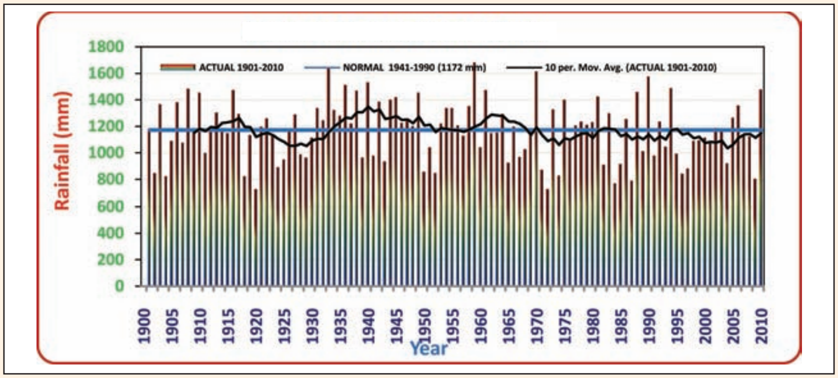


Fig. 3.2: Temporal variability in southwest monsoon rainfall over Vidarbha region

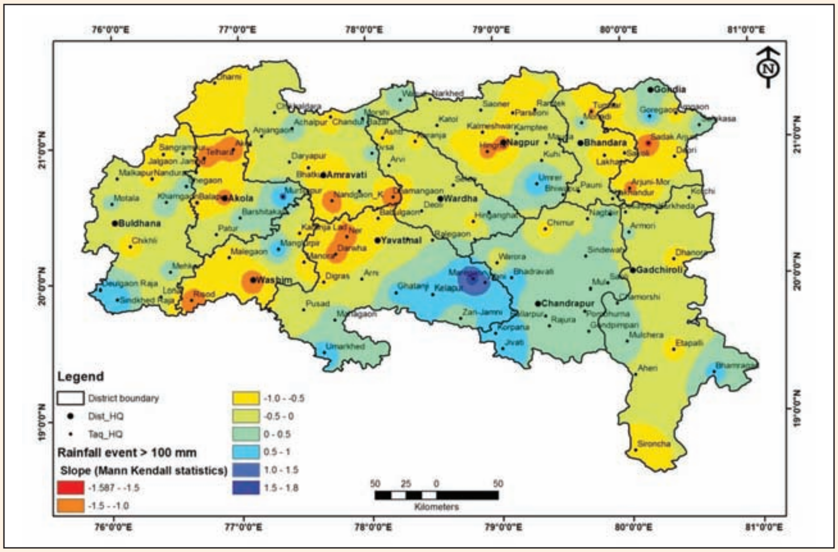


Fig.3.3: Spatial distribution of trends in extreme (> 100 mm) rainfall events during SW monsoon season over Vidarbha

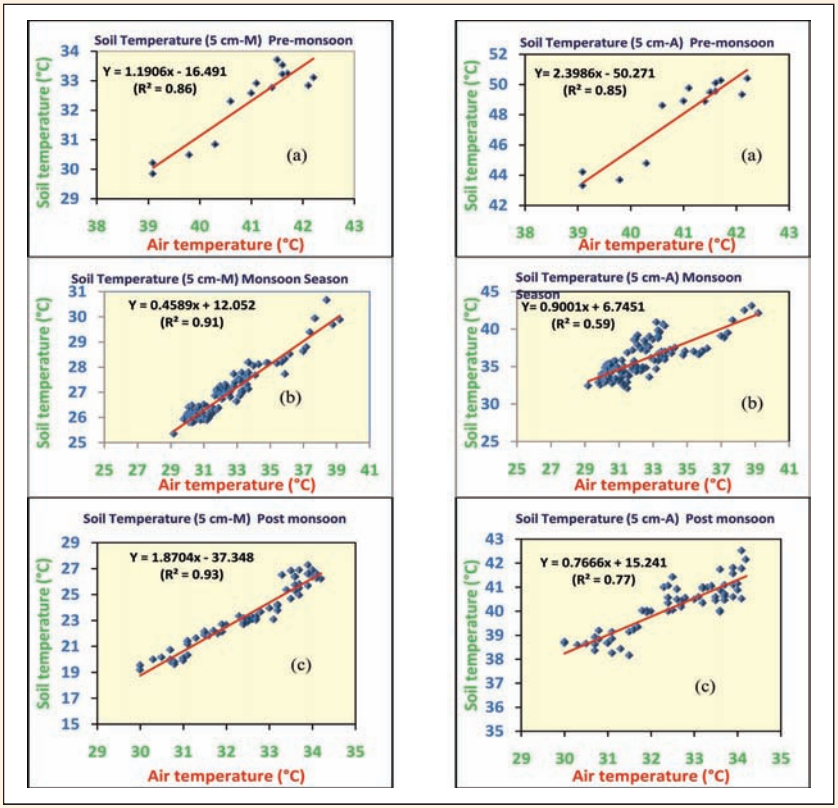


Fig. 3.4: Association between morning (M) and noon (A) soil temperatures at 5 cm depth with air temperature during (a) Pre-monsoon; (b) Monsoon and (c) Post-monsoon seasons

Seasonal trend in soil temperature

Data on soil temperature at 5 cm depth for the period 1986-2011 were analyzed and compared with air temperature to develop a predictive model. Diurnal variations in soil temperature were found to have a close association with corresponding air temperatures. Soil temperature data recorded during pre-monsoon, monsoon and post-monsoon were regressed on concurrent air temperature data for two different times in the day and the resultant association are presented in fig. 3.4 a to c. It could be noticed from the figure that during all the seasons the temperature in the morning hours was closely related to air temperature compared to the afternoon temperature. The relations derived from the present study can be used to predict soil temperature at 5 cm depth, which plays a major role in the seed germination, root growth, microbial activity, etc.

ANAND

The spatial distribution of mean monthly rainfall during the south west monsoon season (June-September) was analysed using long term daily rainfall data and maps are prepared on monthly basis and presented in fig. 3.5. The highest normal rainfall (mm) during June (300-500 mm), July (560 - 640 mm) and August (300 - 420 mm) months

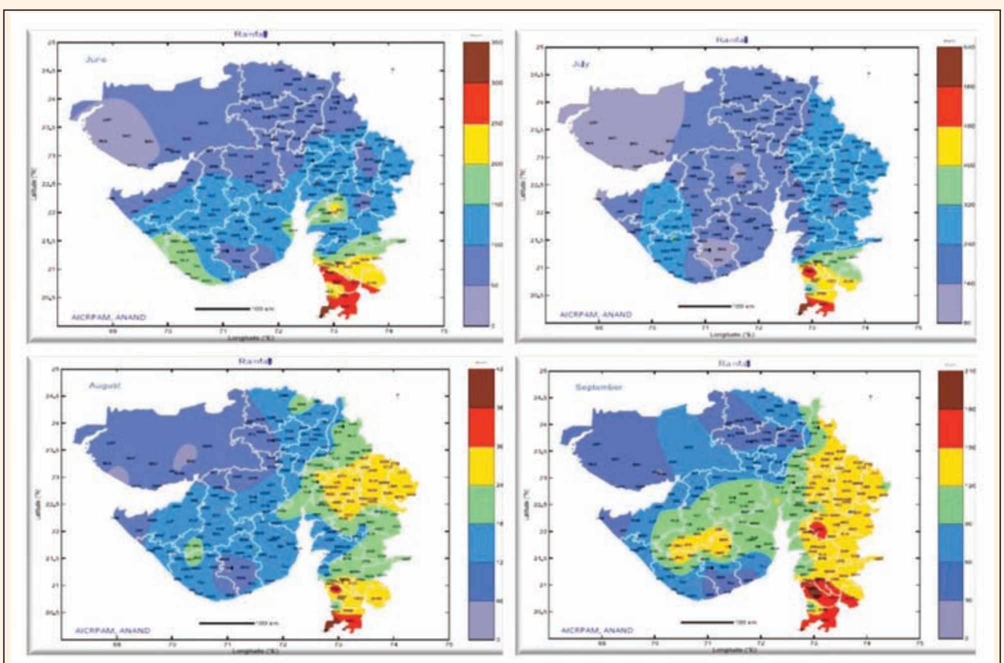


Fig.3.5: Normal rainfall of June, July, August, September months in different talukas of Gujarat state

was noticed over Umargam Tehsil of Valasad district. During the month of June, lowest rainfall was recorded over western region of Kutch district. During July, central and western parts of Kutch district and some talukas of Amreli, Surendranagar districts and Dwarika taluka in Jamnagar district recorded the lowest rainfall. Bhachau and Anjar talukas of Kutch recorded lowest rainfall during the month of August. The parts of Valsad, Surat, Tapi, Navasari, Ahwa, Bharuch and Vadodara districts had highest rainfall in the range of 150 to 180 mm and parts of Kutch, Banaskantha, Patan, Mehasana and Jamnagar districts had lowest rainfall (0 to 30 mm) during September.

BIJAPUR

Meteorological drought frequency under different categories of severity in seven districts of Karnataka viz., Bagalkot, Belgaum, Bijapur, Dharwad, Gadag, Haveri and Uttara Kannada over the period of 1991-2000 in comparison to base period of 1961 - 1990 was analysed and results are presented in fig 3.6. Spatial distribution of meteorological drought frequency is presented in fig.3.7.

It could be noticed from fig. 3.7 that frequency of non-drought years increased in Dharwad and Bagalkot districts, while it decreased in Bijapur, Havery and Uttara Kannada districts. Frequency of mild drought years increased in Bagalkot, Bijapur,

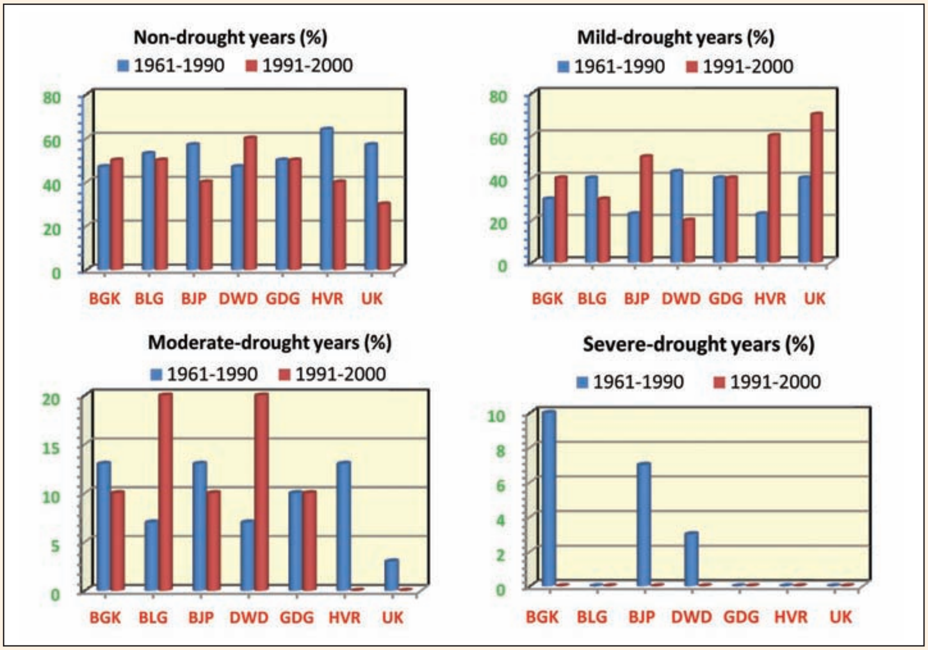
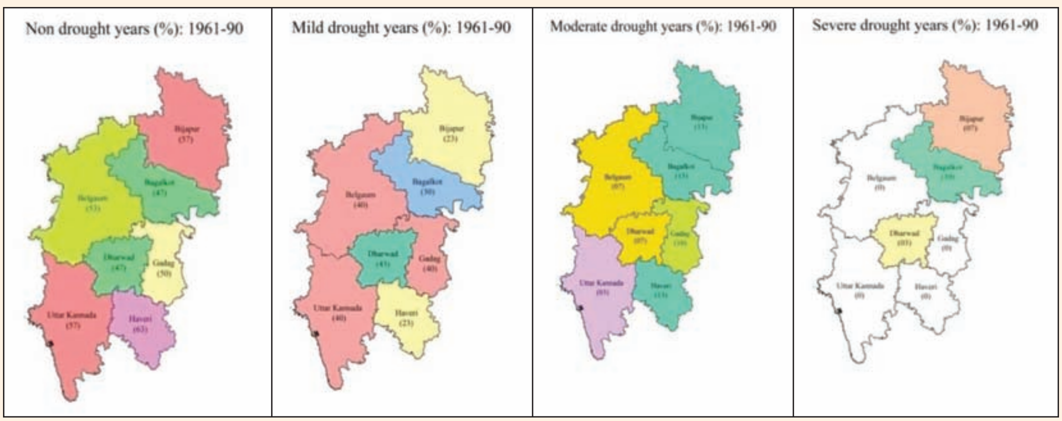


Fig. 3.6: District wise percentage occurrence of drought years during 1991-2000 in comparison with base period (1961-90)

Haveri and Uttara Kannada districts, but decreased in Belgaum and Dharwad districts; frequency of moderate drought years increased in Belgaum and Dharwad districts, but decreased in Haveri district; frequency of severe droughts decreased in Bagalkot, Bijapur and Dharwad districts. During the recent decade, frequency of severe drought years increased considerably in both Bijapur and Dharwad districts.

The frequency of non-drought years and moderate drought years decreased, but mild and severe drought years increased in Bijapur district. On the other hand, the frequency of non-drought years, moderate and severe drought years increased, but mild drought years decreased at Dharwad.

Base period (1961-1990)



During 1991-2000

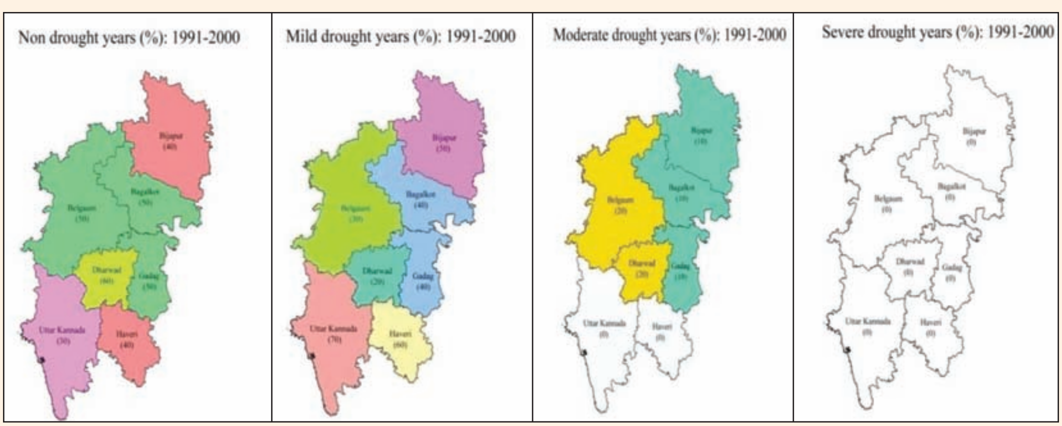


Fig. 3.7: Spatial distribution of frequency of drought categories at Bijapur

DAPOLI

The behaviour of the rainfall pattern at Dapoli during the southwest monsoon seasons of 2010 and 2011 was studied against the normal (mean of 1972-2011) rainfall pattern and the resultant comparison is presented in fig. 3.8. During the year 2011, though the monsoon started on a high positive note there was a subdued rainfall activity during 25th to 28th standard meteorological weeks (SMW) and again during 32 to 34 SMW. During 2010, the onset of monsoon was delayed by almost three weeks and in the later part of both the seasons the monsoon behaved erratically. The rainfall received during 46th SMW of 2010 altered the flowering behaviour of mango (alphonso) and cashew favouring vegetative growth in place of reproductive parts.

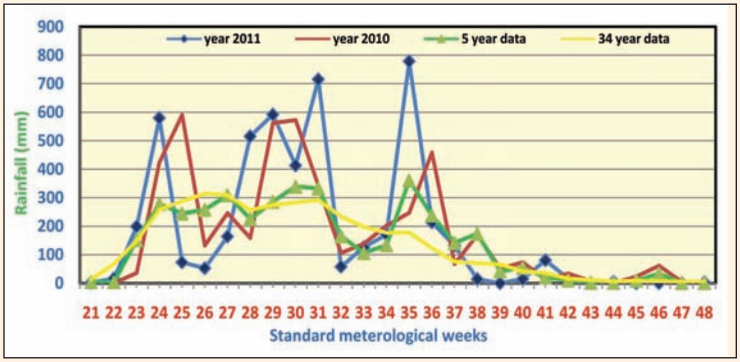


Fig.3.8: A comparison of rainfall pattern during 2010 and 2011 against normal at Dapoli

FAIZABAD

The onset and withdrawal of monsoon for different zones of Eastern UP was studied to detect any shift during the recent period (1994-2011) compared to base period (1976-1994) by considering average of both the time periods. The results of the comparative study (Table 3.2) showed a reduction in the duration of the rainy season by 4 days in

Table 3.2: Shift in onset and withdrawal of monsoon over eastern U.P.

Agroclimatic Zones	1976-94 Onset of monsoon	1976-94 Withdrawal of monsoon	1976-94 Length of rainy season (days)	1994-2011 Onset of monsoon	1994-2011 Withdrawal of monsoon	1994-2011 Length of rainy season (days)	Change in the rainfall pattern
North Eastern Plain Zone	13-15 June	4-6 Oct	111-113	17-19 June	26-28 Sept	102-103	(-9 days) early
Eastern Plain Zone	17-19 June	19-21 Sept	94-95	24-26 June	26-28 Sept	95-96	Normal
Vindhyan Zone	21-23 June	25-27 Sept	96-97	27-29 June	26-28 Sept	92-93	(-4 day) early
Total annual rainfall (mm) 1382 mm			**101 (-8 days)**	**1231 mm (-51 mm)**		**96 (-13 days)**	**(-5days) early**

Vindhyan Zone (VZ) and by 9 days in North Eastern Plain Zone (NEPZ). The onset in both the zones was delayed and in NEPZ zone the monsoon withdrew early causing a reduction in the length of the rainy season. The mean annual rainfall decreased by 3.7% (51 mm) during the recent period and the number of rainy days also decreased by 5%.

KOVILPATTI

The weather parameters recorded at ARS, Kovilpatti on daily basis for the period 1951-2010 were converted into annual and then into decadal means and were compared to identify any changes on a decadal time scale (Table 3.3). The decade 1971-80 recorded highest (782 mm) and 1991-2000 recorded lowest (701.1 mm) rainfall and the number of rainy days remained almost consistent across the decades with a mean of 43 rainy days. Minimum temperature showed a decreasing trend till 1991-2000 but maximum temperature hovered around 35 ± 0.5°C across the decades.

Table 3.3 : Changes in the weather parameters (Annual mean values) in different decades at Kovilpatti

Year	Max T (°C)	Min T (°C)	Rainfall (mm)	Rainy days	RH (%)
1951-1960	34.7	23.3	714.4	45	77.45
1961-1970	34.7	23.2	729.7	43	79.40
1971-1980	35.2	22.7	782.0	41	80.00
1981-1990	35.5	22.5	725.1	40	80.20
1991-2000	35.4	20.8	701.1	44	70.50
2001-2010	35.0	22.5	771.7	44	81.60
Average	**35.1**	**22.5**	**737.3**	**43**	**80.00**

The daily meteorological data recorded at different locations *viz.*, Ambasamuthiram, Aruppukkotai, Srivilliputtur, Killikulam and Madurai were analysed for identifying weather parameters that have undergone drastic changes on a pentad basis (Table 3.4 a to e). The variability in mean annual rainfall was found to be highest at Madurai followed by Killikulam and least variability was noticed at Ambasamuthiram. Among different weather parameters studied excluding evaporation, least variability was noticed in maximum temperature and highest in relative humidity. The open pan evaporation data recorded at two locations showed high variability among different pentads.

Table 3.4a: Pentad-wise averages of annual weather parameters at Ambasamuthiram

Year	Max. T (°C)	Min. T (°C)	RF (mm)	Rainy days	RH (%)
1985-89	34.6	23.1	816.5	50	77.2
1990-94	33.5	24.0	951.9	51	78.4
1995-99	34.1	22.0	868.2	54	77.0
2000-04	33.9	22.6	867.0	47	80.0
2005-09	35.0	20.7	896.9	43	85.5
Average	**34.2**	**22.5**	**880.1**	**49**	**79.6**
CV (%)	**1.7**	**5.5**	**5.6**	**8.5**	**4.3**

Table 3.4b: Pentad-wise averages of annual weather parameters at Aruppukkotai

Year	Max. T (°C)	Min. T (°C)	RF(mm)	Rainy days	RH (%)
1985-89	35.5	21.2	765.9	43	76.4
1990-94	34.8	22.9	846.0	45	74.4
1995-99	34.8	23.0	913.1	50	83.2
2000-04	35.1	23.3	754.2	49	80.0
2005-09	34.9	23.2	839.4	42	79.7
Average	**35.0**	**22.7**	**823.7**	**46**	**78.7**
CV (%)	**0.8**	**3.8**	**7.8**	**7.7**	**4.3**

Table 3.4c: Pentad-wise averages of annual weather parameters at Srivilliputtur

Year	Max. T (°C)	Min. T (°C)	Rainfall (mm)	Relative humidity (%)	Sunshine hours/day	Evaporation (mm/day)
1986-90	32.82	21.50	844.6	81.41	6.63	10.6
1991-95	33.91	22.27	744.4	86.58	6.67	7.7
1996-00	34.66	24.09	844.1	88.65	7.36	5.9
2001-05	34.79	23.33	831.2	86.63	6.61	12.3
Average	**34.05**	**22.79**	**816.1**	**85.81**	**6.82**	**9.6**
CV (%)	**2.6**	**5.0**	**5.9**	**3.6**	**5.3**	**30.0**

Table 3.4d: Pentad-wise averages of annual weather parameters at Killikulam

Year	Max. Temp (°C)	Min. Temp (°C)	Rainfall (mm)	Relative humidity (%)	Wind speed (km/hr)	Sunshine (hours/ day)	Evaporation (mm/day)
1990 - 1994	32.3	22.9	698.3	77.3	5.7	5.2	4.4
1995 - 1999	34.2	24.8	651.3	76.1	7.7	7.2	7.2
2000 - 2004	34.8	24.6	594.9	80.1	6.0	6.2	7.2
2005 - 2010	34.4	26.5	852.4	83.4	6.3	6.2	7.1
Average	**33.9**	**24.7**	**699.2**	**79.2**	**6.4**	**6.2**	**6.4**
CV (%)	**3.2**	**5.9**	**15.8**	**4.1**	**13.8**	**13.1**	**21.6**

Table 3.4e: Pentad-wise averages of annual weather parameters at Madurai

Year	Max. Temp (°C)	Min. Temp (°C)	Relative humidity (%)	Rainfall (mm)
1975 - 79	33.3	23.8	76.8	923.4
1980 - 84	33.8	24.2	73.7	768.7
1985 - 89	35.0	24.4	74.7	742.5
1990 - 94	33.6	23.9	45.5	834.4
1995 - 99	33.7	24.5	62.0	1063.3
2000 - 04	34.2	24.4	74.1	674.1
2005 - 10	33.4	23.5	75.4	1020.5
Average	**33.8**	**24.1**	**68.8**	**860.9**
CV (%)	**1.7**	**1.5**	**16.6**	**16.9**

MOHANPUR

The mean monthly rainfall data for the period 1960-2010 at Mohanpur (Fig.3.9) showed that the rainfall distribution is unimodal with July being the wettest month followed by August. The months of May and October also showed the possibility of receiving good quantum of rainfall.

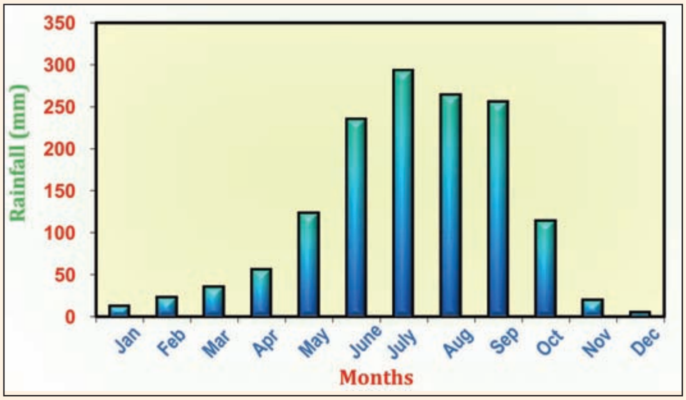


Fig. 3.9: Rainfall pattern at Kalyani (1960-2010) at Mohanpur

Trends in long term annual rainfall

The long term annual rainfall data (1960-2011) of Mohanpur was analysed using Mann Kendall trend tool kit to detect any change in the rainfall pattern. The results indicated that there is a slight increasing trend (4.09 mm/year) in the annual rainfall, which is statistically non-significant. Mohanpur receives an annual rainfall of 1448 mm with a variability of 24.7%. The variability in rainfall pattern presented in fig. 3.10 indicated that during 1982 to 1994 period the annual rainfall was below the long term mean and again during 2008, 2009 and 2010 the rainfall was far below normal. The five year moving average rainfall pattern for the period 1960-2006 (Fig. 3.10) also indicated that the rainfall during 1982-1994 was below the normal rainfall.

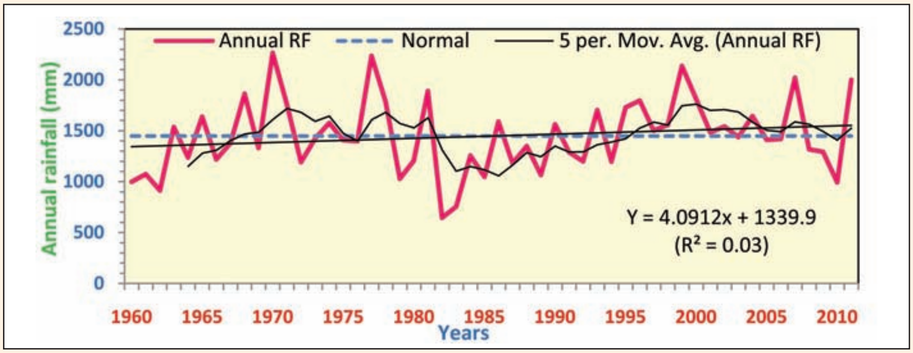


Fig. 3.10: Annual rainfall and five year moving average rainfall trend for the period 1960-2011 at Mohanpur

Onset of monsoon

The date of onset of monsoon for the period 1997-2011 at Mohanpur is presented in fig. 3.11. The normal date of onset of monsoon over lower Gangetic plains of West Bengal is around 8th June and at Mohanpur the normal onset date is 9th June. The data presented in the figure 3.11 indicated that in the recent years there is some variability in the dates of onset of monsoon and the coefficient of variation is about 5%. This variability determines the length of the crop growing season as in some years the onset. As the onset of monsoon ranged from 145 to 174 Julian day.

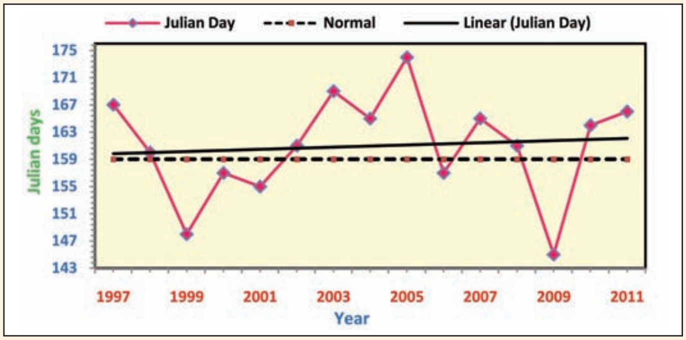


Fig. 3.11: Variation in date of onset of monsoon for the period of 1997-2011 at Mohanpur

Since the October rainfall is crucial for *kharif* and *rabi* crops, the rainfall pattern during the month of October for the period 1960-2010 at Mohanpur is also studied and presented in fig. 3.12. It can be noticed that the rainfall during this month is highly variable and in the recent years (1999-2008) it was above the long term average.

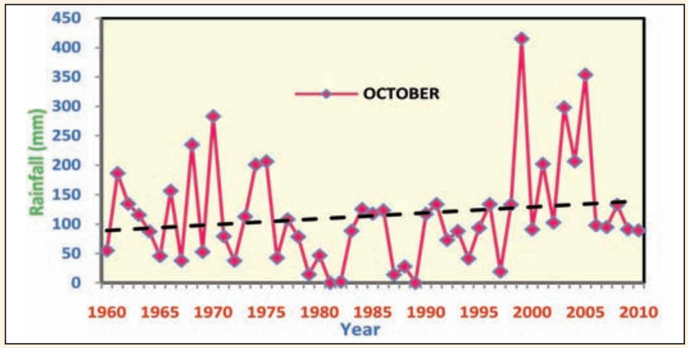


Fig. 3.12: Rainfall in the month of October during 1960-2010 at Mohanpur

PARBHANI

In order to determine the rainfall variability in Marathwada region, the monthly rainfall data for Nanded, Tuljapur, Parbhani, Latur and Aurangabad locations was arranged into five year (Pentad) average values. Monthly rainfall amounts in different pentads (Fig. 3.13 a to e) showed that during the month of May only Nanded received

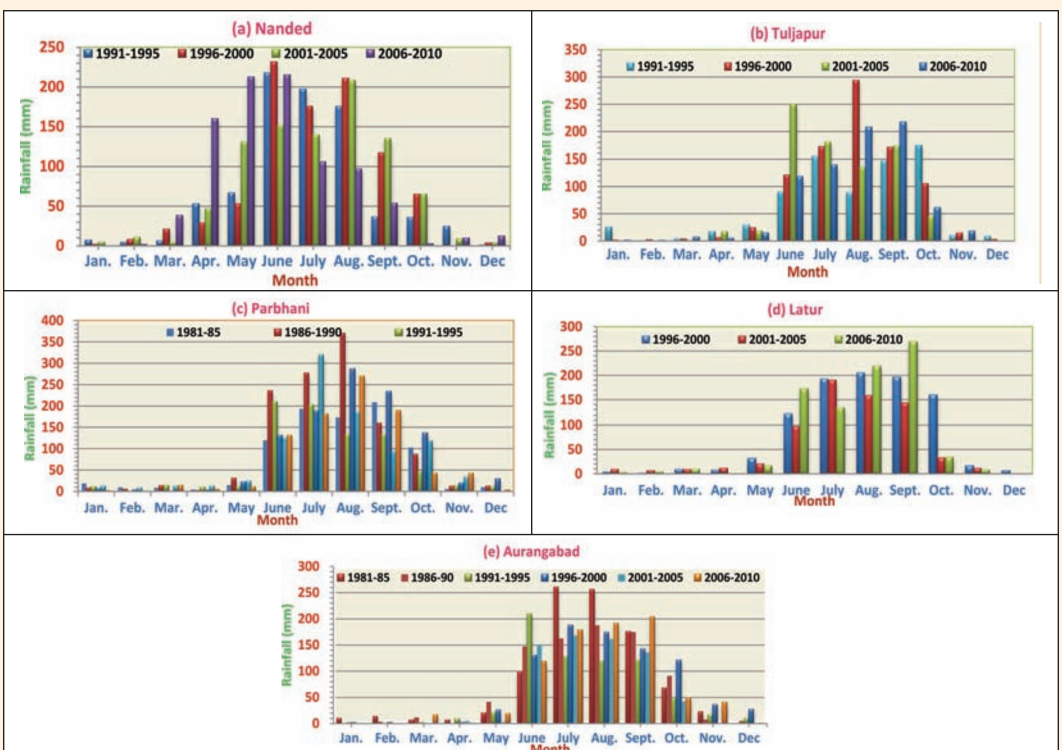


Fig. 3.13 a to e: Monthly rainfall pattern (five year mean) at different locations of Marathwada

considerable amount of rainfall with 50 mm being the lowest. The rainfall during June is highly variable at Tuljapur, Parbhani and Aurangabad. The July rainfall is also highly variable at Nanded, Parbhani and Aurangabad. The rainfall during August and September is highly variable at all the locations.

RANCHI

The behaviour of the southwest monsoon of 2011 over Santhal Paragana, North Chotanagpur, Palamau and Kolhan regions in comparison with decadal rainfall was studied and the results are presented in fig. 3.14 a to d. In Santhal Paragana region, the southwest monsoonal rainfall was above normal during the last two decades and only the post monsoon season rainfall showed a decline during 1991-2000. The 2011 rainfall exceeded the normal by 52%. The decadal mean rainfall during 1961-70 and 2001-2010 was below normal and during the remaining three decades, rainfall was above normal in north Chotanagpur region. However, in Palamau region this is not the case. The decadal mean rainfall showed large variability. Rainfall during southwest monsoon period in 2011 over north Chotanagpur region has exceeded the normal rainfall by 83% with 72 rainy days and over Palamau region exceeded by 32%. The variability in the decadal rainfall over Kolhan region is within ± 4% showing some consistency compared to other regions. The southwest monsoonal rainfall in this region was also above the normal by 10.6%.

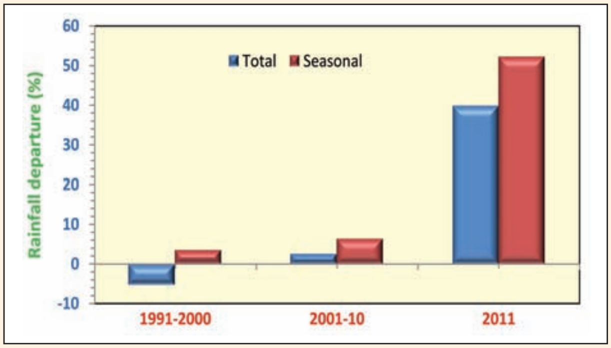


Fig. 3.14 a: Decadal variability in rainfall over Zone IV (Santhal Pargana region)

In North Chotanagpur region, the decade 1991-2000 can be considered as the best period for crop production point of view as total as well as seasonal rain increased by 16.5 % and 19.7 %, respectively (Fig. 3.14 b). Though the seasonal and annual rainfall during1961-70 period was below normal, the rainfall during the later

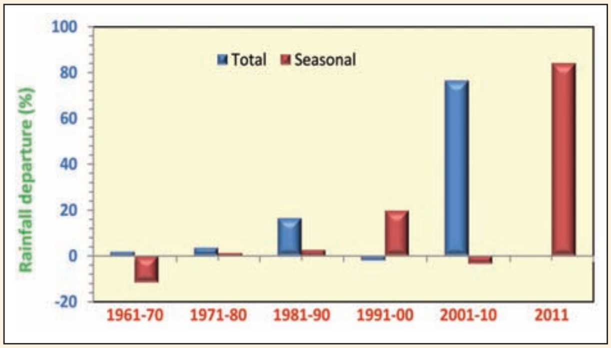


Fig. 3.14 b: Decadal variability in rainfall over Zone IV (North Chotanagpur region)

three decades was above normal. The year 2011 was the wettest with a 76.2% and 83.1% increase compared to normal in annual and seasonal rainfall, respectively. Though the rainfall during 2011 was heavy (1396.7 mm), the rain events were same as that of normal (72 days) which indicates more number of extreme rainfall events during 2011.

In Palamau region, a large variability in decadal rainfall was observed and the 1961-70 decade registered large departure in total (-11.3%) and seasonal (-11.6%) rainfall. The subsequent two decades experienced above normal rainfall and during 2011 this region also experienced far above normal rainfall with a positive departure of 25.6% in the annual and 31.8% in the seasonal rainfall (Fig 3.14 c).

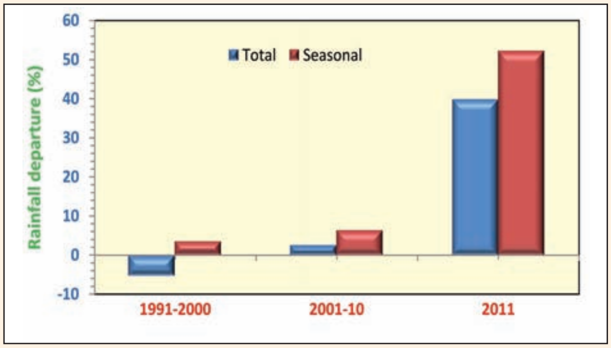


Fig. 3.14 c: Decadal variability in rainfall over Zone V (Palamu region)

In Kolhan region, more consistent rain was observed across various decades and variability in rainfall was ± 4 % among the decades (Fig 3.14 d). Both total and seasonal rainfall was marginally low during 2001-10 and marginally above normal during 1991-2000 decade.

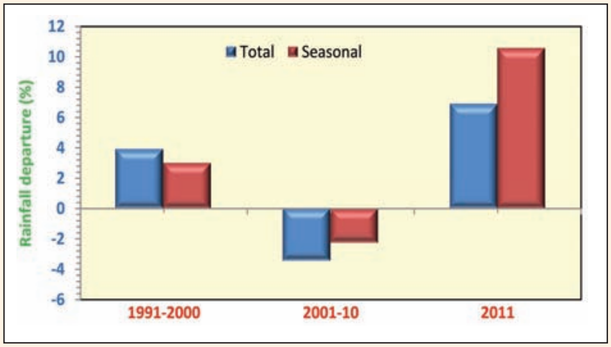


Fig.3.14 d: Decadal variability in rainfall over Zone VI (Kolhan region)

THRISSUR

The onset of southwest monsoon over Kerala is vital in the sense it determines the start of the agricultural operations and mobilization of resources at the farm level. The onset of monsoon over west coast of Kerala is taken as the commencement of the rainy season in India. The date of onset of monsoon over Kerala for 142 years (1870-2011) was analysed and the deviations from the normal date of onset are presented in fig. 3.15.

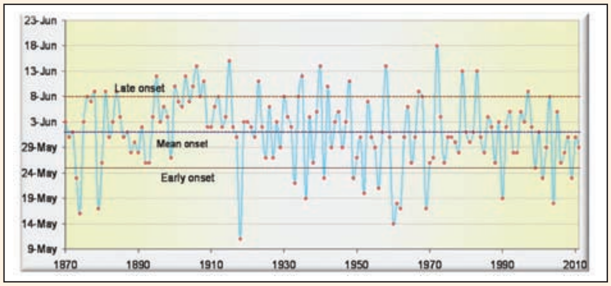


Fig. 3.15: Date of onset of monsoon over Kerala during 1870 to 2011

The onset of monsoon was early on 23rd May, 18th May and 21st May in 2009, 2004 and 2001, respectively. It was late in 2003 (13th June) and 1983(11th June), followed by 1997 (9th June), 1995(8th June) and 2005(8th June). All the remaining years fell under normal onset of monsoon years (June 1 ± 7 days). If the monsoon is early (before 25th May), the total monsoon rainfall is likely to be below normal or normal. Similarly, it is also true when the monsoon was delayed (on or after 8th June).

Onset and behaviour of monsoon at Thrissur

The date of onset of monsoon and rainfall pattern during pre-monsoon and early part of the monsoon season at Thrissur for the period 1998 to 2011 was studied in depth by considering the five day mean rainfall amounts during 15 days on either side of the normal onset of monsoon and the resultant comparison is presented in table 3.5. The data has been segregated further as early onset (prior to 1st June) and late onset (on 1st June and beyond) to study the impact of date of onset on the rainfall pattern and presented in table 3.6 and 3.7. The data clearly shows that the rainfall during both pre-monsoon and early part of monsoon season was higher during the years when monsoon was set prior to 1st June.

Table 3.5: Pentad rainfall (16th May to 15th June) in mm at Thrissur from 1980 to 2011

Year	16-20 May	21-25 May	26-31 May	1-5 June	6-10 June	11-15 June	Date of onset of monsoon
1980	3.0	85.3	10.3	220.7	96.1	20.0	1st June
1981	19.4	0.0	105.8	301.6	121.8	255.2	30th May
1982	120.7	12.8	27.4	65.0	122.8	79.0	30th May
1983	3.5	3.2	0.9	0.0	26.1	90.6	11th June
1984	20.4	0.0	19.0	193.0	54.2	186.1	31st May
1985	26.4	48.8	128.0	127.7	62.0	121.9	28th May
1986	7.0	0.4	31.0	0.8	27.5	108.2	3rd June
1987	4.1	73.9	0.8	165.4	30.0	157.1	2nd June
1988	0.0	8.0	159.2	154.6	177.2	27.7	26th May
1989	28.8	30.6	12.9	11.7	128.9	183.0	3rd June
1990	81.2	141.0	160.7	23.9	66.8	178.9	28th May
1991	0.0	36.3	17.2	240.6	241.3	217.2	2nd June
1992	45.0	0.6	3.6	11.4	306.7	168.5	5th June
1993	31.9	5.4	89.4	23.4	228.2	208.1	28th May
1994	0.8	2.1	28.3	247.9	177.0	188.4	29th May
1995	12.0	0.6	2.0	2.8	67.7	253.0	8th June

Year	16-20 May	21-25 May	26-31 May	1-5 June	6-10 June	11-15 June	Date of onset of monsoon
1996	16.2	1.0	10.2	1.4	41.2	116.1	3rd June
1997	0.0	0.0	28.0	103.2	30.2	48.0	9th June
1998	88.0	11.0	0.4	37.6	52.1	68.4	2nd June
1999	44.4	169.6	137.3	65.1	127.8	141.7	24th May
2000	45.2	18.6	48.5	86.4	305.5	46.9	1st June
2001	2.0	72.8	52.3	36.6	171.5	227.0	21st May
2002	325.3	2.8	44.6	110.6	40.0	209.5	1st June
2003	26.8	0.0	2.0	0.5	58.9	52.9	13th June
2004	115.3	97.2	51.8	351.9	126.5	114.8	18th May
2005	0.0	0.0	67.4	54.4	60.9	44.9	8th June
2006	84.8	55.6	520.3	57.5	2.2	37.4	26th May
2007	0.0	19.6	141.1	1.4	92.3	177.4	28th May
2008	0.3	1.6	6.6	30.1	140.6	93.4	31st May
2009	41.8	101.9	26.0	86.3	151.9	26.9	23rd May
2010	46.5	1.0	32.1	24.7	16.4	307.5	31st May
2011	0.0	3.2	82.1	254.0	135.5	122.7	29th May

Table 3.6: Rainfall distribution during pre-monsoon season

Year	16-20 May	21-25 May	26-31 May	1-5 June	6-10 June	11-15 June	Date of onset of monsoon
1980	3	85.3	10.3	220.7	96.1	20	1st June
1983	3.5	3.2	0.9	0	26.1	90.6	11th June
1986	7	0.4	31	0.8	27.5	108.2	3rd June
1987	4.1	73.9	0.8	165.4	30	157.1	2nd June
1989	28.8	30.6	12.9	11.7	128.9	183	3rd June
1991	0	36.3	17.2	240.6	241.3	217.2	2nd June
1992	45	0.6	3.6	11.4	306.7	168.5	5th June
1995	12	0.6	2	2.8	67.7	253	8th June
1996	16.2	1	10.2	1.4	41.2	116.1	3rd June
1997	0	0	28	103.2	30.2	48	9th June
1998	88	11	0.4	37.6	52.1	68.4	2nd June
2000	45.2	18.6	48.5	86.4	305.5	46.9	1st June
2002	325.3	2.8	44.6	110.6	40	209.5	1st June
2003	26.8	0	2	0.5	58.9	52.9	13th June
2005	0	0	67.4	54.4	60.9	44.9	8th June
Mean	**40.3**	**17.6**	**18.7**	**69.8**	**100.9**	**119.0**	

Table 3.7: Rainfall distribution during early part of monsoon season

Year	16-20 May	21-25 May	26-31 May	1-5 June	6-10 June	11-15 June	Date of onset of monsoon
1980	3	85.3	10.3	220.7	96.1	20	1st June
1981	19.4	0	105.8	301.6	121.8	255.2	30th May
1982	120.7	12.8	27.4	65	122.8	79	30th May
1984	20.4	0	19	193	54.2	186.1	31st May
1985	26.4	48.8	128	127.7	62	121.9	28th May
1988	0	8	159.2	154.6	177.2	27.7	26th May
1990	81.2	141	160.7	23.9	66.8	178.9	28th May
1993	31.9	5.4	89.4	23.4	228.2	208.1	28th May
1994	0.8	2.1	28.3	247.9	177	188.4	29th May
1999	44.4	169.6	137.3	65.1	127.8	141.7	24th May
2001	2	72.8	52.3	36.6	171.5	227	21st May
2004	115.3	97.2	51.8	351.9	126.5	114.8	18th May
2006	84.8	55.6	520.3	57.5	2.2	37.4	26th May
2007	0	19.6	141.1	1.4	92.3	177.4	28th May
2008	0.3	1.6	6.6	30.1	140.6	93.4	31st May
2009	41.8	101.9	26	86.3	151.9	26.9	23rd May
2010	46.5	1	32.1	24.7	16.4	307.5	31st May
2011	0	3.2	82.1	254	135.5	122.7	29th May
Mean	**37.4**	**43.6**	**104.0**	**120.3**	**116.2**	**146.7**	

The rainfall pattern and its intra-seasonal distribution at Thrissur during the period 2001 to 2011 is presented in table 3.8. The year 2007 being the wettest in the period studied followed by 2011. Of the 11 years data considered, rainfall in 7 years was below the normal value.

Table 3.8: Intra-seasonal rainfall distribution at Thrissur from 2001 to 2011

Year	Monthly rainfall (mm)				Total	% change from normal
	June	July	August	September		
2001	676.2	477.7	256.2	206.1	1616.2	-24.7
2002	533.5	354.2	506.6	124	1518.3	-29.2
2003	570.6	492.6	490.1	53.7	1607	-25.1
2004	786.0	369.6	386.9	208.8	1751.3	-18.4
2005	711.4	727.5	346.5	416.1	2201.5	2.6
2006	608.6	519	550.6	522.2	2200.4	2.5
2007	826.5	1131.9	549.7	765.9	3274	52.6
2008	636.7	416.3	321.9	314.2	1689.1	-19.6
2009	565.0	985.8	421.4	276.0	2248.2	-14.4
2010	700.4	552.0	224.1	326.7	1803.2	-6.3
2011	799.6	588.2	713.8	435.2	2536.8	21.1

UDAIPUR

Long-term rainfall data (1973-2010) were analyzed to work out seasonal distribution of rainfall and rainy days in different districts of Western Rajasthan (Table 3.9). The analysis indicated that Nagaur district is the wettest district in western Rajasthan followed by Churu considering the annual as well as the monsoon seasonal rainfall and rainy days. Hanumangarh recorded the lowest number of rainy days as well as total rainfall. During winter season, Sriganganagar recorded highest rainfall and Bikaner received comparatively more rainfall during summer season.

Table 3.9: Season-wise rainfall (mm) distribution in different districts of Western Rajasthan

Districts	South West monsoon	Post monsoon	Winter monsoon	Summer monsoon	Annual
Barmer	234.1 (12)	10.8 (0.6)	3 (0.4)	16.5 (1)	264.4 (14)
Bikaner	217.6 (12)	14.3 (1.8)	13 .1 (1.2)	36.7 (2)	281.7 (17)
Churu	315.5 (16)	11 (1.2)	8.6 (0.8)	29.9 (2)	365 (20)
Sri Ganganagar	223.3 (11)	5.1 (1.2)	18.7 (1.8)	29.1 (2)	276.2 (16)
Hanumangarh	150.3 (7)	10.5 (0.4)	13.7 (1.1)	21 (1)	194.5 (9.5)
Jaisalmer	183.1 (8)	10.8 (1.6)	3.8 (0.4)	13.1 (1)	210.8 (11)
Jodhpur	298.6 (15)	10.8 (1.2)	7.4 (0.8)	22.4 (2)	339.2 (19)
Nagaur	359.6 (17)	13.2 (1.1)	9.3 (0.9)	28.3 (2)	410.3 (21)

(Figures in parenthesis are rainy days)

Probable rainfall in different weeks in western Rajasthan

The dependable rainfall (at 75% probability) during south west monsoon and on annual basis was determined and presented in table 3.10 along with standard deviation and coefficient of variation. The data revealed that dependable annual rainfall was highest in Nagaur district (410.3 mm) and lowest (194.5 mm) in Hanumangarh. The lowest coefficient of variation in the annual rainfall (42.6%) was noticed in Bikaner district where as it was highest in Hanumangarh district (85.8%). The dependable rainfall during monsoon season was lowest (104.0 mm) in Sriganganagar district and highest in Nagaur district (223.0 mm). The rainfall is relatively consistent (CV = 45.4%) with a mean value of 184.5 mm in Jodhpur district.

Table 3.10: Mean and dependable rainfall (mm) in different districts of Western Rajasthan

District	South west monsoon rainfall				Annual rainfall			
	Probability level (75%)	Mean rainfall (mm)	SD	CV	Probability level (75%)	Mean rainfall (mm)	SD	CV%
Barmer	108.8	234.1	171.0	73.0	148.6	264.4	174.1	65.9
Bikaner	140.4	217.6	102.5	47.1	197.0	281.7	120.1	42.6
Churu	198.5	315.5	147.3	46.7	249.5	365.0	160.5	44.0
Sri Ganganagar	104.0	223.3	137.3	61.5	160.4	276.2	151.7	54.9
Hanumangarh	167.5	150.3	135.8	90.3	195.8	194.5	167.0	85.8
Jaisalmer	109.0	183.1	111.2	60.7	129.0	210.8	111.3	52.8
Jodhpur	184.5	298.6	138.5	46.4	205.0	339.2	153.9	45.4
Nagaur	223.0	359.6	212.2	59.0	270.0	410.3	226.4	55.2

KANPUR

Following the IMD criteria of classification of intensity of droughts, the rainfall data for the period 1979-2009 at Kanpur and at Lucknow for the period 1979-2009 (excluding 1990) were analysed. Year-wise categorization of meteorological droughts as depicted in fig.3.16 showed that none of the districts experienced severe drought conditions during the period under study and Kanpur exhibited 20% moderate drought years which was 7% higher than Lucknow district. However, Lucknow experienced 37% mild drought years out of 30 years period which is slightly higher than Kanpur. About 50% of the years are drought free at Lucknow.

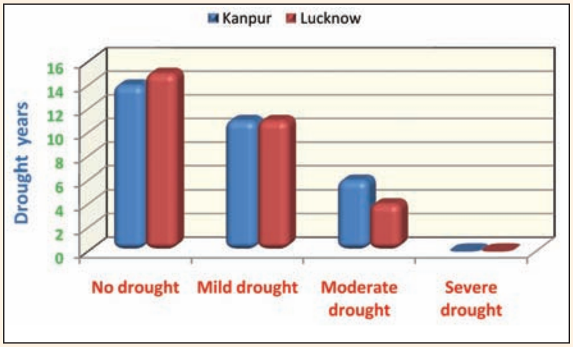


Fig. 3.16: Meteorological droughts of different intensity at Kanpur and Lucknow

Extreme rainfall events

The daily rainfall data of Kanpur for the period 1971-2010 was categorized into four rainfall intensity classes to determine the probability of extreme rainfall events and the results are presented in table 3.11. The frequency table indicates that out of 40 years there were only 397 rainfall events exceeding 25 mm. Further categorization of the rainfall events suggested that there were 20 rainfall events exceeding 100 mm on a single day during the southwest monsoon period in 40 years. The occurrence of extreme rainfall events during southwest monsoon when analysed on a decadal basis (Table 3.12) indicated that there is no significant change in rainfall events exceeding 100 mm. However, number of events with the rainfall in the range of 75-100 mm declined considerably from 13 during the 1971-80 periods to 5 during 2001-2010. So is the case with 50-75 mm rainfall intensity.

