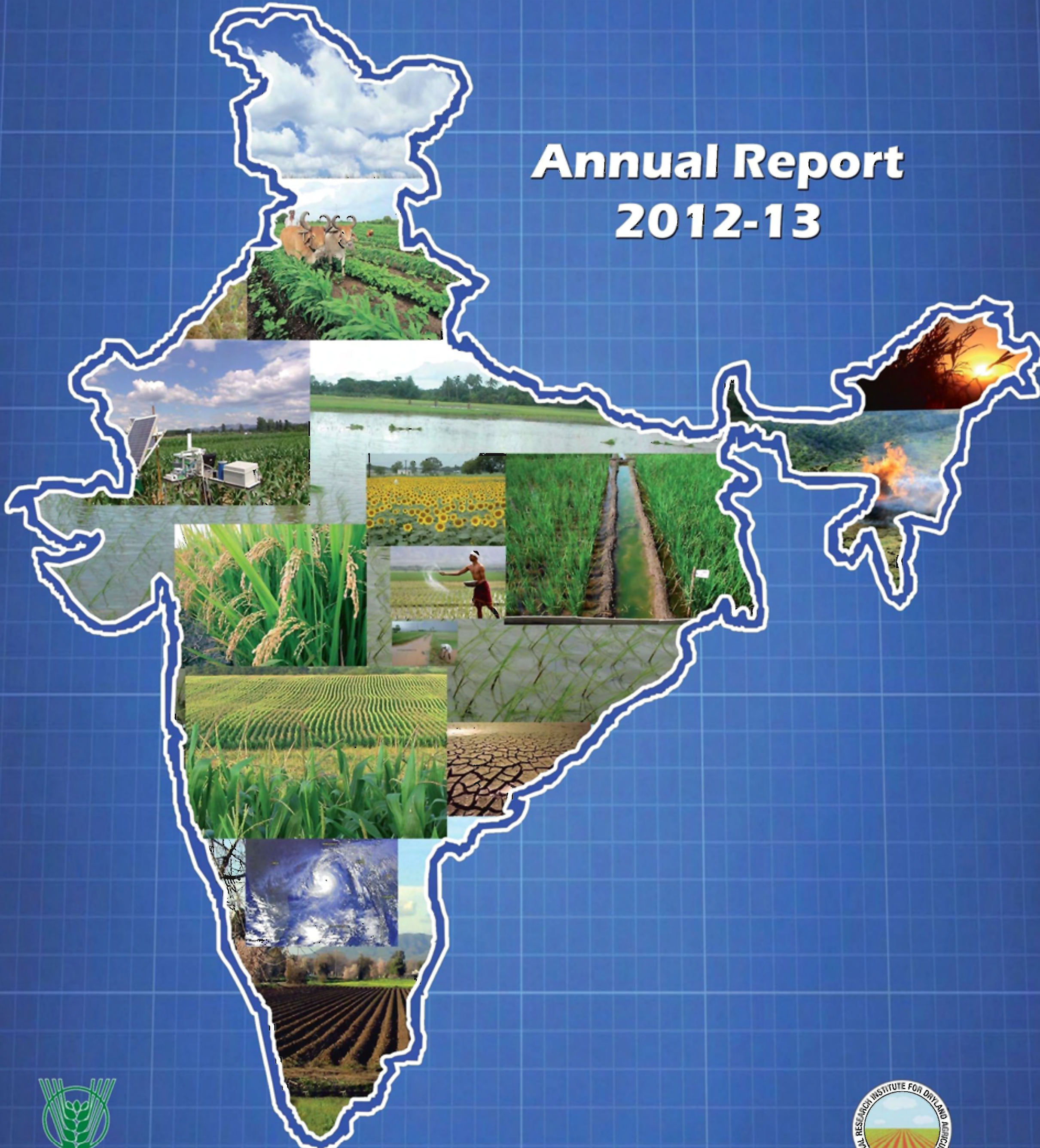
# All India Coordinated Research Project on Agrometeorology



## Annual Report 2012-13

**Central Research Institute for Dryland Agriculture**

(Indian Council of Agricultural Research)

Santoshnagar, Hyderabad - 500 059, Andhra Pradesh

# Co-ordinating Cell

## Scientific

Dr. VUM Rao, Project Coordinator (Agrometeorology)

Dr. P. Vijaya Kumar, Principal Scientist (Agrometeorology)

Dr. B. Bapuji Rao, Principal Scientist (Agrometeorology)

Shri AVM Subba Rao, Scientist Senior Scale (Agrometeorology)

Shri Rajkumar Dhakar, Scientist (Agricultural Physics)

Shri Sarath Chandran MA, Scientist (Agrometeorology) (from 12.04.2013)

## Technical

Shri IR Khandgonda, Senior Technical Officer (Agrometeorology)

## Secretarial

Smt. J. Susheela, Personal Assistant

## Supporting

Shri A. Mallesh Yadav, SSS

## Prepared & Edited by

V.U.M. Rao, B. Bapuji Rao, Raj Kumar Dhakar,
M.A. Sarath Chandran, P. Vijaya Kumar and A.V.M.S. Rao

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## Annual Report 2012-13

**Central Research Institute for Dryland Agriculture**

Santoshnagar, Hyderabad – 500 059, A.P., India

# Contents

# Co-operating Centres

1. Dr. Anil Karunakar, Akola
2. Dr. SN Malleswari Sadhineni, Anantapur
3. Dr. HR Patel, Anand
4. Dr. MB Rajegowda, Bengaluru
5. Dr. S Pasupalak, Bhubaneswar
6. Dr. H Venkatesh, Bijapur
7. Dr. ST Thorat, Dapoli
8. Dr. Padmakar Tripathi, Faizabad
9. Dr. Diwan Singh / Dr. Surendre Singh, Hisar
10. Dr. Manish Bhan, Jabalpur
11. Dr. R Hussain, Jorhat
12. Dr. AP Dubey, Kanpur
13. Dr. A Solaimalai, Kovilpatti
14. Dr. Prabhjyot K. Sidhu, Ludhiana
15. Dr. Saon Banerjee, Mohanpur
16. Dr. Rajendra Prasad, Palampur
17. Dr. MG Jadhav, Parbhani
18. Dr. SR Patel / Dr. J.L. Chaudhary, Raipur
19. Dr. MK Khushu, Rakh Dhiansar
20. Dr. Ramesh Kumar, Ranchi
21. Dr. R.G. Upadhyay, Ranichauri
22. Dr. I.B. Pandey, Samastipur
23. Dr. JD Jadhav, Solapur
24. Dr. B. Ajit Kumar Pillai, Thrissur
25. Dr. NS Solanki, Udaipur

# Preface

The Indian sub-continent is primarily agrarian in nature and depends largely on the performance of monsoon. Weather continues to play a dominant role in agricultural production despite many technological advances made. It is projected that occurrence of extreme weather events are likely to increase further in future due to climate change.