Table 3.11: Frequency distribution of extreme rainfall events in different seasons (1971 to 2010) at Kanpur

Season	Rainfall intensity (mm/day)							
	25 - 50		50 - 75		75 - 100		>100	
	Days	Sum	Days	Sum	Days	Sum	Days	Sum
South- west monsoon	237	8395.2 (90%)	109	6451.0 (94%)	31	2642.0 (94%)	20	2824.0 (94%)
North-east monsoon	16	562.0 (06%)	06	370.6 (05%)	02	168.5 (06%)	01	165.5 (06%)
Winter monsoon	06	223.5 (03%)	01	59.4 (01%)	00	0.0	00	0.0
Summer monsoon	04	131.8 (01%)	00	0.0	00	0.0	00	0.0
Total	263	9312.5	116	6881.0	33	2810.5	21	2989.5

Table 3.12: Frequency distribution of extreme rainfall events during SW monsoon season (1971 to 2010) at Kanpur

Year	Particulars	25 - 50 mm		50 - 75 mm		75 - 100 mm		>100 mm	
		Days	Sum	Days	Sum	Days	Sum	Days	Sum
1971-80	Total	57.0	1992.1	31.0	1815.1	13.0	1159.2	4.0	528.8
	Mean	5.7	199.2	3.1	181.5	1.3	115.9	0.4	52.9
	SD	2.8	106.4	3.2	177.5	1.1	97.2	0.7	97.2
	CV%	48.3	53.4	102.5	97.8	81.5	83.8	174.8	183.9
1981-90	Total	60.0	2116.6	27.0	1580.4	7.0	568.5	6.0	938.8
	Mean	6.0	211.7	2.7	158.0	0.7	56.9	0.6	93.9
	SD	3.3	103.9	1.2	68.1	0.7	55.3	0.8	127.8
	CV%	54.4	49.1	42.9	43.1	96.4	97.2	140.6	136.1
1991-00	Total	65.0	2340.1	28.0	1664.2	6.0	501.0	5.0	613.3
	Mean	6.5	234.0	2.8	166.4	0.6	50.1	0.5	61.3
	SD	3.1	113.9	2.4	145.2	0.7	61.8	0.7	88.1
	CV%	47.7	48.7	85.5	87.2	116.5	123.4	141.4	143.7

Year	Particulars	25 - 50 mm		50 - 75 mm		75 - 100 mm		>100 mm	
		Days	Sum	Days	Sum	Days	Sum	Days	Sum
2001-10	Total	55.0	1946.4	23.0	1391.3	5.0	413.3	5.0	743.1
	Mean	5.5	194.6	2.3	139.1	0.5	41.3	0.5	74.3
	SD	2.7	97.0	1.6	98.7	0.7	59.3	0.7	108.8
	CV%	48.7	49.8	68.1	70.9	141.4	143.5	141.4	146.5

RAKH DHIANSAR

The Koppen's classification of climates was adopted in identifying the climatic types of newly formed districts in Jammu region *viz.*, Kishtwar, Ramban and Reasi. The classification indicated that Kishtwar district falls under sub-class "cfa" with aridity index of 1.14 and moisture index of 14% and with a LGP of 176 days under sub-humid conditions. Ramban fell under "csa" sub-class with aridity index of 0.76, moisture index of 24% and with LGP of 157 days under sub-humid conditions. Similarly, Reasi district also falls under "cfa" sub-class with aridity index of 1.14 and moisture index of 43%. However, the length of growing period showed bimodal tendency with a total growing period of 225 days. Growing period of these newly formed districts are presented in fig. 3.17.

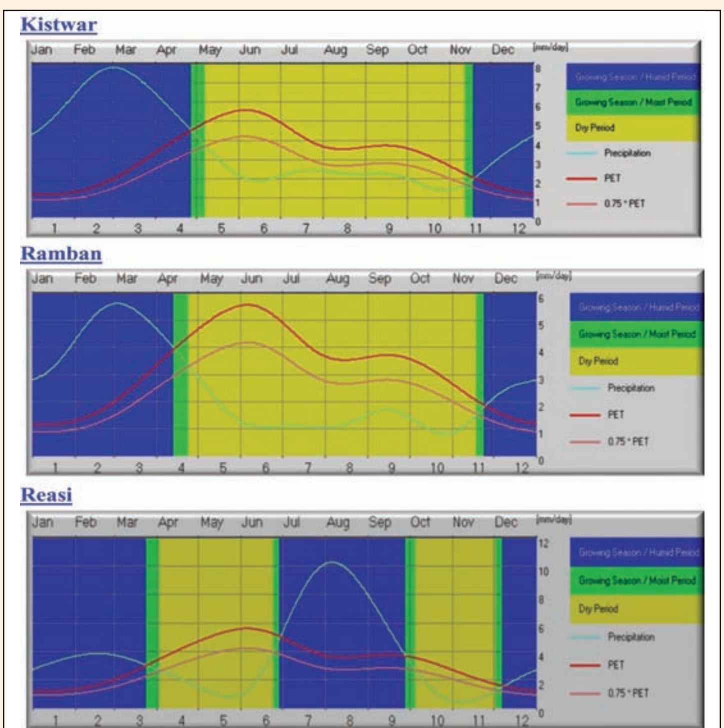


Fig.3.17: Length of growing period in Kistwar, Ramban and Reasi districts of Jammu region

4. CROP-WEATHER RELATIONSHIPS

A comprehensive knowledge on the physiological processes in crop plants such as photosynthesis, transpiration, growth and development as influenced by the process of energy and mass exchange has led to the development of dynamic crop-growth models and these are increasingly applied to estimate the crop yields at regional / national levels. At the same time, traditional empirical-statistical models continued to be developed to understand and quantify the role of weather variables in determining the crop productivity of a given location / region. Crop-weather relationship studies carried out in different crops at different locations are reported here-under.

Rabi 2010-11

Wheat

UDAIPUR

Role of temperature on the phenology and productivity of three wheat cultivars (HI-1544, MP-1203 and Raj-4037) was studied from a four year experiment (2007-08 to 2010-11) which revealed that maximum wheat yields can be realized during the years with mean temperature during reproductive stage prevailing in the range of 17.9 to 19.6°C (Fig.4.1). An increase in the temperature above this optimum range during reproductive phase resulted in a drastic reduction in grain yields which were in the range of 15.8 to 38.1 per cent compared to yields that were realized at a mean temperature of 17.9°C.

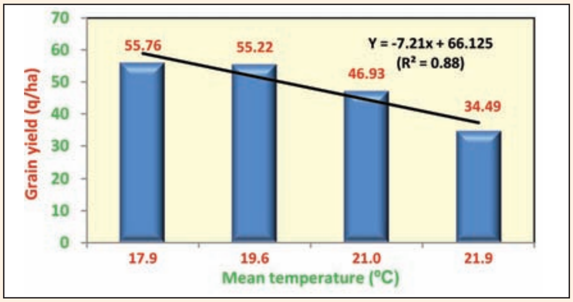


Fig. 4.1: Influence of mean temperature during reproductive stage on wheat yields at Udaipur (2007-08 to 2010-11)

The concept of Heat Use Efficiency (HUE) is being used to evaluate the performance of crop varieties. Early sown crops normally accumulates more heat units than late sown crops, but may not necessarily produce more dry matter/grain yield leading to poor HUE and *vise a versa*. Varieties with high HUE need to be identified for late sown conditions to realize optimum yields. From the *rabi* 2010-11 experimentation it can be concluded that Raj-4037 is a cultivar with high HUE for both dry matter and grain yield (Table 4.1) and 20th November is the optimum sowing date for wheat at Udaipur.

Table 4.1: Accumulated GDD and heat unit efficiency of three wheat cultivars as influenced by sowing time at Udaipur

Treatment	GDD (° day)	Heat use efficiency for total dry matter (kg/ha/° day)	Heat use efficiency for grain yield (kg/ha/° day)
Date of sowing			
5th November	1724	10.1	3.8
20th November	1581	10.9	4.1
5th December	1565	10.3	3.7
20th December	1505	8.4	2.8
Varieties			
HI-1544	1562	10.2	3.8
MP-1203	1642	9.1	3.1
Raj-4037	1577	10.6	4.0

KANPUR

Thermal time requirement and heat use efficiency of three wheat varieties (HD-2733, K-307 and K-9107) were assessed by creating varied environmental conditions through staggered sowings (23th Nov, 8th Dec, 23rd Dec, 2010) which showed that higher thermal time (Fig.4.2) accrued during vegetative and reproductive phases has resulted in higher yields. Among the varieties K-9107 was found to be efficient in harnessing HTU compared to other two varieties (Fig.4.3).

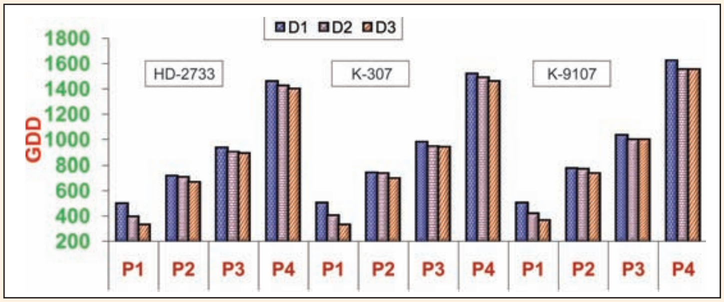


Fig. 4.2: Accumulated GDD during different phenophases of wheat 2010-11 at Kanpur

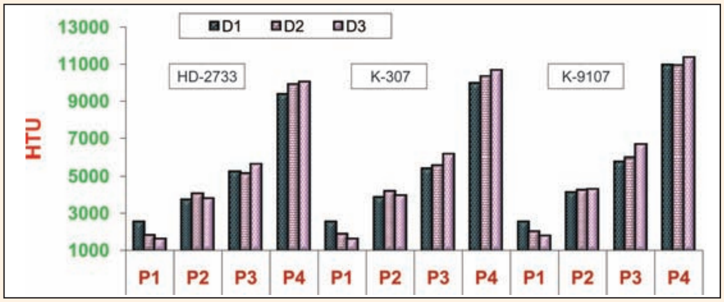


Fig. 4.3: Accumulated HTU during different phenophases of wheat 2010-11 at Kanpur

PALAMPUR

Optimum temperature and threshold limits to produce wheat yields ≥ 3.5 t/ha were identified from eleven years of experimentation (1999-2000 to 2009-10). Maximum temperature in the range of 17.8 to 19.9°C (Optimum 18.6°C) and minimum temperature in the range of 5.2 to 8.0°C (Optimum 6.7°C) during the vegetative and maximum in the range of 20.6 to 27.1°C (Optimum 23.4°C) and minimum in the range of 8.2 to 13.3°C (Optimum 10.9°C) during reproductive phase were found to be optimum to realize higher yields. This hypothesis was tested utilizing the *rabi* 2010-11 yield data which showed that the validity of the hypothesis is reasonably high. The threshold limits could not be validated during vegetative and reproductive phases as the temperatures were within the predetermined limits (Table 4.2) giving no scope to validate the hypothesis.

Table 4.2: Optimum temperature for different phenophases in rainfed wheat at Palampur

Temperatures	Vegetative phase	Reproductive phase	Maturity phase
Yield (≥ 3.5 t/ha)			
Maximum (°C)	17.8 - 19.9* (18.6)	20.6 -27.1 (23.4)	27.7 – 31.2 (29.2)
2010-11	16.5-18.2 (17.4)	19.8-24.0 (22.5)	26.3-27.4 (26.4)
Minimum (°C)	5.2 – 8.0 (6.7)	8.2 – 13.3 (10.9)	15.4 – 18.3 (16.4)
2010-11	5.1-6.9 (5.7)	8.9-11.1 (10.3)	14.4-15.6 (15.0)
Yield (2-3 t/ha)			
Maximum (°C)	17.2 – 22.1 (18.9)	22.2-29.2 (25.9)	27.9 – 32.3 (30.1)
Minimum (°C)	5.3 – 10.1 (7.5)	10.1 – 16.8 (13.8)	15.6 – 19.7 (18.1)
Yield (≤ 2t/ha)			
Maximum (°C)	19.8-20.2 (20.0)	21.0-22.2 (21.7)	27.9 – 28.7 (28.4)
Minimum (°C)	7.4-7.9 (7.7)	10.2 – 10.5 (10.3)	14.9 – 15.4 (15.2)

(*Threshold temperature limits identified)

RAIPUR

Natural resource use by different wheat varieties was quantified in terms of HUE and RUEs facilitating identification of a variety suitable for the late / advanced sowing environments. This was accomplished through staggered sowings of four wheat cultivars (Kanchan, GW-273, Sujata and Amar). Kanchan and GW-273 were found to be superior in their abilities to harness thermal and radiant energies. As the sowings were delayed beyond 5th December, the ability of the varieties to capture the natural resources declined.

It can be inferred from the present investigation that differential response exists for heat and radiation use efficiencies in wheat cultivars and for delayed sowing conditions Kanchan and GW-273 can be chosen over cultivars like Sujata and Amar (Table 4.3).

Table 4.3: Heat use efficiency (g/m^2 deg day) and Radiation Use Efficiency ($g\ MJ^{-1}$) of wheat varieties under varied environments at Raipur

Varieties	D_1-25 Nov.		D_2-05 Dec.		D_3-15 Dec.		D_4-25 Dec.		D_5-05 Jan.	
	HUE	RUE	HUE	RUE	HUE	RUE	HUE	RUE	HUE	RUE
Kanchan	0.37	0.89	0.49	1.14	0.44	1.01	0.36	0.86	0.34	0.82
GW-273	0.37	0.88	0.46	1.09	0.41	0.96	0.36	0.85	0.34	0.84
Sujata	0.42	1.02	0.37	0.88	0.41	0.96	0.38	0.91	0.32	0.79
Amar	0.42	1.02	0.37	0.88	0.38	0.89	0.37	0.89	0.33	0.80
Mean	0.40	0.95	0.42	1.00	0.41	0.96	0.37	0.88	0.33	0.81

RANCHI

Resource capturing and conversion efficiency of three wheat varieties (HUW 468, K 9107 and BG 3) was evaluated under four sowing environments. Wheat *cv.* HUW 468 recorded highest HUE and RUE across the sowing times. The crops sown on 20th November recorded highest yields and *cv.* BG 3 was found to be efficient among the varieties in utilizing the water resource. Wheat *cv.* K 9107 was the poorest among the varieties tested in harnessing the natural resources as revealed by its low HUE, RUE and WUE (Table 4.4).

Table 4.4: Varietal differences in utilization of natural resources under different growing environments at Ranchi

Sowing Date	Variety	HUE (kg/ha °days)	RUE (kg/ha/MJ)	WUE (kg/ha/cm)	Yield (kg/ha)
5th Nov	HUW 468	4.0	2.8	201	5777
	K9107	3.4	2.4	179	5149
	BG 3	4.2	2.9	211	6084
20th Nov	HUW 468	4.3	2.9	205	6411
	K9107	3.1	2.2	157	4884
	BG 3	3.9	2.7	189	5895
5th Dec	HUW 468	3.1	2.2	147	5041
	K9107	2.7	1.9	128	4386
	BG 3	3.2	2.3	150	5138
20th Dec	HUW 468	2.7	1.9	124	4153
	K9107	2.2	1.6	105	3497
	BG 3	2.4	1.7	114	3811

Temperature thresholds

Temperature thresholds and optimum ranges to attain graded yield levels ranging from 3 to 4 t/ha were identified for wheat *cv*. K 1907. During vegetative stage maximum temperature in the range of 22.5 to 24.5°C and minimum temperature 7.0 to 8.0°C was found to be optimum. The thresholds for maximum and minimum temperatures during anthesis, the most thermo-sensitive stage were found to be 27.5°C and 11.5°C respectively, to attain a yield level of 4 t/ha (Table 4.5).

Table 4.5: Temperature thresholds and optimum range to attain graded yield levels for wheat *cv*. K 1907 at Ranchi

Yield >4.0t/ha	Vegetative	Anthesis	Milking	Maturity
Tmax	22.5-24.5 (23.5)	21-27.5 (25.2)	23.5-29.5 (26.3)	30-32.5 (31.2)
Tmin	7-8 (7.1)	7.5-11.5 (9.1)	7-10 (8.6)	11.5-13.5 (12.3)
Yield 4-3t/ha				
Tmax	23-24 (23.5)	23.5-32 (27.2)	24-33 (30.2)	26.5-37 (33.5)
Tmin	6.8-8.5 (7.5)	10-13.1 (11.6)	10-15 (13.4)	13-18 (16.4)
Yield<3t/ha				
Tmax	24-26 (25.1)	30-32 (30.9)	33-35 (34.2)	33-35.5 (34.3)
Tmin	8.1-9.6 (8.9)	12-14.5 (13.3)	14.5-16 (15.4)	15.5-20.5 (17.9)

(Figures in parenthesis are average values)

Thermal sensitive stages of wheat

In wheat cv. K 1907 the period from anthesis to milking was found to be highly sensitive to maximum and minimum temperatures. The association between air temperature that prevailed during different stages of crop growth and grain yield are presented table 4.6.

Table 4.6: Pearson's correlation coefficients between temperature during different phenophases and wheat yields at Ranchi

Temperature/ Stages	Vegetative	Boot-Anthesis	Anthesis - Milking	Milking - Maturity
T Max	-0.56	-0.61	-0.71*	-0.56
T Min	-0.38	-0.80	-0.82*	-0.72

Functional relations developed from the field experimentation were used to estimate changes in wheat yields as a function of maximum and minimum temperatures (Table 4.7). Wheat yields were predicted to decrease by 17.5 and 27.5 per cent with a rise in maximum temperature by 2 to 3°C and 3 to 5°C, respectively. Similarly, a rise in minimum temperature by 3, 4, 5 and 6°C was estimated to cause a reduction in wheat yields by 7.5, 22.5, 25.0 and 27.5 per cent, respectively.

Table 4.7: Projected wheat (*cv.* K 9107) yields under elevated temperatures at Ranchi

Increase in temp. from optimum by (°C)	Maximum temperature		Minimum temperature			
	2-3	3.1-5	3	4	5	6
Per cent decrease in productivity	17.5	27.5	7.5	22.5	25	27.5

RANICHAURI

Growth and development of two wheat varieties (UP-1109 and Sonalika) were studied in relation to thermal time and water use. A significant and positive association (r=0.80) was found between total dry matter produced and accrued thermal time (GDD). The association between these two variables was found to be better expressed by an exponential relation (Fig. 4.4).

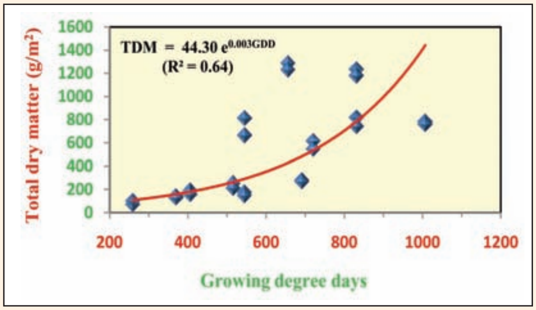


Fig. 4.4: Relationship between dry matter production in wheat and thermal time at Ranichauri

Plant height attained at different growth stages in wheat and thermal time (GDD) were also found to be closely associated (r=0.95) and a quadratic fit presented in fig. 4.5 better explained the association which can be expressed as:

$$\text{Plant Height} = -7E\text{-}05GDD^2 + 0.174GDD - 5.803$$

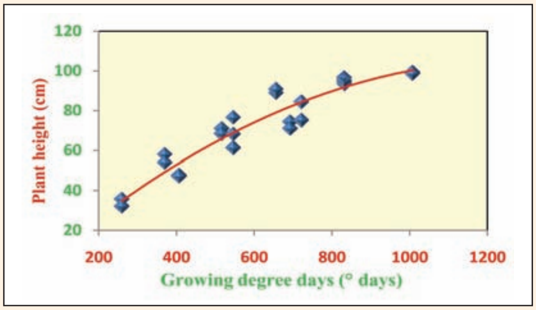


Fig. 4.5: Relation between plant height and thermal time in wheat at Ranichauri

Actual evapotranspiration (AET) in wheat was found to be strongly associated with plant height at different stages of crop growth with a correlation coefficient of 0.95. A logarithmic fit between these two variables accounted for more than 90 per cent variation (Fig. 4.6) and the association can be mathematically expressed as:

Plant Height = 72.73 ln (AET) – 307.5

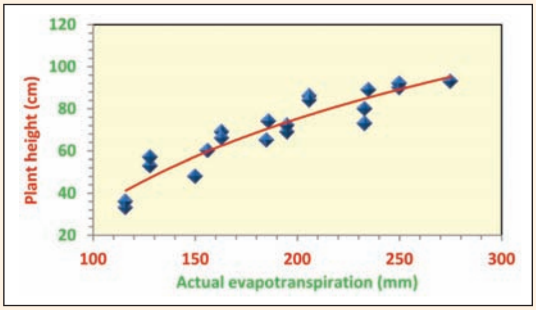


Fig. 4.6: Relation between plant height and Actual evapotranspiration in wheat at Ranichauri

RAKH DHIANSAR

At Rakh Dhiansar, a station in the northern most parts of the country, wheat sown early accumulated more thermal time and heliothermal units over normal and late sown crop. Varietal differences were noticed in their efficiencies in terms of GDD, HTU, PTU and wheat *cv.* RSP-561 accumulated more thermal time and helio thermal units than PBW-343 and DBW-17 (Table 4.8).

Table 4.8: Varietal differences in capturing resources as influenced by sowing time at Rakh Dhiansar

Treat-ments	Emer-gence	50% CRI	Tille-ring	Join-ting	Flag leaf	Emer-gence Heading	Ant-hesis	Milk-ing	Dough	P. Matu-rity
Growing Degree Days (GDD)										
D_1V_1	119.4	324.4	405.6	665.1	885.8	999.6	1148.3	1393.5	1584.8	1843.6
D_1V_2	94.0	224.8	280.3	501.4	758.1	869.0	1032.5	1196.8	1481.4	1785.1
D_1V_3	72.2	156.5	184.4	461.1	625.8	747.9	942.9	1175.0	1410.8	1755.6
Mean	95.2	235.2	290.1	542.5	756.6	872.2	1041.2	1255.1	1492.4	1794.8
CV	24.8	35.9	38.2	19.9	17.2	14.4	9.9	9.6	5.9	2.5
V_1	96.3	241.3	292.8	534.8	760.3	875.4	1045.3	1311.2	1517.2	1866.1
V_2	95.2	237.7	288.7	544.6	756.0	877.1	1060.6	1303.8	1511.7	1777.5
V_3	93	226.6	288.7	548.1	753.4	864.1	1017.8	1150.4	1448.2	1740.7
Mean	94.8	235.2	290.1	542.5	756.6	872.2	1041.2	1255.1	1492.4	1794.8
CV	1.8	3.3	0.8	1.3	0.5	0.8	2.1	7.2	2.6	3.6

Treatments	Emergence	50% CRI	Tillering	Jointing	Flag leaf	Emergence Heading	Anthesis	Milking	Dough	P. Maturity
Helio Thermal Units (HTU)										
D_1V_1	870.1	2366.5	2886.8	3557.6	5489.9	5999.7	6424.5	7921.5	9363.5	10915.7
D_1V_2	595.1	2904.6	1901.5	2301.5	3923.0	4264.3	5359.8	6985.4	8315.2	10697.7
D_1V_3	409.9	977.0	996.9	2083.3	2637.7	3369.7	4665.5	6387.4	7770.9	10663.8
Mean	625.0	2082.7	1928.4	2647.5	4016.9	4544.6	5483.3	7098.1	8483.2	10759.1
CV	37.0	38.2	54.2	30.1	35.6	29.4	16.2	10.9	9.5	1.3
V_1	625.0	1578.5	1839.6	2823.9	4028.6	4572.6	5530.0	7318.3	8578.9	11137.3
V_2	621.2	1563.8	1822.8	2556.3	4021.8	4586.0	5624.7	7224.4	8591.7	10698.1
V_3	620.3	1505.8	1822.8	2562.2	4000.3	4475.2	5295.1	6751.7	8279.0	10441.8
Mean	622.2	1549.3	1828.4	2647.5	4016.9	4544.6	5483.3	7098.1	8483.2	10759.1
CV	0.4	2.5	0.5	5.8	0.4	1.3	3.1	4.3	2.1	3.3
Photo Thermal Units (PTU)										
D_1V_1	1159.6	3370.4	3189.6	6824.6	8981.2	10247.8	11800.6	14625.8	17029.5	20414.6
D_1V_2	946.4	2246.1	2793.0	4926.8	7703.0	8934.8	10820.9	13732.5	16288.3	20201.8
D_1V_3	730.9	1466.4	1819.1	4607.3	6496.8	7662.8	10224.5	13046.3	16041.2	20108.9
Mean	945.6	2361.0	2600.6	5452.9	7727.0	8948.4	10948.7	13801.5	16453.0	20241.7
CV	22.7	40.5	27.1	22.0	16.1	14.4	7.3	5.7	3.1	0.8
V_1	945.6	2424.1	2627.6	5330.6	7771.5	9043.5	10992.2	14160.0	16730.1	21216.6
V_2	942.3	2388.3	2587.1	5497.2	7721.0	8859.8	11189.1	14075.1	16658.1	20175.2
V_3	940.2	2270.6	2587.1	5530.8	7688.6	8942.0	10664.7	13169.5	15970.8	19333.4
Mean	942.7	2361.0	2600.6	5452.9	7727.0	8948.4	10948.7	13801.5	16453.0	20241.7
CV	0.3	3.4	0.9	2.0	0.5	1.0	2.4	4.0	2.5	4.7

Mustard

HISAR

Mustard varieties differed in their utilization of natural resources at Hisar which was quantified through indices like thermal (TUE) and radiation use efficiencies (RUE). Growing environments were created for the three mustard varieties (Kranti, RH-30 and RH-406) by four staggered sowings at 10 day interval. Early sown crop irrespective of varieties recorded higher TUE at all crop growth stages than crop sown late. Mustard *cv.* Kranti recorded highest TUE followed by RH-406 (Table 4.9). Late sown crop faced forced maturity due to higher temperatures during reproductive phase.

Table 4.9: Thermal use efficiency of *Brassica* cultivars at various phenophases under different sowing environments at Hisar

	Thermal Use efficiency (g/m²/° day)		
Sowing dates	50 per cent flowering	Completion of flowering	Physiological maturity
D1-08-Oct-2010	1.76	1.71	1.68
D2-18-Oct-2010	1. 54	1.47	1.40
D3-28-Oct-2010	1.35	1.26	1.21
D4-08-Nov-2010	1.21	1.08	0.94
CD at 5 per cent	0.03	0.04	0.02
SE (d) of D	0.009	0.013	0.006
Varieties			
V1-Kranti	1.63	1.56	1.49
V2-RH 30	1.26	1.19	1.11
V3-RH 406	1.49	1.39	1.32
CD at 5 per cent	0.02	0.02	0.01
SE (d) of V	0.011	0.008	0.007

Radiation use efficiency:

Canopy architecture, leaf orientation and photosynthetic efficiency of individual leaves determine the dry matter production and in turn RUE. Mustard sown early (8th October) was found to be most efficient in the utilization of PAR compared to crop sown on later dates. Light Interception and conversion efficiency was found to be highest in Kranti followed by RH-406 at all stages except at flowering (Table 4.10).

Growth and yield of mustard in relation to weather

Correlation studies carried out revealed that seed yield and yield attributes were significantly and positively correlated with maximum and minimum temperatures, sunshine hours and evaporation during vegetative phase but negatively correlated with the same weather parameters at reproductive phase. On the contrary, relative humidity was found to be correlated positively significant with seed yield and yield attributes at reproductive phase and negatively correlated during vegetative phase (Table 4.11).

Table 4.10: Radiation use efficiency of *Brassica* cultivars at various phenophases under different sowing environments at Hisar

	Radiation use efficiency (g/MJ)		
Sowing dates	50 per cent flowering	Completion of flowering	Physiological maturity
D_1-08-Oct-2010	4.11	4.85	3.87
D_2-18-Oct-2010	3.43	3.88	3.21
D_3-28-Oct-2010	3.02	2.95	2.76
D_4-08-Nov-2010	2.56	2.13	2.59
CD at 5 per cent	0.07	0.12	0.05
SE (d) of D	0.023	0.044	0.019
Varieties			
V_1-Kranti	3.49	3.64	3.29
V_2-RH 30	3.09	3.21	2.91
V_3-RH 406	3.27	3.5	3.12
CD at 5 per cent	0.06	0.05	0.03
SE (d) of V	0.028	0.024	0.015

Table 4.11: Pearson's correlation coefficients between seed yield and yield attributes with weather parameters during different phenophases in mustard at Hisar

Weather parame-ters	Phenophases	Seed yield	Biological yield Kg ha^{-1}	No.of siliquae Kg ha^{-1}	Seeds $siliqua^{-1}$ m^{-2}	1000-seed weight (g)
Tmax	Vegetative phase	0.82**	0.60**	0.80**	0.35*	0.74**
	Reproductive phase	-0.81	-0.63	-0.81	-0.34	-0.75
Tmin	Vegetative phase	0.34*	0.34*	0.35*	0.35*	0.33*
	Reproductive phase	-0.82	-0.63	-0.84	-0.33	-0.76
RH Mean	Vegetative phase	-0.81	-0.61	-0.78	-0.37	-0.75
	Reproductive phase	0.83**	0.60**	0.74**	0.39*	0.74**
BSSH	Vegetative phase	0.81**	0.65**	0.80**	0.33**	0.76**
	Reproductive phase	-0.82	-0.63	-0.79	-0.34	-0.76
Ep	Vegetative phase	0.73**	0.62**	0.72**	0.31*	0.72**
	Reproductive phase	-0.78	-0.60	-0.79	-0.34	-0.75

*(*Significance at (P= 0.05);**Significant at (P= 0.01))*

MOHANPUR

Seasonal evapotranspiration and mustard seed yield

Seasonal evapotranspiration (SET) in mustard was computed using water balance approach and was related with seed yield (Fig.4.7). The relationship between yield and SET showed that yield decreased continuously with increase in SET value. The relation presented in the fig. 4.7 accounted for 37 per cent variation in seed yield due to variations in SET.

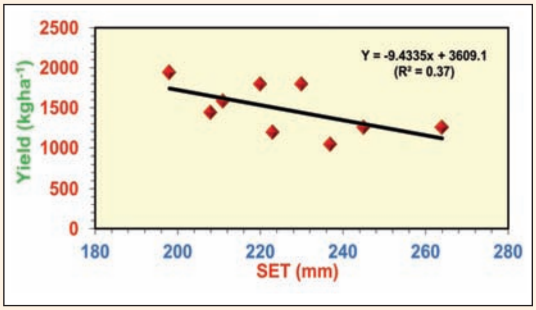


Fig. 4.7: Yield - SET relationship in case of mustard during 2010-11 at Mohanpur

RAKH DHIANSAR

To study the crop weather relationship in mustard crop, two cultivars *viz.*, RL-1359 and RSPR-01 were exposed to different thermal regimes by sowing on 29th Oct, 8th Nov and 17th Nov. 2010.

Transpiration rate in mustard *vs* vapour pressure deficit

Transpiration rate in two mustard cultivars (RL-1359 and RSPR-01) sown on three different dates was recorded with Steady State Porometer (Model LI-1600) on clear sunny days (at 11.00 hours IST) at different stages of the crop. Transpiration rates were recorded on the dorsal and ventral sides of the leaf at three tiers of the canopy (lower, middle and top). Transpiration rates thus recorded were regressed on vapour pressure deficit (VPD) derived from hygroscopic tables during the crop season and the resultant relation (Fig. 4.8) explained 76 per cent variation in transpiration rate due to VPD. The higher the VPD higher is the transpiration rate and *vice versa.*

Y= 8.683 X + 32.346 ... (R^2 =0.76)

Where,
Y= Transpiration rate (μ mol $s^{-1}m^{-2}$) and
X= Vapour Pressure Deficit (VPD) (Kpa)

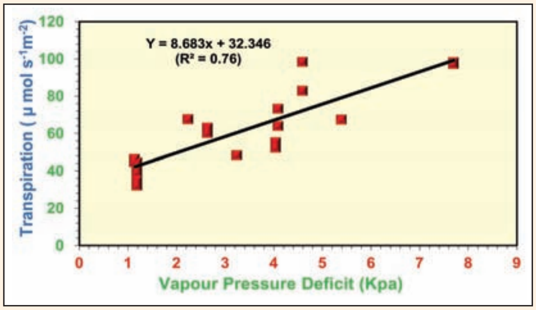


Fig. 4.8: Relationship between transpiration rate and vapour pressure deficit in mustard at Rakh Dhiansar

Potato

JORHAT

Potato tuber production was studied in relation to weather using agroclimatic indices at different phenophases and the association between these two variables as denoted by correlation coefficients is presented in table 4.12. Thermal time and heliothermal units during stolon formation were found to influence comparatively more than at other stages. Hours of sunshine at tuber formation stage is highly correlated with yield. Functional relations were developed using regression technique and the resultant relations are:

Y = 214.53 – 0.12AGDD .... ($R^2 = 0.76$)

Y = 187.46 – 0.03APTU .... ($R^2 = 0.54$)

Y = 214.13 – 0.20ABSH .... ($R^2 = 0.65$)

Y = 193.84 – 0.12AMET .... ($R^2 = 0.78$)

Table 4.12: Pearson's correlation coefficients between tuber yield and agroclimatic indices in potato at Jorhat

Growth Stages	Accumulated growing degree-days	Accumulated heliothermal units	Accumulated photothermal units	Accumulated bright sunshine hours
Stolon formation	0.85	0.76	0.68	0.46
Tuber formation	0.75	0.69	0.79	0.83
Tuber development	0.50	0.52	0.48	0.57
Maturity	0.82	0.76	0.68	0.82

MOHANPUR

Water use efficiency of potato

The water use efficiency of potato as influenced by sowing time and variety was examined and it was found that highest water use efficiency was recorded in the crop sown on 3rd Dec (10.3 kg m^{-3}). Potato *cv.* Chipsona showed highest water use efficiency with a productivity of 11.4 kg at the expense of one cu.m of water whilst Jyoti and Ashoka recorded 7.3 and 7.9 kg m^{-3}, respectively.

Tuber yield *vs* Seasonal ET

Potato yields were regressed on seasonal evapotranspiration computed through water balance method which showed a curvilinear type of relation between these two variables (Fig. 4.9). Tuber yields increased linearly up to seasonal ET of 290 mm and decreased thereafter. The quadratic fit between these two variables accounted for 36 per cent variation in tuber yield and the resultant equation is

Yield = 1.2766 SET - 0.002 SET^2 – 170.69 .... (R^2 = 0.36)

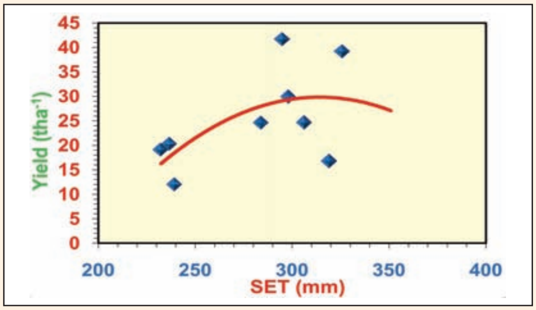


Fig. 4.9: Potato tuber yield as influenced by seasonal ET at Mohanpur

Tuber yield *vs* soil temperature

Potato tuber yield as influenced by soil temperature both during night and day time recorded at 30 cm depth was found to be closely related and a soil temperature of 20 to 22°C was found to be optimum for maximum tuber production and a rise in soil temperature beyond 22°C decreased tuber yields (Fig. 4.10 a & b).

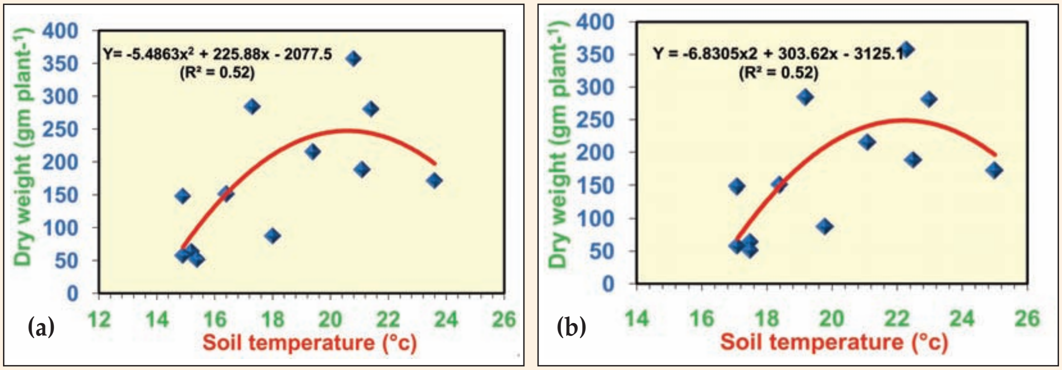


Fig. 4.10: Tuber biomass production in relation to soil temperature at 30 cm depth during (a) morning and (b) afternoon at Mohanpur

Tuber yield *vs* air temperature

Tuber biomass accumulation in potato was found to be influenced by air temperature at the canopy height and it increased gradually up to 29°C and decreased with a further rise in day temperature. Similar response was noticed with minimum (night) temperature. Maximum biomass accumulation in tuber was noticed at a minimum temperature of 15°C which was almost stable up to 17°C and declined with further rise in minimum temperature. Thus, it can be inferred from the present investigation that for maximum tuber production minimum air temperature should be within 15 to 17°C and maximum temperature less than 29°C (Fig. 4.11 a& b).

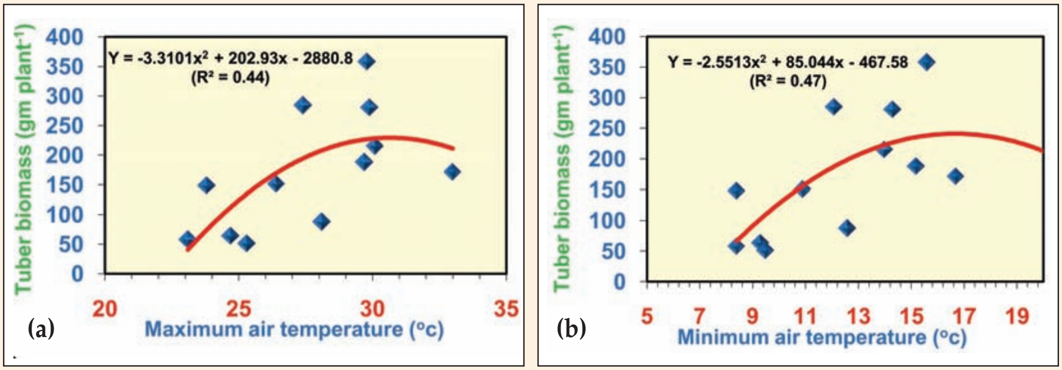


Fig.4.11: Tuber biomass production in relation to (a) maximum temperature and (b) minimum temperature at Mohanpur

Rabi Sorghum

PARBHANI

Grain and fodder yield production in two *rabi* sorghum cultivars (M 35-1 and SPV 1411) was studied under four environmental conditions imposed by staggered sowings and correlation coefficients determined between the weather variables at different phenophases and sorghum grain yields are presented in table 4.13. The crop was found to be less sensitive to weather at boot stage. At flowering, quantum of rain and rain

Table 4.13: Pearson's correlation coefficients between weather variables and grain yield of *rabi* sorghum

Weather variables	Stages					Mean
	Boot stage	Flowering stage	Milk stage	Dough stage	Maturity	
RF	0.12	0.81**	0.08	0.11	0.36	-0.19
RD	0.28	0.82**	0.17	0.71	0.42	-0.15
T_{Max}	-0.49	- 0.84**	0.32	0.03	0.99**	0.13
T_{Min}	-0.49	- 0.87**	-0.11	0.65*	0.82**	-0.20
T_{Mean}	-0.50	- 0.96**	0.16	0.53	0.97**	-0.10
RHI	-0.39	0.96**	0.20	0.91**	0.83**	-0.19
RHII	-0.47	0.95**	0.07	0.41	0.11	- 0.26*
RHmean	-0.45	0.96*	0.17	0.64*	0.79**	- 0.25*
EVP	-0.17	-0.20	0.35	0.33	0.97**	0.26*
BSS	-0.12	0.24	0.32	0.22	0.93**	0.24*

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

events and humidity in the air showed positive association and an inverse association with temperature was noticed. Again during milk stage, the crop has become less sensitive to weather but at dough stage crop turned to be sensitive to humidity. Towards maturity, all weather parameters except rainfall and rainy days were found to have a significant positive influence on the grain yield.

Fodder yield in relation to weather

During early stages (boot stage) of crop growth, sorghum fodder production was found to be less sensitive to weather and as the crop growth advances and reproductive stage commences quantum of rainfall and number of its events and humidity in air had a significant positive association whilst temperature had a negative impact. During dough stage morning RH was found to influence the fodder yield and toward maturity almost all weather parameters except rainfall and rainy days had a positive impact on fodder production (Table 4.14).

Table 4.14: Pearson's correlation coefficients between weather variables and fodder yield of *rabi* sorghum at Parbhani

Weather variables	Stages					Mean
	Boot stage	Flowering stage	Milk stage	Dough stage	Maturity	
RF	0.09	0.85**	0.21	0.03	0.11	- 0.21
RD	0.26	0.86**	0.02	- 0.76**	0.24	- 0.16
T_{Max}	- 0.53	- 0.82**	0.28	0.03	0.99**	0.12
T_{Min}	- 0.54	- 0.90**	- 0.18	- 0.68*	0.85**	- 0.22
T_{Mean}	- 0.54	- 0.97**	0.11	- 0.51	0.98**	- 0.11
RHI	- 0.43	0.98**	0.18	- 0.93**	0.79**	- 0.21
RHII	- 0.52	- 0.97**	- 0.00	- 0.48	0.03	- 0.29**
RHmean	- 0.50	- 0.97**	0.10	- 0.69*	0.75**	- 0.28*
EVP	- 0.19	- 0.15	0.35	0.39	0.98**	0.28*
BSS	- 0.18	0.28	0.35	0.29	0.90**	0.27*

(*Significant at 5%; **significant at 1%)

SOLAPUR

Resources capitalization efficiency of three *rabi* sorghum varieties (M 35 -1, Mauli and Vasudha) was studied in terms of consumptive use, thermal time and RUE by creating variability in the ambient environment through four staggered sowings.

Consumptive use of moisture (CU) during total growth period of sorghum (Fig. 4.12) showed a polynomial relationship with grain yield. The CU of 300 mm was found to be optimum for getting higher grain yield and CU higher than 300 mm resulted in a decrease in sorghum yields. The grain yields when regressed on thermal time (GDD) showed a polynomial relationship (Fig.4.13) which indicated that with increase in GDD there was increase in grain yield up to 1800 GDD and thereafter decrease in yield with increase in GDD. The RUE was also found to have a polynomial relationship with grain yield (Fig.4.14) and if RUE increases from 2.8 to 3.2 g MJ^{-1} the yield increased from 06 to 10 q ha^{-1}. This indicated that with every increase of 0.1 g MJ^{-1} of energy, there is an increase of 0.6 q ha^{-1} of grain yield of sorghum.

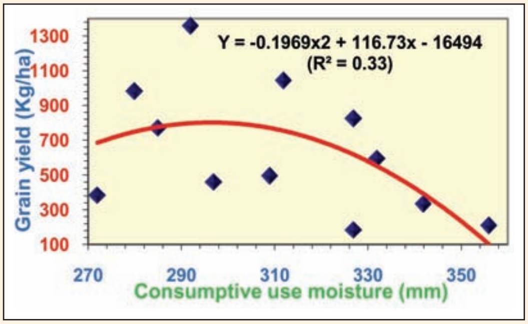


Fig. 4.12: Sorghum grain yield as influenced by consumptive moisture use at Solapur

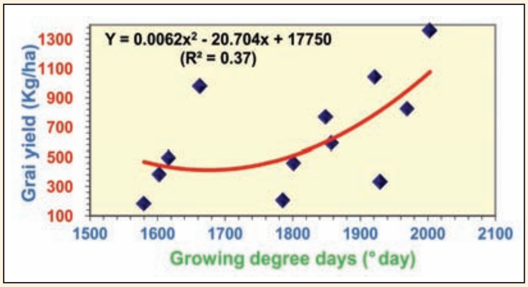


Fig. 4.13: *Rabi* sorghum grain yield as influenced by thermal time at Solapur

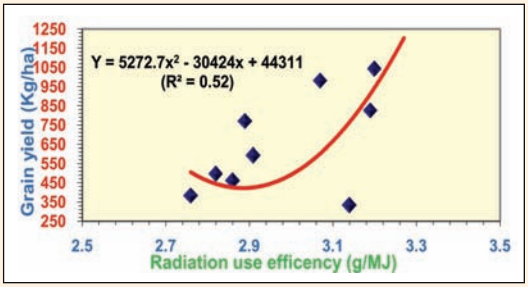


Fig. 4.14: Relation between *Rabi* sorghum grain yield and Radiation use efficiency at Solapur

Sunflower

BIJAPUR

Role of weather at different phenophases on productivity of four sunflower varieties (KBSH-1, Ganga Kavery, Sunnbreed-275, NSP 92-1(E)) was assessed from six years of experimentation. It can be inferred from the correlation coefficients (Table 4.15) that during seedling and vegetative stages, the crop requires considerable atmospheric vapor content during the afternoon period, which helps in reduction of transpiration losses resulting in good vigour of the crop. This is also supported by the positive correlation with cloudiness factor (morning and afternoon cloudiness) and negative correlation with cumulative sunshine duration (cum-BSS) during these two stages. During flower bud initiation and flowering stages, warmer nights are important for sunflower crop to give higher yield.

Table 4.15: Pearson's correlation coefficients between meteorological variables in different growth stages of sunflower and seed yield at Bijapur

Variable	Seedling stage	Leaf development / vegetative stage	Flower bud initiation and development	Flowering	Seed development	Physiological maturity
MAXT	-0.44	-0.37	0.30	0.03	0.31	-0.16
MINT	0.44	0.44	0.58	0.43	0.11	0.13
VP1	0.41	0.37	0.52	0.40	0.20	0.17
VP2	0.60	0.54	0.49	0.52	0.19	-0.01
RH1	0.44	0.34	0.36	0.25	0.12	0.04
RH2	0.62	0.56	0.37	0.46	0.08	0.05
TR	-0.45	-0.48	-0.46	-0.40	-0.02	-0.17
RHR	-0.59	-0.56	-0.17	-0.44	0.01	-0.03
CC I	0.54	0.56	0.32	0.30	-0.06	0.04
CC II	0.50	0.64	0.58	0.45	-0.08	0.16
BSS	**-0.53**	**-0.56**	**-0.32**	**-0.23**	**0.12**	**-0.03**
RF	**0.06**	**0.16**	**0.10**	**0.31**	**-0.03**	**0.09**

Based on the above correlations, models (Table 4.16) were developed to predict the yield of sunflower using the meteorological variables in different stages of the crop with different coefficients of determination.

Table 4.16: Weather based yield prediction models for sunflower crop

Phenological stage	Models	R^2
Seedling (S)	Y = 147.34 CC2(S) + 114.24 VP2(S) - 2405.73	0.44
Vegetative (V)	Y = 23.70 + 199.94 CC2(V) – 16.84 RHR(V)	0.50
S & V	Y = 17.65 RH2 (S) + 134.42 CC2(V) – 14.81 RHR(V) – 741.49	0.60
S, V & F (F: Flowering)	Y = 588.69 + 281.67 CC2(V) -23.27 RH2(V) - 33.82 RHR (V) + 54.71 VP2(F)	0.70

Where:
VP_2 = Afternoon vapor pressure in mm Hg
RH_2 = Afternoon relative humidity in per cent
CC_2 = Afternoon cloud cover in Octa
RHR = Relative humidity range

Maize

KOVILPATTI

Performance of maize *cv.* 900 M Gold during north east monsoon season under four growing environments was studied using agrometeorological indices like AGDD and HUE (Table 4.17). Knee high stage accumulated more thermal units because of longer duration and higher temperatures prevailed compared to other stages. Highest HUE was noticed (51.06 kg/ha/°day) during cob initiation stage in the crop sown in the 41st SMW.

Table 4.17: Influence of sowing dates on growing degree days and heat use efficiency (kg/ha/°day) of Maize at different phenophases at Kovilpatti

Treat-ments	Seedling emergence		Knee high		Tasseling		Cob initiation		Silking		Maturity		AGDD
	GDD	HUE	GDD	HUE	GDD	HUE	GDD	HUE	GDD	HUE	GDD	HUE	
39th SMW	86	11.20	497	6.63	343	12.30	107	47.19	244	24.18	90	124.91	1370
40th SMW	169	5.50	537	5.91	290	14.06	129	37.76	96	59.32	238	45.69	1462
41st SMW	211	4.16	498	6.03	324	11.89	90	51.06	96	56.51	175	58.60	1396
42nd SMW	93	9.04	498	5.78	324	11.37	90	48.91	96	53.69	175	56.12	1278

Maximum temperature in the range of 26.8 - 35.1°C, minimum temperature in 19.3 - 21.9°C range, relative humidity in the range of 85.3 - 95.8 per cent with a well distributed rainfall (555 - 570 mm) were found to be optimum for maize crop during north east monsoon season.

Blackgram

KOVILPATTI

Response of four black gram cultivars (Co 5, Co 6, VBN 4 and VBN 5) to variations in growing environment was assessed in terms of their HUE. Among the cultivars, CO 5 was found to be more efficient in heat use (Table 4.18).

Table 4.18: Influence of sowing time and variety on the yield, yield attributes and heat use efficiency of black gram at Kovilpatti

Treatments	No. of pods/pl	Pod length (cm)	No. of seeds/pod	100 seed wt (g)	Yield (kg/ha)	HUE (kg/ha °days^{-1})
40 SMW	33.7	5.4	6.6	5.7	721	0.105
41 SMW	27.8	5.2	6.0	5.5	524	0.095
43 SMW	18.7	4.5	4.9	5.3	239	0.043
CD	**4.0**	**0.63**	**0.75**	**NS**	**71.53**	**-**
Co 5	29.7	5.8	6.5	5.7	604	0.096
Co 6	24.4	4.6	5.4	5.2	386	0.062
VBN 4	27.4	5.1	5.8	5.6	555	0.092
VBN 5	25.4	4.7	5.7	5.4	433	0.075
CD	**2.9**	**0.43**	**0.50**	**NS**	**49.15**	**-**

Chickpea

ANANTAPUR

Thermal sensitivity of chickpea was assessed in a semi-arid / arid environment and role of moisture use in negating the heat stress was studied in *cv.* JG-11 by sowing the crop thrice at 15 day interval under different irrigation regimes. Crop responded favourably to two irrigations at 35 and 55 DAS and irrigated crop recorded highest HUE due to significant higher yields (Table 4.19). The crop sown early accumulated more thermal time and physiothermal units and showed highest HUE compared to the late sowings.

Table 4.19: Response of chickpea to irrigation and thermal time at Anantapur

Irrigations	GDD (°days)	HTU (°day*hr)	HUE (kg/ha/GDD)	Yield (kg/ha)
Rainfed (I_0)	1534.5	11602.2	0.794	1094
Irrigation at 35 DAS (I_1)	1769.4	13930.1	0.787	1393
Irrigation at 35 & 55 DAS (I_2)	1919.9	15301.6	0.886	1473
Mean	1741.3	13611.3	0.822	68.2
SD	194.2	1870.2	0.05	148.6
Dates of sowing				
27.10.2010 (D_1)	1960.1	14387.8	0.953	1461
11.11.2010 (D_2)	1667.9	13364.5	0.726	1317
24.11.2010 (D_3)	1595.8	13081.7	0.772	1182
Mean	**1741.3**	**13611.3**	**0.81**	**74.3**
SD	**192.9**	**687.1**	**0.12**	**206.3**

SOLAPUR

Two chickpea cultivars *viz.,* Vijay and Digvijay were evaluated for their efficiency in capturing the natural resources through CU and RUE and to determine the optimum ranges of different weather parameters. The cumulative moisture use in chickpea showed that beyond 270 mm of water the yields are declining and RUE of both the cultivars is about 2.45 g/ MJ (Fig. 4.15). Though the coefficient of determination values is relatively low for CU, the relation gives an indication on the type of response. Both the chickpea cultivars are sensitive to maximum and minimum temperatures and yields declined as the temperatures increased. Maximum yields were recorded at a day time (maximum) temperature of 31.5°C and a night time (minimum) temperature of 21.6°C (Fig. 4.16).

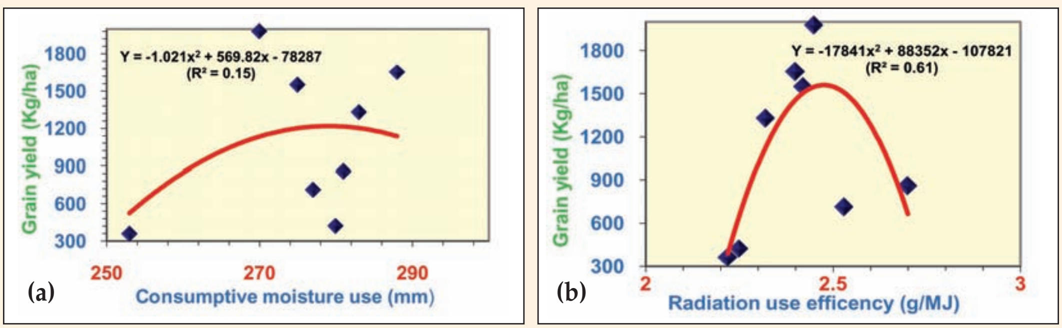


Fig. 4.15: Response of chickpea to (a) moisture and (b) radiation at Solapur

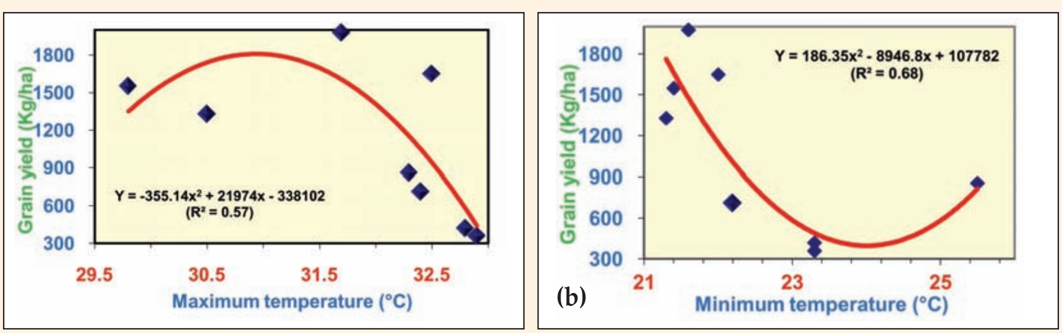


Fig. 4.16: Response of chickpea cultivars to (a) maximum and (b) minimum temperatures at Solapur

JABALPUR

Two *desi* chickpea cultivars *viz.,* JG-315 and JG-11 were studied for their response to temperature and photo-period which indicated that both the cultivars are sensitive to an increase in maximum and minimum temperatures at flowering to physiological maturity. A mean temperature of around 18.0°C during this sensitive stage resulted in reduction in seed yield and there is a linear decrease in seed yields as the mean temperature increased from 18.0 to 25.0°C (Fig. 4.17 a). Both the cultivars responded favourably to increased duration of 50 per cent flowering to maturity, which is a physiologically sensitive stage as reflected in the corresponding values of thermal time, HTU and PTU (Fig. 4.17 b to d). Thus, cultivars taking more number of days to complete this sensitive stage are like to yield more in Jabalpur environment, which should be the selection criteria in the breeding program.

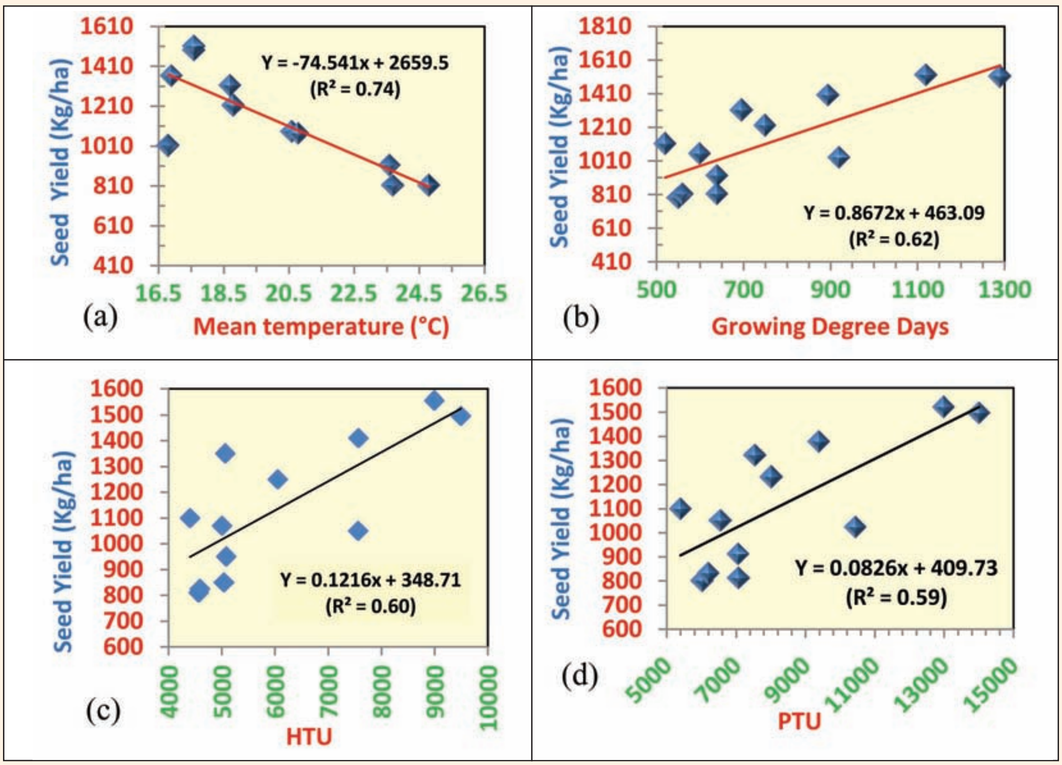


Fig. 4.17: Chickpea seed yields as influenced by (a) mean temperature, (b) GDD, (c) HTU and (d) PTU during 50 per cent flowering to maturity at Jabalpur

FAIZABAD

Variations in dry matter accumulation and seed yields of three chickpea cultivars (Radhey, Pusa 362 and Uday) were examined in relation to temperature, humidity and sunshine. Dry matter produced during vegetative stage when regressed on the hours of bright sunshine (Fig. 4.18) indicated that highest dry matter production can be achieved if the duration of sunshine is 8.3 to 8.6 hours in a day which accounted for 56 per cent variation in the dry matter production. Similarly, dry matter production was found at the optimum rate when the humidity in the air is around 83 to 85 per cent (Fig.

4.19). Seed yields of all the chickpea cultivars were found to be sensitive to temperature during reproductive stage as yield decreased significantly when the day time temperatures increased from 27.2 to 33.2°C (Fig. 4.20). It can be estimated from the trend line that with an increase of 1.0°C in maximum temperature seed yield would decrease by 350 kg/ha.

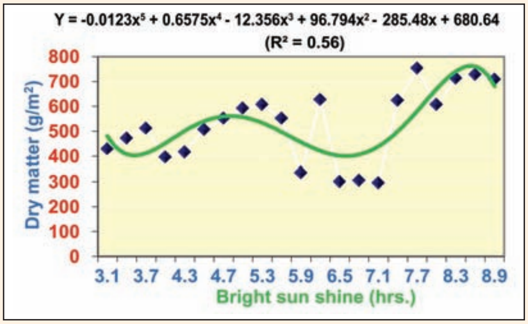


Fig. 4.18: Influence of duration of sunshine during vegetative stage on dry matter production of chickpea at Faizabad

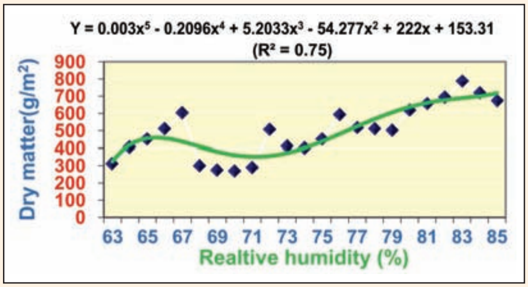


Fig. 4.19: Influence of duration of relative humidity during vegetative stage on dry matter production in chickpea at Faizabad

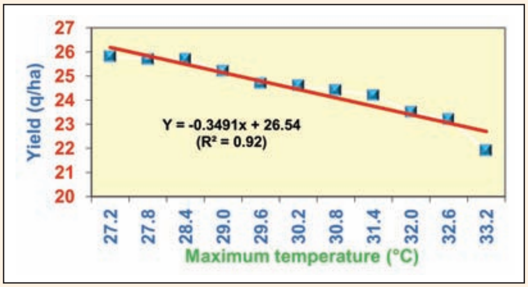


Fig. 4.20: Influence of maximum temperature during reproductive stage on seed yield of chickpea at Faizabad

Vegetables

DAPOLI

Growing vegetables in shade nets is a common practice in peri-urban agriculture to alleviate heat stress during post monsoon and summer seasons. This condition inadvertently creates a reduction in the sunlight at the top of the crop canopies. Information on the crop productivity at reduced solar intensities is thus required to optimize the permeability of the shade nets. In this background, experiments on three vegetables *viz.*, Spinach, Radish and Amaranthus under three shaded levels and eleven dates of sowing (15 day interval) were conducted. Spinach sown on 30th January gave highest leaf yield under open conditions but the yields declined as the incident radiation decreased from 25 per cent to 75 per cent. Radish sown on 30th December in the open, recorded highest yield and yields of this crop also declined as the radiation levels decreased. Amaranthus yields are comparatively influenced to a lesser extent under 25 per cent reduction in the incident sunlight. Sowing of amaranthus can be delayed up to 15th February under reduced sunlight conditions in the shade nets (Table 4.20).

Table 4.20: Yields of Spinach, Radish and Amaranthus (q/ha) as influenced by sowing time and radiation levels at Dapoli

Sowing date	Reduction in sunlight intensity											
	S_1 – Open			S_2 – 25 Per cent			S_3 – 50 Per cent			S_4 – 75 Per cent		
	C1	C2	C3	C1	C2	C3	C1	C2	C3	C1	C2	C3
15th Nov.	37.90	52.98	27.78	33.53	47.02	22.82	28.37	42.26	17.66	27.58	34.92	15.28
30th Nov.	42.26	56.35	23.21	39.88	41.27	19.84	33.93	35.71	16.67	31.03	37.70	13.89
15th Dec.	43.45	49.60	22.62	42.26	44.64	18.25	32.74	37.30	15.87	30.95	32.14	15.48
30th Dec.	45.04	57.54	23.81	41.87	33.73	21.23	36.11	30.95	14.09	26.39	30.95	16.27
15th Jan.	43.25	51.19	23.41	43.65	38.49	18.85	33.33	35.32	16.27	29.17	33.73	18.06
30th Jan.	46.83	50.40	24.21	45.63	36.51	20.63	34.13	30.56	14.09	25.79	30.56	16.27
15th Feb.	45.04	43.85	21.83	46.43	44.05	24.21	34.52	36.71	17.46	25.79	28.37	18.25
3rd Mar.	40.48	50.20	21.03	37.30	42.26	22.62	28.77	34.13	18.65	27.18	25.20	17.06
15th Mar.	38.69	47.42	20.04	36.90	39.88	20.24	32.14	28.37	18.45	26.19	27.98	16.87
30th Mar.	39.09	47.02	22.62	39.48	40.28	20.44	29.37	31.35	14.68	28.37	23.41	12.70
15th Apr.	37.30	46.23	19.05	37.70	37.50	18.45	28.57	28.57	15.08	30.36	25.00	16.27

(C1- Spinach, C2- Radish, C3 - Amaranth)

Cauliflower

THRISSUR

The thermal time requirement of two varieties of Cauliflower was examined by planting the crop on five different dates at an interval of 15 days. An inverse relation was observed between accrued thermal time and the fresh weight of the total plant (Fig. 4.21). The crop experienced cooler weather in early dates of sowing (D_1 and D_2) as reflected in low accumulation of GDD values. This might have helped in putting up more fresh weight compared to other dates of sowing.

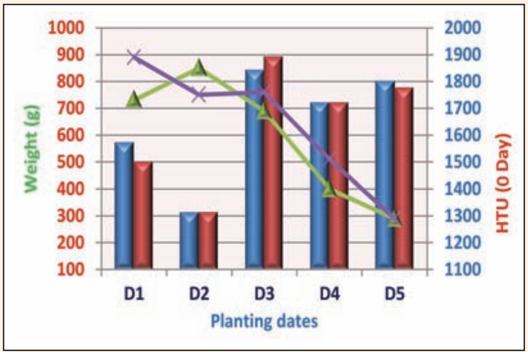


Fig. 4.21: Relation between thermal time (°day) and fresh weight of total plant in cauliflower at Thrissur

Soybean

AKOLA

Experimentation using three soybean varieties *viz.*, JS-335, TAMS-38 and TAMS-98-21 with four sowing dates (28th June, 6th July, 13th July and 21st July, 2011) was carried out to determine the response of soybean to varied weather conditions. Correlation coefficients between seed yield and weather variables at different phenophases presented in table 4.21 showed that during vegetative stage crop responded positively to a rise in maximum and minimum temperatures while during flowering and maturity stages the influence of rainfall was found to be significant and detrimental. On the contrary, crop responded positively to rainfall at other growth stages. A rise in the day time temperature during seed formation and development was found to cause a reduction in seed yield whilst night time temperatures were found to have a beneficial effect on seed yield.

Table 4.21: Pearson's correlation coefficients between seed yield and weather variables in different phenophases of soybean at Akola

Parameters	Vegetative phase	Flowering	Pod formation	Seeed formation	Full seed development	Physiological maturity	Total growing period
Rainfall	0.52**	-0.79**	0.49**	0.82**	0.56**	-0.41**	0.83**
Max.T	0.67**	0.27	0.00	-0.75**	-0.90**	-0.24	-0.54**
Min.T	0.52**	0.16	0.23	0.85**	0.91**	0.27	0.79**
MeanT	0.64**	0.31*	0.14	-0.65**	-0.89**	-0.18**	0.10
RH_I	-0.56**	-0.57**	0.79**	0.89**	0.90**	0.30*	0.10
RH_{II}	-0.59**	-0.78**	0.57**	0.83**	0.88**	0.57**	0.64**
RH_{mean}	-0.58**	-0.76**	0.69**	0.85**	0.89**	0.54**	0.48*
GDD	0.35*	0.02	0.31*	0.19	0.09	0.68**	0.32*
HTU	-0.27	0.12	-0.58**	-0.81**	-0.55**	0.68**	-0.63**

(Significant at 0.05 level; ** Significant at 0.01 level)*

PARBHANI

Six soybean varieties *viz.*, MAUS-158, JS 93-05, MAUS-47, MAUS-71, MAUS-81 and JS-335 were subjected to four different temperature regimes by sowing them on 07th July, 14th July, 21st July and 28th July, 2011 to understand the influence of thermal regime on the crop performance.

Correlation coefficients between weather prevailed during different phenophases and growth and yield of crop are presented in table 4.22. The analysis revealed that temperature has a positive influence on crop growth during pod and seed formation. Rainfall during pod formation stage caused a reduction in seed yield but during seed development stage it has a strong positive association. A well distributed rainfall favours the crop growth during pod development and seed formation stages as evident from the correlation coefficients at both the stages.

Table 4.22: Pearson's correlation coefficients between seed yield and weather variables prevailed during different phenophases of soybean at Parbhani

Parameters	Pod formation	Grain formation	Pod development	Seed development	Mean
Rainfall	- 0.35*	0.49**	0.52**	- 0.10	0.22**
R.Days	- 0.24	0.40**	0.85**	0.02	0.27**
Max.T.	0.37*	0.25	- 0.82**	- 0.00	- 0.11
Min.T.	0.62**	0.60**	- 0.33	- 0.18	0.37**
MeanT	0.35*	0.36*	- 0.82**	- 0.19	- 0.02
T.Range	0.05	-0.02	- 0.80**	0.08	- 0.25**
RH_I	- 0.49**	0.01	0.79**	0.09	0.11
RH_{II}	- 0.17	0.21	0.80**	0.55**	0.24**
RH_{mean}	- 0.29	0.15	0.83**	0.13	0.16*
RH_{Range}	0.00	- 0.26	- 0.68**	- 0.77**	- 0.27**
BSS	0.13	0.18	- 0.84**	- 0.70**	- 0.10
EVP	0.31	0.27	- 0.86**	- 0.41**	- 0.21**
WS	0.14	- 0.28	0.65**	- 0.14	0.13
SMC	0.39*	0.88**	0.62**	0.24	0.13

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

Groundnut

ANAND

Groundnut crop sown with the onset of monsoon (D_1) captured natural resources more efficiently as evident from higher pod yields compared to crop sown at later dates. The results from the experimentation conducted with three varieties (M-335, GG-20 and GG-5) and three sowing environments (8th July, 23rd July and 7th August, 2011) indicated (Table 4.23) that pod and haulm yields decreased by 6% and 13% in D_2 and 36% and 4% in D_3, respectively over D_1 sown crop. Studies on soil moisture depletion revealed a drastic reduction in soil moisture status during peg initiation to pod development stage in case of D_2 and D_3 sowing. Among the varieties, GG-20 was found to be highest pod yielding variety for Anand conditions for the sowing periods tested and GG-5 was found to be a poor performer.

Table 4.23: Groundnut yield contributing attributes as influenced by different treatments at Anand

Treatment	Pod yield (kg/ha)	Haulm yield (kg/ha)	Test wt. (g)	Shelling (%)
Mean for date of sowing				
8th Jul (D_1)	1830	3060	48.9	68.0
23rd Jul (D_2)	1726	2653	45.9	67.0
7th Aug (D_3)	1173	2935	42.0	65.0
S.Em.±	48.6	111	1.34	0.74
C.D. at 5 %	153	NS	4.2	NS
C.V. %	13.07	16.36	12.4	4.43
Mean for variety				
M-335 (V_1)	1650	3333	52.5	69.0
GG-20 (V_2)	1694	2662	46.8	65.0
GG-5 (V_3)	1384	2652	37.5	68.0
S.Em.±	58.7	138.9	1.16	0.87
C.D. at 5 %	170	401	3.36	3
C.V. %	15.80	20.45	10.8	8.14

ANANTAPUR

A pre-released groundnut culture (K-1271) was evaluated along with two released varieties (Vemana and K-6) for their adaptability to differential thermal regimes imposed by sowing at different time periods (10th July, 25th July and 08th Aug, 2011). The response of the genotypes was assessed using agrometeorological indices like GDD and HTU and the comparative response (Table 4.24) that indicated a longer crop duration in D_1 over the other two dates. However, longer crop duration has not resulted in higher pod yields (Table 4.25). Late sown crop though required fewer growing days but ultimately culminated into better utilization of resources as reflected in lower accumulated GDD and HTU values at all phenological stages except emergence. As the crop sown lately experienced higher temperatures at reproductive stage and beyond, it accumulated more quantum of agrometeorological indices and also the higher conversion efficiency might have helped the late sown crop to put up higher yields.

Table 4.24: Days taken from sowing to phenological stages of groundnut and accumulated GDD and HTU at Anantapur

Phenophase	DAS	AGDD	AHTU	Tmax (°C)	Tmin (°C)
		D_1: 10.07.2011			
Emergence	7	114	852	34.3	23.7
50% flowering	29	523	2910	33.2	23.8
Pegging	38	695	3988	34.3	24.0
Pod initiation	56	992	4936	31.6	23.2
Physiological maturity	135	2350	14746	32.6	21.4
		D_2 : 25.07.2011			
Emergence	7	109	646	32.9	23.2
50% flowering	29	515	2746	33.3	23.6
Pegging	40	704	3272	31.2	23.2
Pod initiation	52	923	4618	33.4	22.9
Physiological maturity	128	2159	13682	32.1	20.9
		D_3 : 08.08.2011			
Emergence	7	115	709	34.3	24.0
50% flowering	28	483	1996	31.8	23.2
Pegging	40	702	3428	33.5	22.9
Pod initiation	54	953	5464	33.9	22.6
Physiological maturity	125	2090	13626	31.4	20.1

Table 4.25: Pod yield (kg/ha) and yield attributes of groundnut as influenced by different treatments at Anantapur

Treat-ments	No. of plants/m²	Total No. of pods /m²	Filled pods / m²	Ill filled pods/ m²	Test weight (g)	Shelling (%)	Pod yield (kg/ha)	Haulm yield (kg/ha)
				Dates of sowing				
10.07.2011	29.2	19.3	09.6	4.2	33.5	70.0	510	1275
25.07.2011	30.2	21.5	10.6	2.9	35.4	72.7	599	1499
08.08.2011	31.7	24.4	11.9	2.06	37.9	74.4	749	1872
SEm ±	0.24	0.21	0.15	0.17	0.36	0.26	24.3	60.7
C.D	NS	0.7	0.5	0.58	0.83	0.67	79.2	198.0
				Varieties				
Vemana	30.9	21.5	10.6	3.0	35.2	72.4	605	1514
K-6	31.8	24.0	11.6	2.5	38.8	74.1	822	2055
K-1271	28.6	19.8	09.8	3.7	32.8	70.6	431	1078
SEm ±	0.21	0.22	0.10	0.10	0.42	0.35	18.1	35.2
C.D	NS	0.66	0.3	0.3	0.87	0.72	52.8	132

Cotton

AKOLA

Climatic change influences that are likely to be reflected in cotton crop and perspective adaptation strategies were studied in Bt cotton hybrid, Ankur-651 by sowing at different intervals (7th June, 27th June, 13th July) and under four adaptation strategies like conventional practices, conservation furrows, dead mulch and live mulch. Correlation coefficients worked out between weather variables prevailed during different phenophases and seed cotton yield (Table 4.26) indicated that during first square to first flower period rainfall plays a critical role and excess rainfall had a negative impact on cotton yields. Higher day time temperature during flowering and boll formation stages was found to have negative impact on cotton yields.

Table 4.26 : Pearson's correlation coefficients between weather parameters at different phenophases and seed cotton yield at Akola

Weather parameters / phenophases	Sowing - Emergence	Emergence - First square	First square - First flower	First flower First burst	First boll burst - First picking	First picking - Last picking	Emergence - Last picking
Tmax	0.94**	0.89**	0.12	-0.95**	-0.73**	0.94**	0.93**
Tmin	0.79**	0.88**	0.92**	0.95**	0.91**	0.88**	0.95**
Mean Temp.	0.93**	0.89**	0.86**	-0.94**	0.52	0.91**	0.94**
RH_1	-0.90**	-0.80**	-0.78**	0.95**	0.93**	0.84**	-0.93**
RH_2	-0.94**	-0.84**	-0.47	0.95**	0.95**	0.59*	-0.68*
Mean RH	-0.93**	-0.83**	-0.60*	0.95**	0.95**	0.74**	-0.88**
Wind speed	0.25	0.93**	0.80**	0.93**	0.81**	0.85**	0.94**
Rainfall	-0.26	0.14	-0.84**	0.95**	-0.52	0.83**	0.95**
Sunshine	0.89**	-0.90**	0.25	-0.95**	-0.07	-0.90**	0.68*
Evapo-transpiration	0.94*	0.87**	0.93**	-0.95**	-0.91**	0.89**	0.95**
Rainy days	0.02	-0.25	0.33	0.95**	—	—	0.95**
GDD	0.89**	0.88**	0.82**	0.94**	0.14	0.91**	0.95**
HTU	0.91**	-0.92**	0.68*	-0.94**	0.23	0.92**	0.91**

Water Use

Yield of crops under rainfed conditions is largely controlled by water availability during critical stages. Crop water use efficiency is a parameter that determines plant tolerance to moisture stress conditions. Higher the values higher will be the ability of the plant to tolerate the moisture stress condition and yield relatively higher than the plants with low WUE values. Crop WUE can be improved through efficient management practices. The Rain Water Use Efficiency (RWUE) of cotton as influenced by sowing environment and adaptation strategy was worked out and presented in table 4.27. Crop sown early consumed more water and exhibited high RWUE than the crop sown late. Different adaptation strategies evaluated in the present study did not improve the crop WUE.

Table 4.27: Water use indices of cotton as influenced by different treatments at Akola

Treatment	Seed cotton yield (kg ha^{-1})	Seasonal Rainfall (mm)	Actual crop water use (mm)	Rain water use efficiency (kg ha-mm^{-1})	Water productivity (kg ha-mm^{-1})
Sowing time					
Dry sowing(07 June)	1723	443.9	429.9	3.88	4.01
Monsoon sowing (27 June)	1147	383.6	321.4	2.99	3.57
Late sowing (13 July)	685	327.8	267.8	2.09	2.56
Adaptation strategy					
Conventional practice	1201	385.1	341.8	3.12	3.51
Conservation furrows	1205	385.1	339.9	3.13	3.55
Dead mulch	1177	385.1	336.6	3.06	3.50
Live mulch	1157	385.1	340.4	3.00	3.40

PARBHANI

Response of cotton to variability in the weather conditions was assessed through field experimentation involving three varieties (NH 452, NH 545 and NH 615) and six growing environments (crop sown on 22nd June, 29th June, 06th July, 13th July, 20th July and 27th July, 2011). Response at different growth stages when assessed by correlation coefficients (Table 4.28) indicated that rainfall and rainy days during boll setting to boll bursting significantly influenced the seed cotton yield. A well distributed rainfall throughout the crop season is a requisite for higher yields at Parbhani as evident from the high correlation coefficient values for most of the growth stages. Cotton growth in the initial stages seems to be regulated by temperature as high correlation between yield and both maximum and minimum temperatures were noticed at P_2 (emergence to seedling) and P_3 (seedling to square formation) stages.

Table 4.28: Pearson's correlation co-efficient exhibited by weather parameters prevailed in different phenophases with seed cotton yield (2011-12) at Parbhani

Parameters	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	Pooled
Rainfall	0.34	0.61	-0.02	0.16	0.35	0.77**	-0.01	0.21	0.13**
Rainy days	0.61**	0.72**	-0.53	0.79**	0.60**	0.89**	0.72**	-0.51	0.15**
Tmax.	0.10	-0.17	0.66**	- 0.54**	-0.29	-0.29	-0.02	- 0.72**	0.01
Tmin.	0.02	0.89**	0.91**	0.59**	0.30	0.89**	0.74**	0.92**	0.08

Parameters	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	Pooled
Tmean	0.09	0.64**	0.81**	-0.20	-0.19	0.65**	0.72**	0.58**	0.08
T.range	0.14	- 0.57**	0.21	- 0.79**	-0.37	- 0.75**	- 0.64**	-0.36	-0.08
RH_I	-0.27	0.53**	- 0.90**	0.31	0.54**	0.89**	0.61**	- 0.85**	0.05
RH_{II}	-0.40	0.19	- 0.57**	0.46*	0.49**	0.91**	0.55**	0.53**	0.05
RH_{mean}	-0.36	0.32	- 0.67**	0.35	0.53**	0.77**	0.68**	-0.07	0.06
RH_{range}	0.40	-0.04	0.31	-0.32	-0.39	- 0.92**	-0.29	- 0.88**	-0.06
Evapo-transpiration	0.20	0.67**	0.12	- 0.47**	- 0.74**	- 0.91**	-0.08	0.85**	-0.07
Bright sunshine	- 0.62**	0.05	0.52**	- 0.85**	- 0.53**	- 0.90**	-0.10	- 0.53**	- 0.13**
GDD	0.50	0.88**	-0.29	0.67**	- 0.54**	0.59**	- 0.53**	0.82**	0.08

(*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)

Rice

DAPOLI

Thermal time requirement for attaining different phenophases in hybrid rice (Sahyadri-2) was determined by transplanting the crop at two different times (fortnightly interval) and presented in table 4.29. The thermal time as well as hydrothermal and

Table 4.29: Requirement of GDD, Hydrothermal and Heliothermal units to attain different phenological stages in rice at Dapoli

Growing Degree Days (GDD)					
Sowing Date	Seedling	Tillering	Flowering	Maturity	Total
24 SMW	506.05	546.80	389.65	647.20	2089.70
26 SMW	480.45	545.2	396.75	649.9	2072.30
Hydrothermal Units					
24 SMW	45807.23	52883.10	37241.83	55109.48	191041.63
26 SMW	44759.28	52633.53	36265.9	52816.65	186475.35
Heliothermal Units					
24 SMW	1346.71	566.23	563.06	4009.82	6485.81
26 SMW	927.455	692.125	1165.39	4736.315	7521.29

heliothermal requirements for different growth stages showed that the delay in sowing has not affected significantly the degree days requirement in any of the crop stages. However, heliothermal unit requirement increased with delay in sowing at all the stages for tillering to maturity.

MOHANPUR

Crop varieties differ in their resource use efficiencies like radiation use efficiency, water use efficiency, etc., and rice is no exception. The radiation use efficiency of three rice varieties Satabdi, Baismukhi and a pre-released varieties from RRI was determined by planting the varieties on three different dates (15th June, 29th June and 13th July, 2011). The interception of PAR values accumulated over different growth stages were regressed on accumulation of biomass and the resultant relations for the three different varieties are presented in fig. 4.22 a to c and association between these two variables can be expressed as:

Satabdi	:	Y= 0.0172 APAR + 6.5263	...R2 = 0.61* n = 18 p <0.05
Baismukhi	:	Y= 0.0331 APAR + 3.7243	...R2 = 0.92* n = 18 p <0.05
Pre-released	:	Y= 0.0176 APAR + 5.1299	...R2 = 0.74* n = 18 p <0.05

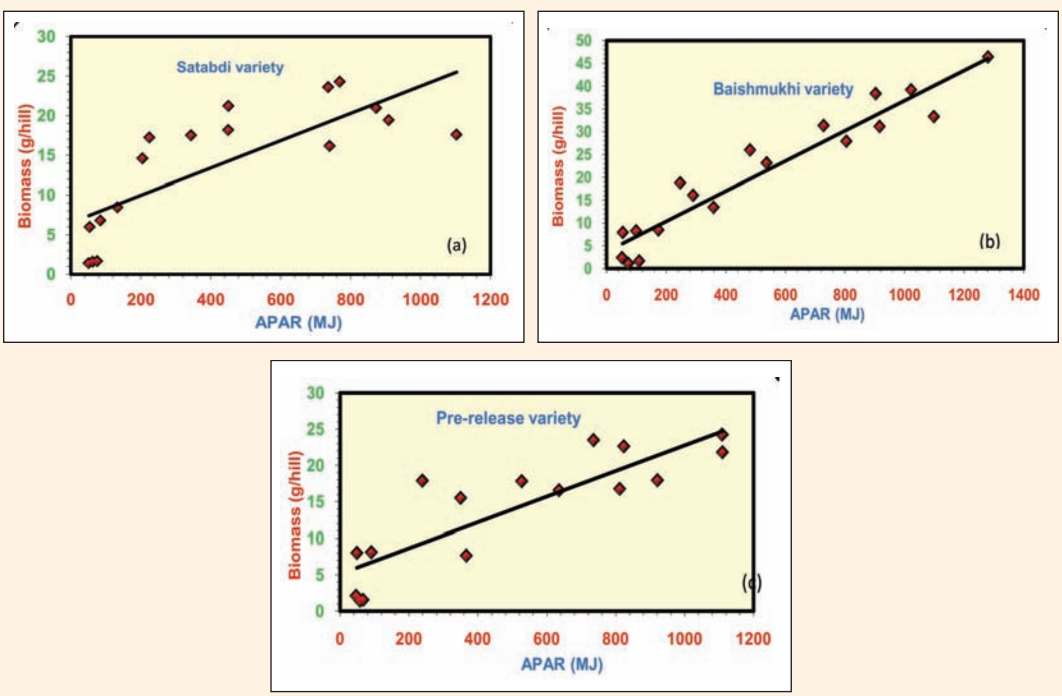


Fig. 4.22: Biomass-APAR relationships of different rice cultivars at Mohanpur

KANPUR

To understand the role of weather on the growth and yield of rice varieties, a field study was conducted with three varieties *viz.*, NDR-359 (V_1), Sarjoo-52 (V_2), CSR-27 (V_3) and three planting dates *viz.*, 10th July (D_1), 20th July (D_2), 30th July (D_3). The response of rice was assessed in terms of correlation between days taken to different phenophases, dry matter production, yield and observed / derived weather variables and presented in table 4.30. Rainfall received at all the growth stages favourably influenced the rice yields while hours of bright sunshine during grain filling and maturity stages has also showed a positive impact. Differences in thermal time accumulation in different phenophases across the dates of sowing and varieties were observed (Fig. 4.23 a to c). For instance, NDR-359 accumulated more heat units in D_3 date of sowing compared to other dates. Likewise, Sarjoo-52 accumulated more HTU in D_3 date of sowing to complete anthesis compared to NDR-359. The variety CSR-27 being photosensitive accumulated lower thermal time and PTU with delay in transplanting ultimately culminating into low yields. Regression was performed to develop prediction equations to determine the harvest date and to estimate the grain yield. The resultant relations are presented in table 4.31 which accounted for 54% to 97% variations in yield.

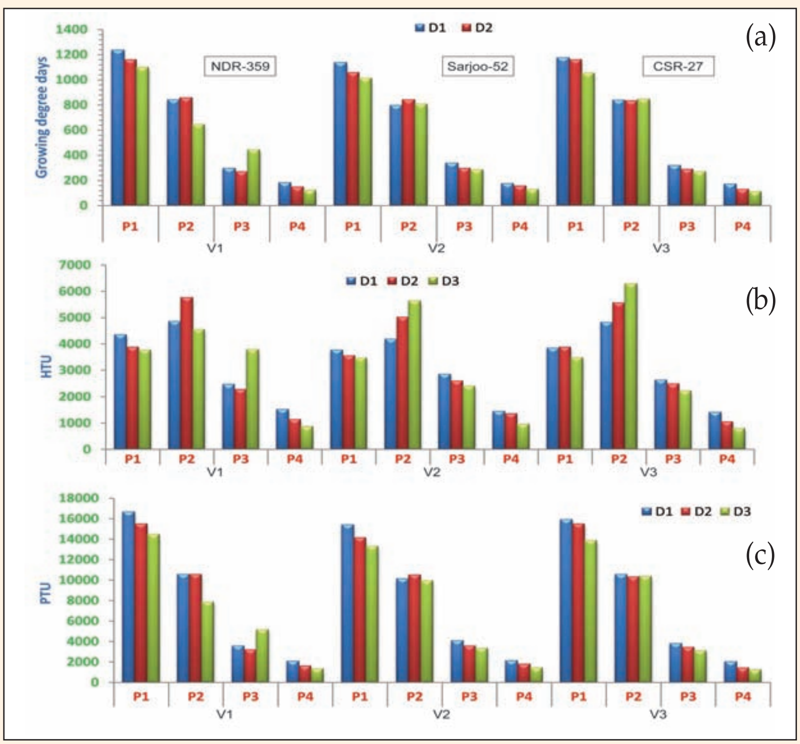


Fig.4.23: GDD, HTU and PTU at different phenophases of paddy at Kanpur

Table 4.30: Pearson's correlation coefficients between grain yield and weather parameters that prevailed during different stages of Paddy

Growth stage	Weather parameters												
	Tmax. °C	Tmin. °C	Tmean °C	Mean soil temp. °C (5 cm)	RH I (%)	RH II (%)	RH mean (%)	SSH	WS	RF (mm)	Eva.	AG DD	Duration
Tillering	0.47	0.64	0.54	-0.12	0.19	0.51	0.52	-0.18	-0.09	0.79	0.96	0.96	0.95
Anthesis	-0.31	0.61	0.64	0.40	0.63	0.55	0.58	-0.32	-0.55	0.84	0.76	0.92	0.85
Grain filling	0.18	0.65	0.63	0.60	-0.35	0.64	0.43	0.43	0.38	0.83	0.89	0.96	0.93
Maturity	0.62	0.48	0.54	0.55	-0.58	-0.06	-0.28	0.66	0.17	0.83	0.97	0.97	0.98

Table 4.31: Regression equations between grain yield / crop duration and weather parameters

Parameters	Equation	R^2
Grain yield (kg/ha.)	Y= - 43604.55 + 4535.52 Tmax. + 1725.80 Tmin. – 4662.66 Soil T	0.54
	Y= -14304.67 + 348.79 BSS + 9.61 Eva. + 3.72 HU	0.97
	Y= - 10706.05 – 12.86 RHm + 1.11 Cu RF + 133.09 Days	0.96
	Y= - 13230.57 – 3.12 AGDD + 0.76 AHTU + 0.51 APTU	0.97
Duration (days)	Y = - 10.17 + 0.18 AGDD – 0.003 AHTU – 0.009 APTU	0.99

RAIPUR

Performance of three rice cultivars (Karma Mahsuri, MTU 1010, Mahamaya) in harnessing natural resources was analyzed in the terms of accumulation of thermal time, photothermal, heliothermal units and phenothermal index. Results of the analysis presented in table 4.32 indicated that irrespective of type of cultivar studied, the crop sown early (D_1 - 10 June) accumulated more agrometeorological indices. The phenothermal index, an indicative of the daily thermal requirement varied among varieties during vegetative, reproductive and maturity stages. Among the varieties, MTU-1010 required more heat units and among the different dates, early sown crop accumulated more thermal time compared to other two dates of sowing.

Table 4.32: Influence of sowing dates on phenology and heat units of different rice varieties at Raipur

Physiological Stages	Karma Mahsuri			MTU 1010			Mahamaya		
	D_1	D_2	D_3	D_1	D_2	D_3	D_1	D_2	D_3
Phenology (Days)									
Seedling	25	25	25	25	25	25	25	25	25
Vegetative	72	71	68	59	56	54	65	63	63
Reproductive	105	102	99	95	91	88	104	102	98
Maturity	138	134	130	120	116	113	129	126	122
Growing degree-days (Cumulative)=Mean temp.-base temp.									
Seedling	491	467	452	491	467	452	491	467	452
Vegetative	1328	1277	1217	1108	1013	973	1208	1135	1129
Reproductive	1895	1808	1747	1719	1614	1556	1877	1808	1729
Maturity	2460	2333	2232	2156	2054	1991	2318	2221	2126
Photothermal Units (Cumulative)=GDD*day length									
Seedling	6521	6182	5964	6521	6182	5964	6521	6182	5964
Vegetative	17435	16668	15765	14612	13300	12692	15889	14854	14683
Reproductive	24502	23219	22223	22332	20838	19939	24280	23219	22016
Maturity	31195	29371	27859	27634	26111	25086	29535	28060	26659
Heliothermal Units (Cumulative)=GDD*SShr									
Seedling	2391	1853	1655	2391	1853	1655	2391	1853	1655
Vegetative	5438	4781	4581	4967	3672	3734	5030	4051	4284
Reproductive	7528	6746	7314	6722	5703	5703	7367	6746	7158
Maturity	11891	11207	11392	9397	8738	9310	10653	10201	10463
Phenothermal index=GDD/days taken for each phenophase									
Seedling	19.6	18.7	18.1	19.6	18.7	18.1	19.6	18.7	18.1
Vegetative	17.8	17.6	17.8	18.1	17.6	18.0	17.9	17.6	17.8
Reproductive	17.2	17.1	17.1	17.0	17.2	17.1	17.2	17.3	17.1
Maturity	17.1	16.4	15.6	17.5	17.6	17.4	17.6	17.2	16.5

(D_1 - 10th June, D_2 - 20th June and D_3 - 30th June)

RANCHI

Different energy conversion efficiencies *viz.*, heat, water and radiation use efficiency in rice were studied in three rice varieties (Vandana, BVD 109, BVD 111) by exposing them to varied environmental conditions through staggered planting (20^{th} June, 30^{th} June and 10^{th} July, 2011). The comparison made among different varieties and sowing dates are presented in table 4.33. The crop planted on 30^{th} June registered higher efficiency values than the crop planted earlier or later. The rice variety Vandana was found to be comparatively more efficient in resource capturing.

Table 4.33: Heat Use Efficiency (HUE), Water Use Efficiency (WUE) and Radiation Use Efficiency (RUE) of paddy varieties as influenced by planting time at Ranchi

Treatment	Heat use efficiency (kg/ha °day)	Water use efficiency (kg/ha mm)	Radiation use efficiency (g/MJ)	Yield (q/ha)
Sowing date				
20^{th} June	1.28	4.7	1.09	19.87
30^{th} June	1.62	6.2	1.37	24.29
10^{th} July	1.62	6.2	1.36	22.4
Variety				
Vandana	1.59	6.0	1.35	23.55
BVD 109	1.44	5.4	1.22	20.93
BVD 111	1.49	5.6	1.26	22.0

Pooled analysis

Data collected from 5 years field experimentation were utilized to identify most critical weather parameter as well as critical crop stage for the said parameter. The results of the analysis expressed as correlation coefficient values (Table 4.34) indicated that vegetative stage is more sensitive to day time temperatures. Rice varieties were found to be sensitive to night time temperatures during grain filling stage. Grain yield decreased by 10.2 q/ha and 2.7 q/ha with a unit rise in maximum temperature at vegetative stage and minimum temperature during grain filling stage, respectively. The association between the grain yields and temperatures are depicted in fig. 4.24 a + b. The crop exhibited surprisingly independent from hours of bright sunshine at all the growth stages. As the crop is rainfed, it responded positively to rainfall during grain filling stage and negatively during flowering stage. The crop was found to be highly sensitive to rainfall at flowering recording an yield decrement of 705 kg/ha with each

100 mm increase in rainfall. This decrement came through a reduction in number of fertile grains per ear and increase in number of chaffy grains. On the contrary, yield increased by 630 kg/ha with each 100 mm additional rainfall during grain filling stage. The divergent behaviour of the influence of rainfall on rice yields at different stages are depicted in fig. 4.25. a + b.

Table 4.34: Pearson's correlation coefficients between weather parameters during different phenophases and grain yield of rice at Ranchi

Parameters/ Stages	Sowing - Germination	Germination - 50% flowering	100% flowering	Milking	Grain filling	Maturity
Max T	-0.46	-0.65**	0.09	0.05	-0.28	-0.07
Min T	-0.36	-0.27	0.12	0.46	0.62**	0.40
Rain	0.48*	0.34	-0.54*	-0.21	0.52*	0.42
RH I	-0.11	0.09	-0.37	-0.06	0.36	0.24
RH II	-0.12	-0.75**	-0.25	-0.13	0.25	0.13
SSH	-0.15	-0.32	-0.11	0.35	-0.13	0.44

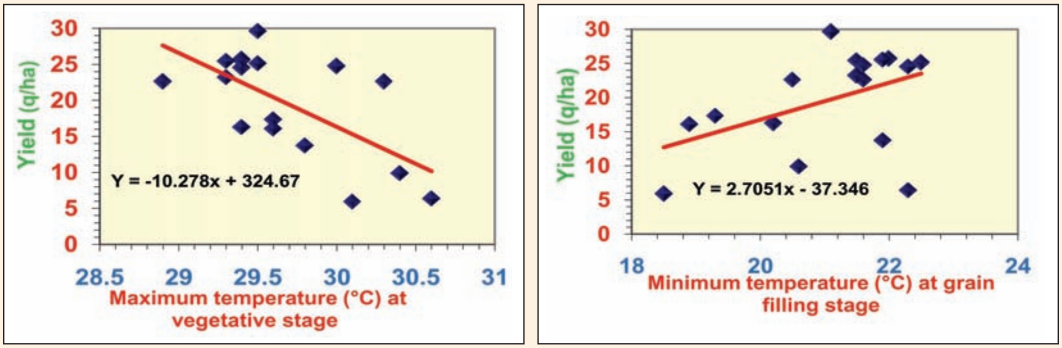


Fig. 4.24: Relation between maximum and minimum temperature during vegetative and grain filling stages, respectively with yield at Ranchi

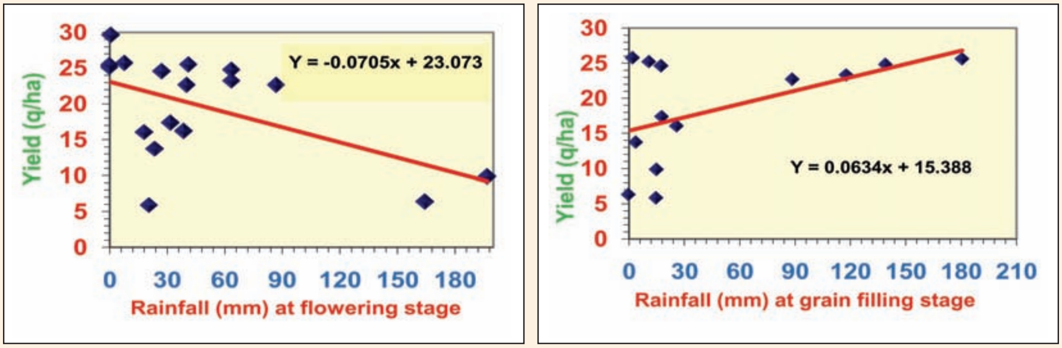


Fig. 4.25: Association between rice yield and rainfall received during flowering and grain filling stages at Ranchi

JABALPUR

Tolerance of nine rice varieties for drought conditions was evaluated using Drought Susceptibility Index (DSI) which can be expressed as

DSI = (1-Yd/Yp)/D

where,

Yd = grain yield of genotype under moisture stress/ rainfed condition

Yp = grain yield of genotype under irrigated condition

D = mean yield of all varieties under moisture stress or rainfed condition/ mean yield of all varieties under irrigated condition.

Rice grain yield data under different moisture regimes with respective DSI values are presented in table 4.35. Higher the DSI values lesser will be tolerance to drought conditions and *vice versa.* It can be inferred from the DSI values that Shubhangi is comparatively drought tolerant with least DSI value whilst, JR 201 is the most susceptible to drought conditions among the varieties evaluated.

Table 4.35: Performance of rice varieties under drought conditions at Jabalpur

Variety	Irrigated		Marginally Irrigated		Rainfed		DSI
	Grain yield (kg/ha)	Biological yield (kg/ha)	Grain yield (kg/ha)	Biological yield (kg/ha)	Grain yield (kg/ha)	Biological yield (kg/ha)	
Anjali	2182	6667	2359	5926	2304	6852	0.55
Dantesh	3344	8704	2982	8704	2874	8519	0.36
DVD109	2463	7593	2456	6852	2267	6482	0.49
IET20859	3670	9815	2793	7593	2944	8333	0.33
IET20863	2467	8148	2993	8148	2630	7778	0.49
JR201	2144	9815	2567	8333	2333	8333	0.56
NDR97	2637	7963	2819	8148	2889	7963	0.46
Subhangi	4048	11482	2689	8889	2937	9074	0.30
Vandana	3044	7963	3378	7963	2474	7222	0.40

SAMASTIPUR

Influence of thermal and moisture environments on the performance of three rice varieties (Rajendra Suhashini, Rajendra Bhagwati, Rajendra Kasturi) was studied by planting at fortnightly intervals (31th May, 14th June, 28th June, 12th July, 2011) and results of the study are presented in table 4.36.

Days taken to complete 50 per cent flowering to maturity stage was found to be altered across different sowing windows. The crop sown on 31st May received highest rainfall and ultimately produced highest yield (48.15 q/ha) and the temperature prevailed during 50 per cent flowering to maturity was also comparatively higher. With a delay in sowing beyond 14th June percentage of chaffy grain per panicle increased.

Table 4.36: Influence of rainfall and temperature on rice yields at Samastipur

Date of sowing	Temperature (°C)		Days taken from 50 % flowering to milking stage	Rainfall (mm)	Percentage of unfilled grain per panicle	Yield (q/ha)
	50 % ear head to maturity	Mean Temp (°C)				
31 May	31.9-25.2	28.6	28	273.4	21.6	48.15
14 June	31.9-22.9	27.5	30	77.8	19.4	44.80
28 June	30.0-18.6	24.4	30	78.4	27.7	40.00
12 July	28.7-17.6	23.2	32	78.4	31.6	35.89

Maize

KOVILPATTI

Heat use efficiency (HUE) is a tool to assess the crop response to its growing environment and HUE of maize (*cv.* 900M Gold) as influenced by sowing time was determined through four staggered plantings (39, 40, 41, 42 SMW). The higher thermal time required for seedling emergence in the crop sown on 41st SMW may be due to delay in emergence as the crop was sown under sub-optimal moisture condition (dry sowing). The crop sown late (42nd SMW) accumulated lower thermal units in all growth stages except silking but this did not reflect in the ultimate yield. The thermal time accrued beyond silking stage had a direct relation on seed yield in crops sown during 39th and 40th SMW. (Table 4.37)

Table 4.37: Performance of maize in terms of thermal time accumulation and heat use efficiency (kg/ha/°day) at Kovilpatti

Treat-ments	Seedling emergence		Knee high		Tasseling		Cob initiation		Silking		Maturity		AG DD	Yield (kg/ha)
	GDD	HUE	GDD	HUE	GDD	HUE	GDD	HUE	GDD	HUE	GDD	HUE		
39th SMW	111	13.23	491	10.09	353	18.71	111	70.38	83	113.35	275	52.69	1424	5218
40th SMW	109	12.65	468	9.95	319	19.45	142	51.63	112	78.72	248	54.91	1398	4894
41st SMW	171	7.75	443	10.07	340	17.45	94	74.83	120	70.71	204	64.67	1372	4731
42nd SMW	99	12.71	435	9.68	325	17.26	91	73.19	127	62.81	220	56.72	1297	4463

UDAIPUR

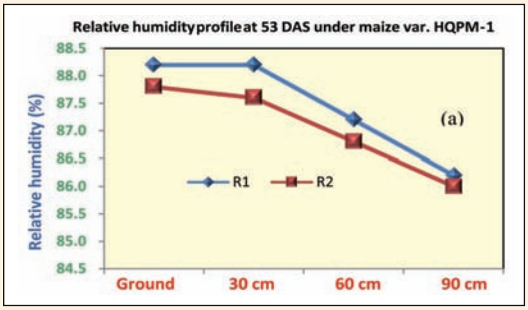
Microclimate in maize crop canopy as modified by planting time and row spacing was studied to understand the crop-micro environment relationships. Temperature profile studied in crop canopies under different planting times *viz.*, 16th Jun, 30th Jun, 15th Jul, 2011 (Table 4.38) indicated that influence of variety and row spacing on air temperature of the microclimate is marginal. Crop sown at a wider spacing recorded slightly higher air temperature in the canopy at different heights compared to the crop sown at closer spacing. Humidity profile was also examined in different treatments (Fig. 4.26 a to c) and a comparison among them revealed that crop sown at a closer spacing (45 cm) experienced humid weather compared to the one sown at a wider spacing (60 cm). This might have helped to maintain a congenial microclimate for the maize crop as the pooled data of three year experimentation (Table 4.39) indicated that closer spacing and early sowing in maize is advantageous over late sown crop at wider spacing.