In this background, the All India Co-ordinated Research Project on Agrometeorology (AICRPAM) is playing a significant role in identifying regions vulnerable to climate change, development of adaptation strategies and dissemination of weather-based agro advisories. Along with this, AICRPAM is doing a remarkable job in the manning of 100 Automatic Weather Stations in KVKs spread across the country to develop and disseminate the Agromet advisories at block level. It is also undertaking research on impacts of temperature and change in rainfall patterns on crops through modelling, designing contingency crop plans for different rainfall situations, development of weather insurance products, decision support systems for crop management and forewarning of pests and diseases through its Network Centres located in different agroclimatic zones of the country.

The efforts of the Co-operating Centres of AICRPAM in pursuing the assigned research programs are commendable. Associated information to develop user friendly products and integrated approaches to assess meteorological hazards and extreme event impacts on agriculture and evaluation of potential risks that are useful for insurance organizations are highly desirable. Strong linkage among Research Institutes / SAUs engaged in managing drylands is desirable to minimize the risks associated with weather variability for sustainable production. The Annual Progress report of 2012-13 contain results of research carried out during *kharif* 2012 and *rabi* 2012-13 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)**
Director

# Acknowledgements

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

The untiring efforts made by the Agrometeorologists of all 25 Cooperating Centres in conducting the experiments as per technical program and in bringing out meaningful results made it possible to compile a comprehensive report. Help rendered by my colleagues, B. Bapuji Rao, Rajkumar Dhakar, M.A. Sarath Chandran, P. Vijaya Kumar and AVM Subba Rao 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. The continuous support received from Shri A. Mallesh Yadav is acknowledged.

**(V.U.M. Rao)**
Project Co-ordinator (Ag. Met.)

# 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 25 Agrometeorological Cooperating Centres of the network are Akola, Anantapur, Anand, Bengaluru, Bhubaneswar, Bijapur, Dapoli, Faizabad, Hisar, Jabalpur, Jorhat, Kanpur, Kovilpatti, Ludhiana, Mohanpur, Palampur, Parbhani, Raipur, Rakh Dhiansar, Ranchi, Ranichauri, Samastipur, Solapur, Thrissur and Udaipur. The Quinquinnial 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 2012-14 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
- Effective rainfall, water balance studies (FAO cropwat) and harvestable rainwater for every week

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

## 2) Crop-Weather Relationships (All Centres)

| Centre | *Kharif* Crop(s) | *Rabi* Crop(s) |
|---|---|---|
| Akola | Soybean | Chickpea |
| Anand | Groundnut | Wheat |
| Anantapur | Groundnut | Chickpea (Nandyal) |
| Udaipur | Maize | Wheat |
| Bengaluru | Pigeonpea | Mango |
| Bijapur | Pigeonpea | Sunflower |
| Bhubaneswar | Rice | ---- |
| Dapoli | Rice | Mango |
| Faizabad | Rice | Chickpea |
| Hisar | Clusterbean/Horticulture | Mustard, Wheat |
| Jabalpur | Soybean | Chickpea |
| Jorhat | Rice | Potato |
| Kanpur | Rice | Wheat |
| Kovilpatti | -- | Blackgram, Greengram, Maize |
| Ludhiana | Rice | Wheat |
| Mohanpur | Rice | Potato |
| Palampur | Tea | Wheat |
| Parbhani | Cotton, Soybean | ---- |
| Raipur | Rice | Wheat |

| Centre | *Kharif* Crop(s) | *Rabi* Crop(s) |
|---|---|---|
| Rakh Dhiansar | Maize | Wheat |
| Ranchi | Rice | Wheat |
| Ranichauri | Finger millet | Wheat |
| Samastipur | Rice | Wheat, Winter Maize |
| Solapur | Pearlmillet | Sorghum, Chickpea |
| Thrissur | Coconut, Rice | Vegetables |

## 3) Crop Growth Modelling

Compilation of phenology for every crop species

| Crop | Lead Centres | Associated Centre |
|---|---|---|
| Wheat | Ludhiana | Palampur, Anand, Jabalpur, Rakh Dhiansar, Samastipur, Ranchi, Hisar, Kanpur, Ranichauri |
| Rice | CRIDA | Mohanpur, Samastipur, Dapoli, Faizabad, Thrissur, Bhubaneswar, Jorhat, Ranchi, Kanpur, Jabalpur, Raipur |
| Groundnut | Anand | Anantapur, Bengaluru |

## 4) Weather Effects on Pests and Diseases

| Centre | Crop(s) | Pests/diseases |
|---|---|---|
| Anand | Mustard | Aphids |
| Anantapur | Groundnut | Leaf miner |
| Akola | Soybean | Spodoptera/Semilooper |
| Bengaluru | Groundnut<br>Redgram | Late leaf spot<br>Heliothis |
| Bijapur | Grapes<br>Pomegranate | Powdery mildew, Downy mildew Anthracnose, Bacterial Leaf Blight |
| Bhubaneswar | Rice | Sheath Blight, Blast |
| Faizabad | Chickpea | Pod borer |
| Jabalpur | Chickpea | Heliothis |

| Centre | Crop(s) | Pests/diseases |
|---|---|---|
| Kovilpatti | Cotton<br>Blackgram | Aphids, Leaf hopper<br>Powdery mildew |
| Ludhiana | Cotton | Sucking pests |
| Mohanpur | Mustard<br>Potato | Aphids<br>Late blight |
| Palampur | Mustard<br>Wheat | Aphids<br>Yellow rust |
| Parbhani | Cotton | Mealy bug, Sucking pests |
| Ranchi | Rice | BLB, Stem borer, Blast |
| Ranichauri | Apple<br>Amaranthus | Apple scab<br>Leaf webber |
| Solapur | Sunflower | Leaf eating caterpillar (Heliothis) |
| Raipur | Rice<br>Chickpea | Stem borer, Leaf blast<br>Heliothis |
| Kanpur | Rice<br>Wheat | Blight, Stem borer<br>Blight |
| Thrissur | Rice | Stem borer, Leaf roller |
| Udaipur | Mustard | Aphids |
| Hisar | Mustard | Aphids |
| Rakh Dhiansar | Mustard | Aphids |

## 5) Agromet Advisory Services (All Centres)

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

# 2. Weather conditions during the year 2012

A brief account of the onset, withdrawal and distribution of rainfall during monsoon and post monsoon seasons of the year 2012 in the country and at 25 centres of AICRPAM is presented hereunder:

## Onset of Southwest Monsoon (June – September)

Arrival of southwest monsoon current over the south Bay of Bengal and south Andaman Sea was delayed during this year by 3 days due to non-conducive conditions for the development of convection over the region and it set in over the region on 23rd May. With the strengthening of cross equatorial flow over the Arabian Sea from 4th June, the rainfall activity over Kerala increased and the monsoon set in over Kerala on 5th June. The SW Monsoon also covered entire Kerala, some parts of coastal Karnataka and south Tamil Nadu and some more parts of south & east central Bay of Bengal on 5th June itself.

The advance of SW Monsoon along the west coast of India was very rapid. The monsoon also covered entire northeast India and some parts of Sub-Himalayan West Bengal & Sikkim, thereafter; there was a hiatus of 6 days. Again with the strengthening of the Arabian Sea branch of the monsoon current, the SW monsoon advanced into most parts of peninsular India including interior Maharashtra by 17th June. The eastern branch of the monsoon advanced further and covered Vidarbha, West Bengal & Sikkim and Odisha on 19th June and Chhattisgarh, Jharkhand and Bihar on 21st June.