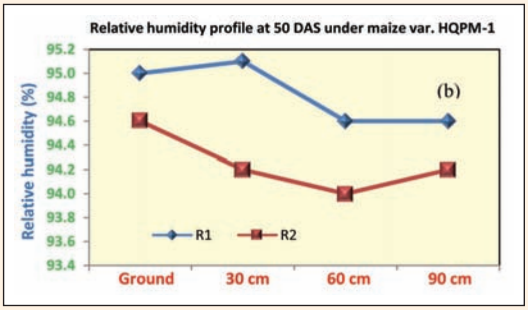
Table 4.38: Temperature (°C) profile in maize varieties sown at different spacings (11 to 2 pm) at Udaipur

Height/ varieties	HQPM-1		PEHM-2		Pratap-1	
	R_1 - 45 cm	R_2 - 60 cm	R_1 - 45 cm	R_2 - 60 cm	R_1 - 45 cm	R_2 - 60 cm
53 DAS under 16th Jun sowing						
Ground	27.6	27.2	27.4	27.1	27.6	27.6
30 cm	27.6	27.6	27.4	27.6	27.5	27.4
60 cm	26.8	27.2	27.2	27.5	27.4	27.6
90 cm	27.0	27.4	27.0	27.6	27.4	27.2
50 DAS under 30th Jun sowing						
Ground	25.6	25.6	25.4	25.2	25.4	25.7
30 cm	25.8	25.4	25.6	25.4	25.2	25.6
60 cm	25.8	25.6	25.4	25.6	25.6	25.6
90 cm	25.9	25.6	25.6	25.8	25.6	26.2
57 DAS under 15th Jul sowing						
Ground	28.2	28.4	28.2	28.2	28.1	28.4
30 cm	28.2	28.6	28.0	28.4	28.2	28.2
60 cm	28.6	28.8	28.2	28.2	28.6	28.6
90 cm	28.5	29.0	28.6	28.5	28.6	28.8

Table 4.39 : Sowing time, row spacing and varietal interactions in maize (2009-2011) at Udaipur

Treatment	Grain yield (q/ha)			
	2009	2010	2011	Mean
Date of sowing				
16th June	34.85	39.82	48.20	40.96
30th June	30.08	33.41	35.81	33.10
15th July	26.23	23.92	29.35	26.50
SEm ±	1.516	0.147	1.340	-
CD (P = 0.05)	4.201	0.462	4.223	-
Row Spacing				
45 cm	31.21	33.56	39.57	34.78
60 cm	29.56	31.21	36.01	32.26
SEm ±	1.238	0.098	1.094	-
CD (P = 0.05)	NS	0.271	3.448	-
Varieties				
HQPM-1	32.15	33.70	37.94	34.60
PEHM-2	30.52	32.73	38.47	33.91
Pratap-1	28.49	30.71	36.95	32.05
SEm ±	1.516	0.194	0.841	-
CD (P = 0.05)	NS	0.565	NS	-





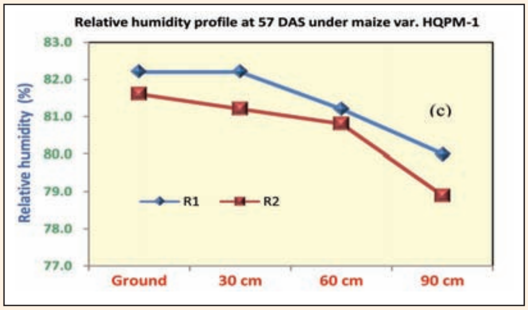


Fig. 4.26 a to c: Relative humidity profile of maize as influenced by row spacing at Udaipur

Pigeonpea

FAIZABAD

Radiation use efficiency (RUE) is a simplification of canopy photosynthesis dynamics and provides a useful quantification of seasonal biomass production when other factors are non-limiting. Radiation use efficiency of pigeonpea varieties was determined under varied environmental conditions imposed at the field level through manipulation of sowing time (Table 4.40). RUE increased almost linearly till pod initiation stage and attained peak value in June 25th sown crop. The July 15th sown crop recorded lowest RUE at all the phenophases due to lower dry matter accumulation. Among the varieties N.Arhar-2 recorded highest RUE at all the stages followed by N.Arhar-1 while lowest RUE was noticed in Bahar variety.

Table 4.40: RUE (g/MJ) of pigeonpea varieties at various phenophases as influenced by sowing time at Faizabad

Treatments	Phenophases					
	4-leaf stage	Start of flowering	50% flowering	Pod initiation	50% Podding	Maturity
Sowing dates						
June 25	1.54	1.67	2.27	2.78	1.97	1.87
July 05	1.27	1.58	2.19	2.65	1.76	1.68
July 15	1.17	1.46	2.15	2.56	1.68	1.67
Varieties						
N Arhar-1	1.26	1.57	2.17	2.37	1.57	1.57
N.Arhar -2	1.31	1.54	2.15	2.56	1.66	1.66
Bahar	1.21	1.47	1.87	1.73	1.31	1.42

Kharif sorghum

PARBHANI

Response of kharif sorghum cultivars (CSH 14, CSH 16) to varied growing environments imposed through staggered sowings (14th June, 28th June, 12th July, 26th July) was assessed and correlation coefficients presented in Table 4.41 indicated that rainfall during boot leaf, flowering and milking stages have a positive influence on the grain yield. Well distributed rainfall during flowering stage seems to be critical for higher seed yield as reflected in its high correlation coefficient value. Diurnal temperature range also showed significant influence on grain yield and as the range widens yields declined. Fodder yields of all the sorghum cultivars presented in table 4.42 showed response akin to seed yield.

Table 4.41: Pearson's correlation coefficients between weather variables and grain yield of sorghum at Parbhani

Weather variables	Stages					Seasonal mean
	Boot leaf	Flowering	Milk	Dough	Maturity	
RF	0.74**	0.79**	0.79**	0.26	0.50	0.11
RD	- 0.05	0.91**	0.57	0.63*	0.73**	0.10
T_{Max}	0.50	- 0.68*	- 0.71**	- 0.61	- 0.08	- 0.09
T_{Min}	0.81**	0.45	0.92**	0.88**	0.93**	- 0.48**
T_{Mean}	0.81**	- 0.39	- 0.62	0.58	0.93**	0.40**
Trange	- 0.24	- 0.87**	- 0.85**	- 0.96**	- 0.86**	- 0.44**
RHI	- 0.22	0.70*	0.67	0.85**	0.83**	0.23
RHII	- 0.63	0.92**	0.78**	0.84**	0.79**	0.30**
RHmean	- 0.50	- 0.90**	0.79**	0.92**	0.81**	0.27**
RHrange	0.87**	- 0.88**	- 0.78**	- 0.42	- 0.69*	- 0.31**
EVP	0.36	- 0.98**	0.17	- 0.76**	- 0.67*	0.04
BSS	- 0.29	- 0.97**	- 0.60	- 0.85**	- 0.80**	- 0.40**
WS	0.69*	0.64	0.76**	- 0.02	-0.15	0.24*

(* Significant at 5%;**significant at 1%)

Table 4.42: Pearson's correlation coefficients between weather variables and sorghum fodder yield at Parbhani

Weather variables	Stages					Seasonal mean
	Boot	Flowering	Milk	Dough	Maturity	
RF	0.78**	0.80**	0.70*	0.22	0.45	0.11
RD	- 0.02	0.88**	0.50	0.60	0.66	0.10
T_{Max}	0.42	- 0.64*	- 0.68*	- 0.56	0.06	- 0.09
T_{Min}	0.77**	0.38	0.90**	0.87**	0.89**	- 0.48**
T_{Mean}	0.78**	- 0.39	- 0.60	0.60	0.93**	0.40**
Trange	- 0.33	- 0.81**	- 0.82**	- 0.94**	- 0.79**	- 0.44**
RHI	- 0.15	0.67*	0.62	0.86**	0.77**	0.23
RHII	- 0.54	0.90**	0.69*	0.80**	0.73**	0.30**
RHmean	- 0.42	- 0.88**	0.73**	0.88**	0.75**	0.29**
RHrange	0.78**	- 0.87**	- 0.68*	- 0.36	- 0.62	- 0.31**
EVP	0.28	- 0.96**	0.22	- 0.77**	- 0.61	0.04
BSS	- 0.39	- 0.93**	- 0.53	- 0.79**	- 0.74**	- 0.40**
WS	0.62	0.59	0.75**	- 0.08	-0.19	0.24*

(*significant at 5%; ** significant at 1%)

Pearl Millet

SOLAPUR

Pearl millet's capacity to adapt to changes in growing environment was quantified using meteorological indices like Growing Degree Days (GDD), Radiation Use Efficiency (RUE) and Moisture Use Efficiency (MUE).

The quantum of water used in the entire crop season, expressed as consumptive moisture use (CUM) when related with its corresponding grain yields indicated that the MUE declined from 5.13 to 3.47 kg/ha.mm., as the sowings were delayed. Among the varieties tested ICTP-8203 was found to be efficient in utilizing moisture (4.71) followed by Shanti (4.28) and Mahyco hybrid (4.24). Grain yield data when regressed on seasonal maximum and minimum temperatures (Fig. 4.27) indicated that pearl millet productivity was at peak when the seasonal maximum temperature was around 32.1 and minimum temperature at 19.8°C.

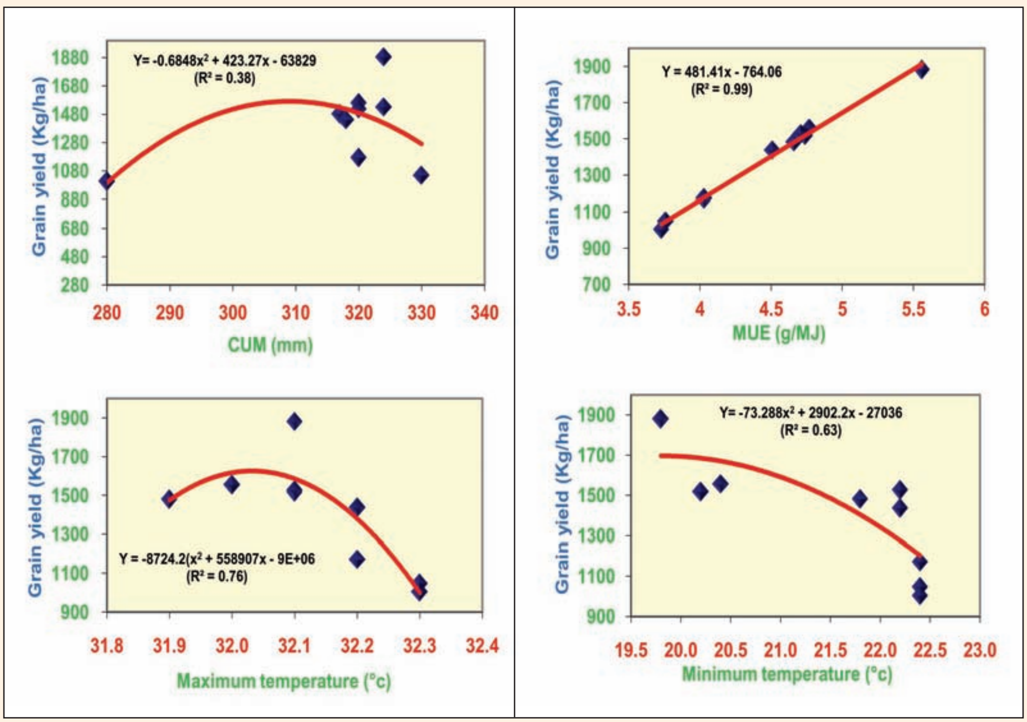


Fig. 4.27: Relations between pearl millet grain yield and different agrometeorological indices at Solapur

Tea

PALAMPUR

An understanding on the influence of temperatures on tea has become mandatory in the light of large variability in temperatures in northern and northeastern parts of India. Thus, an analysis was carried out to identify critical limits of temperature for tea production. The temperature pattern that should prevail during different months in the year to attain highest tea productivity is presented in fig. 4.28. It can be inferred from the figure that maximum and minimum temperatures must not be lower than 16.8 and 6.1°C, respectively and any temperature lower than this, lower will be the production of tea leaves. In order to obtain highest production of tea leaves, the maximum and minimum temperatures, respectively must not exceed 26.6 and 15.5° C during April, 30.1 and 18.5° C during May, 26.7 and 19.1°C during June, 27.9 and 19.7 °C during August and 26.4 and 17.7 °C during September. The fall of maximum and minimum temperature below 24.2 and 13.5° C during October was found to reduce the tea production drastically.

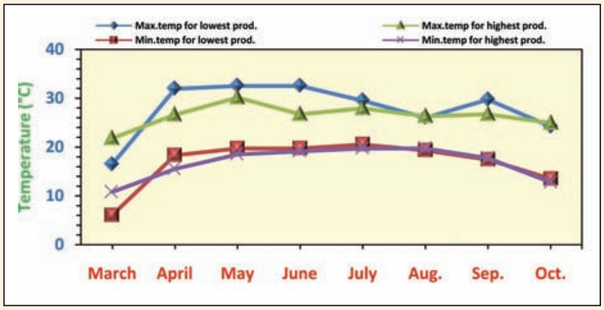


Fig. 4.28: Critical temperatures for optimum tea productivity at University tea garden, Palampur

Milk Production

PALAMPUR

Different animal species have different sensitivities to ambient temperature and the amount of moisture in the air. During hot and humid weather the natural capability of cattle to dissipate heat load by sweating and panting is compromised, and heat stress sets in. A temperature-humidity index (THI) represents the combined effects of air temperature and humidity associated with the level of thermal stress. It is widely used to study the influence of weather conditions on the productivity of milch animals. The association between THI and milk production at Palampur for a period of 12 years was analysed and the results (Table 4.43) indicated that during most part of the year the THI values are lower than 72, which is stated to be critical value for heat stress.

Table 4.43: Milk production as influenced by weather parameters at Dairy Research Farm at Palampur (2000-2011)

Months	Milk Production (Kg)	THI_I	THI_{II}	Mean TH_I
Jan	21475.7	46.5	57.5	52.0
Feb	19810.4	50.8	58.8	54.8
Mar	23414.9	56.7	66.5	61.6
Apr	22974.9	63.2	70.8	67.0
May	24635.5	71.2	70.0	70.6
Jun	22383.0	70.9	69.4	70.1
Jul	22044.6	71.4	71.9	71.6
Aug	21363.1	70.0	70.2	70.1
Sep	19729.7	67.4	67.9	67.6
Oct	19680.9	61.1	61.1	61.1
Nov	18682.7	55.7	58.3	57.0
Dec	20175.2	50.5	58.9	54.7

(*All values are mean of the years, 2000-2011)

Rabi 2011-12

Sunflower

BIJAPUR

Data from a seven year experiment (2005-2011) involving three sowing environments (22nd Aug, 05th Sep, 29th Sep) and four cultivars of sunflower (KBSH-1, Ganga Kavery, Sunbreed 275, NSP 92-1) were utilized to determine the role of weather on its development and seed yield through statistical tools like correlation and regression techniques. Important meteorological variables were identified through correlation analysis performed at different phenological stages (Table 4.44). It can be noticed that highly significant positive correlation of yield exists with afternoon relative humidity in seedling and vegetative stages, with minimum temperature in flower bud initiation stage and with afternoon vapor pressure in flowering stage. The weather variables that have a significant role at different growth stages and expressed highly significant association with seed yield are presented in fig. 4.29 a to d.

Table 4.44: Pearson's correlation coefficients between meteorological variables in different growth stages of sunflower and seed yield at Bijapur

Variable	Seedling stage	Leaf development/ vegetative stage	Flower bud initiation and development	Flowering	Seed development	Physiological maturity
MAXT	-0.57*	-0.38	0.22	0.15	0.21	-0.14
MINT	0.44	0.45*	0.56**	0.46*	0.19	0.11
VP1	0.44	0.40	0.53**	0.43	0.28	0.17
VP2	0.62**	0.54**	0.51**	0.53**	0.25	0.02
RH1	0.45*	0.37	0.43	0.29	0.12	0.03
RH2	0.68**	0.54**	0.41	0.47*	0.13	0.09
Temperature Range	-0.56	-0.50	-0.48	-0.40	-0.12	-0.15
Relative Humidity Range	-0.63**	-0.52**	-0.15	-0.39	-0.06	-0.10
Cumulative Sunshine	-0.60	-0.58	-0.39	-0.21	0.10	0.06
Morning Cloud Cover	0.57	0.48	0.38	0.30	0.03	0.00
Evening Cloud Cover	0.54**	0.54**	0.60**	0.45*	0.02	0.11
EVAP	-0.44	-0.37	-0.13	-0.16	0.05	0.00
RF	0.11	0.12	0.11	0.45	0.00	0.09
GDD	0.06	0.14	0.44	0.48*	0.32	0.20

(*Significant at 5%; **Significant at 1% level of significance)

Regression models were developed to predict seed yield using the meteorological variables in different stages of the sunflower crop during the year 2010-11 (Table 4.45) and these were validated for their accuracy utilizing the data collected on *cv.* KBSH-1 during the year 2011-12. A comparison was made between the observed and predicted yield and expressed in per cent error for all the models developed for different stages.

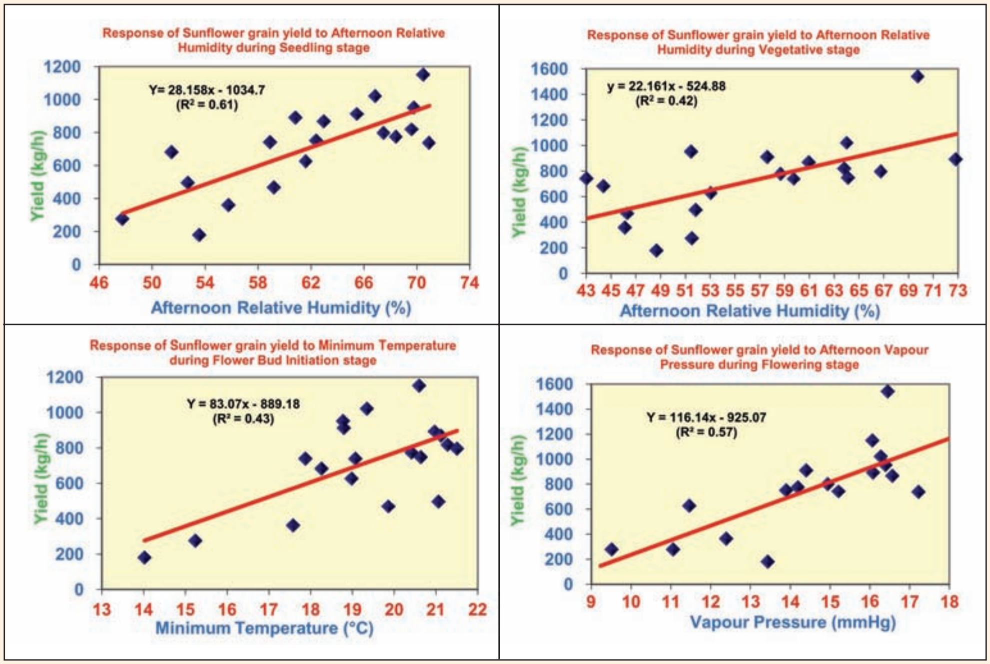


Fig. 4.29: Sunflower seed yield as influenced by (a & b) afternoon RH, (c) minimum temperature and (d) afternoon VP at different growth stages at Bijapur

Table 4.45: Weather based yield prediction models for sunflower crop

Physiological stage	Models		R^2
Seedling (S)	Y = 144.22 VP2(S) – 1978.1	.... S-1	0.36
	Y = 29.271 RH2(S) – 1101	....S-2	0.38
	Y = 147.34 CC2(S) + 114.24 VP2(S) - 2405.73	....S-3	0.44
Vegetative (V)	Y = 89.04 VP2(V) – 833.28	....V-1	0.29
	Y = 20.13 RH2(V) – 420.45	....V-2	0.31
	Y = 23.70 + 199.94 CC2(V) – 16.84 RHR(V)	....V-3	0.50
S & V	Y = 21.71 RH2 (S) + 12.51 RH2(V) - 1346.19	....SV-1	0.48
	Y = 19.1 RH2 (S) + 186.11 CC2(V) - 1620.1	....SV-2	0.54
	Y = 17.65 RH2 (S)+134.42 CC2(V) - 14.81 RHR (V) - 741.49	....SV-3	0.60
S, V & F	Y = 588.69 + 281.67 CC2(V) -23.27 RH2(V) - 33.82 RHR (V) + 54.71 VP2(F)	.......SVF	0.70

Where:

VP2 = Afternoon vapor pressure in mm Hg.; RH2 = Afternoon relative humidity in per cent;
CC2 = Afternoon cloud cover in Octa ; RHR = Relative humidity range.

The alphabets in the parenthesis indicate the stage of the crop

All the models developed using the meteorological variables at seedling stage have been able to predict yield approximately to an extent of ± 10 per cent error in individual dates of sowing / growing environments. Among the models developed using the meteorological variables at vegetative stage model V-1 and model V-2 have been able to predict yield to the extent of less than 10 per cent error whereas the model V-3 has been able to predict 32 per cent less than observed yield in individual date of sowing / growing environment. Among the models developed using the meteorological variables of both seedling and vegetative stage model SV-1 has been able to predict less yield to the extent of less than 5 per cent error whereas the model SV-2 and SV-3 have been able to predict 30 and 40 per cent, respectively less than observed yield in individual date of sowing / growing environment. The model developed using the meteorological variables of seedling, vegetative and flowering stages put together has been able to provide prediction errors of more than 30 per cent in the year 2011-12 (Table 4.46).

The best results were provided by all the models (S-1, S-2 and S-3) which used afternoon vapour pressure, afternoon relative humidity and afternoon cloud cover) in seedling stage, two models (V-1 and V-2) which also used afternoon vapour pressure and afternoon relative humidity) in vegetative stage and one model (SV-1 which use afternoon relative humidity in seedling stage along with afternoon relative humidity in vegetative stage) with average errors of less than ten per cent. Thus it can be inferred from the above analysis that, the atmospheric moisture either in terms of vapor pressure or relative humidity is the most important variable in determining the yield of sunflower crop.

Table 4.46: Validation of yield prediction models of sunflower in the year 2011-12 at Bijapur

Year	Observed yield (kg/ha)	Predicted yield (kg/ha)			Per cent Error		
Seedling stage		**S-1**	**S-2**	**S-3**	**S-1**	**S-2**	**S-3**
22nd Aug	1149.0	790.9	962.6	819.058	-31.16	-16.22	-28.72
5th Sep	494.0	473.6	441.6	258.316	-4.12	-10.61	-47.71
29th Sep	359.0	589.0	532.3	497.048	64.07	48.28	38.45
Average					9.60	7.15	-12.66
Vegetative stage		**V-1**	**V-2**	**V-3**	**V-1**	**V-2**	**V-3**
22nd Aug	1149.0	680.4	640.4	435.898	-40.78	-44.26	-62.06
5th Sep	494.0	618.1	624.3	407.27	25.12	26.38	-17.56
29th Sep	359.0	502.3	507.5	306.044	39.92	41.38	-14.75
Average					8.08	7.83	-31.46

Year	Observed yield (kg/ha)	Predicted yield (kg/ha)			Per cent Error		
Seedling and Vegetative stage		SV-1	SV-2	SV-3	SV-1	SV-2	SV-3
22nd Aug	1149.0	843.6	638.4	662.396	-26.58	-44.44	-42.35
5th Sep	494.0	447.2	298.4	323.049	-9.47	-39.59	-34.61
29th Sep	359.0	441.9	227.3	317.733	23.10	-36.67	-11.49
Average					-4.32	-40.24	-29.48
Flowering Stage			SVF			SVF	
22nd Aug			483.6			-57.91	
5th Sep			406.5			-17.72	
29th Sep			257.9			-28.16	
Average						-34.59	

Mango

DAPOLI

The variability associated with the commencement of flowering in Alphonso mango was found to be 18 days in the period between 49th to 1st SMW that was determined from 14 year field experimental data when subjected to statistical analysis. As preceding weather conditions have a say on the subsequent flowering behaviour, data on meteorological parameters as a mean of 28 preceding days were correlated. The analysis showed that bright sunshine hours was significantly and positively correlated with flowering of Alphonso mango (r = 0.61). Regression analysis with different preceding periods (21 and 28 days) resulted in the development of relations that are presented in table 4.47. It can be noticed that maximum temperature, minimum temperature, RH-I and evaporation that prevailed during preceding 21 days accounted for about 53% variability in flowering. Addition of one more weeks data to the 21 day period has accounted for another 4% variability in flowering with maximum temperature, BSS and evaporation playing a major role.

Table 4.47: Forecasting models on mango flowering using different input weather variables at Dapoli

Sr. No.	Regression equation	R^2
I]	21 days weather parameters before flowering	
1.	Y = 792.875 – 5.420 Tmax + 4.892 Tmin – 5.709 RH-I – 0.504 RH-II – 13.017 BSS + 5.071 Evaporation	0.56*
2.	Y = 692.277 – 6.877 Tmax + 4.149 Tmin – 4.841 RH-I – 7.219 BSS + 6.452 Evaporation	0.55*
3.	Y = 552.826 – 5.671 Tmax + 4.032 Tmin – 4.412 RH-I + 7.197 Evaporation	0.53*
II]	28 days weather parameters before flowering	
1.	Y = -362.023 + 8.807 Tmax – 0.911 Tmin – 1.082 RH-I – 0.205 RH-II + 28.030 BSS + 4.936 Evaporation	0.62*
2.	Y = -376.920 + 8.581 Tmax – 0.985 Tmin – 1.008 RH-I + 28.862 BSS – 4.946 Evaporation	0.61*
3.	Y = -312.831 + 7.705 Tmax – 1.308 RH-I + 25.476 BSS + 6.264 Evaporation	0.61*
4.	Y = -413.958 + 6.809 Tmax + 26.830 BSS + 5.908 Evaporation	0.57*
5.	Y = -302.281 + 4.163 Tmax + 26.633 BSS	0.46
6.	Y = -138.562 + 23.281 BSS	0.38

(* Significant at 5%)

Mustard

HISAR

Resource use efficiency of three mustard varieties (Kranti, RH 30, RH 406) quantified in terms of thermal and radiation use efficiencies were determined from field experimentation involving four sowing environments (16th Oct, 20th Oct, 2nd Nov and 10th Dec). The thermal use efficiency (TUE) at various phenophases under different sowing environments (Table 4.48) revealed that higher TUE was recorded in the 16th October sown crop followed by 20th October, 2nd November and 10th November, at all phenophases. Among *B. species* varieties, Kranti had significantly higher TUE at 50% flowering, completion of flowering and physiological maturity stages followed by RH 406. The decrease in TUE in delayed sowings may probably be due to rapid senescence causing forced maturity due to higher temperatures in the reproductive phase.

Table 4.48: Thermal use efficiency of *Brassica* cultivars as influenced by sowing time at Hisar

Thermal use efficiency (g/m²/°day)			
Sowing dates	**50% Flowering**	**Completion of flowering**	**Physiological maturity**
16th Oct	1.79	1.76	1.71
20th Oct	1.59	1.52	1.45
2nd Nov	1.67	1.31	1.26
10th Nov	1.22	1.11	0.99
CD at 5%	0.04	0.04	0.03
SE (d) of D	0.01	0.01	0.01
Varieties			
Kranti	1.68	1.61	1.53
RH-30	1.46	1.25	1.16
RH-406	1.55	1.43	1.35
CD at 5%	0.03	0.03	0.02
SE (d) of V	0.01	0.01	0.01

Mustard crop sown earlier (16th October) was found to be most efficient in utilizing radiation compared to other three dates of sowing. Among the varieties evaluated, high RUE values were recorded throughout the growing season in Kranti followed by RH 406 (Table 4.49).

Table 4.49: Radiation use efficiency of mustard cultivars at various phenophases under different sowing environments at Hisar

Radiation use efficiency (g/MJ)			
Sowing dates	**50% Flowering**	**Completion of flowering**	**Physiological maturity**
16th Oct	4.15	4.93	3.95
20th Oct	3.51	3.92	3.31
2nd Nov	3.15	3.01	2.82
10th Nov	2.63	2.22	2.63
CD at 5%	0.08	0.13	0.06
SE (d) of D	0.03	0.05	0.02
Varieties			
Kranti	3.56	3.71	3.36
RH-30	3.17	3.32	2.98
RH-406	3.34	3.54	3.19
CD at 5%	0.06	0.06	0.03
SE (d) of V	0.03	0.03	0.01

Energy balance over mustard:

Diurnal variations in different components of the energy balance over mustard canopy were recorded and compared with those recorded on a bare soil. Mustard crop utilized 25-85% of net radiant energy for LE at different phenophases and varietal differences were noticed in partitioning of this net radiation (Fig. 4.30). The RH 30 utilized more net radiation as LE compared to Kranti and RH 406, due to its denser, greener and erect canopy. Whilst the LE component over bare soil was only 50% of the net radiation. The sensible heat flux component was lower than LE in all the sowing dates.

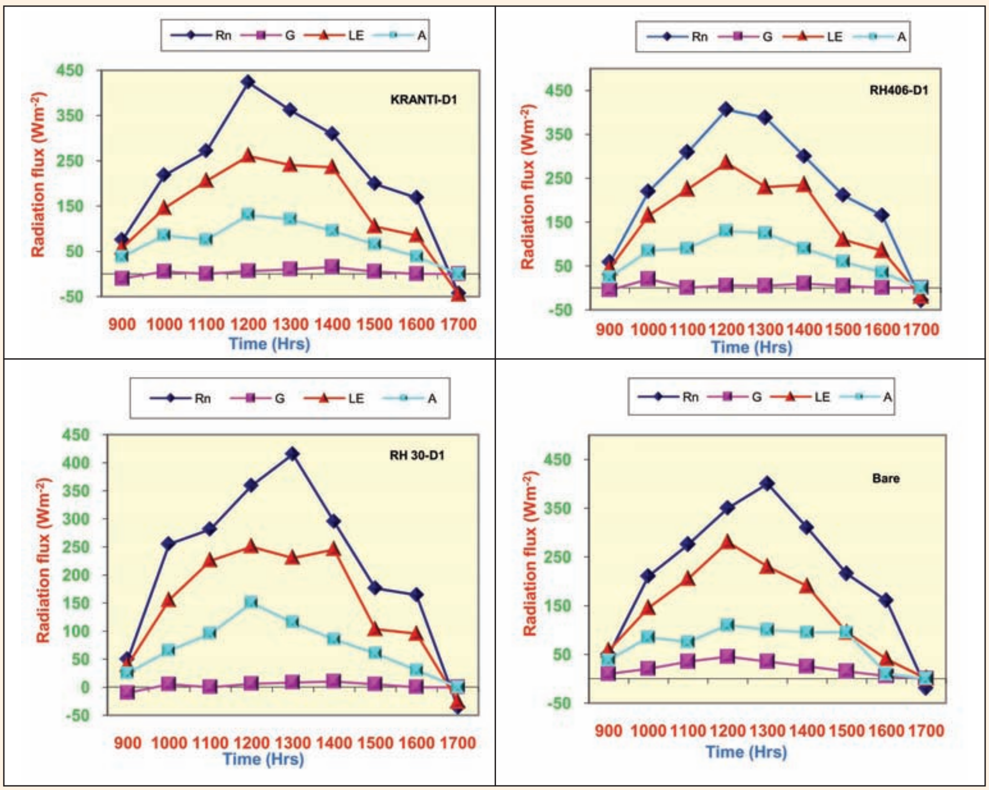


Fig. 4.30: Partitioning of net radiant energy in different mustard varieties at Hisar

MOHANPUR

Biomass accumulation in three mustard varieties (Panchali, B9, Jota) as influenced by variable environmental conditions created through staggered sowings (20th Oct, 4th Nov, 19th Nov, 2011) indicated that the 04th Nov sown crop capitalized the rain that occurred on its 60th day after sowing. This rainfall event coincided with 75th DAS of 20th Oct sown crop and B9 variety could take the advantage of this rain event where variety Panchali failed (Fig. 4.31 a to d).

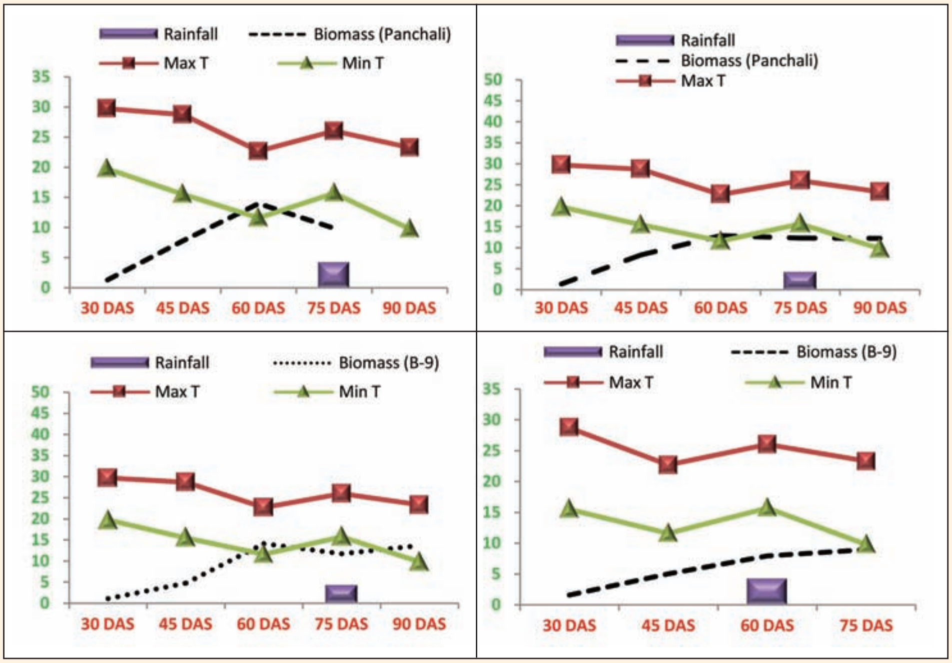


Fig.4.31 a to d: Biomass accumulation of Panchali and B-9 varieties in D_1 (a and b) and D_2 (c and d) at Mohanpur

Varietal differences in the radiation interception and absorption of PAR was studied which showed that variety Jota absorbed PAR to a greater extent because of it's horizontal spread of canopy compared to other two varieties. The intercepted PAR was found to be almost similar across the varieties and 79-86% of the incidence PAR was absorbed (Fig. 4.32).

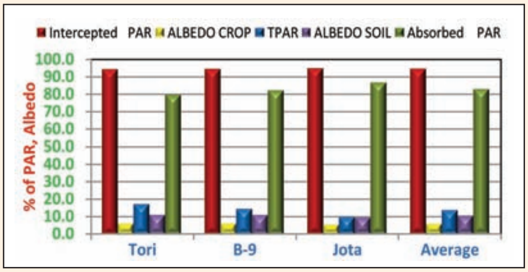


Fig. 4.32: Variations in albedo and PAR absorption by mustard varieties at maturity at Mohanpur

RAKH DHIANSAR

Temporal variations in HUE of mustard was studied in three sowing environments and two varieties (Fig. 4.33 a and b) which indicated that HUE progressed at a slower rate in all the dates as well as varieties in the early growth stages and attained peak values at around 110 DAS. Thereafter there was a gradual decline towards maturity. Early sown crop (12th Oct.) recorded highest HUE that declined as sowings were delayed and among the varieties RL 1359 recorded the highest HUE.

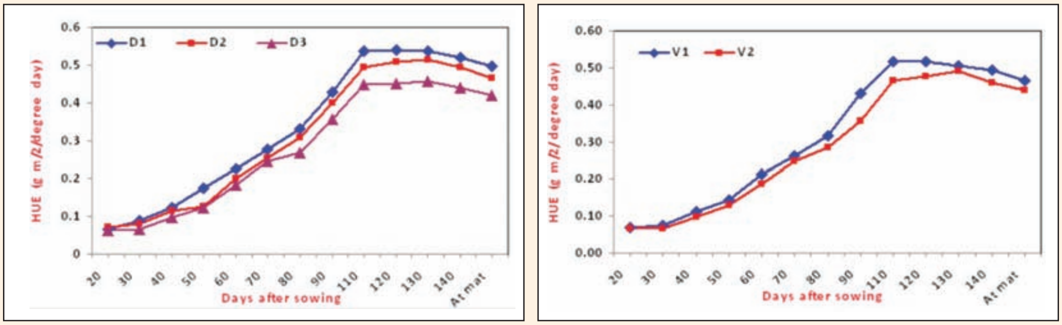


Fig. 4.33 a and b: Heat use efficiency of mustard at different phenophases at Rakh Dhiansar

Chickpea

SOLAPUR

Chickpea growth and developmental data recorded from a four year experimentation was used to understand the role of different weather variables on the crop. Correlation studies were carried out initially to identify critical weather parameters and crop stage so as to develop yield prediction models. Minimum temperature prevailed during branching and humidity at 50% flowering to pod formation and maximum temperature and wind speed during seed filling to pod maturity were found to have significant influence on the ultimate seed yields. The multi-variable regression equation developed from these significant weather variables is presented hereunder:

Yield = 14130.04 – 62.99 X_1 + 139.67 X_2 - 71.95 X_3 - 52.46 X_4 -699.04 X ...(R^2 = 0.72)

where, X_1 = T max during seed filling to pod maturity; X_2 = T min at branching;

X_3 = RH I at 50 % flowering; X_4 = RH II at pod formation and

X_5 = Wind speed during seed filling to pod maturity

JABALPUR

Chickpea seed yield in relation to thermal time was assessed from a field experiment involving seven varieties and three sowing environments which showed a negative association between the two variables (Fig. 4.34). Individual effects of maximum temperature and minimum temperature could not be established properly may be due to insufficient

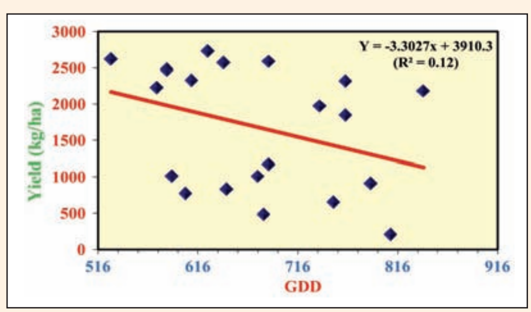


Fig. 4.34: Association between accumulated thermal time for 50% flowering to maturity and chickpea seed yield at Jabalpur

variability in the data set. This relation in figure 4.34 suggests that chickpea should be planted early to avoid higher temperature during flowering to maturity stages.

Wheat

KANPUR

Yield contributing attributes as well as grain yield of wheat as influenced by weather that prevailed during different phenophases were studied to understand the role of weather. Correlation coefficients derived between weather variables and crop data are presented in table 4.50 which revealed that at tillering stage the crop is sensitive to all weather parameters except rainfall. Rainfall at tillering and maturity stage as well as temperature and GDD at tillering stage negatively affected the grain yield.

Table 4.50: Pearson's correlation coefficients between growth, yield attributes and weather parameters prevailed during different stages of wheat at Kanpur

Date of sowing	Growth stage	Weather Parameters											
		Tmax. °C	Tmin. °C	Tmean °C	ST mean. °C (5 cm)	RH I %	RH II %	RH mean %	SSH	WS	RF (mm)	Eva.	AG DD
Grain Yield (kg/ha)	P1	0.71	0.15	0.53	0.73	0.70	-0.89	-0.85	0.85	-0.80	-0.79	0.72	0.25
	P2	-0.90	-0.92	-0.91	-0.90	0.84	0.90	0.90	-0.89	-0.93	0.40	-0.23	-0.79
	P3	-0.88	-0.84	-0.87	-0.90	0.92	0.85	0.90	-0.22	-0.81	0.56	-0.68	-0.35
	P4	-0.96	-0.95	-0.95	-0.94	-0.35	0.92	0.77	0.59	0.54	-0.84	-0.89	-0.72
Dry matter (g/m²)	P1	0.79	0.19	0.58	0.82	0.69	-0.95	-0.92	0.94	-0.85	-0.86	0.86	0.48
	P2	-0.95	-0.95	-0.95	-0.96	0.91	0.92	0.95	-0.91	-0.91	0.54	-0.21	-0.81
	P3	-0.94	-0.94	-0.94	-0.94	0.96	0.93	0.96	-0.17	-0.82	0.43	-0.59	-0.49
	P4	-0.91	-0.90	-0.91	-0.92	-0.37	0.83	0.66	0.58	0.37	-0.89	-0.64	-0.34
No. of Spiklets/ ear	P1	0.75	0.28	0.58	0.78	0.53	-0.81	-0.79	0.82	-0.70	-0.69	0.80	0.53
	P2	-0.83	-0.82	-0.83	-0.84	0.77	0.78	0.80	-0.77	-0.76	0.40	-0.08	-0.65
	P3	-0.82	-0.82	-0.82	-0.81	0.84	0.86	0.86	-0.17	-0.76	0.41	-0.41	-0.44
	P4	-0.75	-0.73	-0.75	-0.75	-0.09	0.72	0.69	0.45	0.31	-0.73	-0.45	-0.15
No. of grains/ ear	P1	0.82	0.29	0.65	0.84	0.63	-0.93	-0.91	0.92	-0.78	-0.77	0.83	0.41
	P2	-0.93	-0.95	-0.94	-0.94	0.84	0.94	0.93	-0.91	-0.94	0.30	-0.13	-0.77
	P3	-0.94	-0.89	-0.92	-0.95	0.96	0.92	0.96	-0.35	-0.86	0.69	-0.61	-0.40
	P4	-0.96	-0.95	-0.95	-0.94	-0.27	0.94	0.83	0.66	0.52	-0.82	-0.79	-0.57
Test wt.(g)	P1	0.74	0.38	0.63	0.76	0.38	-0.74	-0.76	0.78	-0.55	-0.54	0.75	0.50
	P2	-0.78	-0.78	-0.78	-0.79	0.61	0.73	0.70	-0.76	-0.74	0.12	0.01	-0.57
	P3	-0.75	-0.68	-0.72	-0.74	0.80	0.87	0.84	-0.37	-0.73	0.62	-0.37	-0.20
	P4	-0.75	-0.75	-0.76	-0.74	-0.07	0.65	0.64	0.62	0.27	-0.62	-0.52	-0.31

(P_1 = Tillering; P_2 = Panicle initiation; P_3 = Anthesis; P_4 = Maturity)

LUDHIANA

It is stated that high air temperature during early stages of wheat growth results in poor tillering, retarded vegetative growth and early heading. Warmer temperatures during mid-season may curtail the length of the vegetative phase and higher temperatures at ripening may hasten up the process affecting number of grains per ear and test weight. To understand the impact of extreme temperature events on wheat yields in Ludhiana district, average wheat yields of the district for the period 2000-2011 were collected and the trends in yield were studied by considering seven day moving average values of daily maximum and minimum temperatures during the corresponding crop seasons. Out of these 12 years, two years (2003-04, 2008-09) were segregated and considered as representative of heat wave conditions and two years (2010-11, 2011-12) reflecting cold wave conditions. The average wheat yields of Ludhiana district over the study period is 4800 kg/ha. The yields during heat wave conditions declined by 53 kg in 2003-04 and by 408 kg/ha during 2008-09 season. The departures in maximum and minimum temperatures during these years from their normal values are depicted in fig. 4.35 a and b. It is clearly evident from the figure that during early stages of crop

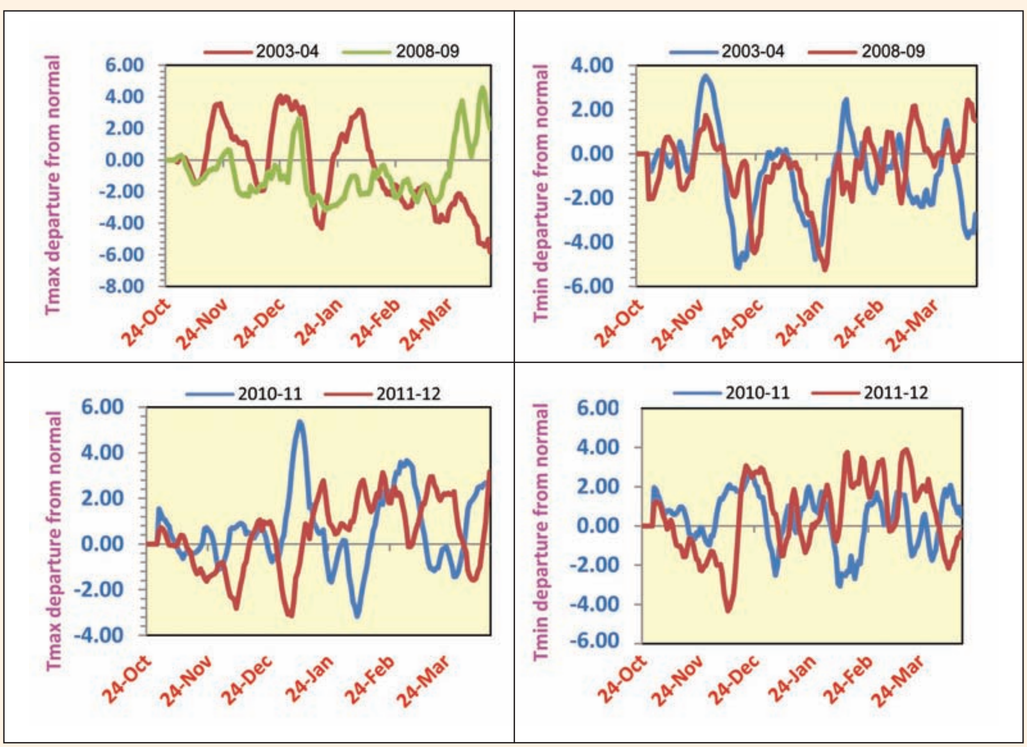


Fig. 4.35 a to d: Departures in maximum and minimum temperatures in contrasting seasons (a, b - heat wave; c, d - cold wave) at Ludhiana

growth in the year 2003-04 the temperatures were above normal and gradually decreased after 15th Feb and a totally different thermal environment prevailed during 2008-09 forcing the wheat crop to experience terminal heat stress resulting in a drastic reduction in yields. Minimum temperature followed the suit.

During 2010-11 and 2011-12 the crop experienced relatively cooler environment and the temperatures dipping below normal both during day and night for quite a long period (Fig. 4.35 c and d) might have probably influenced the wheat yields as yields increased by 2.95% and 11.3% in 2010-11 and 2011-12, respectively.

RAIPUR

Varietal differences in wheat in their efficiency to utilize thermal and radiant energies were studied by sowing four wheat cultivars (Kanchan, GW273, Sujata, Amar) at five different times (25^{th} Nov, 5^{th} Dec, 15^{th} Dec, 25^{th} Dec, 2011, 5^{th} Jan, 2012). Kanchan and GW 273 were the varieties with highest HUE and crop sown on 5^{th} and 15^{th} Dec recorded highest HUE (Fig. 4.36 a). Radiation use efficiency followed similar type of response in sowing time as well as varietal performance (Fig. 4.36 b).

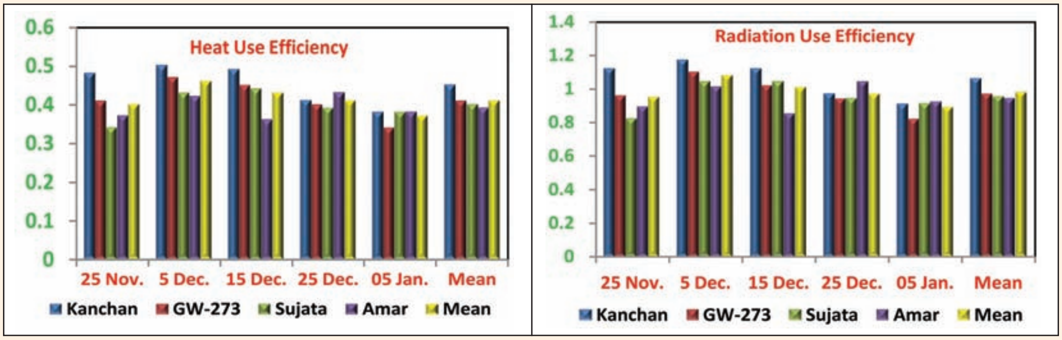


Fig. 4.36: Resource (heat and radiation) use efficiency of wheat varieties under different sowing environments at Raipur

RAKH DHIANSAR

Water use pattern in three wheat varieties (RSP-561, PBW-343, DBW-17) were studied in three different growing environments (08^{th} November, 24^{th} November, 09^{th} December, 2011) in order to identify efficient cultivar and optimum sowing time for efficient water use. The seasonal evapotranspiration of winter wheat increased as sowing time was delayed (Table 4.51) but the efficiency with which the water used declined showing an inverse relation with total water consumed. Among the varieties tested RSP 561 was found to utilize more water but more efficiently resulting in higher grain yields.

Table 4.51 : Water use efficiency (WUE) of winter wheat varieties under different environments at Rakh Dhiansar

Treatments	ET (mm)	Yield ($kgha^{-1}$)	WUE ($kgha^{-1}mm^{-1}$)
		Date of sowing	
8th Nov	199.3	1683	8.4
24th Nov	203.9	1440	7.1
9th Dec	209.9	1365	6.5
		Varieties	
RSP-561	206.2	1545	7.5
PBW-343	202.4	1504	7.4
DBW-17	204.5	1438	7.0

RANCHI

Resource capturing and conversion efficiencies of three wheat varieties were analysed in terms of HUE and RUE which showed that 5th Dec sown wheat was relatively efficient in both the parameters (Fig. 4.37), except for cultivar K 9107. Among the varieties, K 9107 performed well under normal sowing date (20th Nov). A delay in sowing resulted in a gradual decline in these resource use efficiencies.

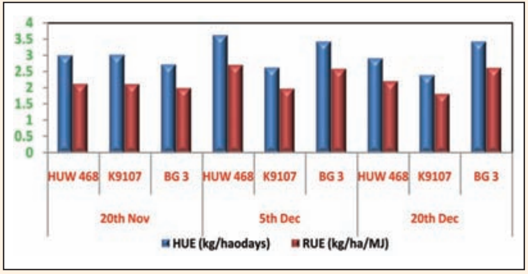


Fig. 4.37: Heat and radiation use efficiencies of wheat cultivars at Ranchi

Temperature *vs* wheat yield

Wheat yields are stated to be influenced by temperatures during winter season and the yield data of K 9107 when correlated with mean maximum and minimum temperatures (Table 4.52) showed that crop is sensitive to both the temperatures during anthesis to milking stages.

Table 4.52: Pearson's correlation Coefficients between temperature and wheat yields at Ranchi

Temperature/ Stages	Vegetative	Boot - Anthesis	Anthesis - Milking	Milking - Maturity
T Max	-0.56	-0.61	-0.71*	-0.56
T Min	-0.38	-0.80	-0.82*	-0.72

SAMASTIPUR

Duration of different phenological stages in wheat cultivars (RW-3711, HD 2824, HD 2733) and their response to variations in thermal environment were quantified using agrometeorological indices like GDD and HUE. The mean temperatures prevailed during different phenophases and the length of each phenophases in days are presented in table 4.53 indicated that most of the phenophases of crop sown late experienced warmer weather conditions. This has resulted into a decline in yields.

Table 4.53: Temperature and agrometeorological indices under different wheat sowing environments at Samastipur

Date of Sowing	Temperature (°C)				Grain yield (kg/ha)	Accumulated heat units up to maturity (°day)	Heat use efficiency (kg/ha/°day)
	50 % flowering to milking stage	Milking to dough stage	50 % flowering to dough stage	50 % flowering to maturity			
25 Nov.	18.4 (6)	20.6 (33)	20.3 (38)	21.7 (48)	49.93	1715.9	2.90
05 Dec.	18.8 (8)	21.9 (33)	21.4 (40)	22.4 (47)	47.42	1638.0	2.89
15 Dec.	19.9 (11)	24.0 (27)	22.9 (37)	23.3 (43)	40.41	1597.0	2.53
25 Dec.	19.3 (9)	25.5 (24)	23.9 (32)	24.3 (38)	35.53	1580.0	2.24

(Figures in the parenthesis indicate days taken)

UDAIPUR

Optimum temperature requirement during sensitive stages of wheat crop was studied by subjecting three varieties (HI 1544, MP 1203, Raj 4037) to four thermal environments (5th Nov, 20th Nov, 5th Dec, 20th Dec, 2011). The days taken to complete the vegetative and reproductive phases in different cultivars and sowing times were regressed on mean minimum temperature prevailed during these stages (Fig. 4.38 a and b). It can be noticed that as the mean temperatures were increasing days to complete each phenophase were decreasing.

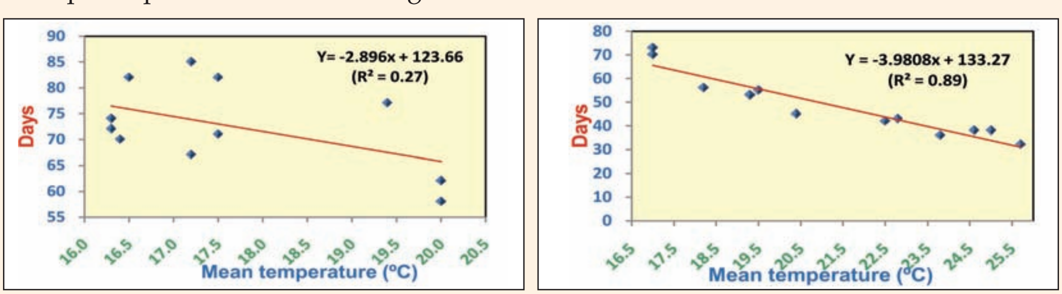


Fig. 4.38: Days taken to complete (a) vegetative and (b) reproductive stages as a function of temperature at Udaipur

Maize

SAMASTIPUR

Response of three varieties of maize (Deoki, Shaktiman 3, Deep Jwala) to thermal time was characterized during different phenological stages under three dates of sowing (10^{th} Nov, 20^{th} Nov, 30^{th} Nov, 2011). At tasseling, cob initiation and silking stages, the crop sown on 20^{th} November accumulated highest heat units. However, at maturity, the crop sown on 10^{th} November accumulated highest heat units. Among the varieties no significant effect was observed in respect of accumulation of thermal time (Table 4.54).

Table 4.54: Accumulation of thermal time by wheat varieties as influenced by sowing time at Samastipur

Treatment	Knee High		Tasseling		Cob initiation		Silking		Maturity	
	DAS	HU	DAS	HU	DAS	HU	DAS	HU	DAS	HU
10^{th} Nov	76.0	771.8	122.4	1251.7	128.1	1322.8	134.6	1420.6	175.9	2280.7
20^{th} Nov	77.5	705.5	125.5	1286.7	129.7	1358.3	135.9	1481.4	170.3	2222.0
30^{th} Nov	90.5	803.9	121.4	1245.8	126.8	1354.4	131.6	1450.5	165.7	2202.7
CD (P=0.05)	1.7	18.6	1.3	18.3	1.6	29.3	1.3	23.6	0.61	15.4
Deoki	81.3	759.0	124.8	1284.1	129.4	1363.6	135.3	1474.6	170.7	2235.9
Shaktiman 3	81.5	763.0	121.6	1238.9	126.8	1322.6	132.6	1424.5	170.6	2233.5
Deep Jwala	81.2	759.1	123.0	1261.1	128.3	1349.3	134.1	1453.4	170.7	2236.2
CD (P=0.05)	NS	NS	1.3	18.3	1.6	29.3	1.3	23.6	NS	NS

(DAS: Days after sowing, HU: Heat Unit)

Rabi sorghum

SOLAPUR

Productivity of three sorghum cultivars (M 35-1, Mauli, Vasudha) was studied in terms of their moisture use pattern from a field experiment involving four sowing dates (12^{th} Sep, 28^{th} Sep, 7^{th} Oct, 17^{th} Oct, 2011). The seasonal consumptive use when regressed on grain yield resulted in a quadratic fit (Fig. 4.39 a) and it can be inferred from the figure that maximum grain yield can be realized with moisture use around 320 mm. The grain yields when regressed on the accumulated thermal time (Fig. 4.39 b) showed that sorghum can yield better in a warmer environment and its seasonal heat unit requirement is above 2000 degree days.

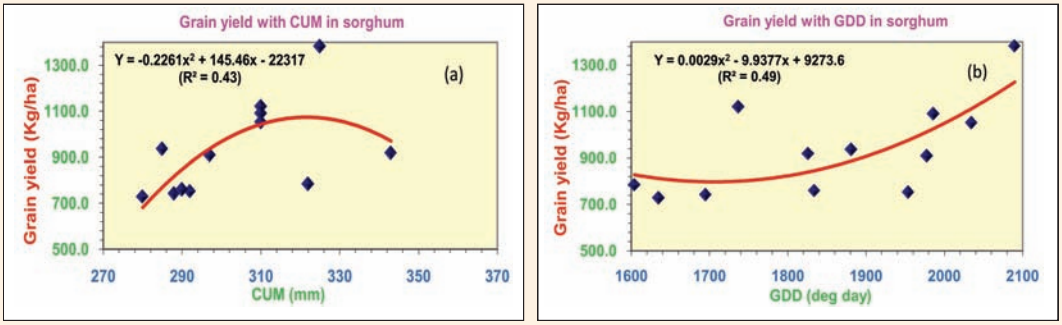


Fig. 4.39: Sorghum grain yields as influenced by (a) consumptive use and (b) thermal time at Solapur

Potato

MOHANPUR

Tuber yields in three potato varieties (Jyoti, Chipsona, Surya) were studied in relation to their water use efficiency by planting them on three different dates (1st Dec, 8th Dec and 15th Dec, 2011). The seasonal evapotranspiration values recorded in different treatments showed that Chipsona variety recorded highest seasonal ET and crop ET was at the maximum in the 15th Dec planted crop. The crop sown on 1st Dec expressed highest water use efficiency that decreased gradually as the sowings were delayed. Among the varieties tested, Jyoti proved to be the most efficient in using the scarce resource *i.e.*, water (Fig. 4.40).

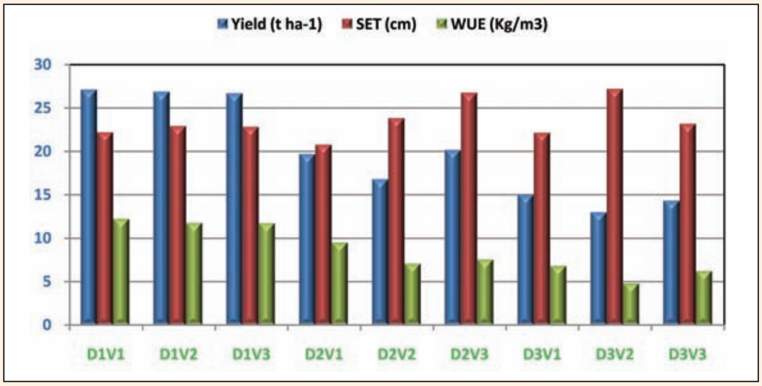


Fig. 4.40: Tuber yield of potato in relation to seasonal evapotranspiration (SET), water use efficiency (WUE) and sowing time at Mohanpur

5. CROP GROWTH MODELING

Rabi 2010-11

Dynamic Models

Wheat

ANAND

CERES-wheat model was calibrated with two year experimental data (2009-11) for four wheat cultivars. The mean per cent error for various parameters is presented in table 5.1. Results showed that model under-estimated days to anthesis for GW-322 (1.72%) and GW-1139 (0.17%), while it over-estimated for GW-496 (3.52%) and GW-366 (8.83%). Days to maturity were found overestimated by the model for all the cultivars. Straw yield was under-estimated by 4.47, 1.46 and 0.50 per cent for GW-322, GW-366 and GW-1139, respectively, while it over-estimated by 0.32 per cent for GW-496 (Table 5.2). Grain yield was over-estimated for GW-322, GW-496, GW-366 and GW-1139. In case of LAI it was under-estimated by 39.01, 44.93, 37.14 and 38.68 per cent for GW-322, GW-496, GW-366 and GW-1139, respectively (Table 5.3). This shows that except for LAI, calibration of other parameters were found satisfactory and remain within reasonable limits.

Table 5.1 : Error (per cent) in CERES-wheat simulated days to anthesis and maturity compared to observed at Anand

Cultivar/ Date of sowing	GW-322						GW-496					
	Days to anthesis			Days to maturity			Days to anthesis			Days to maturity		
	Obs.	Sim.	Error	Obs.	Sim.	Error	Obs.	Sim.	Error	Obs.	Sim.	Error
1 Nov 2009-10	61	54	-11.4	113	114	0.88	60	54	-10	108	112	3.70
15 Nov 2009-10	63	58	-7.94	108	114	5.56	62	58	-6.45	105	112	6.67
30 Nov 2009-10	62	60	-3.23	104	111	6.73	60	60	0.00	102	109	6.86
15 Dec 2009-10	61	60	-1.64	101	108	6.93	58	60	3.45	100	106	6.00
1 Nov 2010-11	67	68	1.49	116	122	5.17	58	63	8.62	110	116	5.45
15 Nov 2010-11	66	72	9.09	115	120	4.35	62	69	11.29	110	119	8.18
30 Nov 2010-11	66	64	-3.03	116	119	2.59	60	65	8.33	108	112	3.70
15 Dec 2010-11	67	69	2.99	113	121	7.08	62	70	12.90	108	120	11.11
Mean			-1.72			4.91			3.52			6.46
SD			6.40			2.22			8.39			2.43
CV %			372.9			45.21			238.3			37.56

			GW-366						GW-1139			
1Nov 2009-10	58	60	3.45	109	117	7.34	61	53	-13.1	116	112	-3.45
15 Nov 2009-10	60	64	6.67	109	116	6.42	65	58	-10.7	110	112	1.82
30 Nov 2009-10	60	66	10.00	107	114	6.54	63	59	-6.35	107	109	1.87
15 Dec 2009-10	58	66	13.79	105	111	5.71	62	59	-4.84	105	106	0.95
1 Nov 2010-11	60	65	8.33	108	117	8.33	69	75	8.70	117	125	6.84
15 Nov 2010-11	61	67	9.84	111	122	9.91	69	74	7.25	120	117	-2.50
30 Nov 2010-11	59	66	11.86	105	111	5.71	58	65	12.07	118	123	4.24
15 Dec 2010-11	60	64	6.67	107	116	8.41	70	74	5.71	116	126	8.62
Mean			8.83			7.30			-0.17			2.30
SD			3.27			1.49			9.69			4.19
CV %			37.03			20.38			34.25			182.0

Table 5.2 : Error (per cent) in CERES-wheat simulated straw and grain yield compared to observed at Anand

Cultivar/ Date of sowing	GW-322						GW-496					
	Straw yield (kg/ha)			Grain yield (kg/ha)			Straw yield (kg/ha)			Grain yield (kg/ha)		
	Obs.	Sim.	Error	Obs.	Sim.	Error	Obs.	Sim.	Error	Obs.	Sim.	Error
1 Nov 2009-10	4325	4138	-4.32	3923	3876	-1.20	3770	3868	2.60	3605	3575	-0.83
15 Nov 2009-10	5468	5232	-4.32	5119	4814	-5.96	4858	4974	2.39	4708	4535	-3.67
30 Nov 2009-10	4946	4943	-0.06	4344	4530	4.28	4512	4855	7.60	4289	4415	2.94
15 Dec 2009-10	4549	4304	-5.39	3946	3987	1.04	4154	4017	-3.30	3523	3752	6.50
1 Nov 2010-11	4695	4586	-4.58	3805	4021	5.68	3459	3562	2.98	2999	3125	4.20
15 Nov 2010-11	7340	6321	-13.88	4935	4895	-0.81	5086	4951	-2.65	4293	4369	1.77
30 Nov 2010-11	4876	5102	-5.23	4169	4521	8.44	4295	4125	-3.96	2960	3210	8.45
15 Dec 2010-11	5491	5603	2.04	4233	4423	4.49	4021	3898	-3.06	2948	3306	12.1
Mean			-4.47			2.00			0.32			3.94
SD			4.66			4.61			4.16			5.08
CV %			104.27			231.08			1281.61			129.06
			GW-366						GW-1139			
1 Nov 2009-10	5023	5132	2.17	3892	3743	-3.83	3737	3787	1.34	3163	3246	2.62
15 Nov 2009-10	4580	4294	-6.24	4022	3771	-6.24	5486	5099	-7.05	4636	4677	0.88
30 Nov 2009-10	4022	3907	-2.86	3428	3338	-2.63	4355	4161	-4.45	4170	4022	-3.55
15 Dec 2009-10	3210	3126	-2.62	3040	3044	0.13	3773	3856	2.20	3238	3578	10.50
1Nov 2010-11	4761	4632	-2.71	3286	3315	0.88	3279	3321	1.28	2375	2541	6.99
15 Nov 2010-11	5631	5489	-2.52	4619	4569	-1.08	5536	5428	-1.95	4345	4521	4.05
30 Nov 2010-11	3991	4125	3.36	3114	3225	3.56	4209	4098	-2.64	2880	3124	8.47
15 Dec 2010-11	4218	4207	-0.26	3408	3460	1.53	3873	4156	7.31	2538	2610	2.84
Mean			-1.46			-0.96			-0.50			4.10
SD			3.09			3.17			4.47			4.49
CV %			211.34			330			901			109.4

Table 5.3 : Error (per cent) in CERES-wheat simulated LAI compared to observed at Anand

Cultivar/ Date of Sowing	LAI											
	GW-322			GW-496			GW-366			GW-1139		
	Obs.	Sim.	Error	Obs.	Sim.	Error	Obs.	Sim.	Error	Obs.	Sim.	Error
1 Nov 2009-10	3.5	1.1	-68.57	3.9	1.1	-71.79	3.9	1.1	-71.7	3.1	1.0	-67.74
15 Nov 2009-10	3.5	1.4	-60.00	4.0	1.8	-55.00	4.0	1.8	-55.0	3.5	1.7	-51.43
30 Nov 2009-10	3.8	1.5	-60.53	3.8	1.8	-52.63	3.8	1.8	-52.6	3.8	1.8	-52.63
15 Dec 2009-10	3.6	2.1	-41.67	3.6	2.1	-41.67	3.6	2.1	-41.6	2.4	2.1	-12.50
1 Nov 2010-11	3.6	4.2	16.67	4.1	3.1	-24.39	4.1	3.1	-24.3	3.4	2.4	-29.41
15 Nov 2010-11	3.9	2.6	-33.33	4.0	2.8	-30.00	4.0	2.8	-30.0	3.7	1.9	-48.65
30 Nov 2010-11	4.1	2.5	-39.02	3.7	1.9	-48.65	3.7	1.9	-48.6	4.1	2.8	-31.71
15 Dec 2010-11	3.9	2.9	-25.64	3.4	2.2	-35.29	3.4	2.2	-35.2	2.6	2.2	-15.38
Mean			-39.01			-44.93			-44.9			-38.68
SD			26.98			15.33			15.3			19.51
CV %			69.16			34.12			34.1			50.43

MOHANPUR

The Info Crop simulation model was used to find out the impact of climate change on growth and yield of wheat. The weather data of Kalyani observatory (2000-2008) were uploaded into the InfoCrop model (using weather converter) and the soil characteristics, different crop management practices followed in the zone were incorporated in to the model.

Wheat yields (*cv. Sonalika*) were reduced by about 640 kg/ha with a temperature rise of 1.0°C for both maximum and minimum temperatures. Due to 1.0°C rise in temperature wheat crop maturity was advanced by five days (Table 5.4).

Table 5.4 : Potential yield of wheat under normal and elevated temperatures (1°C rise) at Mohanpur

Crop	Potential yield		Maturity period	
	Normal condition	+1°C rise	Average	+1°C rise
Wheat	3884*	3248.6	94	89

(* Yield data are average of 2000 to 2008)

Mustard

MOHANPUR

The InfoCrop model was used to find out the impact of climate change on mustard growth and yield. Generally, in Gangetic West Bengal the mustard is sown during mid-October. But simulation under elevated temperature conditions showed that November sown crop gives better yields. Mustard yields were reduced by about 450 kg/ha with a 1.0°C rise in both maximum and minimum temperatures (Table 5.5). Maturity of mustard got advanced by five days due to temperature rise.

Table 5.5: Potential yield of mustard under normal and elevated temperatures (1°C rise) at Mohanpur

Crops	Potential yield		Maturity period	
	Normal condition	+1°C rise	Average	+1°C rise
Mustard	1714*	1277.7	93	88

(* Yield data are average of 2000 to 2008)

RAKH DHIANSAR

Amount of water transpired by the crop has a direct relation with dry matter production in majority of the crops. Campbell and Diaz (1988) model uses empirical or mechanistic sub-model of the water balance components to estimate quantum of water transpired and then simulates dry matter production. This model was validated for mustard varieties with assumed values of 0.25, 0.09 and 0.02 for field capacity, permanent wilting point and air dryness moisture content, respectively for the test site. The maximum rooting depth was held constant at 150 cm with an initial biomass of 0.0035 for cultivars RL-1359 and RSPR-01 as initial boundary conditions. Daily extinction coefficient for mustard was assumed to be 0.04. Dry matter production recorded at 10 day interval from the experimentation were plotted against simulated values in 1:1 ratio and depicted in

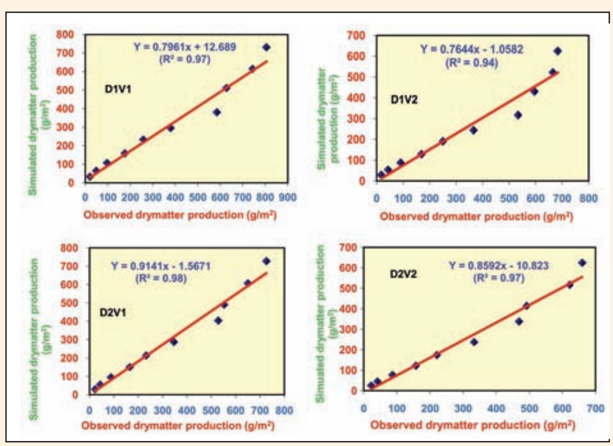


Fig. 5.1 : Simulated and observed dry matter production (g/m²) in mustard crop at Rakh Dhiansar

(Fig. 5.1). A close agreement between the observed and model simulated dry matter production can be noticed and higher coefficient of determination (R^2) values indicate that the model predicted the mustard dry matter accumulation with good accuracy.

Empirical / Statistical Models

Numerical interpretation of weather data in terms of crop-growth and development helps in crop monitoring and forecasting, crop zonation, irrigation water management, crop physiological and morphological studies, climatic impact assessment and forecasting maturity and yield. Though, these models have site specificity, they are simple to use and require least data compared to dynamic crop-growth models. Crop-weather studies carried out at different centers during *rabi* 2010-11 are reported here under.

Wheat

UDAIPUR

Influence of varied weather conditions, created by staggered sowings on the attainment of phenological stages in wheat in terms of GDD are presented in table 5.6. Data indicated that the thermal time requirement (GDD) to attain different phenophases generally decreased as the sowings were delayed. The crop sown on 5th Nov required maximum GDD to attain maturity in all the varieties. The thermal time requirement to complete the growth stage from CRI stage to maturity decreased with a delay in sowing across the varieties. The varieties sown late required least GDD to attain different phenological stages and to complete the life cycle. Varietal response to growing period environment in terms of decrease in duration of crop growth is presented in table 5.7. Among the three varieties MP-1203 seems to be more sensitive to changes in thermal time as its crop duration decreased by two days compared to the other two varieties.

RAIPUR

Partitioning of dry matter into different plant components at different phenological stages, *viz*., tillering, jointing, panicle initiation, anthesis, dough and maturity in three wheat varieties (HD-2733, K-307 and K-9107) as influenced by sowing environments (23rd Nov, 8th Dec and 23rd Dec, 2010) was studied. Among the varieties K-9107 accumulated higher percentage of stem and total dry matter weight at maturity as compared to HD-2733 and K-0307, which seems to be its genetical character but yielded less, probably due to poor weight of spike than HD-2733 and K-0307 (Table 5.8).

Table 5.6 : Days taken to attain different phenological events and thermal time requirement as influenced by sowing time at Udaipur

Variety/ Sowing date	Emergence		CRI		Tillering		Flag leaf		Heading		50% Heading		Milking		Dough		Maturity	
	Days taken	GDD	Days taken	GDD	Days taken	GDD	Days taken	GDD	Days taken	GDD	Days taken	GDD	Days taken	GDD	Days taken	GDD	Days taken	GDD
HI-1544																		
5th Nov	5	89	21	307	30	478	58	775	63	817	71	900	94	1185	115	1470	128	1678
20th Nov	5	65	21	261	30	350	64	716	73	821	78	895	94	1112	115	1445	120	1549
5th Dec	6	66	21	220	30	316	64	701	71	805	74	849	93	1120	105	1333	116	1552
20th Dec	7	78	21	214	30	312	56	656	66	784	72	871	88	1148	100	1387	104	1471
MP-1203																		
5th Nov	5	89	21	307	30	478	80	1006	88	1099	95	1200	111	1415	123	1603	134	1799
20th Nov	5	65	21	261	30	350	76	863	84	981	88	1038	105	1279	120	1549	124	1625
5th Dec	6	66	21	220	30	316	71	805	81	936	84	975	100	1230	114	1509	118	1592
20th Dec	7	78	21	214	30	312	69	828	73	888	78	973	90	1189	104	1471	108	1551
Raj-4037																		
5th Nov	5	89	21	307	30	478	64	826	67	853	75	942	98	1239	117	1502	129	1696
20th Nov	5	65	21	261	30	350	64	716	72	809	80	923	97	1152	115	1445	121	1568
5th Dec	6	66	21	220	30	316	64	701	71	805	75	862	95	1155	111	1449	116	1552
20th Dec	7	78	21	214	30	312	57	672	66	784	71	854	89	1169	101	1408	105	1492

Table 5.7 : Decrease of total duration (days) of wheat 2010-11at Udaipur

Varieties	Decrease in days from D_1 to		
	D_2	D_3	D_4
HI-1544	8	12	24
MP-1203	10	16	26
Raj-4037	8	13	24

Table 5.8 : Influence of date of sowing on dry biomass partitioning (g/m^2) of wheat varieties at Raipur

Variety/ Sowing date	Tillering			Jointing			Panicle initiation			Anthesis				Dough				Maturity			
	Leaf	Stem	Total	Leaf	Stem	Total	Leaf	Stem	Total	Leaf	Stem	Spike	Total	Leaf	Stem	Spike	Total	Leaf	Stem	Spike	Total
HD-2733																					
D_1	165.8 (74.7)	56.2 (25.3)	222.0	172.2 (49.7)	174.3 (50.3)	346.5	287.3 (42.6)	387.0 (57.4)	674.3	263.9 (33.7)	380.9 (48.5)	140.6 (17.9)	785.9	271.7 (23.9)	451.2 (39.7)	413.7 (36.4)	1136.6	207.8 (15.3)	425.2 (31.3)	725.4 (53.4)	1358.4
D_2	159.6 (75.3)	52.4 (24.7)	212.0	173.1 (51.9)	160.5 (48.1)	333.6	295.9 (44.9)	363.2 (55.1)	659.1	278.1 (36.3)	360.0 (47.0)	127.9 (16.7)	766.0	271.5 (25.9)	397.3 (37.9)	379.5 (36.2)	1048.3	173.4 (14.1)	435.5 (35.4)	621.3 (50.5)	1230.2
D_3	147.7 (74.2)	51.4 (25.8)	199.1	168.5 (52.7)	151.3 (47.3)	319.8	288.8 (45.9)	340.3 (54.1)	629.1	262.6 (34.8)	343.9 (48.2)	107.0 (15.0)	713.5	268.4 (28.5)	336.2 (35.7)	337.1 (35.8)	941.7	165.4 (15.5)	418.1 (39.2)	483.2 (45.3)	1066.7
K-307																					
D_1	165.6 (76.1)	52.0 (23.9)	217.6	183.7 (56.1)	143.8 (43.9)	327.5	237.1 (36.4)	414.4 (63.6)	651.5	195.8 (25.3)	501.5 (64.8)	76.6 (9.9)	773.9	177.9 (15.7)	619.7 (54.7)	335.3 (29.6)	1132.9	172.2 (13.2)	551.6 (42.3)	580.3 (44.5)	1304.1
D_2	161.5 (77.6)	49.4 (23.4)	210.9	173.2 (54.3)	145.8 (45.7)	319.0	238.6 (37.7)	394.4 (62.3)	633.0	193.8 (27.2)	475.7 (64.3)	70.3 (9.5)	739.8	167.1 (16.3)	563.3 (54.1)	307.1 (29.6)	1037.5	152.0 (12.7)	520.7 (43.5)	524.3 (43.8)	1197.0
D_3	152.5 (77.8)	43.5 (22.2)	196.0	169.6 (55.2)	137.7 (44.8)	307.3	235.7 (38.3)	379.6 (61.7)	615.3	190.3 (26.8)	470.9 (66.3)	49.0 (6.9)	710.2	160.6 (17.9)	518.7 (55.3)	248.7 (26.8)	928.0	146.2 (13.9)	465.9 (44.3)	431.7 (41.8)	1051.8
K-9107																					
D_1	165.1 (77.3)	48.5 (22.7)	213.6	176.7 (53.3)	154.8 (46.7)	331.5	244.7 (34.7)	460.6 (65.3)	705.3	194.3 (24.3)	535.1 (66.7)	71.9 (9.0)	799.3	191.1 (15.9)	617.9 (51.2)	397.8 (32.9)	1206.8	167.1 (12.9)	167.1 (47.1)	575.6 (41.0)	1404.0
D_2	154.0 (78.6)	41.9 (21.4)	195.9	166.6 (51.2)	158.8 (48.8)	325.4	235.9 (35.1)	436.2 (64.9)	672.1	205.6 (26.3)	522.3 (66.7)	54.8 (7.0)	783.0	177.0 (16.3)	560.1 (51.6)	348.4 (32.1)	1085.5	168.9 (13.2)	597.5 (46.7)	513.0 (40.1)	1279.4
D_3	151.0 (77.6)	43.6 (22.4)	194.6	170.8 (54.7)	141.5 (45.3)	312.3	232.1 (36.7)	400.2 (63.3)	632.3	181.1 (25.3)	481.8 (67.3)	53.0 (7.4)	715.9	153.1 (15.7)	523.5 (53.7)	298.3 (30.6)	974.9	151.9 (13.9)	512.9 (47.2)	422.7 (38.9)	1086.7

Rabi Sorghum

SOLAPUR

Thermal time requirement for the completion of different phenophases in three sorghum varieties (M 35-1, Mauli and Vasudha) was assessed in four thermal environments created through four staggered sowings. Early sown sorghum required more thermal time (GDD) and helio thermal units to attain maturity and varietal differences were noticed in thermal time, with M 35-1 requiring more GDD compared to other two varieties. During *rabi* 2010-11, sorghum sown early received more rainfall compared to late sown crop because of which the late sown crop suffered from terminal drought and as a result duration of the late sown crop was shortened (Table 5.9).

Table 5.9 : Growing degree days required to complete phenological stages as influenced by sowing dates in *rabi* sorghum (2010-11) at Solapur

Sowing Time	Phenological stage							
	Emer.	3 leaf	PI	Flag leaf	50% flowering	Soft dough	Hard dough	Phy. Maturity
S_1V_1	81	87	344	519	241	237	201	220
S_1V_2	70	71	301	439	147	219	168	165
S_1V_3	76	77	290	503	207	229	191	213
S_2V_1	93	98	356	491	247	249	213	223
S_2V_2	75	76	306	444	152	224	171	169
S_2V_3	85	84	299	512	216	238	202	222
S_3V_1	102	108	325	525	232	258	221	232
S_3V_2	81	82	312	449	158	229	177	175
S_3V_3	94	92	308	523	222	245	209	229
S_4V_1	84	87	321	503	213	234	197	210
S_4V_2	73	74	304	442	149	222	171	168
S_4V_3	77	78	292	504	210	231	194	216

Chickpea

JABALPUR

Chickpea, a cool season crop, is relatively more sensitive to temperature compared to other crops grown during *rabi* season. The sensitivity of two chickpea cultivars, *viz*., JG-315 and JG-11 was assessed in six thermal environments created by differential sowings. The thermal time requirement to attain important phenological stages of chickpea is presented in table 5.10. The data indicated that early sown crop accumulated more thermal units than the late sown crop primarily due to high temperatures. As the sowings were delayed, temperatures decreased resulting in low GDD accumulation. This could be noticed in the crop sown in the month of December. The crop sown during January was again subjected to higher temperatures resulting in accumulation of more thermal units compared to the crop sown during December.

Table 5.10 : Thermal time requirement of chickpea to attain different phenophases at Jabalpur

Date of sowing	50 % Flowering		50 % Pod initiation		Physiological maturity		Harvest	
	Days	GDD	Days	GDD	Days	GDD	Days	GDD
11th Oct	43	820	69	1190	138	2002	143	2086
30th Oct	53	834	73	1029	125	1719	141	2004
20th Nov	58	705	82	1000	109	1418	125	1720
10th Dec	64	713	74	864	99	1265	107	1446
30th Dec	61	729	70	894	91	1306	107	1446
19th Jan	51	731	60	888	80	1312	94	1646

Kharif 2011

Statistical / Empirical models

Groundnut

ANANTAPUR

The regression models based on thermal time to predict various phenological events like flowering, pod initiation and maturity in groundnut developed earlier were tested using the data recorded from the field experimentation of 2011. Varying growing environments for groundnut were created by sowing the crop on 07th July, 23rd July and 06th Aug, 2011. Model's performance was compared against observed data and presented in table 5.11. Models developed to predict flowering and pod initiation performed with reasonable accuracy ± 2 days in all dates of sowing but models developed to predict maturity did not perform well with error ranging from - 5 to -16 days.

Table 5.11 : Validation of phenological models in groundnut at Anantapur

Phenological event	Prediction equation	Predicted	Actual
	Early sowing (07.07.2011)		
Flowering	Y = 0.0604 X – 2.3237	24	23
Pod initiation	Y = 0.0526 X + 3.5424	51	53
Maturity	Y = 0.0353 X + 39.716	119	124
	Normal sowing (23.07.2011)		
Flowering	Y = 0.0604 X – 2.3237	21	20
Pod initiation	Y = 0.0526 X + 3.5424	52	54
Maturity	Y = 0.0353 X + 39.716	114	130
	Late sowing (06.08.2011)		
Flowering	Y = 0.0479 X + 3.212	20	20
Pod initiation	Y = 0.0495 X + 5.7102	49	51
Maturity	Y = 0.0237 X + 59.227	111	127

(Variable X = Growing degree days)

Rice

FAIZABAD

Empirical models utilizing different weather parameters as input to predict grain yields in rice were developed involving the field data from three transplanting dates *viz.*, 05^{th} July, 15^{th} July and 25^{th} July, 2011. The mean values of different weather parameters for different time periods when regressed on grain yields resulted in the following relations:

July 5^{th} transplanted crop:

0-60 days	Y=-145.11+3.98 Tmax+2.50 Tmin-0.044 rainfall	(r=0.77)
0-75 days	Y= 24.22+0.75 Tmax-0.23 Tmin-0.040 rainfall	(r=0.73)
0-90 days	Y= 94.15-2.69 Tmax+0.98 Tmin+0.05 rainfall	(r=0.79)

July 15^{th} transplanted crop:

0-60 days	Y=-62.11+2.46 Tmax+0.889 Tmin-0.0211 rainfall	(r=0.69)
0-75 days	Y= -11.14+0.79 Tmax+0.90 Tmin-0.026 rainfall	(r=0.83)
0-90 days	Y= 68.85-54.30 Tmax-0.76Tmin+0.012 rainfall	(r=0.68)

July 25th transplanted crop:

0-60 days	Y=23.11+0.44 Tmax-0.23 Tmin-0.008 rainfall	(r=0.73)
0-75 days	Y= 25.53+0.20 Tmax-0.068 Tmin-0.001 rainfall	(r=0.46)
0-90 days	Y= 26.83-0.059 Tmax+0.232Tmin-0.002 rainfall	(r=0.68)

Kharif Sorghum

PARBHANI

Grain yields of *kharif* sorghum were correlated with seasonal mean weather parameters and step-wise regression was performed to identify critical weather parameters and the resultant relations are presented hereunder:

Step: 1	Y = - 240.07 + 90.2Tmin	....(R^2 = 0.23	SE = 405.5)
Step:2	Y = 414.89 + 70.5Tmin – 35.8BSS	....(R^2 = 0.25	SE = 404.6)
Step:3	Y = -770.1–19.8Tmin- 90.3 BSS+129.7 Tmean	....(R^2 = 0.30	SE = 394.0)
Step:4	Y = - 324.8 + 104.5Tmean–107.3 BSS–0.95 RF	....(R^2 = 0.33	SE = 386.7)

The above relations indicated that weather variables accounted for about 33% yield variations only in *kharif* sorghum. Thus, further improvement in the model is necessary for yield prediction.

Dynamic modeling

Rice

FAIZABAD

CERES-rice model was validated with field data involving three rice cultivars (Sarjoo-52, NDR-359, Pant Dhan-4) and the genetic coefficients estimated by iterative method for these three cultivars are listed in table 5.12. The explanation for each of the genetic coefficients is also furnished.

Table 5.12 : Genetic coefficients estimated for three rice cultures at Faizabad

Genotypes	P_1	P_2R	P_5	P_2O	G_1	G_2	G_3	G_4
Sarjoo-52	470.0	170.0	400.0	12.2	46.0	0.02	1.00	0.80
NDR-359	600.0	150.0	410.0	12.0	42.0	0.02	1.00	0.80
Pant Dhan-4	620.0	160.0	300.0	12.0	45.0	0.02	1.00	0.80

The details of genetic coefficients are as follows:

P_1 - Time period (expressed as growing degree days [GDD] in °C above a base temperature of 9°C) from seedling emergence during which the rice plant is not responsive to changes in photoperiod.

P_2O - Critical photoperiod or the longest day length (in hours) at which the development occurs at a maximum rate.

P_2R - Extent to which phasic development leading to panicle initiation is delayed (expressed as GDD °C) for each hour increase in photoperiod above P_2O.

P_5 - Time period in GDD °C from beginning of grain filling (3 to 4 days after flowering) to physiological maturity with a base temperature of 9°C.

G_1 - Potential spikelet number coefficient as estimated from the number of spikelets per g of main culmn dry weight (less lead blades and sheaths plus spikes) at anthesis.

G_2 - Single grain weight (g) under ideal growing conditions, i.e. non-limiting light, water, nutrients, and absence of pests and diseases.

G_3 - Tillering coefficient (scaler value) relative to IR64 cultivar under ideal conditions

G_4 - Temperature tolerance coefficient

MOHANPUR

Performance of a rice crop growth model, DSSAT-rice was evaluated using experimental data of *cv.* Shatabdi planted on three different dates *viz.*, 15th June, 29th June and 13th July, 2011. The CERES model performed well in the estimation of grain yields in second and third date of plantings with an error range of -1% to +3%. However, for the first date of planting the model largely over-estimated the yields (30%). A comparison on the observed and model estimated yields is presented in fig. 5.2.

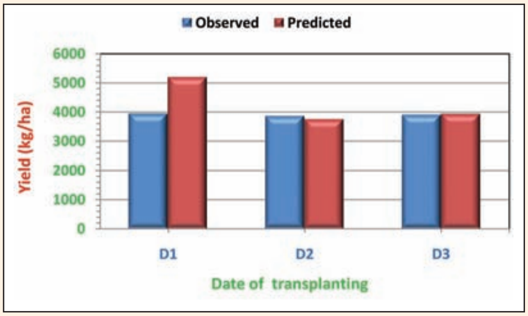


Fig. 5.2 : Comparison between observed and predicted grain yield of rice at Mohanpur

Model performed very well in predicting leaf dry weight in all dates of sowing and the 1:1 line graph between observed and predicted (Fig. 5.3) showed that a good correlation between the observed and predicted yield as revealed by high R^2 value of

0.77. Stem dry weights in different dates of sowings as predicted by the model were regressed on observed values and the resultant 1:1 line (Fig. 5.4) indicated a good fit between the observed and predicted stem dry weights.

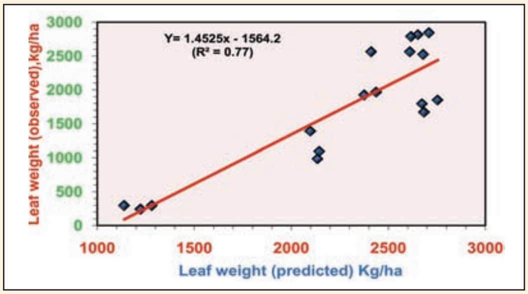


Fig. 5.3: Relationship between observed and predicted leaf weight at Mohanpur

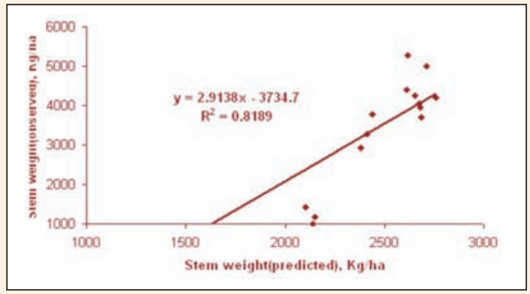


Fig. 5.4: Relationship between observed & predicted stem weight of rice at Mohanpur

LUDHIANA

AquaCrop model

The accuracy of AquaCrop model in simulating the grain yields of rice under differential irrigation treatments were tested using experimental data of *cv.* PAU-201 of *kharif* 2009 season. The different water regimes that were considered are irrigation after one day of disappearance of water (I_1), irrigation after two days of disappearance of water (I_2), irrigation after three days of disappearance of water (I_3) and Tensiometers guided irrigation as recommended to soil matric tension of 150 ± 20 cm (I_4). The model simulated biomass and grain yields were compared with measured data and comparison is presented in table 5.13. The model did not respond to irrigation regimes imposed and thus may not be suitable to predict yields using the irrigation schedules considered in the present investigation.

Table 5.13 : Comparison of measured and AquaCrop simulated grain and biomass yield of rice (*Kharif* 2009) at Ludhiana

Treatments	Grain yield (t ha^{-1})			Biomass (t ha^{-1})		
	Measured	Simu lated	% diffe rence	Measured	Simu lated	% diffe rence
I_1	7.40	7.50	1.29	17.39	17.43	0.21
I_2	7.28	7.50	2.83	17.12	17.43	1.78
I_3	7.22	7.50	3.74	16.68	17.43	4.34
I_4	7.37	7.50	1.63	17.15	17.43	1.62
CD (0.05)	NS	NS	-	NS	NS	-

InfoCrop model

Growth and yield of three rice cultivars (PAU-201, PR-115, PR-116) simulated using InfoCrop model were compared with two years experimental data (*kharif* 2008 and 2009) and the results of comparison are presented in fig. 5.5 a to d. The simulated values for days taken to anthesis and physiological maturity deviated from the observed by -13 to +14 days and -13 to +20 days, respectively. The model erred by -16 to +10% and -10 to +38% in simulating the grain yield and LAI, respectively.

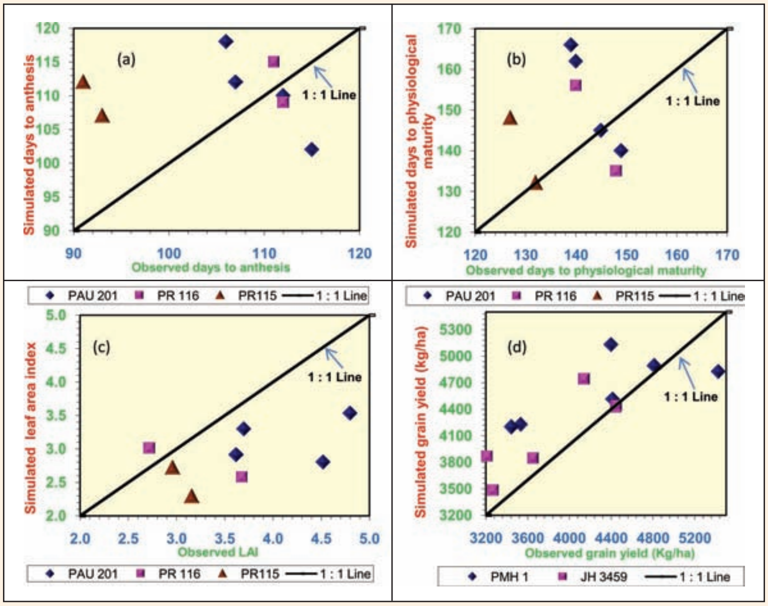


Fig. 5.5 a to d: Comparison of observed and simulated (a) days to anthesis; (b) days to physiological maturity; (c) leaf area index; (d) grain yield of rice cultivars at Ludhiana

RAIPUR

CERES rice model was employed to estimate potential productivity of rice at Raipur, determine the yield gap and assess the future climatic change effects on rice yields.

Potential productivity of rice cultivars IR-36 and IR-64 under water non-limiting conditions in sandy loam soils of Raipur was simulated to be 7.11 and 6.95 t/ha, respectively (Table 5.14).

Yield gap analysis

A comparison made between yield and yield attributes under water non-limiting and water limiting conditions to determine the yield gap due to availability of irrigation water showed that through a better irrigation scheduling, the yields of rainfed IR-36 and IR-64 can be enhanced by 0.72 t/ha. Leaf area index, panicle number and biomass were also higher under irrigated condition than under rainfed conditions (Table 5.15).

Table 5.14 : Production potential of IR-36 and IR-64 rice varieties at Raipur

S. No	Parameters	IR-36	IR-64
1.	Leaf area index (peak value)	5.19	5.25
2.	Panicle number (no/sq. m)	296.53	301.02
3.	Number of grains/panicle	104.21	92.36
4.	Grain weight at maturity (g/unit)	0.0230	0.0250
5.	Harvest index at maturity	0.555	0.525
6.	Biomass yield at maturity (t/ha)	12.806	13.235
7.	Grain yield at maturity (t/ha)	7.108	6.951
8.	Duration of crop (days)	98	101

Table 5.15 : Productivity of rice cultivars under water limiting and non-limiting conditions at Raipur

S. No	Parameters	IR-36		IR-64	
		Irrigated	Rainfed	Irrigated	Rainfed
1.	Leaf area index (peak value)	5.19	4.27	5.25	4.27
2.	Panicle number (no/sq.m)	296.53	286.09	301.02	289.02
3.	Number of grains/panicle	104.21	97.10	92.36	86.16
4.	Grain weight at maturity (g/unit)	0.0230	0.0230	0.0250	0.0250
5.	Harvest index at maturity	0.555	0545	0525	0516
6.	Biomass yield at maturity (t/ha)	12.806	11.714	13.235	12.074
7.	Grain yield at maturity (t/ha)	7.108	6.389	6.951	6.226
8.	Duration of crop (days)	98	98	101	101

Assessment of climate change impacts

Decline in rainfall pattern is forecasted by several model studies for Chattisgarh region and considering these forecasts, simulations were made with a 10%, 20% and 30% decrease in total seasonal rainfall. CERES model outputs for different reductions in rainfall are presented in table 5.16 along with yields simulated with normal rainfall. The simulations indicated that the yields would decrease by 0.61t/ha in case of IR-36 and by 0.57 t/ha in IR-64 across all the rainfall scenarios tested.

Table 5.16 : Performance of rice cultivars in different seasonal rainfall scenarios at Raipur

S. No	Parameter	Normal rainfall	10% less	20% less	30% less
		IR-36			
1.	Leaf area index (peak value)	4.27	3.89	3.89	3.89
2.	Panicle number (no/sq.m)	286.09	265.37	265.37	265.37
3.	Number of grains/panicle	97.10	94.73	94.73	94.73
4.	Grain weight at maturity (g/unit)	0.0230	0.0230	0.0230	0.0230
5.	Harvest index at maturity	0.545	0.547	0.547	0.547
6.	Biomass yield at maturity (t/ha)	11.714	10.567	10.567	10.567
7.	Grain yield at maturity (t/ha)	6.389	5.782	5.782	5.782
8.	Duration of crop (days)	98	98	98	98
9.	Rainfall (mm)	691.8	618.0	549.4	480.0
10.	Rainy days	76	76	73	69
		IR-64			
1.	Leaf area index (peak value)	4.27	3.90	3.90	3.90
2.	Panicle number (no/Sq.m)	289.02	268.51	268.51	268.51
3.	Number of grains/panicle	86.16	84.23	84.23	84.23
4.	Grain weight at maturity (g/unit)	0.0250	0.0250	0.0250	0.0250
5.	Harvest index at maturity	0.516	0.519	0.519	0519
6.	Biomass yield at maturity (t/ha)	12.074	10.896	10.896	10.896
7.	Grain yield at maturity (t/ha)	6.226	5.654	5.654	5.654
8.	Duration of crop (days)	101	101	101	101
9.	Rainfall (mm)	696.2	621.8	552.8	482.9
10.	Rainy days	77	77	74	70

SAMASTIPUR

Rice yields of cultivar R. Mansuri were simulated using DSSAT model and the simulated values under different sowing dates showed that days taken to anthesis and maturity were predicted very accurately but the model over-estimated the grain yield by 12.5% (Table 5.17). **Genetic Coefficients -** P_1=980.0, P_2R=170.0, P_5=320, P_20=11.2, G_1=40.0, G_2=0.024, G_3=1.000, G_4=1.000

Sowing time - 25th June, 10th July, 25th July and 15th August.

Table 5.17 : Performance of DSSAT rice model for *cv.* R. Mansuri at Samastipur

Variables	Simulated Mean	Observed Mean	R^2
Anthesis days	112	112	0.69
Maturity days	138	139	0.82
Yield (kg/ha)	3330	3070	0.77

Maize

LUDHIANA

Growth and development of two maize cultivars *viz.,* PMH-1 and JH-3459 as simulated by InfoCrop model for *kharif* 2006 and 2007 seasons were compared with experimental data and the resultant comparisons on 1:1 line are presented in fig. 5.6 a to c. It can be noticed from figure 5.6 (a) that the model over-estimated days to silking in majority of the runs and under-estimated days to physiological maturity (Fig. 5.6 b). The model simulated grain yields were within the range of -11 to +21% of the observed.

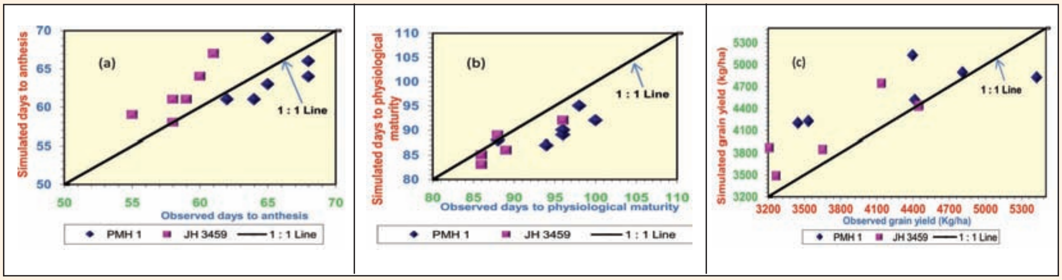


Fig. 5.6 a to c: Comparison of observed and simulated (a) days to silking; (b) days to physiological maturity; (c) grain yield of maize cultivars under different environments at Ludhiana

RAKH DHIANSAR

Maize yields of Jammu district were simulated for a period of 20 years (1991-2011) using a pre-calibrated CERES-maize model. The model parameterization is done with experimental data of Rakh Dhiansar station and then the model was upscaled to estimate district yields. The model over-estimated the district yields in majority of the years but simulated trend line closely following the observed one (Fig. 5.7).

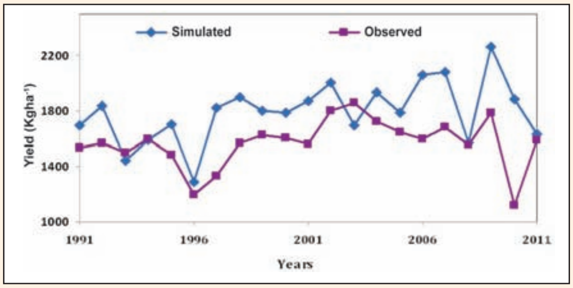


Fig. 5.7: CERES-maize simulated and observed maize yields for Jammu district at Rakh Dhiansar

Soybean

AKOLA

DSSAT-soybean model simulated the phenological events in three soybean cultivars *viz.,* JS-335, NRC-37 and TAMS98-21 very close to the observed. The D-index of the agreement values for all the varieties were near to unity for all the phenological stages, yield and harvest index (Table 5.18). The percent error in prediction was relatively high for first pod initiation stage compared to other phenological stages. The model could predict the seed yields with a reasonable accuracy but slightly over-estimated in all the varieties and for NRC-37 the model over-estimated the yield by 19.4%. The errors in predicting straw yields for all the cultivars were large compared to seed yields.

Table 5.18: Performance of DSSAT-soybean model for three soybean cultivars at Akola

Date of sowing	Anthesis day			First pod day			First seed day			Physiological maturity			Seed Yield			Straw Yield			Harvest index		
	O	P	Error	O	P	Error	O	P	Error	O	P	Error	O	P	Error	O	P	Error	O	P	Error
JS-335																					
S1	38	37	-2.63	49	45	-8.16	61	58	-4.92	92	90	-2.17	2111	2434	15.30	1536	1840	19.79	0.58	0.57	-1.73
S2	37	36	-2.70	48	44	-8.33	59	57	-3.39	89	88	-1.12	2049	2179	6.34	1509	1770	17.30	0.58	0.55	-4.17
S3	36	36	0.00	47	44	-6.38	57	57	0.00	85	86	1.18	1702	1780	4.58	1426	1860	30.43	0.54	0.49	-10.1
S4	36	36	0.00	46	44	-4.35	57	57	0.00	84	83	-1.19	1036	988	-4.63	1375	1970	43.27	0.43	0.33	-22.3
Mean	37	36	-1.33	48	44	-6.81	59	57	-2.08	88	87	-0.83	1725	1845	5.40	1462	1860	27.70	0.53	0.49	-9.58
SD			1.54			1.86			2.48			1.42			8.17			11.84			9.19
RMSE			0.71			3.35			1.80			1.32			180.0			419.2			0.06
PE			1.92			7.06			3.08			1.51			10.44			28.28			10.68
D-index			1.00			0.99			1.00			1.00			0.99			0.98			0.99
NRC-37																					
S1	40	37	-7.50	52	45	-13.4	65	61	-6.15	100	93	-7.00	1665	1984	19.16	1597	1930	20.85	0.51	0.51	-0.78
S2	39	35	-10.2	52	44	-15.3	63	59	-6.35	95	91	-4.21	1575	1781	13.08	1558	1710	9.76	0.50	0.51	1.19
S3	39	35	-10.2	50	44	-12.0	61	60	-1.64	91	88	-3.30	1073	1339	24.79	1488	1840	23.66	0.42	0.42	0.24
S4	38	35	-7.89	50	44	-12.0	60	60	0.00	88	85	-3.41	897	695	-22.5	1348	1900	40.95	0.40	0.27	-33.0

Date of sowing	Anthesis day			First pod day			First seed day			Physiological maturity			Seed Yield			Straw Yield			Harvest index		
	O	P	Error	O	P	Error	O	P	Error	O	P	Error	O	P	Error	O	P	Error	O	P	Error
Mean	39	36	-8.98	51	44	-13.2	62	60	-3.54	94	89	-4.48	1303	1450	8.63	1498	1845	23.80	0.46	0.43	-8.09
SD			1.49			1.60			3.21			1.73			21.30			12.91			16.63
RMSE			3.54			6.80			2.87			4.56			252.8			375.0			0.07
PE			9.07			13.33			4.61			4.87			19.40			25.04			14.42
D-index			1.00			0.99			0.99			1.00			0.99			0.98			0.99
TAMS 98-21																					
S1	42	41	-2.38	54	52	-3.70	67	69	2.99	102	100	-1.96	1765	2138	21.13	2127	2680	26.00	0.46	0.44	-2.42
S2	39	39	0.00	52	50	-3.85	64	66	3.13	98	96	-2.04	1667	1720	3.18	2094	2510	19.87	0.44	0.41	-7.92
S3	40	38	-5.00	51	48	-5.88	62	64	3.23	93	91	-2.15	1242	1203	-3.14	1790	2320	29.61	0.41	0.33	-18.8
S4	39	37	-5.13	51	47	-7.84	62	61	-1.61	90	86	-4.44	821	495	-39.7	1698	2230	31.33	0.33	0.18	-44.0
Mean	40	39	-3.13	52	49	-5.32	64	65	1.93	96	93	-2.65	1374	1389	-4.63	1927	2435	26.70	0.41	0.34	-18.2
SD			2.44			1.96			2.36			1.20			25.24			5.07			18.45
RMSE			1.50			2.87			1.80			2.65			249.8			510.5			0.08
PE			3.75			5.52			2.83			2.76			18.10			26.49			20.40
D-index			1.00			0.99			1.00			1.00			0.99			0.98			0.98

Rabi **2011-12**

Dynamic modeling

Wheat

ANAND

CERES-wheat model was evaluated using three years of experimental data for four cultivars (GW-322, GW-496, GW-366, GW-1139). A comparison was made between model simulated and observed values for different growth and development parameters like days to anthesis, maturity and grain yield. The model could predict the days taken to anthesis with reasonable accuracy with per cent error values ranging from -0.17 to 12.9 in different cultivars (Fig. 5.8). However, the model slightly over-estimated the days taken to maturity with model error ranging from +2.3 to 11.1% (Fig. 5.9). Simulated grain yields were found to be very close to the observed (Fig. 5.10) with a mean per cent error of -0.96 to 4.10. Thus, it can concluded that CERES-wheat model validated with calibration coefficients determined for Anand condition can be made use of in further studies.