The shifting of east-west trough at sea level close to foot hills of Himalayas from 25th June–3rd July caused prolonged stagnation of the Northern Limit of Monsoon and there was a hiatus for about 11 days from 22nd June – 2nd July. A break like situation prevailed during 25th - 29th June. Due to the sluggish advance, there was a lag of nearly 2 weeks in the advance of the SW Monsoon over the west central and parts of east Uttar Pradesh for the monsoon rainfall to commence. Heat wave to severe heat wave conditions prevailed over the northern plains during this period.

There had been a rather steady advance from 3rd July and the southwest monsoon covered the entire country on 11th July, 4 days earlier than its normal date of 15th July.

## Rainfall distribution during monsoon season

The actual rainfall during SW monsoon season (June to September) in different sub-divisions of the country during the year 2012 are given in the table below along with respective long period average (LPA) values and deviations from normal.

**Table 2.1: Sub-divisional rainfall during 2012 monsoon season**

| Sl. No. | Centre | Actual | Normal | Excess or deficit | Deviation (%) |
|---|---|---|---|---|---|
| 1 | Andaman & Nicobar Islands | 2055 | 1629 | 426 | 26 |
| 2 | Arunachal Pradesh | 1846 | 1768 | 78 | 4 |
| 3 | Assam & Meghalaya | 1738 | 1793 | -54 | -3 |
| 4 | Naga, Mani, Mizo, Tripura | 1123 | 1497 | -374 | -25 |
| 5 | Sub-Himalayan West Bengal | 2091 | 2006 | 85 | 4 |
| 6 | Gangetic West Bengal | 957 | 1168 | -211 | -18 |
| 7 | Orissa | 1144 | 1150 | -6 | -1 |
| 8 | Jharkhand | 939 | 1092 | -153 | -14 |
| 9 | Bihar Plains | 813 | 1028 | -215 | -21 |
| 10 | East Uttar Pradesh | 799 | 898 | -99 | -11 |
| 11 | West Uttar Pradesh | 548 | 769 | -221 | -29 |
| 12 | Uttarakhand | 1122 | 1229 | -107 | -9 |
| 13 | Haryana, Chandigarh & Delhi | 283 | 466 | -183 | -39 |
| 14 | Punjab | 266 | 492 | -226 | -46 |
| 15 | Himachal Pradesh | 696 | 825 | -129 | -16 |
| 16 | Jammu & Kashmir | 559 | 535 | 24 | 5 |
| 17 | West Rajasthan | 295 | 263 | 32 | 12 |
| 18 | East Rajasthan | 677 | 616 | 61 | 10 |
| 19 | West Madhya Pradesh | 996 | 876 | 120 | 14 |
| 20 | East Madhya Pradesh | 1022 | 1051 | -29 | -3 |
| 21 | Gujarat Region | 647 | 901 | -254 | -28 |
| 22 | Saurashtra & Kutch | 311 | 474 | -162 | -34 |
| 23 | Konkan & Goa | 2818 | 2914 | -97 | -3 |
| 24 | Madhya Maharashtra | 546 | 729 | -183 | -25 |
| 25 | Marathwada | 458 | 683 | -225 | -33 |
| 26 | Vidarbha | 1032 | 955 | 77 | 8 |
| 27 | Chhattisgarh | 1228 | 1147 | 80 | 7 |

| Sl. No. | Centre | Actual | Normal | Excess or deficit | Deviation (%) |
|---|---|---|---|---|---|
| 28 | Coastal Andhra Pradesh | 656 | 581 | 75 | 13 |
| 29 | Telangana | 787 | 755 | 32 | 4 |
| 30 | Rayalaseema | 357 | 398 | -42 | -10 |
| 31 | Tamil Nadu & Pondicherry | 244 | 317 | -74 | -23 |
| 32 | Coastal Karnataka | 3088 | 3084 | 4 | 0 |
| 33 | North int. Karnataka | 326 | 506 | -180 | -36 |
| 34 | South int. Karnataka | 508 | 660 | -152 | -23 |
| 35 | Kerala | 1548 | 2040 | -492 | -24 |
| 36 | Lakshadweep | 1147 | 999 | 149 | 15 |

The season rainfall from 1$^{st}$ June to 30$^{th}$ September 2012 was excess only in one sub division (Andaman & Nicobar Islands) which constitutes 0.3% of the total area of the country, normal in 22 meteorological sub divisions (67% of the total area of the country) and deficient in 13 meteorological sub divisions (32.7% the total area of the country).

In June, deficient or scantly rainfall was observed over most of the sub divisions (27 out of 36). Excess rainfall was observed over 2 sub divisions (Sub Himalayan West Bengal & Sikkim and Assam & Meghalaya) and normal over Andaman & Nicobar Islands, Lakshadweep, Konkan & Goa, Coastal Karnataka, Telangana, Arunachal Pradesh and NMMT (Nagaland, Manipur Mizoram, and Tripura). During July, the rainfall over most of the sub divisions from northwest India except 2 sub divisions (east Uttar Pradesh and Uttarakhand) was deficient or scanty. Other sub divisions that received deficient/ scanty July rainfall were Kerala, all 3 sub divisions from Karnataka, Andaman and Nicobar Islands, sub divisions from Gujarat and NMMT. The remaining 19 sub divisions received normal and 2 sub divisions (west Madhya Pradesh and Rayalaseema) excess rainfall. In August, rainfall activity picked up and rainfall over 19 sub divisions was normal and 7 sub divisions received excess rainfall. However, the August rainfall in 10 sub divisions (mostly from east and northeast India and Gujarat along with Marathwada) was deficient or scanty. In September, normal/excess rainfall was observed over 28 sub divisions. However, NMMT, Haryana, west Uttar Pradesh and 5 sub divisions from interior and eastern part of south Peninsula were deficient. Gujarat state was deficient/scanty during the first 3 months and excess in September. There were only three sub divisions (Konkan & Goa, Telangana and Arunachal Pradesh) that were normal/excess throughout the season.

## Flood situation

Incessant rainfall associated with the monsoon low pressure systems and active monsoon conditions in the presence of strong cross equatorial flow and deep monsoon trough, often caused flood situations over various states during different parts of the season. Some of the sub-divisions/states which experienced flood situations are Arunachal Pradesh, Assam, West Bengal & Sikkim, Jammu & Kashmir, Uttar Pradesh, Gujarat, Madhya Pradesh, Rajasthan, coastal Karnataka and Kerala.

## Withdrawal of monsoon

The southwest monsoon withdrew from extreme parts of west Rajasthan on 24th September with a delay of more than 3 weeks as the normal date of withdrawal from extreme western parts of Rajasthan is 1st September. On the same day, it also withdrew from some parts of northwest India, Saurashtra & Kutch and north Arabian Sea. It further withdrew from some more parts of northwest India, Gujarat State, west Madhya Pradesh on 26th September and from most parts of Uttar Pradesh, some parts of Bihar, some more parts of Madhya Pradesh and Gujarat on 8th October.