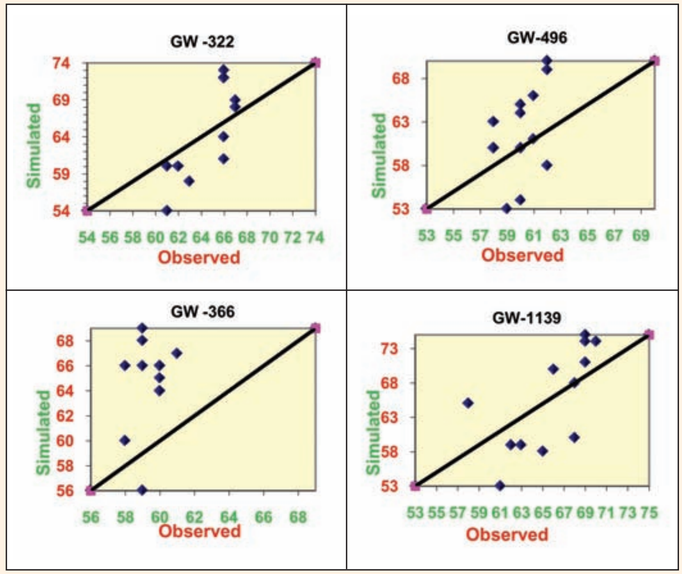


Fig. 5.8: Observed and simulated days to anthesis in four wheat cultivars at Anand

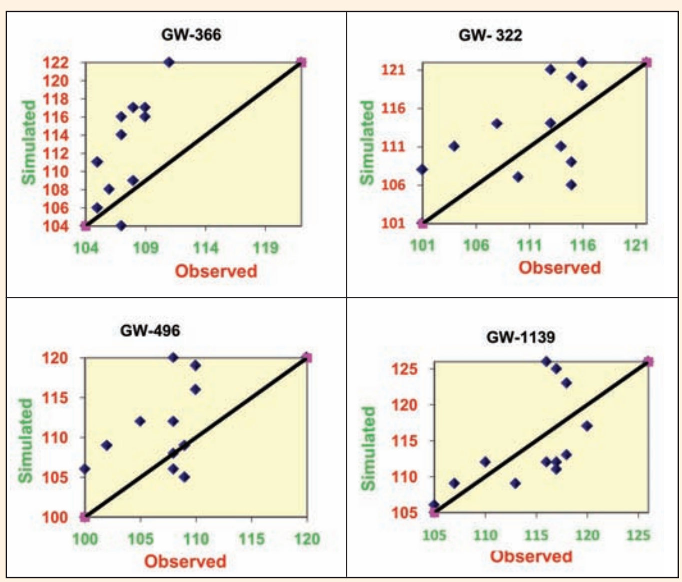


Fig. 5.9: Observed and simulated days to maturity in four wheat cultivars at Anand

Grain yields of wheat *cv.* HUW-234 simulated using CERES-wheat model under three different sowing dates (25th Nov, 10th Dec, 25th Dec, 2011) were compared with observed yields and the error associated in the yield prediction is presented in table 5.19. The model could predict the grain yields of wheat with less than 10% mean error in different dates of sowing thus indicating the suitability of the model in predicting wheat yields at Faizabad.

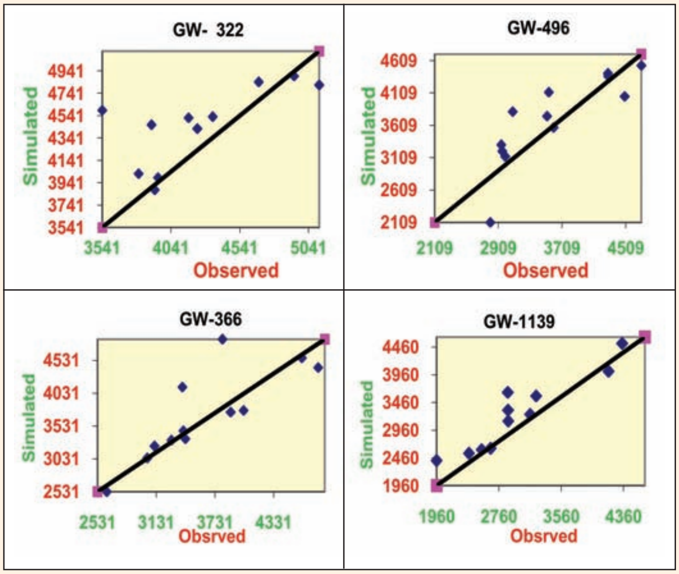


Fig. 5.10: Observed and simulated grain yield in four wheat cultivars at Anand

Table 5.19 : Comparison of observed and simulated wheat yields at Faizabad

Date of sowing	Simulated yield (kg/ha)	Observed yield (Kg/ha)	Error %
25th Nov. 2011	4567	4405	3.5
10th Dec. 2011	4031	3712	7.9
25th Dec. 2011	3502	3200	8.6

LUDHIANA

Performance of three wheat cultivars (PBW-343, PBW-502, PBW-550) in terms of growth and development recorded from three year experimentation (2006-2010) were compared with InfoCrop simulated values. Days taken to anthesis predicted by the model was found to be over-estimating in all environments except one (Fig.5.11). The model could predict days to anthesis with error ranging from -13 to 14 days.

The model was found to be largely over-estimating the LAI and grain yield and either over-estimating or under-estimating test weight of grains as well as grain yields. It can be summarized that several parameters of InfoCrop model need to be calibrated to improve its accuracy in prediction of wheat yields at Ludhiana.

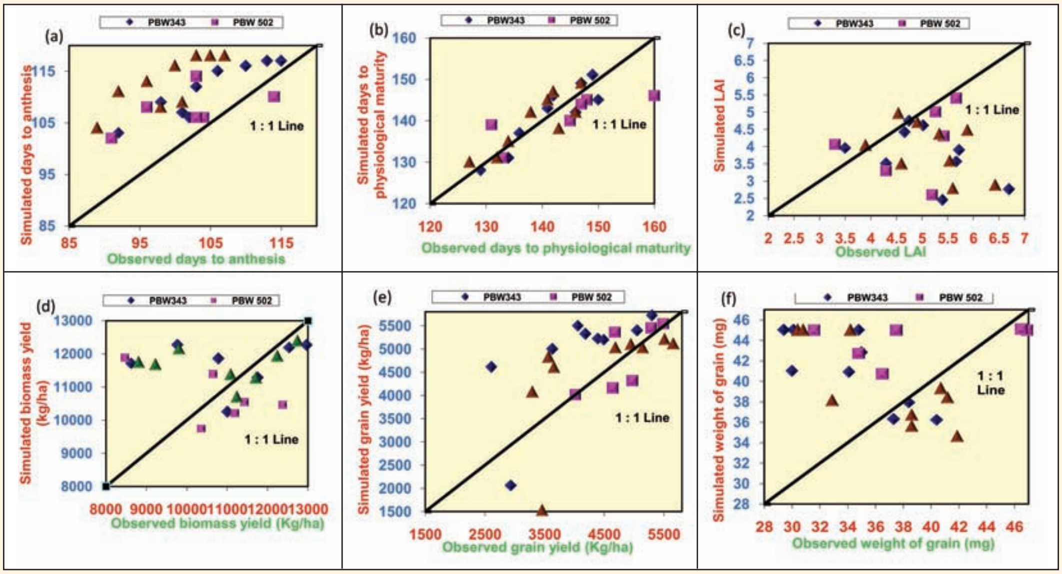


Fig. 5.11: Comparison between observed and simulated (a) days to anthesis; (b) days to physiological maturity; (c) leaf area index; (d) yield of biomass; (e) grain yield at Ludhiana and (f) grain test weight.

Statistical / Empirical models

KANPUR

Weather parameters / agrometeorological indices influencing the wheat growth and development were identified through correlation analysis and those weather parameters/ agrometeorological indices showing significant correlations were used to develop yield / crop development prediction equations through regression technique. The resultant relations are presented in Table 5.20. The relation involving derived agromet indices could account for 98% and 96% variation in days taken to maturity and grain yield, respectively.

Table 5.20 : Regression equations relating yields and duration of wheat with weather parameters at Kanpur

Parameters	Equation	R^2
Grain yield (kg/ha.)	Y= 29573.19 + 1806.52 Tmax. + 2253.92 Tmin. – 4846.53 Soil T	0.94
	Y= 19289.29 – 1848.66 BSS – 21.35 Eva. + 1.42 HU	0.97
	Y= -20887.80 + 463.58 RHm – 16.57 Cu Rf – 27.27 Days	0.85
	Y= 10016.21 + 17.38 GDD -2.39 HTU +1.09 PTU	0.96
Duration (days)	Y= 33.19 + 0.27 GDD – 0.015 HTU – 0.006 PTU	0.98

6. WEATHER EFFECTS ON PESTS AND DISEASES

Rabi 2010-11

Mustard

ANAND

Mustard aphid, *Lipaphis erysimi,* is a key pest of mustard crop determining the crop productivity on many occasions. Forewarning the incidence and development rate of aphids is an important component in the agro-advisories. This calls for the development of decision support system involving weather variables as input. Hence, studies were conducted for nine years to study the incidence of aphid on mustard in relation to weather. Correlation coefficients between weather parameters and aphids presented in table 6.1 and fig.6.1 indicated that weather has a dominant role on the incidence and development of aphids on mustard. Wind speed above 2 kmph, sunny days (BSS > 7 hrs), maximum temperature above 28.0°C and morning relative humidity in the range of 85-90% are most conducive weather conditions for the spread of aphids. The period 51st and 52nd SMW is ideal time for aphid infestation.

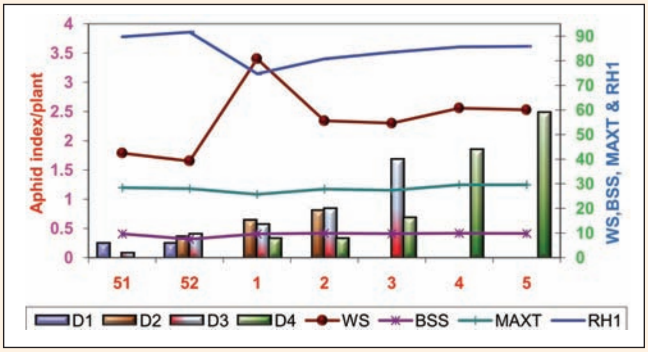


Fig. 6.1 : Relationship of mustard aphid and weather parameters in different dates of sowing at Anand

Table 6.1 : Pearson's correlation coefficients between aphid index and weather parameters (2002-03 to 2010-11) at Anand

Date of Sowing	EP	BSS	WS	MAXT	RH1	RH2	VP2
D_1 - 10th Oct.	-0.16	-0.08	0.09	0.03	0.25(*)	0.31(**)	0.24(*)
D_2 - 20th Oct.	-0.25(*)	-0.32(**)	0.40(**)	-0.26(*)	0.15	0.37(**)	0.09
D_3 - 30th Oct.	-0.14	-0.24(*)	0.28(*)	-0.24(*)	0.01	0.14	-0.06
D_4 - 10th Nov.	0.26(*)	-0.22(*)	0.21	-0.04	-0.11	-0.04	0.08

Mustard saw fly

Variations in the mustard saw fly infestation in relation to weather conditions prevailed during different dates of sowing was studied. Mustard saw fly infested the crop in all the dates of sowing (Fig. 6.2). Higher relative humidity (>80%) coupled with higher maximum temperature (>25°C) were found to favour the infestation of saw fly.

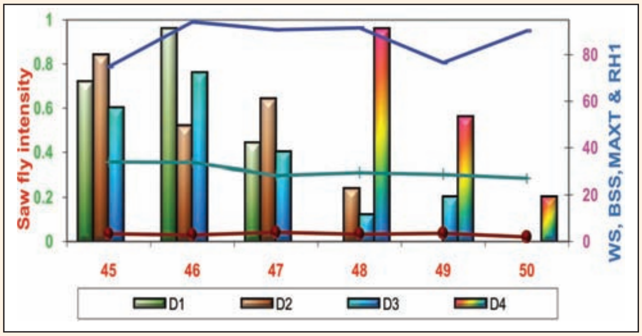


Fig.6.2: Relationship of mustard saw fly and weather parameters in different dates of sowing at Anand

White rust

White rust infestation at weekly intervals in the crop sown on different dates when examined critically showed that disease infestation commenced during second week of January in all the sowing dates. Disease persisted for longer period in D_4 sowing compared to other dates of sowing and infestation gradually disappeared after 6th SMW. Higher relative humidity and maximum temperature were found favourable for the incidence and spread of the white rust in mustard (Fig. 6.3).

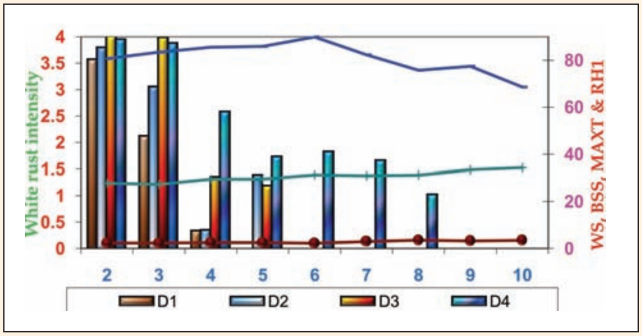


Fig. 6.3: Relationship of mustard white rust and weather parameters in different dates of sowing at Anand

Cotton

HISAR

Leaf curl disease

A five year experimentation to study the incidence of leaf curl in cotton (2005-2011) in relation to weather parameters revealed that maximum temperature (-0.55), minimum temperature (-0.61), wind speed (-0.78), evaporation (-0.63) and rainfall (-

0.14) were found to have negative correlation with disease development whereas, morning relative humidity (0.45), evening relative humidity (0.20), sunshine hours (0.20) and cumulative rainfall (0.78) have positive association. The optimum range of maximum and minimum temperatures for development of leaf curl disease in cotton was from 33.0 to 37.0°C and 23.0 to 28.0°C, respectively. There was an exponential relationship between disease development and cumulative rainfall (sigmoid growth curve) i.e., the rate of disease development was initially slow till the accumulation of 100 mm rainfall and thereafter disease development increased sharply. The sunshine hours showed a linear relationship with disease indicating that the clear days favored its development (Fig.6.4).

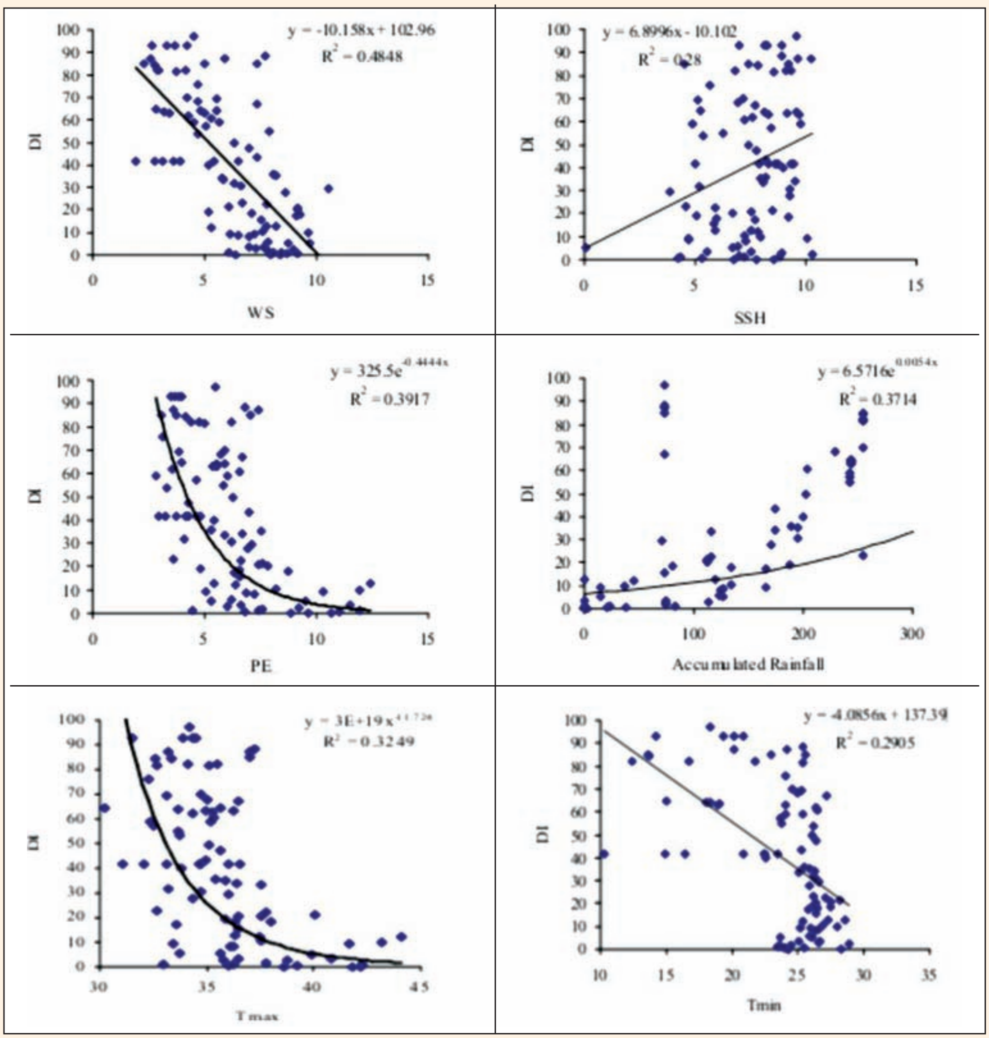


Fig. 6.4 : Leaf curl disease incidence in cotton in relation to meteorological parameters at Hisar

KOVILPATTI

Role of weather variables on the aphid infestation in cotton *cv.* NCS 145 Bt when examined revealed that minimum temperature, relative humidity and rainfall play a major role in the aphid population dynamics. The pest damage was noticed after the receipt of heavy rainfall during 44th SMW and pest population increased later as the minimum temperature dropped and RH increased. A linear regression accounted for 84% variation in aphid damage which is the number of infested plant in the total population in the plot expressed as percentage. The regression model thus obtained is:

Y = 47.351 – 3.418 Min.T + 0.329 RH .... (R^2= 0.84)

Where, Y = Aphid damage after establishment

Potato

MOHANPUR

Late blight disease

Late blight disease infestation in potato was monitored at weekly interval on five randomly selected plants in each plot and ratings on 0 to 50 scale with an increment of five units was adopted to develop per cent disease incidence using the formulae:
PDI = (Sum of all ratings X 100) / (Number of observations X Maximum disease rating).

The variations in PDI were studied in relation to weather which revealed a significant correlation with mean maximum temperature (R^2 = 0.70), mean minimum temperature (R^2 = 0.81) and soil temperature (R^2 = 0.64). No association between PDI and RH was noticed. As most of the period during December and first fortnight of January, the morning RH in the Indo-Gangetic plains is near to 100%, late blight incidence was intense as the crop reached maturity (Fig. 6.5 a&b).

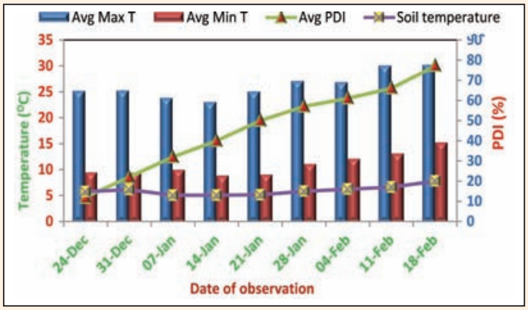


Fig. 6.5 a: Relationship between potato late blight and air and soil temperatures at Mohanpur

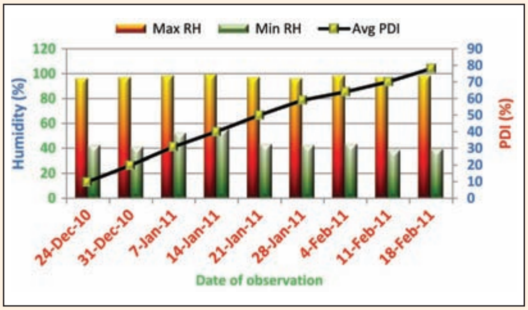


Fig. 6.5 b: Variations in potato late blight and RH over potato growing season at Mohanpur

Grape

BIJAPUR

Flea beetle and Thrips

Regression models were developed by taking individual meteorological parameters as independent variables at different lead times for flea beetle and thrips on grape (Tables 6.2 and 6.3). It was observed that the flea beetle can be forecasted using minimum temperature with more or less similar accuracy at different lead times. However, the models give scope to update forecast of flea beetle every week and if necessary on day-to-day basis also.

On the other hand, accuracy of the minimum temperature based models to forecast thrips improves as the lead time reduces. So, it would be possible to improve the forecast of thrips with further experimentation.

Table 6.2 : Regression models developed for forecast of Flea beetle on grapes with different lead periods at Bijapur

Lead time (Weeks)	Flea Beetle							
	Minimum temperature	R^2	Sunshine duration	R^2	Afternoon RH	R^2	Rainfall	R^2
3	Y = 16.39–0.59 (MinT)	0.49	Y=1.27+ 0.69(BSS)	0.38	Y=15.35-0.81 (RH2)	0.41	Y=6.83- 0.04 (RF)	0.37
2	Y = 16.17–0.59 (MinT)	0.50	Y=12.74-0.41 (RH2)			0.41		
1	Y = 15.71–0.56 (MinT)	0.47						
0	Y= 16.28 - 0.61 (MinT)	0.51	Y=0.35+ 0.76(BSS)	0.39	Y=14.31- 0.71 (RH2)	0.41		

Table 6.3 : Regression models developed for forecast of Thrips on grapes with different lead periods at Bijapur

Lead time (Weeks)	Thrips					
	Minimum temperature	R^2	Morning time RH	R^2	Afternoon RH	R^2
3	Y=80.73-3.19 (MinT)	0.37	Y=188.76-1.91 (RH1)	0.37	Y=83.06-1.23 (RH2)	0.40
2	Y=87.16-3.60 (MinT)	0.42	Y=183.93-1.84 (RH1)	0.38	Y=72.74-0.95 (RH2)	0.35
1	Y=87.07-3.60 (MinT)	0.43	Y=179.67-1.79 (RH1)	0.37	Y=72.87-0.96 (RH2)	0.35
0	Y=91.29-4 (MinT)	0.46	Y=182.19-1.82 (RH1)	0.39	Y=80.0.9-1.08 (RH2)	0.40

Kharif 2011

Weather influences not only the developmental rhythm of crops but also growth, survival of insect pests and causative organisms of diseases. Development of these pests in relation to weather if properly assessed/understood can help in reducing the crop yield losses. Any sudden outbreak of the pests covering large area may be linked to the congenial weather. Identifying the congenial weather thus becomes a pre-requisite to forewarn the pest/disease outbreak. Development of weather based tools to predict insect pest and disease incidence and development are needed in all crops and regions. The research results carried out on this aspect at different centers are reported here:

Groundnut

ANANTAPUR

Incidence of leaf miner on groundnut as a function of weather parameters was studied from a long term field experiment. The polynomial relation developed from the analysis of pest and weather data accounted for 91% of the variation in leaf miner damage. In present investigation the number of plants damaged due to groundnut leaf miner (GLM) were recorded from unit area and then converted in to per cent of total plant population in that area. The polynomial thus derived is:

$$Y = 0.47 + 0.004\,X_1 + 0.12X_2 - 0.019X_3 - 0.26X_4 \qquad ....(R^2 = 0.91)$$

where,

Y = Predicted GLM damage

X_1 = Tmin; X_2 = RH-I; X_3 = RH-II and X_4 = Sunshine hours.

The above model developed from long term data was field tested using *kharif* 2011 and the performance of the model in terms of per cent deviation in different dates of sowing is presented in table 6.4. The model under-estimated the damage in the first two dates of sowing and over-estimated in the next three dates of sowing. The under-estimation ranged from 10.5 to 25.5% and over-estimation from 26.5 to 80.3%. It can be inferred from the statistical analysis that further experimentation is needed to develop a model with less error compared to the present one.

Table 6.4 : Testing of groundnut leaf miner prediction model at Anantapur

Date	Predicted GLM (%)	Actual GLM (%)	Percent deviation	Date	Predicted GLM (%)	Actual GLM (%)	Percent Deviation
D_1 (10.06.2011)				D_2 (24.06.2011)			
28.07.11	7.7	21.8	-64.68	**28.07.11**	7.8	6.9	13.04
04.08.11	8.1	9.7	-16.49	**04.08.11**	8.2	8.8	-6.82
16.08.11	7.2	11.5	-37.39	**16.08.11**	7.3	12.2	-40.16
22.08.11	8.9	10.3	-13.59	**22.08.11**	9	10.9	-17.43
29.08.11	8.8	14.2	-38.03	**29.08.11**	8.8	11	-20.00
05.09.11	8.3	9.4	-11.70	**05.09.11**	8.4	8.7	-3.45
12.09.11	7.8	6.2	25.81	**12.09.11**	7.8	7.2	8.33
18.09.11	7.3	2.9	151.72	**18.09.11**	7.4	7.3	1.37
				17.10.11	8.1	6.6	22.73
Total	64.1	86	-25.47	**Total**	65	72.7	-10.59
D_3 (10.07.2011)				D_4 (25.07.2011)			
22.08.11	9	3	200.00	**29.08.11**	8.8	6.7	31.34
29.08.11	8.8	11.3	-22.12	**05.09.11**	8.4	6	40.00
05.09.11	8.4	13.3	-36.84	**12.09.11**	7.8	6.3	23.81
12.09.11	7.8	6.1	27.87	**18.09.11**	7.4	7.4	0.00
18.09.11	7.4	7.4	0.00	**17.10.11**	8.1	2.8	189.29
17.10.11	8.1	3.2	153.13	**24.10.11**	7.2	2.7	166.67
24.10.11	7.2	1.4	414.29	**31.10.11**	8.7	4.5	93.33
31.10.11	8.7	3.3	163.64	**07.11.11**	7.9	6	31.67
07.11.11	7.9	4.8	64.58				
Total	64.3	50.8	26.57	**Total**	64.3	42.4	51.6
D_5 (09.08.2011)							
12.09.11	7.8	4.8	62.50				
18.09.11	7.4	4.5	64.44				
17.10.11	8.1	3.4	138.24				
24.10.11	7.2	0	0.00				
31.10.11	8.7	1.7	411.76				
07.11.11	7.9	5	58.00				
Total	111.4	61.8	80.26				

BANGALORE

Tikka disease incidence (%) on three groundnut cultivars (TMV-2, JL-24, K-134) was studied for six years to develop a forewarning model. Preliminary analysis suggested the role of already existing pathogen, hours of bright sunshine, rainfall and thermal time during 60-90 DAS on the disease spread. Hence, these three weather parameters were used in developing the forewarning model on the development of the disease from the six years data set. The models derived for the three varieties that can be used at 80 DAS and 90 DAS are presented in table 6.5.

Table 6.5 : Weather based forewarning models for Tikka disease development on groundnut at Bangalore

Stage	Model
80 days	$Y = 44.12 - 0.247 X_1 + 0.118 X_2 + 0.260 X_3 + 1.476 X_4$
V1 – 80 days	$Y = 57.46 - 0.241 X_1 + 0.118 X_2 + 0.078 X_3 + 3.637 X_4$
V2 – 80 days	$Y = 48.62 - 0.316 X_1 + 0.185 X_2 + 0.342 X_3 + 0.935 X_4$
V3 – 80 days	$Y = 40.71 - 0.230 X_1 + 0.068 X_2 + 0.275 X_3 + 1.954 X_4$
90 days	$Y = 91.05 - 0.084 X_1 + 0.088 X_2 - 0.345 X_3 - 0.613 X_4$
V1 – 90 days	$Y = 121.79 - 1.024 X_1 + 0.680 X_2 + 0.894 X_3 + 0.152 X_4$
V2 – 90 days	$Y = 70.44 - 0.091 X_1 - 0.050 X_2 + 0.157 X_3 + 0.194 X_4$
V3 – 90 days	$Y = 79.72 - 0.558 X_1 + 0.400 X_2 + 0.542 X_3 + 0.285 X_4$

The above models were tested using field data of *kharif* 2011 for the three cultivars and per cent incidence observed and predicted were compared (Fig. 6.6). The models performed well for all the three cultivars in predicting the development of the disease.

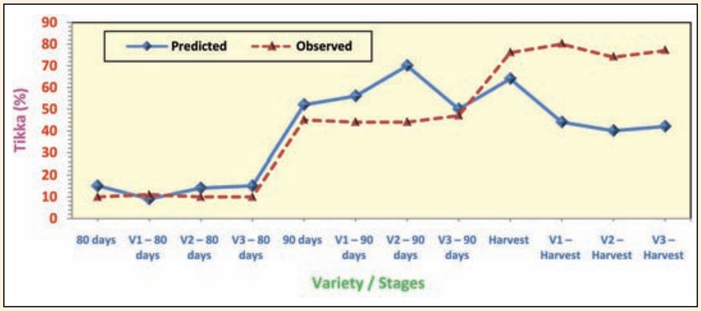


Fig. 6.6: Testing of forewarning models on Tikka disease development in groundnut at Bangalore

Pigeonpea

BANGALORE

Pod borer and Fusarium wilt:

Pod borer as well as fusarium wilt incidence in pigeonpea varieties sown on three different dates (01st June, 06th July, 15th July, 2011) and at three different plant densities of 74000, 49000, 37000 plants /ha were recorded and pod borer incidence was expressed in per cent damage (Table 6.6). The cultivar TTB-7 was found to be more susceptible over the other two varieties. There was no influence of spacing on the pest population but as the sowing time was delayed, pest population declined gradually. Fusarium wilt incidence at different stages expressed in percentage (Table 6.7) indicated that early sown crop is susceptible compared to late sown crop. Variety TTB-7 is more prone to fusarium wilt and VRG-2 is the least susceptible among the varieties tested.

Table 6.6 : Incidence of pod borer (% damage) on redgram as influenced by sowing time, variety and plant spacing at Bangalore

Varieties	Pod Borer damage (%)											
	Dates of sowing											
	01.06.2011				06.07.2011				15.07.2011			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
TTB-7	19.92	27.83	21.5	23.09	17.18	15.15	28.97	20.43	14.22	21.64	9.38	15.08
BRG-1	13.82	15.92	17.6	15.79	7.08	9.86	17.71	11.55	11.55	8.06	22.07	11.06
BRG-2	26.39	17.94	9.47	17.93	13.75	24.4	9.65	15.93	11.56	20.45	8.92	13.64
Mean	20.04	20.56	16.21	18.94	12.67	16.47	18.78	15.97	11.28	21.39	9.79	14.15

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

Table 6.7 : Incidence of fusarium wilt (% damage) on redgram as influenced by sowing time, variety and plant spacing at Bangalore

Varieties	Fusarium wilt damage (%)											
	Dates of sowing											
	01.06.2011				06.07.2011				15.07.2011			
	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean	S_1	S_2	S_3	Mean
TTB-7	70.99	39.61	35.99	48.86	61.77	34.13	22.63	39.51	21.14	30.97	29.15	27.09
BRG-1	3.64	47.88	43.55	31.69	3.80	41.38	17.89	21.02	3.31	9.45	7.29	6.68
BRG-2	2.50	14.74	12.63	9.96	46.83	5.77	10.49	2.84	2.84	5.19	7.01	5.01
Mean	25.71	34.08	30.72	30.17	37.47	27.09	17.00	21.12	9.10	15.20	14.48	12.93

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

FAIZABAD

Incidence of pod borer (*Helicoverpa armigera*) on pigeonpea *cv.* Arhar-1sown on three different dates (25th June, 5th July, 15th July) was monitored weekly by taking larval count on 5 plants from each plot and then averaged to arrive at weekly larval population on per plant basis. The fluctuations in the larval population were related to the observed and derived weather parameters to understand the role of weather on this pest. The accumulated thermal time (AGDD) requirement for the pest to appear as a mean of dates of

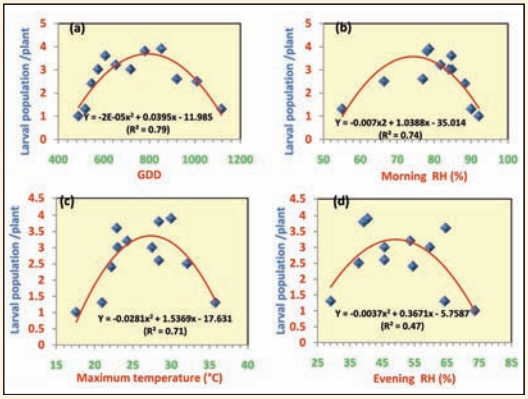


Fig. 6.7 a to d: Association between larval population and (a) GDD (b) morning RH (c) maximum temperature (d) evening RH at Faizabad

sowing was found to be 488 ^{0} day and larval population reached its peak value at an AGDD value of 854 ^{0} day (fig. 6.7 a). The larval population was found to be influenced by maximum temperature and relative humidity and the association between the independent and dependent variables are presented in fig. 6.7 (b) to (d).

Black gram

KOVILPATTI

Functional relation was developed using minimum temperature and relative humidity to predict incidence of powdery mildew on black gram utilizing the field data of *kharif* 2011 season. The relation obtained through linear regression is

Y = 46.177 - 0.297 RH - 0.994 Min. T ....(R^2 = 0.88)

Y = Disease incidence after establishment

Cotton

KOVILPATTI

Incidence of aphids on cotton *cv.* NCS-145 Bt was recorded in terms of number of infested plants per plot to total number of plants in that plot and expressed as aphid damage in per cent. The intra seasonal variability in the aphid population was related with corresponding weather variables and the step-wise regression resulted in the following relation:

Y = 38.852 - 0.173 RH - 0.570 Max. T ...(R^2 = 0.80)

Where, Y= Aphid damage (%)

LUDHIANA

Sucking pests like white fly, jassid and thrips incidence in cotton was monitored in three varieties sown on three different dates (25th April, 5th May, 13th May, 2011) so as to develop functional relations which can be used as forewarning models for the development of Decision Support System. The fluctuations in the population of these insects were initially correlated with corresponding weather parameters and those weather variables having significant correlation values are only presented in table 6.8. The higher minimum temperatures were found to favour all the three pests considered in RCH-134 in first and second dates of sowing whilst RCH-314 in first date of sowing only. The incidence of thrips on RCH - 314 and 134 in the third date of sowing was found to be influenced by afternoon RH.

Table 6.8 : Pearson's correlation coefficients between Jassid, white fly and thrips count and weekly meteorological parameters in cotton cultivars sown on three different dates at Ludhiana

Meteorological parameter / Varieties	Min T (°C)			RH 2
	Jassids	White fly	Thrips	Thrips
D_1 - 25th April 2011				
RCH-308	0.45	0.21	0.29	0.28
RCH-314	0.66**	0.60*	0.59*	0.15
RCH-134	0.58*	0.55*	0.56*	0.50*
D_2 - 4th May 2011				
RCH-308	0.41	0.53*	0.29	0.45
RCH-314	0.29	0.14	0.51*	0.42
RCH-134	0.51*	0.54*	0.68**	0.22
D_3 - 13th May 2011				
RCH-308	0.63**	0.60*	0.44	0.57*
RCH-314	0.53*	0.51*	0.34	0.50*
RCH-134	0.42	0.27	0.49	0.44

Analysis of the pooled data irrespective of the cultivars to determine the role of weather on the incidence of different pests on cotton and expressed in terms of correlation coefficients are presented in table 6.9. The results indicated that minimum temperature favours the incidence of key pests of cotton. Management options like adjusting the sowing time to avoid the pest incidence may not be a suitable criteria for this location.

Table 6.9 : Pearson's correlation coefficients between pest count and weekly meteorological data in crop sown on different dates (pooled over cultivars) at Ludhiana

Sowing dates	Minimum Temperature (°C)
White fly	
25th April 2011	0.50*
4th May 2011	0.45
13th May 2011	0.52*
Jassid	
25th April 2011	0.60*
4th May 2011	0.61*
13th May 2011	0.56*
Thrips	
25th April 2011	0.57*
4th May 2011	0.54*
13th May 2011	0.45

Rice

MOHANPUR

Role of weather on the incidence of aphid in *kharif* rice varieties (Pre-release, Baismukhi, IET-4786) was studied in the crop planted on three different dates (15th June, 29th June, 13th July, 2011). The statistical analysis carried out could not result in statistically significant association. However, the relations obtained are presented in table 6.10. The low coefficient of determination values in the relations may be due to small data set which is a result of single season experimentation.

Table 6.10 : Association between weather parameters and aphid population in rice at Mohanpur

Weather parameter	Relation derived	R^2
Max Temperature (°C)	$Y = 0.059e^{0.2279x}$	0.24
Min Temperature (°C)	$Y = 5.7633e^{0.0937x}$	0.03
Bright Sunshine (hrs)	Y = 5.1899x + 24.42	0.03

Rabi 2011-12

Mustard

ANAND

Aphid incidence on mustard measured in terms of weekly aphid index (0-5 scale) from a field experimentation conducted for nine years involving four sowing dates in each year were analyzed to figure out the role of weather on its incidence. In general the aphid appeared 7-9 weeks after sowing (WAS) and among the sowing dates 10th Oct sown crop recorded lowest aphid index compared to other dates. Thermal time requirement for the aphids to appear was computed as a mean of nine years and presented in fig. 6.8. It can be noticed from the figure that the thermal time requirement decreased progressively as sowings were delayed. Aphids appeared on 64 DAS in first date of sowing and days taken for its appearance gradually declined with delay in sowing and

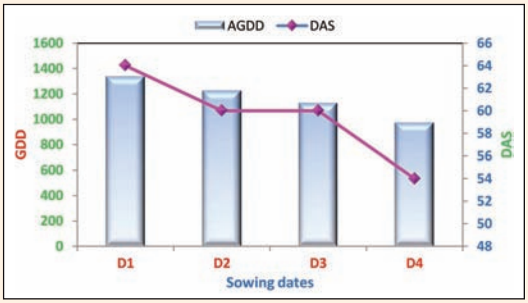


Fig. 6.8: Relation between thermal time accumulation, days after sowing and aphid appearance in different dates of sowings at Anand

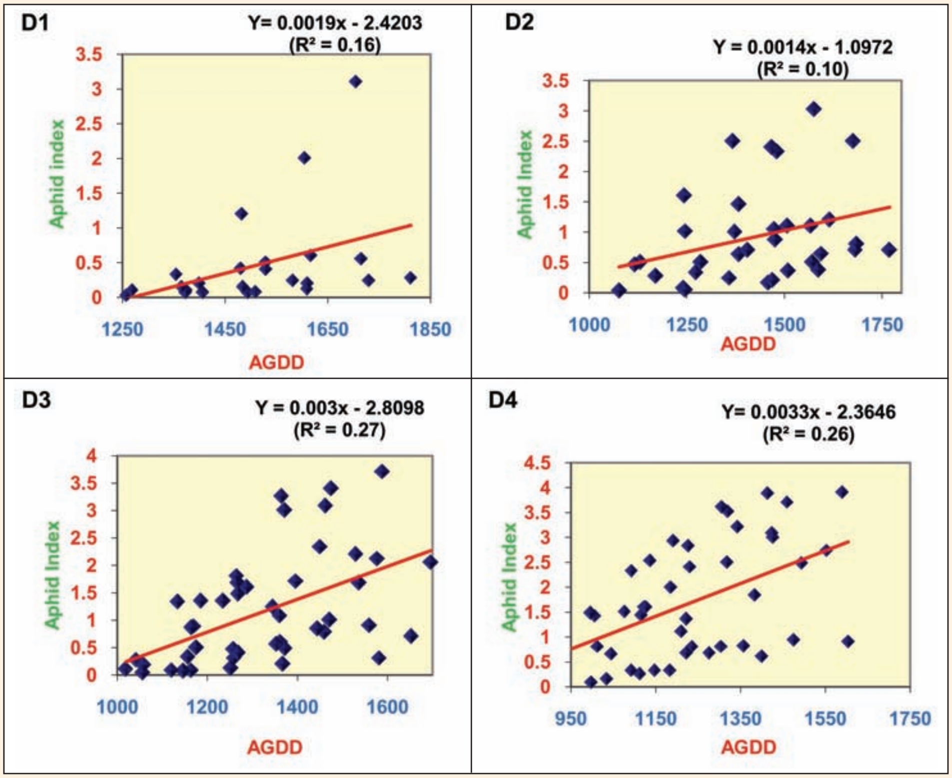


Fig. 6.9: Association between thermal time and aphid index in different dates of sowing at Anand

reached a value of 54 in the November 10th sown crop. The aphid index values (seasonal peak) when tried to related with accumulated thermal time (Fig. 6.9) resulted in poor association between these two variables. Development of a forewarning model requires identification of critical weather parameter (s) that facilitates accurate forecast. Correlation coefficients were worked out between different weather parameters and aphid index values to identify those critical weather parameters. The correlation coefficients values for different dates of sowings are presented in fig. 6.10 which indicated that vapour pressure in general has a positive influence on the aphid infestation across the sowing dates. Maximum temperature was found to have a negative influence on the aphid infestation in mustard.

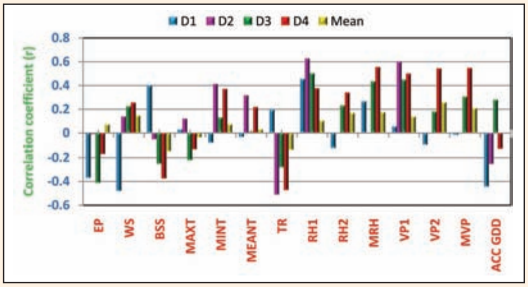


Fig. 6.10: Pearson's correlation coefficients between aphid index and weather parameters at Anand

PALAMPUR

Fluctuations in aphid population on mustard crop recorded during the month of February for a period of nine years were used to develop a conceptual model. Data when analytically studied indicated that rainfall around 30 mm and minimum temperature of 13°C during February are congenial for aphid incidence and subsequent buildup. The conceptual model proposed for development is presented in fig. 6.11.

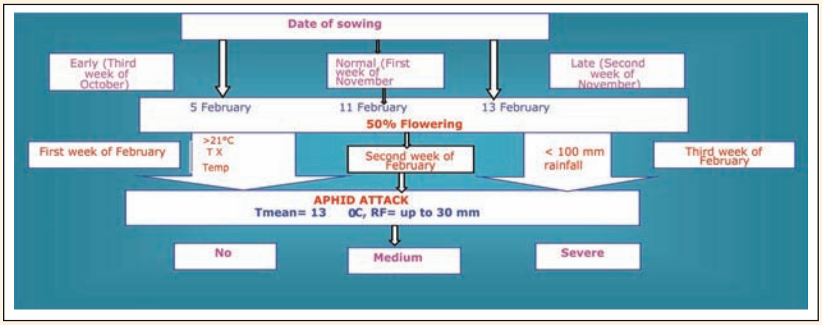


Fig. 6.11: Conceptual model on mustard aphid incidence for Palampur

RAKH DHIANSAR

Role of preceding weather conditions on the aphid population in mustard was assessed through creating three divergent environments by sowing the crop on 12th Oct, 22nd Oct and 1st Nov of 2011. The day of attainment of peak pest population was monitored closely in two mustard cultivars (RL-1359, RSPR-01) and the weather conditions that prevailed during the 10 preceding days from the date of peak attainment were correlated with aphid population and the resultant correlation coefficients are presented in table 6.11. The correlation coefficients indicated the role of temperature in regulating the aphid population. Further studies are required from a large data base to establish a valid hypothesis.

Table 6.11: Pearson's correlation coefficients between aphid population at peak incidence and weather parameters during preceding 10 days at Rakh Dhiansar

Weather parameter	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
Sowing Date: 12-10-2011										
MaxT	-0.10	-0.21	-0.14	-0.08	0.00	-0.10	-0.13	-0.16	-0.23	-0.21
MinT	-0.23	-0.44**	-0.35*	-0.36*	-0.32*	-0.41**	-0.56**	-0.50**	-0.50**	-0.54**
Mean Rh	-0.08	-0.20	-0.26	-0.31*	-0.28	-0.18	-0.26	0.03	-0.13	-0.20
RF	0.22	0.20	0.18	0.06	0.04	-0.17	-0.08	0.11	0.03	-0.02

Weather parameter	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
Sowing Date: 22-10-2011										
MaxT	-0.33*	-0.32	-0.35*	-0.23	-0.34*	-0.28	-0.29	-0.15	-0.29	-0.29
MinT	-0.12	-0.08	-0.05	-0.06	0.19	0.10	-0.01	-0.09	-0.15	0.00
Mean RH	0.49**	0.60**	0.44**	0.26	0.51**	0.34*	0.30	0.11	0.29	0.29
RF	-0.02	0.08	-0.02	0.16	0.42**	0.75**	0.02	-0.08	0.33**	0.05
Sowing Date: 01-11-2011										
MaxT	-0.35*	-0.34*	-0.34	-0.40*	-0.50**	-0.38*	-0.44**	-0.30	-0.28	-0.38*
MinT	-0.14	-0.27	-0.27	-0.37*	-0.08	0.08	0.16	-0.16	-0.03	0.13
Mean RH	0.30	0.24	0.17	0.17	0.35**	0.34**	0.28	0.17	0.37**	0.16
RF	-0.15	-0.09	-0.13	-0.06	0.42*	0.61**	0.02	-0.00	0.07	-0.18

UDAIPUR

Aphid population was monitored periodically on top 10 cm inflorescence of mustard variety Bio 902 under three sowing dates *viz.*, 12th Oct, 27th Oct and 11th Nov, 2011 (Table 6.12) indicated that late sown crop (11th Nov) escaped the peak infestation period of aphids and the flowering stage of the crop sown on 12th Oct matched with the peak population stage resulting in almost failure of the crop. Studies on identifying the congenial weather for aphid infestation are to be continued to draw meaningful results.

Table 6.12 : Aphid population on top 10cm inflorescence of mustard variety Bio-902 at Udaipur

	23rd Nov	30th Nov	7th Dec	14th Dec	21st Dec	28th Dec	4th Jan	11th Jan	18th Jan
12th Oct	5	25	50	250	400	650	600		
27th Oct			15	28	35	38	30	35	
11th Nov						10	30	38	40
Max. T	31.9	27.0	31.3	24.4	26.4	26.0	22.3	21.5	24.7
Min T	12.6	13.2	14.4	4.9	7.0	8.2	8.0	4.5	8.1
Mean T	22.3	20.1	22.9	14.7	16.7	17.1	15.2	13.0	16.4
Mean RH	57.7	66.5	64.5	51.8	66.7	68.3	70.2	66.7	74.8

Chickpea

JABALPUR

Population dynamics of *Helicoverpa armigera* in chickpea was studied by counting larval population per square meter at the interval of one week (Table 6.13). Low larval population (1-2 larva /m^2) was noticed during the 3-10 SMW and a rise in the population was noticed thereafter which coincided with a rise in maximum and minimum temperatures. Correlation coefficients did not indicate any role of weather which might be probably due to single year of experimentation. Further experimentation in the ensuing seasons is required to develop functional relations between pod borer and weather parameters.

Table 6.13 : Average counts of *H. armigera* larvae on chickpea at Jabalpur

SMW	Weather parameters											Larva/m²
	T. max	T min.	BSS	RF	RH I	RH II	WS	VP I	VP II	EVP	RD	
52	24.9	7.4	7.4	0	89	32	2.6	7.7	7.9	2.1	0	0
1	23	12	5.8	28.6	95	69	3.3	11.2	13.5	1.1	1	0
2	20.2	6.3	7.1	0	93	41	4	8	7	1.9	0	0
3	23.7	7.1	8.6	0	90	36	3.4	7.8	7.6	2.3	0	1
4	21.5	9	6.8	13.2	89	57	3.5	8.7	10.2	1.9	2	1
5	20.8	8	4.5	7.6	91	46	3.5	8.1	9.2	1.6	1	1
6	26.4	8.8	8.6	0	89	30	4	8.6	7.3	2.7	0	2
7	27.6	10.4	8.3	0	90	42	3.8	10	11.2	2.3	0	1
8	30.5	9.8	9.6	0	86	28	3.1	9.3	9	3.3	0	1
9	31.1	10.4	9.1	0	86	24	2.8	9.2	7.3	3.5	0	1
10	30.8	11.6	8.3	0	76	18	4.9	8.9	6	4.8	0	3
11	31.8	13.2	7.8	0	69	23	4.4	9.3	8	4	0	0
Correlation coefficients	0.16	0.01	0.21	-0.21	-0.11	-0.28	0.44	-0.14	-0.32	0.35	0.02	

Safflower

SOLAPUR

Incidence of alternaria leaf spot in safflower over a period of five years (2006-07 to 2010-11) was studied in relation to weather conditions prevailed to develop forewarning models that may help in resorting to prophylactic measures. The disease incidence and development was found to be a function of crop stage and weather variables like minimum temperature, morning relative humidity and rainfall. The analysis revealed that sub-normal temperature coupled with above normal humidity and rainfall contributed significantly for the disease incidence and its spread under different sowing situations. Safflower was found to be susceptible to *Alternaria carthami* at all growing stages, but susceptibility increased as the plants matured. Further, the per cent disease intensity (PDI) has progressed at linear rate throughout the plant growth and it was negatively correlated with maximum temperature under late sown conditions, while it was positively correlated with rainfall, minimum temperature, relative humidity (morning and evening) and age of the crop (Table 6.14).

Table 6.14 : Correlation and regression coefficients between a*lternaria* leaf spot in safflower and different variables at Solapur

Parameter	Correlation coefficients			Regression coefficients					
				Linear			Non-linear		
	Early	Normal	Late	Early	Normal	Late	Early	Normal	Late
Constant (Y)				-4.94	404.08	-72.36	-514.62	1569.77	279.20
T_{max}	0.72**	0.38	-0.12	-	-10.71	-	-	-78.45	-
T_{min}	0.73**	0.56*	0.64*	8.06	-	-1.46	-12.47	-	3.73
RH-I	0.40	0.22	0.45	-1.34	-0.57	1.32	14.73	-10.66	-9.33
RH-II	0.36	0.28	0.70**	-1.32	-	-	0.35	-	-
Rainfall	0.29	0.29	0.59*	0.17	-0.27	-0.28	0.02	-0.18	-0.28
Crop age	0.94**	0.96**	0.89**	1.39	0.37	0.50	2.94	2.46	2.02
R^2				0.98	0.95	0.92	0.99	0.99	0.99

(Table value of r at 5 % (*) = 0.53 at 1 % (**) = 0.66)

The data were then subjected to step down regression by including only significant factors under all sowing conditions for predicting the incidence of alternaria leaf spot using linear and non-linear models (Table 6.15). Coefficient of determination (R^2) was improved significantly when non-linear regression models were fitted.