## Post-monsoon (October - December) rainfall

From the sub-divisional wise Post- Monsoon (October – December) season rainfall it was noticed that rainfall was excess in 2 sub-divisions, *viz.* Telangana and Coastal Andhra Pradesh; normal in 13 sub-divisions, *viz.*, Arunachal Pradesh, Assam & Meghalaya, Gangetic West Bengal, Jharkhand, Odisha, Chhattisgarh, Konkan & Goa, Madhya Maharashtra, Rayalaseema, Coastal Karnataka, North interior Karnataka, Tamil Nadu & Pondicherry and Andaman & Nicobar Islands; deficit in 9 sub-divisions *viz.*, Jammu & Kashmir, Nagaland, Manipur, Mizoram, Tripura, Sub-Himalayan West Bengal & Sikkim, Bihar, Vidarbha, Marathwada, South Interior Karnataka, Kerala and Lakshadweep; and scanty / no rain in remaining 12 sub-divisions.

During the year, 2 out of 25 centers of the All India Coordinated Research Project on Agrometeorology, *viz.*, Raipur and Jammu received excess rainfall, 13 centers received normal rainfall and remaining 10 centers received either deficit / scanty rainfall (Table 2.2).

**Table 2.2: Annual rainfall at different AICRPAM centers during 2012**

| S.No. | Centre | Actual | Normal | % Departure |
|---|---|---|---|---|
| 1 | Akola | 737 | 846 | -9 |
| 2 | Anand | 883 | 853 | 3 |
| 3 | Anantapur | 446 | 567 | -21 |
| 4 | Bengaluru | 572 | 914 | -37 |

| S.No. | Centre | Actual | Normal | % Departure |
|---|---|---|---|---|
| 5 | Bhubaneswar | 1240 | 1549 | -20 |
| 6 | Bijapur | 526 | 594 | -12 |
| 7 | Dapoli | 3654 | 3625 | 1 |
| 8 | Faizabad | 878 | 1001 | -12 |
| 9 | Hisar | 507 | 452 | 12 |
| 10 | Jabalpur | 1354 | 1253 | 8 |
| 11 | Jorhat | 1776 | 1824 | -3 |
| 12 | Kanpur | 733 | 867 | -15 |
| 13 | Kovilpatti | 393 | 732 | -46 |
| 14 | Ludhiana | 497 | 733 | -32 |
| 15 | Mohanpur | 1345 | 1607 | -16 |
| 16 | Palampur | 2559 | 2324 | -10 |
| 17 | Parbhani | 688 | 963 | -29 |
| 18 | Ranchi | 1100 | 1389 | -21 |
| 19 | Ranichauri | 1307 | 1243 | 5 |
| 20 | Raipur | 1717 | 1173 | 46 |
| 21 | Rakh Dhiansar | 1421 | 1117 | 27 |
| 22 | Samastipur | 880 | 1235 | -29 |
| 23 | Solapur | 534 | 711 | -25 |
| 24 | Thrissur | 1736 | 2782 | -38 |
| 25 | Udaipur | 693 | 617 | 12 |

# 3. Agroclimatic Characterization

Characterization of crop growing environment is a pre-requisite in crop planning and evolving strategies to overcome climate /weather induced changes in the meso / micro climate. Anomalies in climatic variables need to be properly understood to make agricultural sector resilient. Thus, historic data on climatic variables have to be analyzed using appropriate statistical tools enabling the development of location specific technologies / adaptative strategies. The analysis carried out by different centers on the agroclimatic characterization is reported hereunder:

## Anand

Mean seasonal maximum temperatures during winter, summer, monsoon, post monsoon seasons as well as on annual basis were analyzed using long term data and maps on their spatial distribution are presented in Fig. 3.1. Mean maximum temperature of winter season over Gujarat state ranges between 25 to 31°C. Parts of Banaskantha, Mehsana, Ahmedabad, Junagadh, Jamnagar and Kutch districts experience cooler temperatures compared to other parts of the state during winter season. During summer season, Banaskantha was found to be the hottest district in the state. During this season, parts of South Gujarat and coastal areas of Saurashtra and Kutch regions experience cool weather compared to other regions. Almost a similar trend was observed during monsoon and post-monsoon seasons. The mean annual maximum temperature of the state ranges between 29 to 36°C with Vav, Thrad and Radhanpur blocks of Banaskantha district experiencing highest mean annual temperatures. On the other hand, parts of South Gujarat, coastal area of Saurashtra and Kutch remain cool as compared to other places.

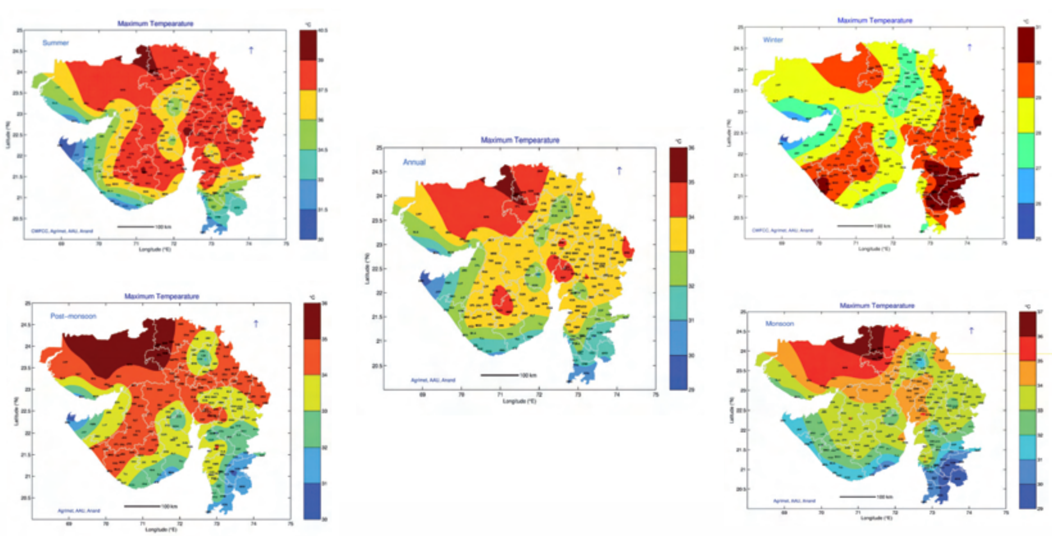


**Fig. 3.1:** Spatial distribution of mean maximum temperature of winter, summer, monsoon, post-monsoon seasons and on annual scale in Gujarat.

## Akola

Long term monthly, seasonal and decadal rainfall data (1901-2011) of different districts of Vidarbha region were analyzed using Mann-Kendall trend test to detect any changes in rainfall patterns.

## Monthly rainfall

A significant decreasing trend was observed in July rainfall in Chandrapur and Bhandara districts; in September rainfall in Yavatmal and Chandrapur districts. A significant increasing trend in June rainfall was observed in Gondia and Gadchiroli districts. August month's rainfall showed increasing trend across majority of the districts except Bhandara and Gondia (Table 3.1).