Table 6.15 : Linear and Non-linear relations to predict a*lternaria* leaf spot in safflower under three sowing situations at Solapur

Sowing condition	Multiple regression	Equation	R^2 value
Early	Linear	PDI=-4.941+8.058*T_{min}-1.342*RH-I-1.323*RH-II+0.173*RF+1.387*Crop age	0.98
	Non-linear	PDI=-514.620-12.467*T_{min}+ 14.731*RH-I+0.345*RH II+0.019*RF+ 2.943*Crop age +0.394*T_{min} ^2-0.096*RH-I ^2-0.009*RH-II^2+0.003* RF^2-0.016 *Crop age^2	0.99
Normal	Linear	PDI= 404.077-10.707*T_{max}-0.570*RH-I-0.268*RF+0.371*Crop age	0.95
	Non-linear	PDI= 1569.773-78.451*T_{max} -10.661 *RH-I-0.177*RF+2.462 *Crop age+1.226*T_{max} ^2 +0.076*RH-I^2+0.002 *RF^2-0.012*Crop age^2	0.99
Late	Linear	PDI= -72.362-1.463*T_{min}+1.321 *RH-I-0.277*RF+0.499*Crop age	0.92
	Non-linear	PDI= 279.200+3.734*T_{min}-9.331 *RH-I-0.280*RF+2.018 *Crop age-0.100*T_{min}^2+ 0 .062*RH-I^2+0.013 *RF^2-0.012*Crop age^2	0.99

7. SUMMARY

Agroclimatic characterization

- Variability of monsoonal rainfall in Vidarbha region of Maharashtra was found to be more than 25% with a mean rainfall of 993.3 mm over the period of 1998-2011. It was also observed that rainfall events under 25-50 mm and 50-75 mm category significantly increased while decreasing trend was noticed in case of >100mm rainfall events.
- Association between air temperature and soil temperature at 5 cm depth was found to be close in the morning hours rather than afternoon hours. Models were developed to predict soil temperature at 5 cm from air temperature.
- Large spatial variability in normal monsoonal rainfall was observed in Gujarat with highest rainfall over Umargam and Valsad and lowest over Kutch districts.
- Meteorological drought frequency analysis under different categories of severity in North Karnataka revealed that frequency of severe drought years increased in Bijapur and Dharwad districts.
- Duration of the rainy season was reduced by 4 and 1 days in Vindhyan and North Eastern plain Zone of UP, respectively because of late onset and early withdrawal of monsoon over the period of 1994-2011 in comparison to 1976-94.
- Analysis of pentad-wise annual rainfall at five locations of Tamil Nadu revealed that highest variability was found at Madhurai followed by Killikulam and least at Ambasamuthiram.
- Long term (40 years) annual rainfall at Mohanpur showed a non-significant increasing trend (4.09 mm/year) with a mean rainfall of 1448 mm and CV of 24.7%.
- At Mohanpur, about 5% variability was found in the dates of onset of monsoon. It was also noticed that October rainfall is highly variable and it was above the long term average in the recent years.
- Rainfall during monsoon season was found to be highly variable at different locations of Marathwada region of Maharashtra. It was highly variable at Tuljapur, Parbhani, and Aurangabad during June and July whereas during August at Nanded, Tuljapur, Parbhani Latur and Aurangabad.
- Analysis of 142 years data on the onset of monsoon over Kerala revealed that if the monsoon is early (before 28th May), the total monsoon rainfall is likely to be below normal or normal.

- The data of onset of monsoon and rainfall pattern at Thrissur showed that the rainfall during both pre-monsoon and early part of monsoon season was higher during the years when monsoon was set prior to 1st June.
- In Western Rajasthan, Nagaur district received highest dependable annual rainfall and Hanumangarh received lowest. The lowest CV in the annual rainfall was noticed in Bikaner district (42.6%), whereas it was highest in Hanumangarh district (85.8%).
- Meteorological drought frequency analysis carried out for Kanpur and Lucknow revealed that none of the districts experienced severe drought during 1979 -2009 period.
- Decadal analysis of extreme rainfall events during monsoon season at Kanpur showed that there was no significant change in rainfall events exceeding 100 mm while it was on declining trend in the range of 75-100 mm.
- Newly formed districts in Jammu region *viz.*, Kisthwar, Ramban and Reasi falls under Cfa, Csa and Cfa sub class of warm temperature rainy climates with mild winters, respectively according to Koppen climatic classification.

Crop-weather relationships

Rabi 2010-11

Wheat

- The mean temperature in the range of 17.9°C to 19.6°C during reproductive stage was found to be optimum for achieving maximum wheat yields at Udaipur.
- Wheat *cv.* Raj-4037 and 20th November sowing date were found to be suitable based on GDD and HUE at Udaipur.
- At Kanpur, *cv.* K-9017 was found to be efficient in harnessing HTU compared to other two varieties studied.
- Optimum temperature for producing wheat yield =3.5 t/ha at Palampur were identified to be in the range of 17.8 to 19.9°C for maximum temperature and 5.2 to 8°C for minimum temperature during vegetative stage. Similarly, during reproductive stage ranges for maximum temperature and minimum temperature were 20.6 to 27.1°C and 8.2 to 13.3°C, respectively.
- At Raipur, Kanchan and GW-273 cultivars of wheat and 25th November and 5th December sowing dates were found to be better in terms of resource use efficiency (HUE and RUE).

- At Ranchi, wheat *cv.* HUW 468 harnessed higher RUE and HUE across the sowing dates compared to other cultivars studied.
- The thresholds for maximum and minimum temperature during anthesis were found to be 27.5°C and 11.5°C respectively, to attain a wheat yield of 4 t/ha at Ranchi. The anthesis to milking stage was found to be highly sensitive to maximum and minimum temperatures.
- At Ranichauri, GDD was having an exponential relation with total dry matter (R^2=0.64) and quadratic relation with plant height (R^2=0.95).
- The wheat *cv.* RSP-561 was more efficient in terms of GDD, HTU, and PTU compared to other cultivars studied at Ranichauri.

Mustard

- At Hisar, higher RH during reproductive phase was found favorable for producing more seed yield while it was having detrimental effect during vegetative stage.
- The relationship between yield and seasonal ET at Mohanpur showed negative association with a R^2 value of 0.37.
- The vapour pressure deficit at Rakh Dhiansar explained 76% variation in transpiration rates of mustard crop.

Potato

- Crop sown on 3rd December and *cv.* chipson was found to be efficient in water use among the dates and varieties studied at Mohanpur.
- The relationship between tuber yields and seasonal ET at Mohanpur showed that tuber yields increased linearly up to a seasonal ET of 290 mm and decreased thereafter.
- Soil temperature of 20-22°c was found to be optimum for maximum tuber production at Mohanpur.
- At Jorhat, hours of sunshine at tuber formation stage and thermal time and helio thermal units during stolon formation were found to influence relatively more than at other stages.

Rabi sorghum

- At Parbhani, crop was found to be highly sensitive to weather during flowering and dough stages while less sensitive during booting and milk stages for grain yield.
- At Solapur, consumptive use of 800 mm was found to be optimum for getting higher grain yield. The polynomial relationship between GDD and grain yield showed an increase in grain yield up to 1800 GDD there after it decreased.

Sunflower

- Pooled analysis of seed yield and weather variables during different phenological stages at Bijapur revealed that warmer nights during flower bud initiation and flowering stages and atmospheric vapour content in the afternoon during seeding and vegetative stages are important to achieve higher yield.

Maize

- Performance of maize *cv.* 900 M gold at Kovilpatti in terms of AGDD and HUE showed that knee high stage accumulated more thermal units while highest HUE was noticed during cob initiation stage.

Black gram

- Among the cultivars, Co 5 was found to be more efficient in heat use at Kovilpatti.

Chickpea

- Irrigated crop responded favorably to two irrigations at 35 and 55 DAS and recorded higher HUE compared to rainfed crop at Anantapur.
- Performance of chickpea cultivar in terms of consumptive use of moisture and RUE showed that beyond 270 mm of CUM and RUE of 2.45 g/MJ the yields are declining at Solapur.
- The mean temperature beyond 18°C during flowering to physiological maturity stage was found to be detrimental at Jabalpur.
- The duration of 50% flowering to maturity should be the selection criteria in breeding program at Jabalpur as increased duration resulted in higher HTU and PTU values.
- At Faizabad, highest dry matter production can be achieved provided 8.3 to 8.6 sunshine hours/ day (R^2 =0.56) and 83 to 85% RH prevails (R^2 = 0.75) during the crop growth.

- At Faizabad, there was a decrease in yield @ 350kg/ha with an increase of 1°C over the temperature range of 27.2°C to 33.2°C

Vegetables

- At Dapoli, the yields of spinach, radish and amaranthus decreased gradually with the reduction in sunlight intensity (under shade). Amaranthus yields were comparatively less influenced under 25% shade.
- An inverse relation was observed at Thrissur between GDD and fresh weight of the total cauliflower plant.

Kharif 2011

Soybean

- At Akola, seed yields of soybean were positivity correlated with temperature during vegetative stage, rainfall during all stages except flowering and maturity stages and minimum temperature during seed formation stage. On the contrary, it was negatively correlated with maximum temperature during seed formation.
- The temperature during pod and seed formation stages and rainfall during pod and seed development and seed formation stages influenced the crop growth positively at Parbhani.

Groundnut

- Among the varieties, early sown GG-20 variety was found to be the highest pod yielding variety for Anand conditions.
- At Anantapur, early sown crop accumulated more HTU but it did not reflect in yield and in lower HUE.

Cotton

- Correlation analysis between seed cotton yield and weather parameters at Akola showed that rainfall during first square to first flower period and temperature during flowering and boll formation stages play a critical role in cotton.
- Different adaptation strategies *viz.*, conservation practice, conservation furrows, dead and live mulches did not improve the crop WUE at Akola.

- Correlation coefficients between seed yield and weather variables at Parbhani revealed that temperature seems to regulate the cotton growth in the initial stage whereas rainfall and rainy days during boll setting to boll bursting significantly influenced the seed cotton yield.
- The optimum range of maximum and minimum temperatures for development of leaf curl disease in cotton at Hisar was found to be 33.0 to 37.0°C and 23 to 28°C, respectively.
- Aphids damage on cotton at Kovilpatti commenced with the receipt of rainfall (during 44^{th} SMW) and increased with prevalence of low minimum temperature and high RH.

Rice

- The delay in sowing of rice crop at Dapoli did not affect the degree day requirement but HTU requirement increased during all stages.
- The interception of PAR explained about 61%, 92% and 74% variation in biomass of varieties Satabdi, Baismukhi and a pre-released culture, respectively at Mohanpur.
- Correlation coefficients between grain yield and weather parameters at Kanpur during different phenophases indicated that rainfall during all growth stages and bright sunshine hours during grain filling and maturity stages have a positive impact.
- Among the varieties studied at Raipur, MTU-1010 required more heat units and among the sowing dates, early sown crop accumulated more thermal time.
- The crop planted on 30^{th} June and variety Vandana were found to be more efficient in utilizing natural resources at Ranchi.
- Minimum temperature during grain filling stage and rainfall during grain filling and flowering stages were identified as critical weather parameters in rice crop at Ranchi.
- Shubhangi variety was found to be most drought tolerant among varieties evaluated based on drought susceptible Index (DSI) at Jabalpur.
- Delay in sowing beyond 14^{th} June resulted in increased percentage of chaffy grains per panicle in rice crop at Samastipur.

Maize

- The crop sown late (42nd SMW) at Kovilpatti accumulated lower thermal units in all growth stages except silking but it did not reflect in the ultimate yield. The thermal time beyond silking stage had a positive association with seed yield in crop sown during 39th and 40th SMW.
- Pooled analysis of three year experimentation at Udaipur revealed that closer row spacing (45 cm) and early sowing (16th June) in maize is advantageous to maintain a congenial microclimate in maize crop.

Pigeonpea

- Early crop sown (25th June) recorded highest RUE and it increased almost linearly till pod initiation stage. Among the varieties, N. Arhar-2 recorded highest RUE at all the stages.

Kharif sorghum

- Crop responded positively to rainfall during boot leaf, flowering and milking stages but negatively to diurnal temperature range at all stages for grain yield at Parbhani.

Pearl millet

- At Solapur, moisture use efficiency declined from 5.13 to 3.47 kg /ha.mm with the delay in sowing. Among the varieties tested, ICTP-8203 was found to be efficient in utilizing moisture.
- The seasonal maximum and minimum temperatures around 32.1°C and 19.8°C, respectively were found to be optimum for pearlmillet productivity at Solapur.

Tea

- The cardinal temperature for tea leaves productivity at Palampur were identified and maximum and minimum temperatures must not be lower than 16.8 and 6.1°C, respectively.

Livestock production and weather

- The animals of Palampur faced no heat stress during most part of year as reflected by mean THI value which were less than 72 over the period studied (2000-2011).

Rabi 2011-2012

Sunflower

- The weather variables such as afternoon RH during seedling and vegetative stages, minimum temperature during bud initiation stage and afternoon vapour pressure during flowering stage were found to be critical for sunflower yield at Bijapur.

Mango

- At Dapoli, analysis of 14 year data on the effect of preceding weather on subsequent flowering in mango brought out that maximum temperature, minimum temperature, RH-I, evaporation prevailed during the preceding 21 days accounted for 53% variability in flowering while 28 days preceding weather (maximum temperature, BSS and evaporation) accounted for 57% variability.

Mustard

- Energy balance over mustard at Hisar showed that 25-85% of net radiant energy was utilized as LE at different phenophases. Among the varieties, RH-30 utilized more net radiant energy as LE compared to Kranti and RH 45.
- At Mohanpur, intercepted PAR was found to be almost similar across the varieties. However, Jota variety absorbed more PAR compared to other varieties because of its horizontal spread of canopy.
- Temporal variation in HUE of mustard at Rakh Dhiansar showed that it progressed at slower rate in the early growth stages and attained peak at around 110 DAS and thereafter declined gradually, irrespective of sowing dates as well as varieties.

Chick pea

- Minimum temperature during branching, maximum temperature and wind speed during seed filling to pod maturity and humidity at 50% flowering to pod formation were found to be critical and accounted for 72% variation in seed yield of chick pea at Solapur.
- At Jabalpur, the analysis suggested that crop should be planted early to avoid higher temperature during flowering to maturity stage.

Wheat

- Correlation analysis of yield in relation to weather parameters brought out that rainfall at tillering and maturity stages as well as temperature at tillering stage negatively influenced the grain yield at Kanpur.
- Pooled analysis of 12 years yield data of Ludhiana district showed that in the year 2008-09 yields were declined more as compared to 2003-04 due to terminal heat stress experienced as a result of heat wave conditions.
- Khanchan and GW 273 varieties and sowing dates (5thand 15th December sown crop) recorded highest RUE and HUE among the varieties and thermal regimes studied at Raipur.
- Seasonal evapotranspiration of winter wheat increased but water use efficiency decreased with the delay in sowing at Rakh Dhiansar.
- Performance of wheat cultivar K-9107 and 5th December sowing date were found to be superior in terms of HUE and RUE than other cultivars and dates of sowing at Ranchi.
- Anthesis to milking stage was found to be most sensitive to both maximum and minimum temperatures at Ranchi.
- Quantification of thermal environment in terms of GDD and HUE at Samastipur showed that crop sown late experienced warmer weather condition (15th Dec) during most of the phenophases and ultimately resulted into lower yield.
- At Udaipur, increased mean temperature was found to decrease the duration of vegetative and reproductive phases.

Maize

- Varietal differences in their thermal time accumulation were not noticed and 20th November sown crop was found to efficient in HUE at Samastipur.

Rabi sorghum

- At Solapur, sorghum was found to yield better in a warmer environment and its seasonal heat unit requirement is above 2000 degree days.

Potato

- Among the varieties tested at Mohanpur, Jyoti proved to be most efficient in utilizing the water resource.

Crop-weather Modeling

Rabi 2010-11

Dynamic models

Wheat

- Calibration of parameters for CERES-wheat model were found satisfactory and within reasonable limits except LAI for Anand conditions.
- InfoCrop simulated wheat yields were reduced by about 640 kg/ha and crop maturity was advanced by 5 days with 1.0 °c rise in temperature at Mohanpur.

Mustard

- Mustard yields were declined by 450 kg/ha and maturity advanced by 5 days with a 1.0°C rise in temperature as simulated by InfoCrop model at Mohanpur.
- Campbell and Diaz model simulated dry matter production of mustard crop were found in good agreement with observed one (R^2 ranging from 0.94 to 0.98) at Rakh Dhiansar.

Empirical/Statistical models

Wheat

- Earliest sown crop (5th Nov) required maximum GDD to mature and thermal time requirement from CRI to maturity decreased with a delay in sowing at Udaipur.
- At Raipur, variety K-9107 accumulated higher percentage of stem and dry matter at maturity compared to HD-2233 and K-0307 but yielded less, probably due to poor weight of spike.

Rabi Sorghum

- Among the varieties and sowing dates studied at Solapur, early sown crop and variety M 35-1 required more thermal time than others.

Kharif 2011

Statistical/ empirical models

Groundnut

- Regression models based on thermal time developed from previous experimental data were found to predict flowering and pod initiation with reasonable accuracy (± 2 days) but not for maturity (error ranging from -5 to-16 days) across the sowing dates at Anantapur.

Kharif Sorghum

- Yield prediction model based on weather variables accounted for only 33% variation at Parbhani. Thus, further improvement in the model is necessary for yield prediction.

Rabi 2011-2012

Dynamic modeling

Rice

- At Faizabad, genetic coefficients of three rice cultivar (Sarjoo-52, NDR-359, Pant Dhan-4) were estimated for CERES-rice model.
- DSSAT-rice model simulated the grain yields with reasonable accuracy (-1% to 1.3%) in 2nd and 3rd date of planting while largely overestimated (30%) in 1st date of planting at Mohanpur. There were good agreement in model output and observed values for leaf dry weight and stem dry weight.
- AquaCrop model did not respond to differential irrigation regimes imposed and thus may not be suitable to predict yields of rice for irrigation schedules at Ludhiana.
- The percentage error in prediction of days to anthesis, physiological maturity, LAI and grain yield using InfoCrop model were in the range of -13 to +14 days, -13 to +20 days, -10 to+38% and -16 to +10%, respectively at Ludhiana.
- CERES- rice model simulations with reductions in rainfall (10%, 20%, 30%) for Raipur location revealed that yields would decrease by 0.61 t/ha in case of IR-36 and by 0.57 t/ha in IR-64 across all the rainfall scenarios tested.
- DSSAT-rice model predicted the days taken to anthesis and maturity very accurately but over-estimated the grain yield by 12.5% at Samastipur.

Maize

- Validation of InfoCrop model at Ludhiana resulted in over-estimation for days to milking and under-estimation for days to physiological maturity.
- Estimation of district yields of Jammu using CERES-maize model showed over-estimation of yield in majority of the years but simulated trend line closely followed the observed one.

Soybean

- DSSAT-soybean model could predict the seed yields with a reasonable accuracy for JS-335 and TAMS 98-21 but over-estimated the yield by 19.4% for NRC-37 variety at Akola.

Rabi 2011-12

Dynamic models

Wheat

- CERES-wheat model could predict all parameters of growth and development with reasonable accuracy and it can be used for further studies for Anand condition.
- Validation of CERES-wheat model at Faizabad showed prediction of grain yields with less than 10% mean error in different dates of sowing.

Statistical model

- Yield prediction models based on critical weather parameters identified through correlation analysis could account for 98% and 96% variation in days taken to maturity and grain yield, respectively at Kanpur.

Weather effects on pest and diseases

Rabi 2010-11

Mustard

- Weather conditions *viz;* wind speed (>2 kmph), BSS (>7 hrs), maximum temperature (>28.0°C) and morning RH (85-90%) are identified as most conducive for the spread of aphids at Anand.
- Higher RH (>80%) coupled with higher maximum temperature (>25°C) were found to favor infestation of saw fly and white rust at Anand.

Potato

- Quantification of late blight disease infestation in terms of percent disease intensity (PDI) and it's relation to weather at Mohanpur showed significant correlation with air and soil temperatures.

Grape

- Forewarning models on flea beetle in grapes at Bijapur were developed through regression which can be used with 55 ± 5% accuracy using minimum temperature with different lead periods.

Kharif 2011

Groundnut

- The validation of polynomial relation developed for leaf miner damage in groundnut at Anantapur for the year 2011 showed that further experimentation is needed to develop a model with low errors.
- Forewarning models on tikka disease development in groundnut at Bangalore performed well for all the three cultivars in predicting the development of the disease.

Pigeon pea

- At Bangalore, the cultivar TTB-7 was found to be more susceptible to pod borer and fusarium wilt. There was no influence of spacing on the pest population but as the sowing was delayed, pest population declined gradually.
- The accumulated thermal time (AGDD) requirement for the appearance of pod borer on pigeon pea at Faizabad was found to be 448°C day and larval population reached its peak value at a GDD value of 854°day.

Cotton

- Higher minimum temperatures were found to favor sucking pests like white fly, Jassid and thrips in cotton CV. RCH-134 in 25th April and 4th May dates of sowing while RCH-314 in 25th April date of sowing at Ludhiana.
- The optimum range of maximum and minimum temperature for development of leaf curl disease in cotton at Hisar was found to be 33.0 to 37.0°C and 23 to 28°C, respectively.

- Aphid pest damage on cotton at Kovilpatti commenced with the receipt of rainfall (during 44th SMW) and increased with prevalence of low minimum temperature and high RH.

Rice

- Relations derived between weather parameters and aphid population in rice at Mohanpur could not result in statistically significant association, may be due to single season experimentation.

Rabi 2011-12

Mustard

- Thermal time requirement for the appearance of aphid on mustard at Anand decreased progressively as sowings were delayed.
- Correlation between aphid index and weather parameters at Anand brought out that vapour pressure influences positively and maximum temperature had a negative influence on aphid infestation in mustard.
- Rainfall around 30 mm and minimum temperature of 13°C during February at Palampur was found to be congenial for aphid incidence and its subsequent build up on mustard.
- Role of 10 preceding days weather conditions from the date of peak attainment of aphid in mustard at Rakh Dhiansar indicated that temperature regulates the aphid population but further studies are required to establish a valid hypothesis.
- Monitoring of aphid population on mustard at Udaipur indicated that late sown crop (11th November) escaped the peak infestation period and it matched with the flowering stage of the crop sown on 12th October.

Chickpea

- Single year experimentation on population dynamics of *Helicoverpa armigera* in chick pea at Jabalpur could not result any significant relation between weather parameters and pest population.

Safflower

- Forewarning models were developed for alternaria leaf spot in safflower at Solapur under three sowing environments using linear and non-linear models. Coefficient of determination was improved significantly when non-linear regression models were fitted.

8. RESEARCH PUBLICATIONS

AICRPAM Coordinating Unit

Peer Reviewed Research Publications:

Bapuji Rao, B. and Bhavani. B. 2010. Climate change - Likely effects on the population dynamics of brinjal shoot and fruit borer *(Luecinodes orbonalis Guen.)*. *Indian Journal of Dryland Agriculture Research and Development.* 25 (2): 58-62

Bapuji Rao, B., Linitha Nair, Rao, V. U. M., Khushu, M. K. and Hussain, R. 2012. Assessing the impacts of increased temperature on mustard *(Brassica juncea* L.) yields uising real time data from diverse environments. *Cruciferae Newsletter.* 31: 31-33.

Bapuji Rao, B., Pramod, V.P. and Rao, V. U. M., 2011. Reliability of downscaling rainfall data in the estimation of rainfall trends: A case study. *Journal of Agrometeorology,* 14 (Special issue) :162-168.

Bapuji Rao, B., Sandeep, V.M., Rao, V. U. M. and Rao, A.V.M.S. 2011. Climatic change and crop water requirements: An assessment for future climates. *Journal of Agrometeorology,* 14 (Special issue) :125-129.

Khushu, M.K., Tiku, A.K., Bapuji Rao, B., Rao, V.U.M., Mahender Singh. and Charu Sharma. 2012. Transpiration responses to vapor pressure deficit in mustard (*Brassica juncea* L.). *Cruciferae Newsletter.* 31: 34-36

Rao, V. U. M., Linitha Nair, Bapuji Rao, B., and Vijaya Kumar, P. 2011. Climatic sensitivity of mustard crop in northern India: An assessment of yields in future climates from real time data. *Journal of Agrometeorology,* 14 (Special issue) :10-18.

Rao, V.U.M., Bapuji Rao, B., Linitha Nair, Diwan Singh, Chandersekhar. and Venkateswarlu, B. 2011. Thermal sensitivity of mustard (*Brassica juncea* L.) crop in Haryana. *Journal of Agrometeorology* 13 (2): 131-134.

Rao, V.U.M., Bapuji Rao, B., Linitha Nair, Patel, H. R., Rao, A.V.M.S. and Vijaya Kumar, P., 2011. Climatic variability and Productivity of Rainfed Groundnut in Middle Gujarat Agroclimatic Zone. *Indian Journal of Dryland Agriculture and Development.* 26 (2) : 44-49

Rao, V.U.M., Bapuji Rao, B., Rao, A.V.M.S., Manikandan, N. and Venkateswarlu, B. 2011. Assessment of rainfall trends at micro and macro level in Andhra Pradesh. *Journal of Agrometeorology*. 13 (2): 80-85

Saikia, U. S., Venkatswarlu, B., Rao, G. G. S. N., Korwar, G. R., Rao, V. U. M., N. N. Srivastava, Mandal, U. K., Goswami, B. and Manoranjan Kumar. 2011. Estimating wheat productivity for north western plain zone of India in relation to spatial-thermal variation. *Journal of Agrometeorology.* 13 (1): 9-16

Srivastava, N.N., Rao, V.U.M., Saikia, U.S., Vijaya Kumar, P. and Subba Rao, A.V.M., 2011. Modelling diurnal pattern of relative humidity from daily air temperature and relative humidity data of Hyderabad. *Journal of Agrometeorology*. 13(1): 25-30

Technical Bulletins:

Bapuji Rao, B., Ramana Rao, B.V., Subba Rao, A.V.M., Manikandan, N., Narasimha Rao, S.B.S., Rao, V.U.M. and Venkateswarlu, B. 2011. Assessment of the impact of increasing temperature and rainfall variability on crop productivity in drylands - An illustrative approach. Research Bulletin 1/2011, Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad, Andhra Pradesh, India. 32p.

Rao, V.U.M., Bapuji Rao, B., Khandgonda, I.R., Rao, A.V.M.S., Vijaya Kumar, P., Dagar, J.C. and Venkateswarlu, B. 2011. Perception of Indian Farmers on Climate Change - An Assessment and Awareness Programme. Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad, Andhra Pradesh, India. 33p.

Rao, V.U.M., Subba Rao, A.V.M., Bapuji Rao, B., Ramana Rao, B.V., Sravani, C. and Venkateswarlu, B. 2011. El Niño Effect on Climatic Variability and Crop Production : A Case Study for Andhra Pradesh, Research Bulletin No. 2/2011. Central Research Institute for Dryland Agriculture, Santoshnagar, Hyderabad, Andhra Pradesh, India. 36 p.

Book chapters:

Rao, G. G. S. N., Rao, A.V. M. S. and Rao V. U. M. 2011. Climate change – Impacts and mitigation strategies. In: *Climate Change Adaptation Strategies in Agriculture and Allied Sectors.* (ed. Prasada Rao, GSLHV.,). Scientific Publishers (India), Jodhpur. pp 1-14.

Rao, G. G. S. N., Rao, A.V. M. S., Vanaja, M., Rao, V. U.M. and Ramakrishna, Y. S. 2010. Impact of regional climate change over India. In: *Climate Change and Agriculture over India.* Prentice- Hall India Pvt. Limited, New Delhi pp13-42.

Rao, V.U.M., Rao, A.V.M.S., Rao, G.G.S.N., Satyanarayana, T., Manikandan, N. and Venkateswarlu, B. 2011. Impact of climate change on crop water requirements and adaptation strategies. In : *Challenges and opportunities in Agrometeorology* (Eds. Attri, S.D., Rathore, L.S., Sivakumar, M.V.K. and Dash, S.K.,). Springer-Verlag Publications, pp. 311-319

Papers presented in Symposium / Conference / Seminar / Workshop:

Bapuji Rao, B., Manikandan, N., Rao, V. U. M. and Rao, A.V.M.S. 2011. Trends in annual and seasonal evaporation at different locations of India. Proceedings of the National seminar on Agrometeorological research and services to combat climate change challenges, 9-10 December 2011. BCKV, Kalyani.

Bapuji Rao, B., Rao, V.U.M., Sandeep, V.M., Rao, K. V. and Venkateswarlu, B. 2011. Rainfall variability in Andhra Pradesh and agricultural productivity of downstream Krishna river basin: problems and prospects in 2030's. Paper presented at Tropmet 2011, Dec 14-16, 2011, NRSC, Hyderabad.

Linitha Nair, Bapuji Rao, B., Rao, V.U.M., Patel, H.R. and Diwan Singh. 2011. Sowing strategies for yield optimization in mustard (*Brassica juncea L.,*) in varied climates in relation to weather variables. Paper presented at Tropmet 2011, Dec 14-16, 2011, NRSC, Hyderabad.

Triveni, U., Bapuji Rao, B., Harisatyanarayana, N., Latha, P., Venugopala Rao, N. and Rao, V.U.M. 2011. Mesta (*Hibiscus sabdariffa*) fibre yields as influenced by weather parameters in north-coastal districts of Andhra Pradesh. Paper presented at Tropmet 2011, Dec 14-16, 2011, NRSC, Hyderabad.

AICRPAM Centres

Akola

Peer reviewed research papers:

Bhagyasree Adepawar, Anil Karunakar, Parlawar, N. D. and Chavan, K.R. 2011. Effect of weed management practices on productivity of black gram. *Research on crops.* 12(1).

Bhoyar, *S. R.,* Ingole, P. G., Paslawar, A. N., Bhale, V. M. and Karunakar, A.P. 2010. Bio-energetic of castor based intercropping system. *J. Oilseed Research.*

Papers presented in Symposium / Conference / Seminar / Workshop:

Anil Karunakar, Nagdeve, MB., Wanjari, SS., Parlawar, ND., Ganvir, MM., Deshmukh, TS. and Tupe, AR. 2011. Rainfall variability at selected locations in Vidarbha Subdivision. Abstract PP 165. National Seminar – Agrometeorological Research and Services to Combat Climate Challenges. December 9-10, 2011 BCKV, Mohanpur, West Bengal.

Anil Karunakar, Shirsat, AS., Nagdeve, MB. and Ganvir, MM. 2011. Adaptation strategies to rainfall variability Abstract PP 24. National Seminar – Agrometeorological Research and Services to Combat Climate Challenges. December 9-10, 2011 BCKV, Mohanpur, West Bengal.

Anil Karunakar, Shitole, M.M., Nagdeve, M.B., Ganvir, M.M., Sakhare, S.B. and Gabhane, V.V., 2012. Studies on productivity and agro-meteorological indices in castor genotypes under varied growing environment. Proceedings of the seminar on Breaking yield barriers in major field crops. 6-7 January 2012. PDKV, Akola. pp.300.

Ganvir, M.M., Nagdeve, M. B., Patode, R. S. and Anil Karunakar., 2010. Tillage and nutrient management effects on rainwater, energy use and yield of cotton-sorghum rotation, extended summaries. National seminar on Engineering Agriculture for Evergreen Revolution held at Tirupati, organized by ISAE, Acharya NGRAU and CRIDA, Hyderabad , 24-25 September, 2010.

Ganvir, M.M., Nagdeve, M.B., Anil Karunakar, Gabhane, V.V., Patode, R.S. and Sakhare, S.B. 2012. Response of cotton productivity to land configuration and nutrient module under rainfed condition. Proceedings of the seminar on Breaking yield barriers in major field crops. 6-7 January 2012. PDKV, Akola. pp.123.

Patode, R. S., Nagdeve, M. B., Ganvir, M.M. and Anil Karunakar. 2010. Effect of tillage and nutrient management on yield , rainwater and energy use of cotton-sorghum rotation , 45th ISAE Convention and International Symposium on water for agriculture organized by ISAE, New Delhi and Dr.PDKV, Akola at Nagpur, January 17-19, 2011.

Supe, M.S., Nagdeve, M.B., Tiwane, A.P., Karunakar, A.P. 2012. Energy conservation in cotton under rainfed condition. Proceedings of the 46th Annual ISAE Convention and International Symposium. 27-29 February 2012. Agricultural Technology University at Pantnagar.. pp.298

Anand

Peer reviewed research papers:

Lunagaria, M.M., Patel, H.R., Shah, A.V., Yadav, S.B., Karande B.I. and Vyas Pandey. 2011. Validation of PRECIS baseline (1961-90) simulation for middle Gujarat Agro-climatic zone. *J. of Agrometeorology.* 13(2):92-96

Sevak Das, Vyas Pandey, Patel H.R. and Patel, K.I, 2011. Effects of weather parameters on pest-disease of okra during summer season in middle Gujarat. *J. of Agrometeorology*. 13 (1): 38-42

Shamin, M., Shekh, A.M., Vyas Pandey, Patel, H.R. and Lunagaria, M.M. 2010. Sensitivity of CERES-Rice model to different differential environmental parameters on the productivity of aromatic rice in middle Gujarat 2010 *J. of Agrometeorology*. 12 (2):213-216.

Book Chapters:

Pandey, V. and Patel, H.R. 2011. Climate change and its impact on wheat and maize yield in Gujarat. In *Challenges and opportunities in Agrometeorology* (Eds. S.D. Attri *et al.,*). Springer-Verlag Berlin, Heidelberg. pp.321-334

Patel, G.G., Patel, H.R., Shekh, A.M., Ujinwal, M.K., Patel, J.S., Pandey, V., Vadodaria, R.P. and Bhatt, B.K. 2010. Role of weather parameters on seed yield of mustard in middle Gujarat Agro-climatic region. In : *Agrometeorology services for farmers* (Ed. Vyas Pandey),AAU, Anand, pp.79-83.

Patel, H.R., Shekh, A.M., Patel. G.G., Guled, P.M., Shroff,J.C., Pandey ,V., Vadodaria, R. P., and Bhatt, B.K. 2010. Role of weather parameters on seed yield of wheat in middle Gujarat Agro-climatic region. In : *Agrometeorology services for farmers* (Ed.Vyas Pandey), AAU, pp.38-45.

Shroff, J.C., Patel, H.R., Pandey, V., Patel, G.G., Kathiria K.B., Patel J.J., Vadodaria, R.P. and Bhatt, B.K. 2010. Development of weather based models for predicting outbreak of pest of okra in middle Gujarat region. In : *Agrometeorology services for farmers* (Vyas Pandey, Ed.), AAU, Anand. pp.282-288.

Varshneya, M.C., Kale, Nanaji, Vaidya, V. B. and Pandey ,V. 2010. Forecasting and Validation of Rainfall for Barshi (M.S.) based on Astro-meteorological Principle of Rainfall Conception. In : *Agrometeorology services for farmers* (Ed. Vyas Pandey), AAU, Anand. pp.163-171.

Papers presented in Symposium / Conference / Seminar / Workshop:

Choudhary, D., Patel, H. R., Yadav, S. B., Lunagaria, M. M. and Pandey, V. 2011. Calibration and validation of rabi maize using Info Crop for middle Gujarat region. Proceedings of the National seminar on Agrometeorological research and services to combat climate change challenges, 9-10 December 2011. BCKV, Kalyani.

K. I. Patel, S. K. Mishra, B.I. Karande, and Vyas Pandey. 2011. District wise yield prediction models for mustard in north Gujarat region. Proceedings of the National seminar on Agrometeorological research and services to combat climate change challenges, 9-10 December 2011. BCKV, Kalyani.

Lunagaria, M M., Vyas Pandey. and Patel, H R. 2011. Climatic trend analysis at selected stations of Gujarat (India): parametric and non parametric approach. Proceedings of the National seminar on Agrometeorological research and services to combat climate change challenges, 9-10 December 2011. BCKV, Kalyani.

Patel, G. G., Patel, H. R., Mishra, S. K., Yadav S. B. and Pandey, V. 2011. Calibration and validation of DSSAT (CERES-wheat) model for different cultivars of wheat at Anand. Proceedings of the National seminar on Agrometeorological research and services to combat climate change challenges, 9-10 December 2011. BCKV, Kalyani.

Patel, H. R., Lunagaria, M. M., Karande, B. I., Yadav, S. B., Shah, A.V. and Pandey, V. 2011. Impact assessment of climate change on maize yield of Godhra station in middle Gujarat region. Proceedings of the National seminar on Agrometeorological research and services to combat climate change challenges, 9-10 December 2011. BCKV, Kalyani.

Sudhir Kumar, Mishra, Shekh, A.M., Patel, H.R., Patel, G.G. and Vyas Pandey. 2011. Thermal and radiation use efficiency of wheat cultivars under varying environmental conditions in middle Gujarat region. Proceedings of the National seminar on Agrometeorological research and services to combat climate change challenges, 9-10 December 2011. BCKV, Kalyani.

Vyas Pandey. and Patel, HR. 2011. Impact of climate change on wheat productivity. Proceedings of the Training Workshop on Climate change and its impact on agriculture. 8-11 August 2011. Extension Education Institute, AAU, Anand.

Vyas Pandey. 2011. Climate change and Agriculture : Global perspective. Proceedings of the Training Workshop on Climate change and its impact on agriculture. 8-11 August 2011. Extension Education Institute, AAU, Anand.

Vyas Pandey. 2011. Impact of Climate Change on Agriculture and its Adaptation Strategies. Proceedings of the National Seminar on Food Security. Feb 26, 2011, Ahmedabad Management Association, Ahmedabad.

Vyas Pandey. 2011. Importance of Agrometeorological observations. Proceedings of the Workshop on Hydrological data management. Feb 16, 2011. Department of Civil Engineering, MSU, Vadodara.

Yadav, S. B., Patel, H. R., Patel, G. G., Lunagaria, M. M.,. Karande, B. I., Shah, A. V. and Pandey, V. 2011. Impact assessment of climate change on groundnut yield of middle Gujarat region. Proceedings of the National seminar on Agrometeorological research and services to combat climate change challenges, 9-10 December 2011. BCKV, Kalyani.

Yadav, S. B., Patel, H. R., Patel, G. G., Lunagaria, M. M., Karande, B. I., Shah, A.V. and Pandey, V.2011. Calibration and validation of PNUTGRO (DSSAT v4.5) model for two groundnut cultivars (Robut 33-1 and GG-2) in middle Gujarat region. Proceedings of the National seminar on Agrometeorological research and services to combat climate change challenges, 9-10 December 2011. BCKV, Kalyani.

Popular articles:

Patel, H.R. 2010. Abohava badalavani krishi uparni asaro. Paryvan bhachao pradushan ghatado, March 2010. (In Gujarati)

Patel, H.R. 2010. Gujaratma abohava badalav ane teni krishi parni asro. Paryvan bhachao pradushan ghatado, March 2010. (In Gujarati)

Patel, H.R. 2010. Vaisik tapamanne nathavana upayo. Paryvan bhachao pradushan ghatado, March 2010. (In Gujarati)

Patel, H.R. 2011. Greenhouse ma juda juda havamanna paribalonu vyavashtapan. *Krishijivan*. January 2011. (In Gujarati)

Anantapur

Popular articles:

Anonymous. 2011. Jaatheeya Vaathaavarana Anukula Vyavasaya Pathakam (NICRA). *Vyavasayam.* (In Telugu)

Narasimha Rao, S.B.S., Mrudula, G., Anitha, V., Venkatachalapathi, V. and Ravindranatha Reddy, B. 2011. Verusanagapai vatahvarana prabhavam. Annadatha. October 2011. (In Telugu)

Narasimha Rao, S.B.S., Venkatachalapathi, V. and Ravindranatha Reddy, B. 2010. Popular article in telugu on *rabi* verusanaga pai vatahavarana prabhavam. *Vyavasayam*. November, 2010 (In Telugu)

Bangalore

Peer reviewed research papers:

Devaraju.K, Raju.N.S.,Ramesh.H.S. and Rajegowda M.B. 2010. Prediction of annual and seasonal rainfall of Doddamaragowdanahalli watershed area in Mysore District, Karnataka. *Int. J. Agri. Sci.* 1:341-345.

Books:

Statistical Analysis of Hundred years Rainfall Data of Karnataka. Published by UAS, Bangalore. 2012.

Papers presented in Symposium / Conference / Seminar / Workshop:

Rajegowda, M.B., Pavithra. B.V., Shilpa.C.N., Padmashri, H. S., Janardhan Gowda, Soumya, D.V. 2011. Impact of Climate Change on principle crop yield of Karnataka. Proceedings of the International conference on Adaptive Management of Ecosystems : The knowledge system of societies for adaptation and mitigation of impact of Climate Change. 19-21 October 2011. ISEC, Bangalore.

Rajegowda, M.B., Padmashri, H. S., Janardhan Gowda, C.N., Shilpa, B.V., Pavithra, Soumya, DV. 2011. Impact of education, age and land holding on understanding the aspects in climate change – a case study. Proceedings of the International conference on Adaptive Management of Ecosystems : The knowledge system of societies for adaptation and mitigation of impact of Climate Change. 19-21 October 2011. ISEC, Bangalore.

Popular articles:

Rajegowda, M.B., Janardhana Gowda, N.A,Jagadeesha.N., Ravindra babu, B.T. and Girish.J. 2010. Prasaktha Mungaru. Maleya Munsoochaneya Ondu Vihangama Nota. Krushi Kayaka. 3(2): 4-5. (In Kannada)

Rajegowda, M.B., Janardhana Gowda, N.A. and Jagadeesha. N. 2011. Karnataka Rajyadalli Maleyallada Badalavaneya Pakshinota. Krushi Kayaka. 1(1):9-10. (In Kannada)

Rajegowda, M.B., Janardhana Gowda, N.A., Jagadeesha, N., Ravindra babu, B.T. and Girish.J., 2010. Karnatakadalli Hingaru Maleya (Eshanya Marutha) Vitharane mattu Hanchike. Krushi Kayaka. 3(3): 4-5. (In Kannada)

Rajegowda, M.B., Shilpa, C.N., Pavitra, B.V. and Janardhana Gowda, N.A. 2011. Krushi Salaha Havamana Varadhiyannu Raitha Kutumbagalige Talupisuva Vidhaanagalu. Krushi Kayaka.1(2):45-47. (In Kannada)

Leaflets:

Hawamana Bhadavalane mathu Krishi (Kannada) - 2010

Krishi Mathu Hawamana (Kannada) - 2010.

Dapoli

Peer reviewed research papers:

Bure, S. D., Shinde, P. P., Sawant , A. V. and Bal, A. S. 2011. Scheduling of drip irrigation to groundnut (*Arachis hypogaea* L.) under planting layout, and transparent polythene mulch. *J. Agric. Res. Technol* 36 (3) : 478 – 482

Shinde, P. P., Bure, S. D., Rajemahadik, V. A. and Sawant, A. V. 2011. Response of watermelon to drip irrigation and mulches. *J. Agric. Res. Technol* 36 (3) : 521 – 523

Shinde, P. P., Salunkhe, S. M. and Dahiphale, A. V. 2010. Response of brinjal (*Solanum melongena* L.) to placement of fertilizers and organic manure under drip irrigation. *J. Maharashtra Agric. Univ.* 35 (1): 17 – 22

Talpade, N. R., Shinde, P. P. and Nangale, Y. H. 2011. Response of chilli (*Capsicum annum*) to fertigation and poultry manure levels grown under black polythene mulch. *J. Agric. Res. Technol* 36 (3): 355 – 358

Papers presented in Symposium / Conference / Seminar / Workshop:

Gosavi, S. P., Nevase, V. B., Pawar, L. G. and Govekar, Y. R. 2010. Shifting of weed flora and distribution of invasive weeds in terrestrial ecosystems of coastal Maharashtra, National Symposium at Tamil Nadu Agricultural University, Coimbatore on 30 Nov -1 Dec, 2010

Navalgi, S. S., Nevase, V. B., Gosavi, S. P. and Jagatap, D. N. 2010. Effect of sowing time and weed control measure on the performance of dibbled rice (*Oryza sativa).* Tamil Nadu Agricultural University, Coimbatore on 30 Nov -1 Dec, 2010

Nayakawadi, T. M., Shinde, P. P., Bure, S. D. and More, V. G. 2010. Effect of fertilizer levels and plant spacing on soil nutrient status and uptake by brinjal grown under drip irrigation. 9th National Symposium of ISCAR, Goa, October, 27 – 30, 2010. pp. 78

Nevase, V. B., Gosavi, S. P. and Mahadkar, U. V. 2010. Management of parasitic weed cuscuta on Lablab purpureus grown after *Kharif* rice (*Oryza sativa*). Tamil Nadu Agricultural University, Coimbatore on 30 Nov -1 Dec, 2010

Nevase, V. B., Pawar, L. Go. and Gosavi, S. P. 2010. Studies on possibilities of green manuring to dibbled hybrid rice Sahyadri. National symposium at Tamil Nadu Agricultural University, Coimbatore on 30 Nov -1 Dec, 2010

Faizabad

Peer reviewed research papers:

Kumar, A., Tripathi, P., Singh, K.K. and Mishra, A.N. 2011. Impact of climate change on agriculture in eastern Uttar Pradesh and Bihar states (India). *Mausam*. 62 (2) : 171 - 178.

Book Chapters:

Mishra, S.K., Tripathi, P., Mishra, S.R. and Mishra, A.N. 2010. Economic impact of weather based agro-advisories of wheat crop in eastern Uttar Pradesh. In : *Agrometeorological services for farmers.* Anand Agri. University, Anand. pp. 210-219.

Mishra,S.K., Tripathi,P., Mishra, S.R. and Mishra, A.N. 2010. Seasonal verification of scores for medium range weather forecasting for eastern Uttar Pradesh. In : *Agrometeorological services for farmers.* Anand Agric. University. Anand. pp. 201-209.

Technical / Research Bulletins:

Tripathi, P., and Singh, A.K. 2010. Crop management and contingent plan. Technical bulletin. Dept. of Agril. Meteorology, N.D.U.A.T. , Kumarganj.

Papers presented in Symposium / Conference / Seminar / Workshop:

Singh, A.K., Tripathi, P., Kumar, A. and Mishra, S.R. 2011. Effect of climatic variability on livestock production and management in eastern India with special reference to Eastern U.P. Proceedings of the 24th Annual Conference of National Environmental Academy, 28-29 December 2011, Banglore.

Hisar

Books:

Jyoti Bhardwaj, Surender Singh. and Diwan Singh. 2010. Dewfall Dynamics in Indian Mustard. Lambert Academic Publishing, Germany. 80p.

Medida Sunil Kumar, Diwan Singh. and Surender Singh. 2010. Weather Responses in Soybean. VDM Publishing, Saarbrucken, Germany. 78p.

Surender Singh. 2010. Regional Monsoon Dynamics. Lambert Academic Publishing, Germany. 100p.

Book Chapters:

Diwan Singh, Surender Singh. and Rao, VUM. 2010. Implications of Climatic Change for Sustainable Agriculture in Haryana. In: *Climate Change and Agriculture over India.* (Eds. Rao *et al.,*). PHI Learning Private Limited, New Delhi. pp. 244-258.

Rana, MK., Surender Singh. and Singh, R. 2011. Climatic impact on vegetable production. In: *Fundamentals of Vegetable Production.* (Ed. Rana, MK.). New India Publishing Agency, Delhi. pp.158-196.

Technical / Research Bulletins / Course manual:

Diwan Singh, Niwas, R., Singh, R., Singh, S. and Khichar, M.L. 2010. Disaster Management. Course Manual. Dept of Agril Meteorology, CCSHAU, Hisar. 137p.

Diwan Singh, Shekhar, C., Singh, R. and Singh, S. 2010. Contingency Crop Plan for Pearl Millet in Western Agroclimatic zone of Haryana. Technical Bulletin. Dept of Agril Meteorology, CCSHAU, Hisar. 24p.

Diwan Singh, Shekhar, C., Singh, S. and Singh, R. SW, 2010. Monsoon based Contingent Crop Management Practices for Haryana. Technical Bulletin. Dept of Agril Meteorology, CCSHAU, Hisar. 40p.

Diwan Singh, Singh, R., Anurag, Shekhar C., Rao, VUM. and Singh, S. 2010. Agroclimatic Atlas of Haryana. Technical Bulletin. Dept of Agril Meteorology, CCSHAU, Hisar, 80p.

Diwan Singh, Singh, S., Shekhar, C., Singh, R. and Rao, VUM. 2010. Agroclimatic Features of Hisar Region. Technical Bulletin. Dept of Agril Meteorology, CCSHAU, Hisar. 64p.

Papers presented in Symposium / Conference / Seminar / Workshop:

Diwan Singh, Chander Shekhar, Surender Singh and VUM, Rao. 2011. Climatic variation over Haryana: Agroclimatic Analysis. Proceedings of the National seminar on Agrometeorological research and services to combat climate change challenges, 9-10 December 2011. BCKV, Kalyani.

Sheokand, R N., Sheoran, O P. and Surender Singh. 2012. Role of ICT in sustainable agriculture development. Proceedings of the National Seminar on Sustainable Agriculture and Food Security: Challenges in Changing Climate (*Abstract*). 27-28 March 2012, CCSHAU Hisar, pp.365.

Suchandan Bemal, Diwan Singh and Surender Singh. 2010. Impact analysis of climatic variability on rice productivity using crop modeling techniques in Haryana, India. Proceedings of the International Conference on Decadal Predictability. 16-20 August, 2010. AS ICTP, Trieste, Italy.

Sukhbir Singh, Surender Singh and Diwan Singh. 2012. Dynamics of rainfall during SW Monsoon: Concern for sustainable crop production in India. Proceedings of the National Seminar on Sustainable Agriculture and Food Security: Challenges in Changing Climate (*Abstract*). 27-28 March 2012, CCSHAU Hisar, pp.109.

Surender Singh and Diwan Singh 2010. Recent Fog trends and impact on wheat productivity in NW plains in India. Proceedings of the conference of 5th International Conference on Fog, Fog Collection and Dew. 25-30 July, 2010. Munster, Germany. pp. 208-211.

Surender Singh, Diwan Singh, Nehra, DS. and Nandal, DPS. 2011. Agrometeorological variations vis a vis fodder yield under poplar plantation. Proceedings of the National seminar on Agrometeorological research and services to combat climate change challenges, 9-10 December 2011. BCKV, Kalyani.

Surender Singh, Diwan Singh and Rao, V.U.M. 2012. Digital Agrometeorological Information System: An option for climate resilient and sustainable agriculture. Proceedings of the National Seminar on Sustainable Agriculture and Food Security: Challenges in Changing Climate (*Abstract*). 27-28 March 2012, CCSHAU Hisar, pp.94.

Surender Singh, Josef Eitzinger and Diwan Singh. 2011. Climate change induced farming uncertainty: The regional concerns. Proceedings of the International Conference on current knowledge of Climate Change Impacts on Agriculture and Forestry in Europe. 3-6 May, 2011. Toplcianky, Slovakia. pp 93-94.

Surender Singh, Orivaldo Brunini and Diwan Singh. 2011. Real time agrometeorological information for contingent measures in attaining sustainable crop production. Proceedings of the National seminar on Agrometeorological research and services to combat climate change challenges, 9-10 December 2011. BCKV, Kalyani.