**Table 3.1. District-wise monthly rainfall trend (slope values) in Vidarbha region (1901-2011)**

| District | June | July | August | September | Rainfall during South west monsoon | |
|---|---|---|---|---|---|---|
| | | | | | Mann-Kendall test statistic | Trend |
| Akola | -0.24 | -0.79 | +2.96*** | -0.72 | +0.44 | + |
| Amravati | -1.07 | -0.46 | +2.44** | -1.17 | +0.25 | + |
| Buldana | -1.00 | -0.92 | +2.84*** | -1.25 | -0.31 | - |
| Washim | 0.32 | -0.47 | 1.5 | -1.10 | +0.32 | + |
| Yavatmal | -0.20 | -1.33 | +1.88* | -1.95* | -0.75 | - |
| Wardha | -1.17 | -1.41 | +1.69* | -1.61 | -1.61 | - |
| Nagpur | -1.17 | -0.58 | 0.21 | -1.10 | -1.36 | - |
| Chandrapur | -0.24 | -1.93* | 1.11 | -1.67* | -1.37 | - |
| Bhandara | -0.88 | -1.91* | -1.72* | -1.04 | -3.22*** | - |
| Gondia | 0.23 | -0.25 | -0.61 | -0.48 | -0.67 | - |
| Gadchiroli | 1.01 | -0.78 | +1.87* | -1.40 | +0.07 | + |

(+ Increasing trend; - Decreasing trend)

(* Significant at p=0.1; ** Significant at p=0.05; *** Significant at p= 0.01)

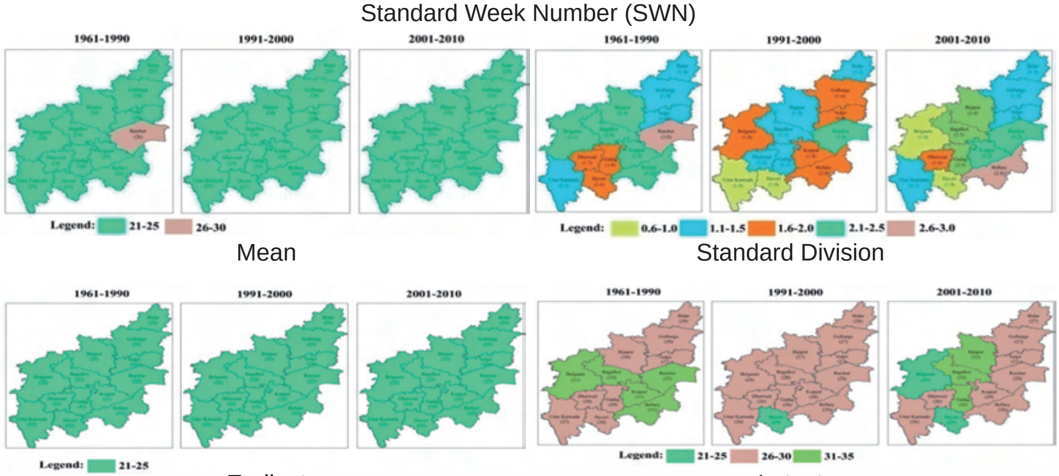
## Monsoon season rainfall

Out of the 11 districts, 10 districts did not show statistically significant trend in monsoon rainfall. Bhandara district only showed statistically significant (0.01) decreasing trend. Among the remaining districts, non-significant increasing trend was noticed in Akola, Amravati, Washim and Gadchiroli districts, and in Buldana, Yavatmal, Wardha, Nagpur, Chandrapur and Gondia districts a non-significant decreasing trend was observed (Table 3.1).

## Bijapur

Changes in the time of onset and end of rainy period, duration of rainy period and their variability during the periods 1961-90, 1991-2000 and 2001-2010 at the district level are presented in Fig. 3.2. It could be noticed that the mean onset of monsoon is delayed by one week (25th SMW) in the northern dry zone districts (Bijapur, Bagalkot, Gadag, Bellary etc), while it is advanced to 23rd SMW in the districts of northern transition zone (Belgaum and Dharwad). Standard deviation of onset of rainy season has also increased in the drier districts than those in the northern transition zone. Thus, there is more instability in the time of onset of rainy season in the districts of northern dry zone, which is also indicated by the delay in the latest onset week. The end of rainy season is advanced to 44th SMW in most of the districts of north Karnataka. However, the variability of end of rainy season has increased in Bagalkot, Dharwad and Haveri districts. Of particular importance is the earliness experienced in the end of rainy season in Uttara Kannada district. Also of significant importance is the duration of the rainy period. While there were only three districts each in 1961-90 and 1991-2000 which experienced rainy period with duration of 18-20 weeks, there are now nine districts that experienced reduced duration in the decade 2001-2010. Bijapur and Bagalkot districts showed highest standard deviation of 5 weeks duration of rainy period.

District wise onset of rainy season in Northern Karnataka
Standard Week Number (SWN)



District wise end of rainy season in Northern Karnataka
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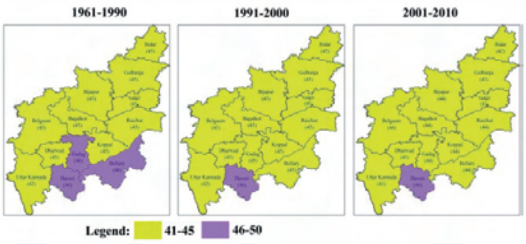
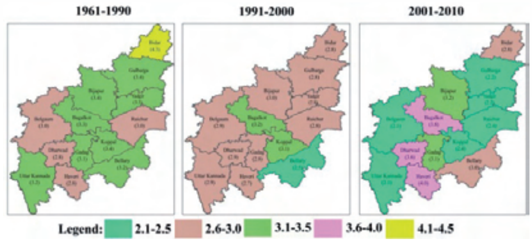
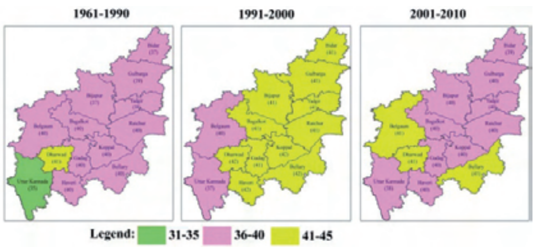


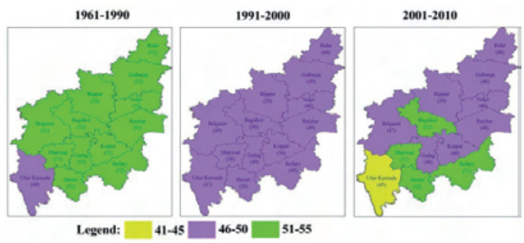

Mean




Standard Division

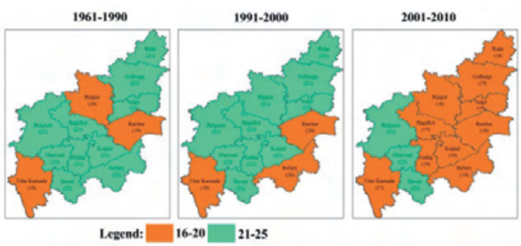



Earliest

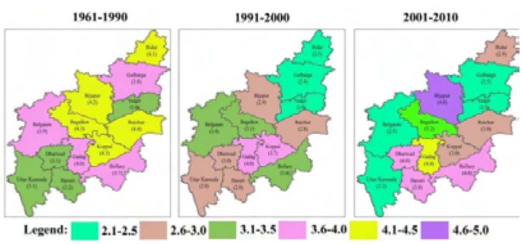



Latest

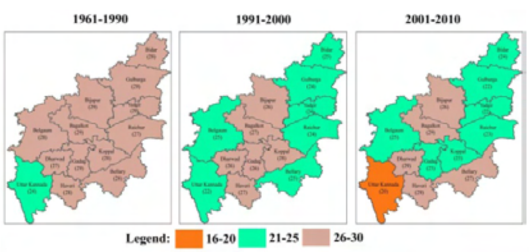
District wise duration of rainy season in Northern Karnataka
Standard Week Number (SWN)



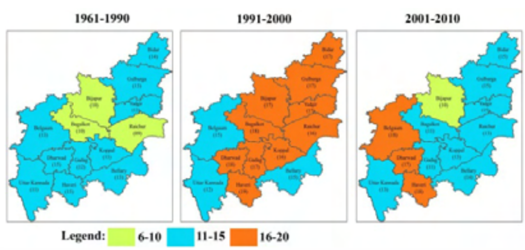

Mean




Standard Division




Maximum




Minimum

**Fig. 3.2:** Changes in onset, end and duration of rainy season at district level in northern Karnataka

## Bengaluru

Potential evapotranspiration (PET) on a daily basis was estimated by Penman's method. Monthly PET values were determined from the daily values. Trends in monthly PET over the period 1979-2011 (Fig. 3.3) showed that the mean monthly PET values for February, March, April, May and December months had a significant decreasing trend.

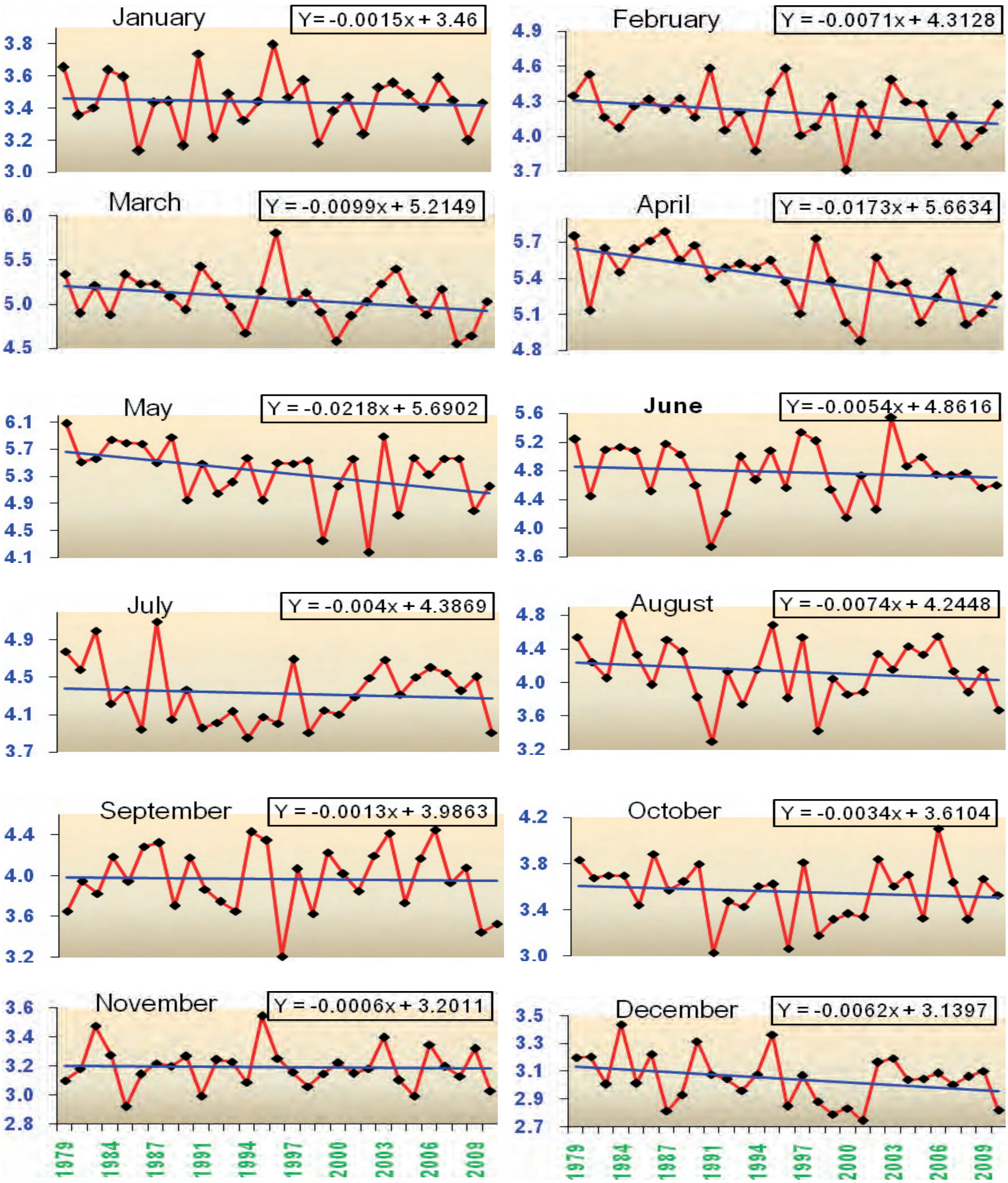



**Fig. 3.3:** Mean monthly PET for different months at Bengaluru.

## Variability in length of growing period

Data from field experiments for the period 1987-88 to 2012-13 were used to determine the variability in the length of growing period (LGP). The LGP for the crops sown in different SMW with the corresponding mean rainfall conditions are presented in Table 3.2. The probability of a particular SMW to be a wet week is also worked out and presented. Though the average length of LGP was highest in case of sowing in 26th SMW but the probability of getting rain during this week is relatively low thus making the week more risky for sowing. Range and average rainfall over different sowing weeks along with probability of sowing week being wet in the growing season *i.e.*, from sowing to harvest is presented in Table 3.3.

**Table 3.2:** Particulars of LGP (days) and rainfall recorded during different SMW at Bengaluru

| SMW | LGP (days) | | | | Rainfall (mm) | | | |
|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean | Variability | Max | Min | Mean | P(W) |
| 26 | 130 | 157 | 147 | 12 | 47.6 | 0.0 | 8.2 | 0.256 |
| 27 | 120 | 164 | 140 | 15 | 135.4 | 0.0 | 17.9 | 0.436 |
| 28 | 116 | 142 | 127 | 9 | 106.4 | 0.0 | 25.0 | 0.641 |
| 29 | 118 | 138 | 127 | 9 | 150.1 | 0.0 | 24.6 | 0.564 |
| 30 | 119 | 141 | 132 | 9 | 101.8 | 0.0 | 26.9 | 0.718 |
| 31 | 121 | 157 | 143 | 11 | 146.0 | 0.0 | 31.1 | 0.769 |