Surender Singh. and Ram Niwas. 2012. Climate Resilient Agriculture and Agrometeorology. Proceedings of the National Seminar on Sustainable Agriculture and Food Security: Challenges in Changing Climate. 27-28 March 2012, CCSHAU Hisar, pp. 34-37.

Popular articles:

Kamlesh Kumar, Surender Singh and Diwan Singh. 2010. El Niño/La Niña: The Weather Children of Tropics. In: SPECTRUM-PG Magazine, CCS HAU Hisar March, 2010. pp 35-36.

Suchandan Bemal, Diwan Singh and Surender Singh. 2010. CO_2 Sequestration: Remedial Options to Combat Global Warming. In: SPECTRUM-PG Magazine, CCS HAU Hisar March, 2010. pp 37-38.

Jabalpur

Technical Bulletins:

Bhan, M., Bisen, A., Shrivastava, V. and Sharma, A. 2012. Chhattarpur zila ka varsha vishleshan, fasal prabhandan, awam sookhe ka prabandhan vikalp. Technical bulletin. AICRPM – NICRA project, JNKVV, Jabalpur. (In Hindi)

Papers presented in Symposium / Conference / Seminar / Workshop:

Agrawal, K.K. 2010. Climate Change and Agriculture: Adaptation and Mitigation Option. Proceedings of the National Seminar on Climate Change Adaptation and Mitigation: The way ahead. March 19 - 20, 2010. Xavier Institute, Jabalpur.

Agrawal, K.K. 2010. Climate Change and Agriculture: Adaptation and Mitigation Option. Proceedings of the National Seminar on Climate Change Adaptation and Mitigation: The way ahead. March 19 - 20, 2010. Xavier Institute, Jabalpur.

Agrawal, K.K., Bhadauria, U.P.S., Jha, A. and Jain, S. 2010. Crop weather relationship studies on chickpea for improving crop adoption to climate change. Proceedings of the National Symposium on Climate Change and Rainfed Agriculture. February 18-20, 2010. CRIDA, Hyderabad.

Agrawal, K.K., Jain, Sanjay. and Bhadauria, U.P.S. 2010. Rainfall and temperature variability in different district of Madhya Pradesh. Proceedings of the Seminar on People's Agenda on Climate Change. February 26-27, 2010. Don Bosco School, Panjim, Goa.

Agrawal, K.K., Jha, A.K., Jain, Sanjay. and Bhadauria, U.P.S. 2010. Effect of Planting Techniques of Rice on Soil Properties. 14th Vasantrao Naik Memorial National Seminar on Soil Security for Sustainable Agriculture. February 27-28, 2010. College of Agriculture, Nagpur.

Bhadauria, U.P.S., Agrawal, K.K. and Jain, Sanjay. 2010. Mitigation of Climate Change Through Agro Advisory Services. Proceedings of the on People's Agenda on Climate Change. February 26-27, 2010. Don Bosco School, Panjim, Goa.

Bhadauria, U.P.S., Tomar, D.S., Agrawal, K.K. and Tomar, V.S. 2010. Effect of Changing environments on evapotranspiration, water use and seed yield of sunflower under rainfed conditions. Proceedings of the National symposium on Climate Change and Rainfed Agriculture. February 18-20, 2010. CRIDA, Hyderabad.

Paradkar, V.K., Tiwari, D.K.,Reedy, R.K., Agrawal, K.K. and Bhadauria, U.P.S. 2010. Climate and its variability in rainfall and rainy days in Chhindwara district of Madhya Pradesh. Proceedings of the Seminar on People's Agenda on Climate Change. February 26-27, 2010. Don Bosco School, Panjim, Goa.

Shrivastava, Kumar Atul, Dubey, Kumar Alok and Agrawal, K.K. 2010. Environment Eco-Friendly-Biodiesel. Proceedings of the Seminar on People's Agenda on Climate Change. February 26-27, 2010. Don Bosco School, Panjim, Goa.

Upadhyay, A. P. and Agrawal, K.K. 2010. Climate Change Adaptation Strategies for Sustainable crop Production. Proceedings of the National Seminar on Climate Change Adaptation and Mitigation: The way ahead. March 19 - 20, 2010. Xavier Institute, Jabalpur.

Kovilpatti

Peer reviewed research papers:

Sankaranarayanan, K., Satheeshkumar, N., Solaimalai, A. and Sankaran, N. 2011. Ratoon ratio and ratoon index of multicut fodder sorghum varieties as influenced by intercropping and nitrogen levels. *Crop Research*, 42 (1-3): 44 - 46.

Sankaranarayanan, K., Satheeshkumar, N., Solaimalai, A. and Sankaran, N. 2011. Effect of intercropping and nitrogen levels on growth of multicut fodder sorghum varieties. *Crop Research*, 42 (1-3): 40 – 43

Sankaranarayanan, K., Satheeshkumar, N., Solaimalai, A. and Sankaran, N. 2011. Nutrient uptake in multicut fodder sorghum under sole and intercropping situations with different nitrogen levels. *Crop Research*, 42 (1-3): 47 - 50.

Technical Bulletins:

Anandaraju, P., Sankarapandian, R., Solaimalai, A., Jawahar, D. and Paramathma, M. 2011. Suriyakanthiyil tharamana vithai urpathi seiyum tholilnuppankangal. NADP-RKVY Project, Agricultural Research Station, Kovilpatti.

Raja, R., Solaimalai, A., Subbulakshmi, S., Jawahar, D. and Rao V.U.M. 2011. Length of Growing period for Tamil Nadu. Technical bulletin. Agricultural Research Station, Kovilpatti, Tamil Nadu. 275p.

Solaimalai, A., Subbulakshmi, S., Ragavan, T., Babu, R. and Jawahar, D. 2010. Weather based cotton farming for southern agro-climatic zone of Tamil Nadu. Agricultural Research Station, Kovilpatti.

Book Chapters:

Ragavan, T. and Umamaheswari, S. 2010. Malazikku pin thankum sulalukkuketra sakupadi tholinuppankkal. In: Manavari velanmai valampera navina sakupadi tholinuppakkal. (Eds. Nagarajan, S.S. and Subramanian, V.). Agricultural Research Station, Kovilpatti. pp.108-110 (in Tamil).

Ragavan, T., Umamaheswari, S., Solaimalai, A. and Subbulakshmi, S. 2010. Velan vanilai sarntha manavari pairsakupadi. In: Manavari velanmai valampera navina sakupadi tholinuppakkal. (Eds. Nagarajan, S.S. and Subramanian, V.). Agricultural Research Station, Kovilpatti. pp.6-18 (in Tamil).

Solaimalai, A., Subbulakshmi, S. and Jawahar, D. 2010. Makkacholathin palveru payanpadukal. In: Manavariyl makkacholathin magasulai athikarikka puthiya tholilnuppankkal. NABARD's Beneficiaries Training guide, Agricultural Research Station, Kovilpatti. pp.50 - 53 (in Tamil).

Solaimalai, A., Ragavan, T., Umamaheswari, S. and Subbulakshmi, S. 2010. Manarivi pairkalil Kalainirvagam. In: Manavari velanmai valampera navina sakupadi tholinuppakkal. (Eds. Nagarajan, S.S. and Subramanian, V.). Agricultural Research Station, Kovilpatti. pp.46-54 (in Tamil).

Solaimalai, A., Subbulakshmi, S. and Uma maheswari, C. 2010. Manavari pairkalil orukinaith kalainivaga muraikal. District level famers' exhibition technological guide. pp.15 – 17 (in Tamil).

Subbulakshmi, S., Ragavan, T., Solaimalai, A. and Umamaheswari, S. 2010. Manarivil angaka velan tholinuppankkal. In: Manavari velanmai valampera navina sakupadi tholinuppakkal. (Eds. Nagarajan, S.S. and Subramanian, V.). Agricultural Research Station, Kovilpatti. pp.114-122 (in Tamil).

Subbulakshmi, S., Solaimalai, A. and Uma maheswari, C. 2010. Manavari ankaka Velanmai tholilnuppankkalum avartin nanmaikalum. District level famers' exhibition technological guide. pp.8 – 14 (in Tamil).

Subbulakshmi, S., Solaimalai, A., Rangrajan, T. and Umamaheswari, C. 2010. Manavari makkacholam sakupadi muraikal. In: Manavariyl makkacholathin magasulai athikarikka puthiya tholilnuppankkal. NABARD's Beneficiaries Training guide, Agricultural Research Station, Kovilpatti (in Tamil).

Uma maheswari, C., Subbulakshmi, S., Solaimalai, A. and Jawahar, D. 2010. Velan vanilai ottiya Makkachola sakupadi tholilnuppankkal. In: Manavariyl makkacholathin magasulai athikarikka puthiya tholilnuppankkal. NABARD's Beneficiaries Training guide, Agricultural Research Station, Kovilpatti. pp.54 – 60 (in Tamil).

Uma maheswari, C., Subbulakshmi, S., Solaimalai, A. and Jawahar, D. 2010. Velan vanilai ottiya Makkachola sakupadi tholilnuppankkal. District level famers' exhibition technological guide. pp.1 – 4 (in Tamil).

Umamaheswari, S., Ragavan, T., Solaimalai, A. and Subbulakshmi, S. 2010. Vivasaikalukkana vanilai munarivipumaiyam - Oru kannottam. In: Manavari velanmai valampera navina sakupadi tholinuppakkal. (Eds. S.S. Nagarajan and V. Subramanian). Agricultural Research Station, Kovilpatti. pp.1-5 (in Tamil).

Papers presented in Symposium / Conference / Seminar / Workshop:

Babu, R. and Ragavan, T. 2010. Decadal analysis of rainfall data in the context of climate change and its impact on crop management in Kovilpatti, Tamil Nadu. Proceedings of the National symposium on Climate change and rainfed agriculture. February 18 – 20, 2010. CRIDA, Hyderabad.

Jothimani, S. and Ragavan, T. 2010. Soil moisture as influenced by climatic parameters in dryland vertisols of southern Tamil Nadu. Proceedings of the National symposium on Climate change and rainfed agriculture. February 18 – 20, 2010. CRIDA, Hyderabad.

Ragavan, T., Sathyamoorthy, N.K. and Sathyavelu, A. 2010. Influence of sowing environments and in situ moisture conservation measures on the performance of rainfed cotton under vertisols of semi-arid region. Proceedings of the National symposium on Climate change and rainfed agriculture. February 18 – 20, 2010. CRIDA, Hyderabad.

Ragavan, T., Venkatraman, N.S. and Babu, R. 2010. Inter row and inter plot water harvesting systems on the productivity of rainfed pearl millet under vertisols of semi arid region in Tamil Nadu. Proceedings of the National symposium on Climate change and rainfed agriculture. February 18 – 20, 2010. CRIDA, Hyderabad.

Ragavan, v. and Venkatraman, N.S. 2010. Studies on the evapotranspiration at different phonological stages of rainfed cotton under dryland vertisols of southern agroclimatic zone of Tamil Nadu. Proceedings of the National symposium on Climate change and rainfed agriculture. February 18 – 20, 2010. CRIDA, Hyderabad.

Solaimalai, A. and Murugesan, N. 2011. Foliar fertilization of potassium on summer irrigated cotton. Proceedings of the National seminar on Soil health improvement for enhancing crop productivity (*Abstracts*). 17-18 March 2011, Tamil Nadu Agricultural University, Coimbatore, p.85.

Solaimalai, A., Ragavan, T., Subbulakshmi, S. and Jawahar, D.2011. Performance of sorghum based intercropping system in rainfed vertisol. Proceedings of the National Workshop on Dryland Development and Maximizing Crop Productivity (*Abstracts*). 12-13 May 2011, Tamil Nadu Agricultural University, Coimbatore, p.75.

Solaimalai, A., Subbulakshmi, S. and Jawahar, D. 2011. Evaluation of Land configuration methods and weed management practices on rainfed maize. Proceedings of the National Workshop on Dryland Development and Maximizing Crop Productivity (*Abstracts*). 12-13 May 2011, Tamil Nadu Agricultural University, Coimbatore, p.95.

Umamaheswari, C., Subbulakshmi, S., Solaimalai, A. and Jawahar, D. 2011. Weather based advisories - a practical guide for weather based decision making in dryland agriculture. Proceedings of the National Workshop on Dryland Development and Maximizing Crop Productivity (*Abstracts*). 12-13 May 2011, Tamil Nadu Agricultural University, Coimbatore, p.66.

Popular articles:

Ragavan, T. and Mageswari, M. 2010. Pudhiya tholil nutpa anugumurai tharumvelan sulal mantram. Dinamani on 7.1.2010. (In Tamil)

Ragavan, T. and Mageswari, M. 2010. Puvi veppamadaithalai kuraipom. Dinamani on 14.1.2010. (In Tamil)

Solaimalai, A., Subbulakshmi, S., Selvarani, A., Porkodi Kamalam, A. and Jawahar, D. 2011. Pal orpathiai perukka thivanacholam sakupai. *Kalathumedu* 1 (4): 33-35. (In Tamil)

Solaimalai, A., Antharaju, P., Porkodi Kamalam, A., Subbulakshmi, S.and Jawahar, D. 2011. Bt paruthi sakupadiyl athika maksul perum valimuraikal. *Kalathumedu* 1 (5): 15-21. (In Tamil)

Solaimalai, A., Porkodi Kamalam, A. and Jawahar, D. 2011. Athikavaruvai tharum inippu makkacholam sakupadi. *Kalathumedu* 1 (4): 27-29. (In Tamil)

Solaimalai, A., Porkodi Kamalam, A., Antharaju, P., Subbulakshmi, S., Suguna, S. and Umamaheswari, C. 2011. Manavariyl pirachanaikuriya kalaikalin melanmai muraikal. *Kalathumedu* 1 (9): 36-40. (In Tamil)

Solaimalai, A., Porkodi Kamalam, A., elvarani, A.S. and Subbulakshmi, S. 2011. Pairkalivukalilirunthu compost thayarikkum muraikal. *Kalathumedu* 1 (7): 10-16. (In Tamil)

Solaimalai, A., Rangaraj, T. and Awahar, D.J. 2011. Velanmaiyl urachelavai kuraikka nagara marthrum alai kalivuporukkalai payanpaduthuvoom. *Kalathumedu* 1 (11): 44-48. (In Tamil)

Solaimalai, A., Subbulakshmi, S.and Jawahar, D. 2011. Vellanmai arachi nilaythil karutharankam. Dinakaran, 05 April 2011. p.16. (In Tamil)

Solaimalai, A., Subbulakshmi, S. and Jawahar, D. 2011. Kovilpattiyl vanilai martarum kuritha karutharanku. Dinamalr, 05 April 2011. p.11. (In Tamil)

Solaimalai, A., Subbulakshmi, S. and Jawahar, D. 2011. Vivachaikal karutharanku. Dinamani, 05 April 2011. p.2. (In Tamil)

Solaimalai, A., Subbulakshmi, S., Porkodi Kamalam, A. and Jawahar, D. 2011. Puvi vepamadaithalum, vilaivukalum, thadukkum muraikalum. *Kalathumedu* 1 (4): 15-17. (In Tamil)

Solaimalai, A., Subbulakshmi, S., Umamaheswari, C. and Jawahar, D. 2011. Vanilai martramum vilaivukalum. Dinamani, 26 May 2011. p.8. (In Tamil)

Solaimalai, A., Subbulakshmi, S.and Jawahar, D. 2011. Pairkalil valarum ottuni kalaikalum athan orunginatha kattupattu mariakalum. *Kalathumedu* 1 (10): 45-48. (In Tamil)

Suguna, S., Subbulakshmi, S., Selvarani, A., olaimalai, A.S., Porkodi Kamalam, A. and Jawahar, D.2011. Mavupoochiyum athan melanmaiyum. *Kalathumedu* 1 (8): 18-22. (In Tamil)

Suguna, S., Subbulakshmi, S., Selvarani, A., Solaimalai, A. and Porkodi Kamalam, A. 2011. Orunkiatha pairpathukappil thavara poochikolikal. Kalathumedu, 1 (8): 9-12. (In Tamil)

Suguna, S., Subbulakshmi, S., Selvarani, A., Solaimalai, A. and Porkodi Kamalam, A. 2011. Eyairkai velanmaiyl karumpu sagupadi. *Kalathumedu* 1 (8): 23-29. (In Tamil)

Ludhiana

Peer reviewed research papers:

Brar, M. S., Sandhu, S S., Preeti Sharma. and Amandeep Singh. 2012. Effect of Potassium Application on Sunflower (*Helianthus annus* L.) Grown on Potassium deficient soils in North eastern parts of Punjab. *Indian Journal of Ecology*. 38 (2) :189-193.

Brar, M.S., Preeti Sharma, Amandeep Singh, Dhillon, N.S. and Sandhu, S.S. 2010. Effect of potassium nutrition on yield, quality and nutrient uptake by sunflower. *Journal of Indian Society of Soil Science*. 58 (3): 244-346.

Brar, M.S., Preeti Sharma, Amandeep Singh. and Sandhu, S.S. 2012. Nitrogen Use Efficiency (NUE), Growth, Yield Parameters and Yield of Maize (*Zea mays* L.) as affected by K Application. *Electronic International Fertilizer Correspondent*. 30:3-6.

Kingra, P K. and Prabhjyot-Kaur. 2011. Agroclimatic indices for prediction of pod yield of groundnut (*Arachis hypogaea* L.) in Punjab. *J. of Research (PAU)*. 48 (1&2) : 1-4.

Kingra, P K. and Prabhjyot-Kaur. 2011. Phenology and growth dynamics of *Brassica* species under different environmental conditions in central Punjab. *J. of Research (PAU)*. 48 (1&2) : 16-21.

Mukherjee, J., Gebru, G., Bal, S. K., Singh, H. and Prabhjyot-Kaur. 2011. Wheat yield prediction by agro-meteorological model of Rupnager district of Punjab. *Geobios*. 38(2-3) : 117-120.

Mukherjee, J., Gebru, G., Sood, A., Mahey, R.K., Bal, S. K., Singh, H. and Prabhjyot-Kaur. 2010. Wheat yield and acreage prediction using LISS-III and AWiFS sensors data of Indian remote sensing satellite of Rupnager district of Punjab, India. *Italian J. of Remote Sensing*. 42 (3): 115-127

Prabhjyot-Kaur, Harpreet Singh, Bal, S.K., Sandeep Singh Sandhu. and Amarinder Singh. 2011. Quantitative evaluation of weather variability and rice yields in Punjab, India – A case study. *J. of Research (PAU)*. 48 (1&2) : 5-15.

Sandhu, S.S., Mahal, S.S., Vashist, K.K., Buttar, G.S., Brar, A.S. and Maninder Singh. 2012. Crop and water productivity of bed transplanted rice as influenced by various levels of nitrogen and irrigation in northwest India. *Agricultural Water Management*. 104: 32–39.

Book chapters:

Prabhjyot-Kaur and Harpreet Singh. 2011. Climate variability trend analysis in Punjab over the past three decades. In : *Impact of climate change on fruit crops* (Eds Dhillon, W.S. and Aulakh, P.S.), Narendra Publishing House, New Delhi, pp.167-176

Prabhjyot-Kaur, Harpreet Singh. and Hundal, S S. 2010. Amelioration of heat stress in soybean (*Glycine max. L.*) by microclimate modification techniques in Punjab. In : *Emerging trends in watershed management* (Eds. Yadav, R.P. *et al.,*). Satish Serial Publishing House, New Delhi. pp.409-418

Prabhjyot-Kaur. and Hundal, S S. 2010. Climate change and agriculture over Punjab. In : *Climate change and agriculture over India* (Eds : Prasada Rao *et al.,*). PHI Learning Limited, New Delhi pp. 210-225

Prabhjyot-Kaur. and Hundal, S S. 2010. Global climate change vis-à-vis crop productivity. In : *Natural and anthropogenic disasters* – Vulnerability, preparedness and mitigation (Editor Jha, M.K.). Capital Publishing Company, New Delhi and Springer, The Netherlands. pp.413-431

Technical Bulletins:

Kamal Vatta, Prabhjyot-Kaur, Harpreet Singh. and Tinku Grover. 2012. Vulnerability of Punjab agriculture to climate change – A district wise analysis. Punjab Agricultural University, Ludhiana. 44p.

Prabhjyot Kaur, Harpreet Singh, Amarinder Singh, S K Bal, Sandeep Singh Sandhu, Ashu Bala. and Chamandeep Singh. 2011. Climate change – Reasons, effect and adaptation / mitigation options. AICRPAM – NICRA, Dept. of Agricultural Meteorology, PAU, Ludhiana. 4p.

Prabhjyot Kaur, Sandeep Singh Sandhu, Harpreet Singh, Gill, K K., Bal, S K., Ashu Bala. and Amarinder Singh. 2012. Weather based decisions for wheat cultivation in Punjab. Dept. of Agricultural Meteorology, PAU, Ludhiana. 60p.

Papers presented in Symposium / Conference / Seminar / Workshop:

Amarinder Singh, Prabhjyot Kaur. and Harpreet Singh. 2012. Testing of INFOCROP-Rice model for growth and yield prediction of rice cultivars in central irrigated plains of Punjab. Proceedings of National seminar on Sustainable agriculture and food security (*Abstract*), 27-28 March 2012, CCSHAU, Hisar, p.105.

Ashu Bala. and Prabhjyot Kaur. 2012. Effect of abiotic stresses on rice productivity in central irrigated plains of Punjab state. Proceedings of National seminar on Sustainable agriculture and food security (*Abstract*), 27-28 March 2012, CCSHAU, Hisar, p.105.

Bal, S K, Choudhury, B U., Anil Sood, Mukherjee, J., Harpreet Singh. and Prabhjyot-Kaur. 2011. Climatic characterization of Punjab using Geographic Information System. Proceedings of International conference on Preparing agriculture for climate change (*Abstract*). 6-8 February 2011, PAU, Ludhiana. p.411.

Bal, S.K., Choudhury, B.U., Anil Sood., Mukherjee, J., Harpreet Singh and Prabhjyot-Kaur. 2011. Climatic characterization of Punjab using Geographic Information System. Proceedings of International conference on Preparing agriculture for climate change (*Abstract*). 6-8 February 2011, PAU, Ludhiana. p.411

Bal, S.K., Choudhury, B.U., Anil Sood, Mukherjee, J., Harpreet Singh. and Prabhjyot-Kaur. 2010. Crop diversification plan for Indian Punjab using remote sensing and Geographical Information System. Proceedings of the National seminar on Impact of climate change on fruit crops, 6 - 8 October 2010, PAU, Ludhiana.

Bal, S.K., Choudhury, B.U., Anil Sood, Gurjot Singh, Mukherjee, J., Harpreet Singh. and Prabhjyot- Kaur. 2010. Establishing relationship between Leaf Area Index of wheat crop and different spectral indices in Indian Punjab. Proceedings of the ISRS Annual Convention & National Symposium on GIS and Remote Sensing in Infrastructure development. 1-3 December, 2010, Lonavala, Maharashtra.

Harpreet Singh, Prabhjyot Kaur, Sandhu, S. S., Ashu Bala, Amarinder Singh, Harinder Singh. and Chamandeep Singh. 2012. Perception of Punjab farmers towards climate change and its mitigation / adaptation strategies. Proceedings of National seminar on Sustainable agriculture and food security (*Abstract*), 27-28 March 2012, CCSHAU, Hisar, p.96

Harpreet Singh, Prabhjyot-Kaur , Mukherjee, J., Bal, S K. and Singh, B. 2011. Assessment and mapping of temperature variability in Punjab – Geospatial and analytical approach. Proceedings of National seminar on Sustainable agriculture and food security (*Abstract*), 27-28 March 2012, CCSHAU, Hisar, p.412.

Harpreet Singh, Prabhjyot-Kaur, Mukherjee, J. and Bal, S.K. 2010. A Methodological approach of assessing climatic variability using GIS in Indian Punjab. Proceedings of the ISRS Annual Convention & National Symposium on GIS and Remote Sensing in Infrastructure development. 1-3 December, 2010, Lonavala, Maharashtra.

Harpreet Singh, Prabhjyot-Kaur, Mukherjee, J., Bal, S K. and Singh, B. 2011. Assessment and mapping of temperature variability in Punjab – Geospatial and analytical approach. Proceedings of International conference on Preparing agriculture for climate change (*Abstract*). 6-8 February 2011, PAU, Ludhiana. p.412

Hundal S S, Prabhjyot-Kaur, Singh, H. and Ghahreman, N. 2010. Dynamic crop simulation models and their applications: Indian experience with DSSAT models. Proceedings of the first international conference on Plant, water, soil, and weather modeling. 14-15 November 2010. International Centre for Science, High Technology and Environmental Sciences, Kerman, Iran. pp. 1-20

Mukherjee , J.,Kaur, M., Mahey R K., Kaur, R., Sood, A., Bal, S K., Singh, H., Prabhjyot-Kaur. and Kumar, P.B. 2011. Prescription mapping of *Echinochloa crusgalli* in rice of Ludhiana using Geographical Information System (GIS) in changing climatic scenario. Proceedings of International conference on Preparing agriculture for climate change (*Abstract*). 6-8 February 2011, PAU, Ludhiana. p.407

Mukherjee, J., Kaur, M., Mahey R K., Kaur, R., Sood, A., Bal, S K., Singh, H., Prabhjyot-Kaur. and Kumar P, B. 2011. Prescription mapping of *Echinochloa crusgalli* in rice of Ludhiana using Geographical Information System (GIS) in changing climatic scenario. Proceedings of International conference on Preparing agriculture for climate change (*Abstract*). 6-8 February 2011, PAU, Ludhiana. p.407.

Mukherjee, J., Lakhwinder Singh, Bal, S.K., Harpreet Singh. and Prabhjyot-Kaur. 2010. Calibration and Validation of Rice (*Oryza sativa*) potential growth process in Central Punjab of India by utilizing WOFOST Model. Proceedings of the 4th National Seminar on Agrometeorology-Needs, Approaches and Linkages for rural development. 26-27 November, 2009, CCSHAU, Hissar, Haryana.

Mukherjee, Joydeep, Kang, G.S., Dhawan, A.K., Bal, S.K., Prabhjyot-Kaur. and Harpreet Singh. 2010. Cropping system analysis of Bathinda and Muktsar districts of Punjab using AWiFS and LISS data. Proceedings of the ISRS Annual Convention & National Symposium on GIS and Remote Sensing in Infrastructure development. 1-3 December, 2010, Lonavala, Maharashtra.

Prabhjyot Kaur, Harpreet Singh. and Amarinder Singh. 2012. Impact of futuristic climate change scenarios on wheat yield in Punjab using INFOCROP-Wheat model. Proceedings of National seminar on Sustainable agriculture and food security (*Abstract*), 27-28 March 2012, CCSHAU, Hisar, p.93.

Prabhjyot-Kaur, Harpreet Singh, Mukherjee, J. and Bal, S K. 2011. Changing rainfall scenarios in Punjab – A variability trend analysis. Proceedings of International conference on Preparing agriculture for climate change (*Abstract*). 6-8 February 2011, PAU, Ludhiana. p.411

Prabhjyot-Kaur, Harpreet Singh, Mukherjee, J. and Bal, S K. 2011. Changing rainfall scenarios in Punjab – A variability trend analysis. Proceedings of National seminar on Sustainable agriculture and food security (*Abstract*), 27-28 March 2012, CCSHAU, Hisar, p.411.

Prabhjyot-Kaur. and Harpreet Singh. 2010. Climate variability trend analysis in Punjab over the past three decades. Proceedings of the National seminar on Impact of climate change on fruit crops, 6 - 8 October 2010, PAU, Ludhiana.

Prabhjyot-Kaur. and Harpreet Singh. 2010. Climatic Variability trend analysis in the region over the past three decades. Proceedings of the National seminar on Impact of climate change on fruit crops, 6 - 8 October 2010, PAU, Ludhiana.

Sandhu, S. S., Mahal, S.S., Vashisht, K.K. and Maninder Singh. 2010. Water scarcity: Causes and management in Punjab. proceedings of the Regional workshop of water availability and management in Punjab. 13-15 December, 2010. Punjab University, Chandigarh.

Popular articles:

Amrinder Singh, Prabhjyot-Kaur and Harpreet Singh. 2010. Mausami badlaw – Kaaran, asar ate anukoolan vidhiaan (Climatic change – Reasons, Impact and Adaptation strategies). Changi Kheti. July 2010. pp.30. (In Punjabi)

Ramanjit Kaur, Prabhjyot-Kaur. and Rajni. 2010. Global warming and its impact on agriculture. Progressive Farming. May 2010 : 16-17.

Online Publications:

Prabhjyot-Kaur . and Harpreet Singh. 2010. Best management practices for cotton –oilseed brassica cropping system of Punjab. EcoLearnIT RLO#425. Available at: http://EcoLearnIT.ifas.ufl.edu/viewer.asp?rlo_id=425&final_id=67

Prabhjyot-Kaur, Romesh Khera. and Samanpreet Kaur. 2010. Empirical estimation of Evapotranspiration. EcoLearnIT RLO#317. Available at: http://EcoLearnIT.ifas.ufl.edu/viewer.asp?rlo_id=317&final_id=57

Prabhjyot-Kaur. and Romesh Khera .2009. Best management practices for soil and water use for major cropping systems of Punjab. EcoLearnIT RLO#82. Available at: http://EcoLearnIT.ifas.ufl.edu/viewer.asp?rlo_id=82

Prabhjyot-Kaur. and Romesh Khera. 2010. Soil Water Balance Dynamics - Some Modelling Concepts. EcoLearnIT RLO#320. Available at: http://EcoLearnIT.ifas.ufl.edu/viewer.asp?rlo_id=320

Romesh Khera. and Prabhjyot-Kaur. 2010. Soil moisture measurements. EcoLearnIT RLO#84. Available at http://EcoLearnIT.ifas.ufl.edu/viewer.asp?rlo_id=84& final_id=63

Samanpreet Kaur, Rajan Aggarwal . and Prabhjyot-Kaur. 2010. Improving operational efficiency of tubewells in Punjab. EcoLearnIT RLO#46. Available at: http://EcoLearnIT.ifas.ufl.edu/viewer.asp?rlo_id=318&final_id=46

Mohanpur

Peer reviewed research papers:

Banerjee, S., Bhattacharya, I., Khan, S. A. and Huda, A.K.S. 2010. Weather sensitivity of downy mildew and Alternaria blight of mustard in the Gangetic West Bengal, India. *J. Science Foundation*. 8 (1 & 2): 77-81.

Banerjee, S., Mukherjee, A., Mukhopadhaya, A., Saikia, B., Bandyopadhaya, S. and Chatterjee, S. 2010. Agro-climatic characterisation of two selected stations in the southern West Bengal, India. *J. Science Foundation*. 8 (1 & 2): 49-54.

Chakraborty, D., Mazumder, S. P., Garg, R. N., Banerjee, S. Santra, P., Singh, R. and Tomar, P. K. 2011. Pedotransfer functions for predicting points on the moisture retention curve of Indian soils. *Indian J. Agril. Sci.,* 81 (11): 1030-1036

Chakraborty, P.K., Mukherjee, A. and Biswas, M. 2010. Diurnal variation in temperature and humidity profile within sesamum canopy and its impact on growth process under different dates of sowing. *Journal of Agrometeorlogy*. 12: 69-73.

Chatterjee, S. K. and Banerjee, S. 2010. Changing Irrigation Requirement of Potato in the New Alluvial Zone of West Bengal. *Vikas Vani Journal.* IV (2): 72-75.

Mukherjee, A. and Sarkar, S. 2010. Relationship between Actual evapotranspiration estimated by water balance method and soil moisture depletion method. *Journal of Agrometeorlogy*. II (Special issue): 111-114

Mukherjee, A., Chakravarti, A.K. and Debnath, A. 2010. Effect of different mulches on water use pattern and performance of rainfed rape seed crop in Gangetic plain of West Bengal. *Journal of Agrometeorlogy.* 12: 77-80

Mukherjee, A., Kundu, M., Sarkar, S. 2010. Role of irrigation and mulch on yield, evapotranspiration rate and water use pattern of tomato (*Lycopersicon esculentum* L.) *Agricultural Water Management*. 98 : 182-189

Mukherjee, A., Sarkar, S., Chakravarty, P.K. 2012. Marginal analysis of water productivity function of tomato crop grown under different irrigation regimes and mulch managements. *Agricultural Water Management* 104 : 121-127

Book Chapters:

Saha, G., Lepcha, L., Banerjee, S., Deka, N., Nanda, M.K., Maity, G.C. and Khan, S.A. 2010. Studies on assessment of benefits of weather-based agroadvisories in jute-boro rice cropping system in West Bengal. In : *Agrometeorological Services for Farmer* (Ed. Vyas Pandey), Anand Agricultural University, Anand, pp.178-183.

Saikia, B., Sarmah, K. and Banerjee, S. 2010. Impact of radiation on thermal environment of *Brassica campestries*, var. yellow sarson. In : *Agrometeorological Services for Farmer* (Ed. Vyas Pandey), Anand Agricultural University, Anand, pp.51-58.

Palampur

Peer reviewed research papers:

Prasad, R. and Rana, R.S. 2010. Length of rainy season and climatic water balance as influenced by climate change in the sub temperate and sub tropical mid hills of Himachal Pradesh. *Journal of Agricultural Physics*. 10: 44-49.

Rakesh Kumar, Ramesh, K. , Singh, R.D. and Rajendra Prasad. 2010. Modulation of wild marigold (*Tagets minuta* L.) phenophases towards the varying temperature regimes –a field study. *Journal of Agrometeorology.* 12(2) 234-240.

Rana, R. S., Bhagat, R. M., Singh, M. M., Kalia, V., Singh, S. and Prasad, R. 2012. Trends in climate over Himachal Pradesh. *Journal of Agrometeorology.* 14 (1): 104-109.

Papers presented in Symposium / Conference / Seminar / Workshop:

Kumari, V., Chaudhary, H. K., Prasad, R., Kumar, A. and Jambhulkar, S. 2011. Effect of mutagenesis on germination, growth and in Ethiopian mustard (*Brassica carinata* A. Braun): Proceedings of the 5th National Seminar on Multi sectoral innovations for rural prosperity (*Abstract*). 19-21 May 2011. MOBILIZATION Society and National Dairy Research Institute, Karnal,. Haryana, pp.79-80.

Kumari, V., Chaudhary, H.K., Prasad, R., Kumar, A., Jambhulkar, S. and Sharma, S. 2011. Frequency and spectrum of mutations induced by gamma radiation in Ethiopian mustard (*Brassica carinata* A. Braun): Proceedings of the 5th National Seminar on Multi sectoral innovations for rural prosperity (*Abstract*). 19-21 May 2011. MOBILIZATION Society and National Dairy Research Institute, Karnal,. Haryana, p.92.

Rana, R.S., Singh, M.M., Prasad, R. and Katoch, V. 2011. Application of medium range weather forecasting in organic farming in mountain agriculture: Proceedings of the National symposium cum Brainstorming workshop on Organic Agriculture (*Abstract*). 19- 20 April 2011. Department of Organic Agriculture, CSKHPKV, Palampur and Organic Agricultural Society of India, p.67.

Parbhani

Papers presented in Symposium / Conference / Seminar / Workshop:

Phenology and grain yield of *kharif* sorghum influenced by weather at Parbhani. Proceedings of the National symposium on Climate change and rainfed Agriculture. 18-20 February, 2010, CRIDA, Hyderabad.

Role of weather variables in outbreak of bollworm in cotton at Parbhani. Proceedings of the National symposium on Climate change and rainfed Agriculture. 18-20 February, 2010, CRIDA, Hyderabad.

Raipur

Papers presented in Symposium / Conference / Seminar / Workshop:

Patel, S.R., Choudhary, S., Sastri, A.S.R.A.S., Naidu, D. and Singh, R. 2010. Impact assessment of Agrometeorological information services in Central plain zone of Chhattisgarh. Proceedings of the National Symposium on Food Security in context of climate change. October 31- November 01, CSAU&T, Kanpur. pp.20.

Patel, S.R., Sastri, A.S.R.A.S. and Choudhary, S. 2010. Influence of different sowing dates on yield and heat use efficiency of wheat (*Triticum aestivum*) varieties. Proceedings of the XIX National Symposium on Resource Management Approaches Towards Livelihood Security. December 2-4, UAS, Banglore, pp.453.

Patel, S.R., Sastri, A.S.R.A.S., Singh, R. and Naidu, D. 2010. Assessment of rice yield under rainfed and irrigated condition in Chhattisgarh using crop simulation model. Proceedings of the National symposium on Climate change and rainfed Agriculture. 18-20 February, 2010, CRIDA, Hyderabad.

Rakh Dhiansar

Book Chapters:

Khushu, M. K., Singh, Mahender and Sharma Anil. 2010. Climate Change and Agriculture over Jammu and Kashmir. In: *Climate Change and Agriculture over India.* (Eds. Prasada Rao, G.S.L.H.V, Rao, G.G.S.N and Rao V.U.M.). PHI Learning, New Delhi.

Papers presented in Symposium / Conference / Seminar / Workshop:

Kohli Anshuman and Khushu, M.K. 2010. Development of a rural rain measuring network for improving the integrated Agromet Advisory Services in hilly regions. Proceedings of the 5th JK Science Congress, 8 – 10 February, 2010. University of Jammu.

Tiku, A.K., Khushu, M.K., Kaul, V., Guleria, S., Gupta, Moni. and Wali, V.K. 2010. Effect of various Agro-Techniques on Olive (Olea Euopaea) crop production. Proceedings of the 5th JK Science Congress, 8 – 10 February, 2010. University of Jammu.

Ranichauri

Peer reviewed research papers:

Prasad, S., Prasad, B. and Singh, R. K. 2010. Pre-germinated seed treatment with soaking, heating, chilling and its integration for rice (*Oryza sativa* L.) seed invigoration, Oryza.

Popular articles:

Shambhoo Prasad, Singh R.K., and Kashyap, P.S. 2010. Alkathin Thank: Parvatiya Kisano ka Jal Bank. Kisan Bharti. August 2010. pp.13-14. (In Hindi)

Samastipur

Peer reviewed research papers:

Sattar, A. 2010. Rainfall probability analysis for different agroclimatic zones of Bihar. *Journal of Agrometeorology*.12(2):261-262

Book Chapters

Sattar, A. and Singh, V.P. 2012. Jalbayu paribartan ebam krishi: Bihar paridrish mei ek adhyayan. In: Jalbayu Paribartan ebam Fasal Utpadan. pp.1-10 (In Hindi)

Sattar, A. and Singh, V.P. 2012. Jalbayu paribartan ebam krishi: Bihar paridrish mei ek adhyayan In: Jalbayu Paribartan ebam Fasal Utpadan. Rajendra Agricultural University, Pusa, Bihar. pp.1-10 (In Hindi)

Papers presented in Symposium / Conference / Seminar / Workshop:

Nilanjaya, Narayan, A. and Sattar, A. 2010. Aerobic rice: An adaptive strategy under changing climatic condition in Bihar. Proceedings of the National Symposium on Climate Change & Rainfed Agriculture. 18-20 February 2010, CRIDA, Hyderabad.

Sattar, A. and Kumar Udit. 2011. Climate change and horticultural production system: An overview under Bihar perspectives. Proceedings of the seminar Development horticulture in Bihar-Issues and Strategies. 28-29 January 2011, Patna

Popular articles:

Sattar, A. and Bobade. 2012. Jalbayu paribartan ke paridrish mei mausam purbanuman ki upyogita. Adhunik Kisan. 1 : 5-7 (In Hindi)

Solapur

Peer reviewed research papers:

Apotikar, V.A. Solanki, A.V., Jadhav, J.D. and Londhe, V. M. 2012. Studies on leaf temperature and air temperature under various levels of irrigation in potato. *Contemporary research in India*. 2 (1): 246-254.

Apotikar, V.A. Solanki, A.V., Jadhav, J.D. and Londhe, V.M. 2012. Mulching and irrigation effects on stomatal conductance and stomatal resistance in relation to haulm yield of potato. *Contemporary research in India*. 2 (1): 206-213.

Apotikar, V.A., Solanki, A.V., Jadhav, J.D. and Londhe, V. M. 2012. Effect of sowing windows radiation on light use efficiency and radiation interception in potato. *Contemporary research in India*. 2 (1): 12-17.

Apotikar, V.A., Solanki, A.V., Jadhav, J.D. and Londhe, V.M. 2012. Irrigation levels and mulching effects on photosynthesis rate in potato. *Contemporary research in India*. 2 (1): 79-83.

Bawdekar, V.R., Jadhav, J.D., Bhore, A.V. and Kadam, J. R. 2011. Meteorological parameters in relationship with growth and yield of safflower under dry land condition. *Journal of Oilseed Research*. 29 (1): 308-309.

Bhore, A.V., Jadhav, J.D., Khadatare, S. V. and Kadam, J.R. 2011. Crop phenology and thermal indices in relation to seed yield of safflower. *Journal of Oilseed Research*. 29 (1): 281-284.

Katwate, M.T., Thorve, S.B. and Jadhav, J. D. 2011. Grain yield as influenced by varities and fertilizer levels in sesamum (*Sesamum indicum* L.). *Advance Research Journal of Crop Improvement*. 2 (1): 1-6

Palve D.K., Oza S.R., Jadhav, J. D. and Ghule, P.L. 2011. Nutritional effect on different growth functions in soybean. *International Journal of Agril. Sciences*. 6 (1):144-149.

Palve D.K., Oza S.R., Jadhav, J. D., Shete, M.B. and Patil, J.B. 2011. Effect of different nutrition on post harvest studies in soybean. *Asian Science*. 1 (1): 51 - 57.

Palve, D.K., Oza, S.R., Jadhav J. D. and Ghule P.L. 2011. Growth studies of soybean under different nutritional requiremrnt. *Advance Research Journal of Crop Improvement*. 02 (01). 086-091

Palve, D.K., Oza, S.R., Jadhav, J. D. and Ghule, P.L. 2011. Studies on physio-chemical properties of soil under nutritional requirement studies in soybean. *Asian Journal of Soil Sciences*. 6 (1):144-149.

Shinde,V.A., Jadhav, J.D., Bawdekar, V.R. and Kadam, J.R. 2011. Model for phenophase prediction in safflower growth using agro meteorological indices sown under different environments of Maharashtra. *Journal of Oilseed Research*. 29 (1): 245-247.

Thorve, S.B., Katwate, M.T. and Jadhav, J.D. 2010. Effect of fertilizer levels on growth parameters of sesamum (*Sesamum indicum* L.) cultivars. *Advance Research Journal of Crop Improvement*. 1(2): 137 - 144

Thorve, S.B., Katwate, M.T. and Jadhav, J.D. 2011. Oil, protein content and uptake studies under varying levels of fertiliser in sesamum cultivars. *Asian Journal of Soil Science*. 6(1): 153-158.

Thorve, S.B., Katwate, M.T. and Jadhav, J.D. 2011. Response of sesamum (*Sesamum indicum* L.) cultivars under varying levels of fertiliser under rainfed. *Asian Journal of soil science*. 6(1): 1 - 10

Technical Bulletins:

Akashe, V.B. and Jadhav, J.D. 2011. Badaltya hawamanat kid rogachi samasya ani upay. MPKV/ EXT/PUB N0. 758/2011. (In Marathi)

Kadam, J.R. and Jadhav, J. D. 2011. Contingency crop planning of 10 Districts of MPKV Rahuri Jurisdiction, Maharashtra. MPKV/RES/PUB No. 39/2011.

Papers presented in Symposium / Conference / Seminar / Workshop:

Jadhav, J. D. , Kathamale, D. K., Bavadekar, V. R. and Kadam, J.R. 2010. Seasonal Rainfall variability and Probability Analysis for efficient crop planning under climate change situation in Scarcity Zone of Maharashtra. Proceedings of the National Symposium on Climate Change and Rainfed Agriculture, 18-20 February 2010, CRIDA, Hyderabad. pp. 41-42.

Kathamale, D.K., Jadhav, J. D. and Kadam, J.R. Contigent crop planning under delayed monsoon condition in rainfed production system of the scarcity zone of Maharashtra. Proceedings of the National Symposium on Climate Change and Rainfed Agriculture, 18-20 February 2010, CRIDA, Hyderabad. pp. 47-48.

Kathmale, D.K., Jadhav, J.D., Yadav, S T. and Kadam, J.R. 2010. ITK-based Rainfall Variability Analysis for Crop Planning under Climate Change Situation in Scarcity Zone of Maharashtra. Proceedings of the National Symposium on Climate Change and Rainfed Agriculture, 18-20 February 2010, CRIDA, Hyderabad pp.34-36.

Popular articles:

Jadhav, J.D. and Kadlag, A.D. 2010. Climate change in Solapur. Smarnika. 23 Dec 2010. ZARS, Solapur.

Patil, S.V. and Jadhav, J.D. 2010. Contingent crop planning under aberrant weather situation. Smarnika. 23 Dec 2010. ZARS, Solapur.

Thrissur

Books:

Rao, G.S.L.H.V.P., Rao, G.G.S.N. and Rao, V.U.M. 2010. Climate Change and Agriculture over India. PHI Learning (Pvt.) Limited, New Delhi. 328p.

Book Chapters:

Rao, G.S.L.H.V.P. and Gopakumar, C.S. and Krishnakumar K.N. 2012. Impacts of climate change in horticulture across India. In: *Adaptation and Mitigation Strategies for Climate Resilient Horticulture.* pp.1-11.

Technical Bulletins:

Rao, G.S.L.H.V.P. and Gopakumar, C.S. 2011. Climate change and its impacts in plantation crops. KAU Publication. 255p.

Rao, G.S.L.H.V.P. and Gopakumar, C.S. 2011. Climate change impacts on monsoon and Indian food grains production. KAU Publication. 92p.

Rao, G.S.L.H.V.P. and Krishnakumar, K.N. 2011. Climate change and coconut productivity in Kerala. KAU Publication. 219p.

Papers presented in Symposium / Conference / Seminar / Workshop:

Rao, G.S.L.H.V.P. and Gopakumar, C.S. and Krishnakumar K.N. 2012. Impact of climate change on agriculture in Kerala. Compendium on Climate Change: Plantations Crops and Spices of Kerala. pp. 91-101

Rao, G.S.L.H.V.P. and Gopakumar, C.S. and Krishnakumar K.N. 2012. Impact of climate change on monsoon onset and monsoon rainfall over Kerala from 1870 to 2011. Proceedings of the OCHAMP 2012, 21-25, February 2012, IITM Pune.

Udaipur

Peer reviewed research papers:

Dashora, L.N. and Solanki, N. S. 2010. Effect of integrated nutrient management on productivity of urdbean under rainfed conditions. *Journal of Food Legumes.* 23 (3 & 4): 249-250.

Solanki , N.S., Mundra, S.L. and Ameta, O.P. 2011. Influence of different weather parameters on population of mustard aphid *(Lipaphiserysimi Kalt.). Indian Journal of Applied Entomology* 25(1):10-14.

Solanki, N.S., Dashora, L.N., Dilip Singh, Jagdish Choudhary. and Dadheech, R.C. 2010. Rainfall Analysis for Crop Planning in Udaipur Region of Rajasthan. *International Journal of Tropical Agriculture.* 28 (1-2): 193-198.

Solanki, N.S., Dilip Singh. and Sumeriya, H. K. 2011. Resources utilization in maize (*Zea mays*) based intercropping system under rainfed condition. *Indian Journal of Agricultural Sciences* 81(6):511-515.

Book chapters:

Solanki, N.S. 2010. Radiation use and rain water use efficiency in maize based intercropping system under rainfed condition. In : *Agrometeorological Services for Farmers.* (Ed. Vyas Pandey). Anand Agricultural University, Anand. pp. 59-66

Technical Bulletins:

Solanki, N.S. and Chouhan, G.S. 2011. Rainfall Features of South-East Rajasthan. Technical Bulletin. MPUAT, Udaipur. 123p.

Popular articles:

MkW- jes'k pUnz nk/khp ,oa **MkW- ukjk;.k flag lksyadh** ¼2010½] 'kq"d [ksrh esa Qly mRiknu c<kus ds mik;A jktLFkku [ksrh&izrki] tqykbZ 2010] 24&26-

9. STAFF POSITION AT COOPERATING CENTERS DURING 2012

Centre	Positions Sanctioned and Filled (F) / Vacant (V)					
	Agro-meteoro-logist	Junior Agronomist	Senior Technical Assistant	Meteoro-logical Observer	Field Assistant	Junior Clerk
Akola	F	-	-	F	F	-
Anantapur	V	F	F	F	F	V
Anand	F	F	V	F	F	F
Bangalore	F	F	V	V	F	F
Bhubaneswar	F	-	-	V	V	-
Bijapur	F	-	-	F	V	-
Dapoli	F	-	-	F	F	-
Faizabad	F	F	F	F	F	F
Hisar	V	F	V	F	F	F
Jabalpur	V	F	F	V	F	V
Jorhat	F	-	-	F	F	-
Kanpur	F	-	-	V	V	-
Kovilpatti	F	F	F	F	F	F
Ludhiana	F	F	F	F	F	F
Mohanpur	F	F	F	V	F	F
Palampur	F	-	-	F	V	-
Parbhani	F	-	-	F	F	-
Ranchi	F	F	V	F	F	F
Ranichauri	F	F	F	F	F	V
Raipur	F	-	-	V	V	-
Rakh Dhiansar	F	-	-	F	F	-
Samastipur	F	-	-	V	F	-
Solapur	F	F	F	V	F	V
Thrissur	F	-	-	F	F	-
Udaipur	F	-	-	F	V	-
Total posts sanctioned	25	12	12	25	25	12
Total posts filled	22	12	08	17	19	08

10. ALL INDIA COORDINATED RESEARCH PROJECT ON AGROMETEOROLOGY

Centre-wise and Head-wise R.E. allocation (Plan) for the year 2011-12

S. No	Name of the center	Pay & Allowances	T.A. Share	Recurring	I.T.	TSP	Total ICAR
1	Akola	1880000	10000	50000	10000		1950000
2	Anand	2930000	10000	50000	10000	1000000	4000000
3	Anantapur	2730000	10000	50000	10000		2800000
4	Bangalore	7260000	10000	50000	10000		7330000
5	Bhubaneshwar	2130000	10000	50000	10000	1000000	3200000
6	Bijapur	1930000	10000	50000	10000		2000000
7	Dapoli	1880000	10000	50000	10000		1950000
8	Faizabad	3930000	10000	50000	10000		4000000
9	Hisar	3330000	10000	50000	10000		3400000
10	Jabalpur	4630000	10000	50000	10000	400000	5100000
11	Jorhat	2270000	10000	50000	10000	300000	2640000
12	Kanpur	1230000	10000	50000	10000		1300000
13	Kovilpatti	2930000	10000	50000	10000		3000000
14	Ludhiana	4430000	10000	50000	10000		4500000
15	Mohanpur	4430000	10000	50000	10000		4500000
16	Palampur	2200000	10000	50000	10000	200000	2470000
17	Parbhani	1830000	10000	50000	10000		1900000
18	Raipur	2830000	10000	50000	10000	1400000	4300000
19	R.Dhiansar	2330000	10000	50000	10000		2400000
20	Ranchi	4730000	10000	50000	10000	600000	5400000
21	Ranichauri	2930000	10000	50000	10000		3000000
22	Samastipur	930000	10000	50000	10000		1000000
23	Solapur	2430000	10000	50000	10000		2500000
24	Thrissur	3190000	10000	50000	10000		3260000
25	Udaipur	2430000	10000	50000	10000	100000	2600000
	Total	**737,50,000**	**2,50,000**	**12,50,000**	**2,50,000**	**50,00,000**	**805,00,000**


Training - cum - Review Meeting of
AICRPAM- NICRA
CRIDA


Dr. VUM RAO
Dr. O.P. BISHNOI


WORKIN GROUP MEETING
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