**Table 3.3:** Details on rainfall range during crop growing season with corresponding probabilities at Bengaluru

| Sowing period (SMW) | Harvest period (SMW) | Rainfall range (mm) | Mean | RF probability range |
|---|---|---|---|---|
| 26 | 47 | 335.4-1137.4 | 670.7 | 0.231-0.795 |
| 27 | 46 | 332.4-1113.8 | 647.5 | 0.256-0.795 |
| 28 | 46 | 327.8-1104.6 | 625.5 | 0.282-0.795 |
| 29 | 47 | 307.0-1066.4 | 616.5 | 0.231-0.795 |
| 30 | 48 | 307.4-1048.2 | 601.2 | 0.128-0.795 |
| 31 | 51 | 273.8-1030.6 | 587.7 | 0.077-0.795 |

It was inferred that the probability of wet week above 0.5 is during 28th SMW to 45th SMW and the crop sown during 28th SMW can produce normal yield. Although northeast monsoon ceases by 45th SMW, the moisture stored in soil profile can support the crop during harvesting stage for 4-5 weeks *i.e.*, up to 49th or 50th week. Crop sown during 31st SMW still has about 130 to 135 days till 50th SMW. Therefore, period from 28th to 50th SMW can be considered as the mean LGP for this station with a SD of nine days. On the other hand, if sowing is advanced by two weeks (26th SMW), SD becomes 15 days. Similarly, if sowing is delayed by 4 weeks (upto 32nd SMW) then LGP will have a SD of 11 days. Thus, the crop sown during 28th to 30th SMW, experience LGP with a low SD (nine days). Hence, the period from 28th to 48th SMW is the mean LGP for this station. The yield also showed that the crop sown during 28th to 30th SMW recorded considerably higher yields compared to early or late sown crop.

# Dapoli

## Trends in temperature anomalies

Inter-annual variations in maximum and minimum temperature anomalies for the period 1983 to 2012 at Dapoli are presented in Fig. 3.4. During the recent periods (2002-2012) anomalies in maximum temperatures always remained positive. An increasing trend in maximum temperature and minimum temperature was noticed during this current decade. Prior to 2001 anomalies were largely negative in case of both maximum and minimum temperatures. Similar trend was also observed in case of mean temperature.

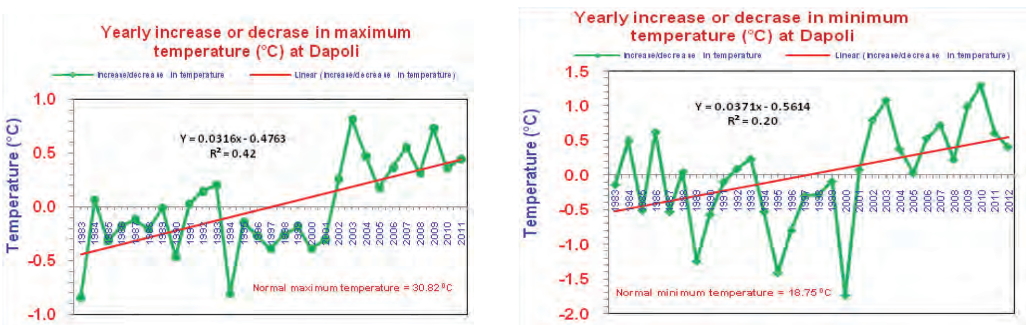



**Fig. 3.4:** Trends in maximum and minimum temperature anomalies at Dapoli

## Onset and withdrawal of monsoon

Time of the onset and withdrawal of monsoon at any given place is important for crop planning. Data for a period of 39 years (1973-2012) were used to determine the mean week of onset and withdrawal of monsoon at Dapoli and their inter-annual variability (Fig. 3.5). The mean week of commencement of monsoon at Dapoli is found to be 23rd SMW (4th to 10th June) and the 6th June is the most probable date of onset of monsoon. It was observed that the monsoon withdraws latest by 40th SMW (1st to 7th October) and 5th October can thus be considered as the date of withdrawal of monsoon.

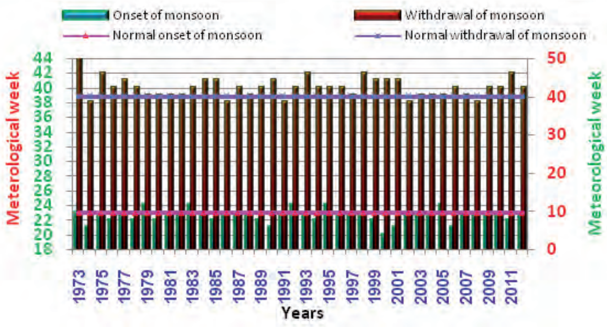



**Fig. 3.5:** Variability in onset and withdrawal of monsoon at Dapoli

## Hisar

Historic data (1980-2010) on extreme weather events like frost, fog and dew were analyzed for their frequency distribution (Table 3.4). On an average, Hisar region had 6 frost events, 22 fog events and 127 dew events during the winter/*rabi* seasons. Maximum number of frost events (29) and fog events (49) were recorded during the winter season of year 2007-08. The maximum number of dew events (168) occurred in early 80s thereafter showing a decreasing trend in the region. An increasing trend in frost as well as fog occurrences and a slight decreasing or no trend in dew occurrences over the reported period was noticed.

**Table 3.4: Occurrence of frost, fog and dew events at Hisar during 1980-2010 period**

| Time Series → Events | 1980-90 | 1991-00 | 2000-10 | 1980-2010 |
|---|---|---|---|---|
| Frost - Highest | 6 (1985-86, 1986-87)* | 18 (1996-97) | 29 (2007-08) | 29 (2007-08) |
| Lowest | 0 (6 seasons) | 0 (1992-93) | 0 (08-09,09-10) | 0 |
| Average | 2 | 8 | 7 | 6 |
| Fog - Highest | 18 (1981-82) | 41 (1998-99) | 49 (2007-08) | 49 (2007-08) |
| Lowest | 2 (1983-84) | 13 (1990-91) | 16 (2005-06) | 2 (1983-84) |
| Average | 11 | 22 | 34 | 22 |
| Dew - Highest | 168 (82-83, 83-84) | 150 (1994-95) | 150 (2004-05) | 168 (82-83, 83-84) |
| Lowest | 116 (1989-90) | 97 (1998-99) | 67 (2009-10) | 67 (2009-10) |
| Average | 144 | 116 | 122 | 127 |

***** years of occurrence

## Jabalpur

Temporal variability in onset, withdrawal and frequency of rainy days at Jabalpur during the SW monsoon for the period of 1967-2012 is presented in Fig. 3.6. Onset of monsoon over the last 36 years varied from 1st June to 13th July with a mean date of 15th June. Withdrawal of monsoon varied from 11th August to 27th October with a mean date of 15th September. Analysis showed that mean duration of monsoon is 94 days with a CV of 18% while mean number of rainy days are 51 with a CV of 19%. Further, it was also observed that if monsoon sets in early, the number of rainy days are more and duration of monsoon is longer and *vice-a-versa* (Table 3.5). It can be concluded from the study that early onset of monsoon result in its delayed withdrawal.

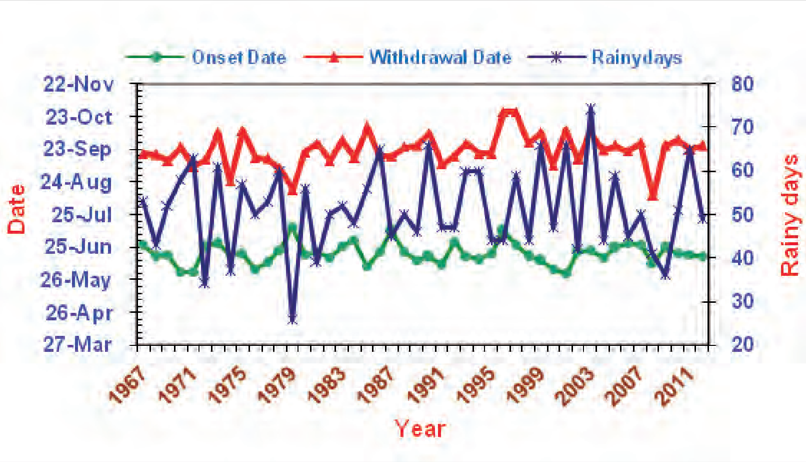



**Fig. 3.6:** Onset, withdrawal of SW monsoon with number of rainy days during 1967-2012 period at Jabalpur

**Table 3.5: Mean rainy days and duration of monsoon as related to the onset of monsoon in different fortnights at Jabalpur**

| Onset of monsoon | Rainy days | Duration |
|---|---|---|
| 1st FN of June | 54.07 | 102.07 |
| 2nd FN of June | 51.7 | 94.6 |
| 1st FN of July | 40.75 | 72 |

# Jammu

## Spatial distribution of temperature and humidity over Jammu province

Daily temperature and humidity data of Jammu province were analyzed and the spatial distribution of normal annual maximum, minimum temperature and RH with their isolines (isotherms and isohumes) are presented in Fig. 3.7. Mean annual maximum and minimum temperature of the province are 21.5°C and 8.5°C, respectively. High temperature zone is on the south-west end of the province with a mean annual maximum temperature greater than 28°C. Excluding this part of the province, most of the sub tropical zone has mean annual maximum temperatures ranging from 22.0°C to 28.0°C. Such wide variations in mean annual maximum temperature were absent in the intermediate zone which has the temperatures ranging from 20°C to 22°C with few exceptions where temperatures are less than 20°C. The mean annual minimum temperature in the intermediate zone has very less variance as clearly evident from the map that only two isotherms 8°C and 10°C are covering the entire zone whereas in sub tropical zone the variations are severe with the mean minimum temperature touching 10°C and exceeding 16°C.

Relative humidity (RH) directly influences the water condition of plant and indirectly affects leaf growth, photosynthesis, pollination, occurrence of diseases and finally economic yield. Normal annual mean relative humidity showed a notable spatial variation across the Jammu province. Mean relative humidity over the entire province is almost uniform except over the south-western dry sub humid part where it goes below 65%. Across Poonch and majority of Rajouri district mean relative humidity is above 70%. The mean RH values of the province ranges between 65% to 70%.

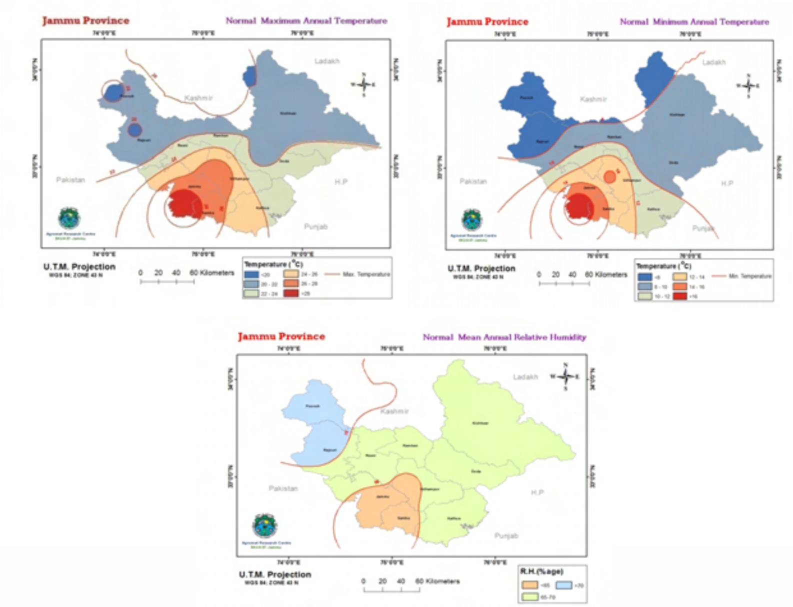



**Fig 3.7:** Spatial distribution of mean annual maximum, minimum temperatures and relative humidity over Jammu province.

## UV-B Radiation

Diurnal variation in ultraviolet-B radiation (280-320nm) recorded on three different dates *viz.*, 22nd June 2012, 11th Nov 2012 and 7th Jan 2013 under different environmental conditions like highest day temperature, lowest day temperature and cloudy day (8 octa), respectively were studied and the diurnal pattern is presented in Fig. 3.8. From the figure it can be noticed that UV-B radiation was high coinciding with high day time, temeperature and *vice-a-versa*. However, the UV-B radiation was more on cloudy day than the day with lowest temperature. The diurnal variation in UV-B radiation is thus not governed by temperature alone. If it is governed by temperature solely, peak UV-B radiation would have occurred during 1400 -1500 hours when air attains the maximum temperature during the day. However, peak UV-B radiation was observed at noon.

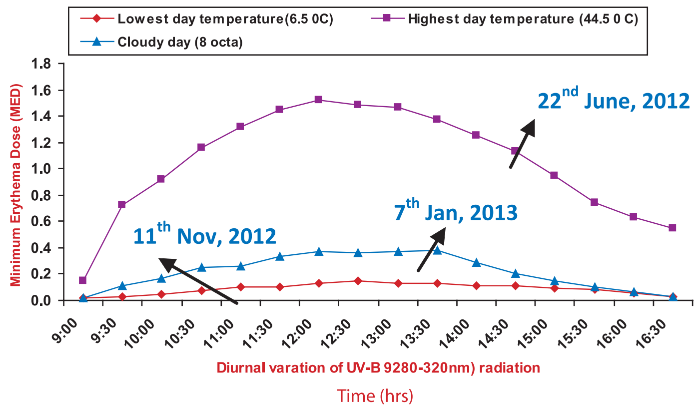



**Fig. 3.8:** Diurnal variation in UV-B radiation (280 - 320 nm) recorded under different weather conditions at Jammu.

# Kanpur

## Trends in annual maximum and minimum temperatures

The long term annual maximum and minimum temperature data (1971 - 2012) of Kanpur were analyzed to detect any change in the temperatures. The variabilities in maximum and minimum temperatures are presented in Fig.3.9. The mean annual maximum and minimum temperatures of Kanpur are 31.3°C and 18.7°C with variabilities of 2.1 and 3.3 per cent, respectively. The trend fitted showed that there is an increasing trend @ 0.23°C / decade in the annual maximum temperature and decreasing trend @ -0.16°C/ decade in minimum temperature. The five year moving average of temperatures depicted in figure shows that annual maximum temperature was below the long term average during 1971 to 1986 period and minimum temperature was above the long-term normal during the very recent pentad *i.e.*,1997-2012.

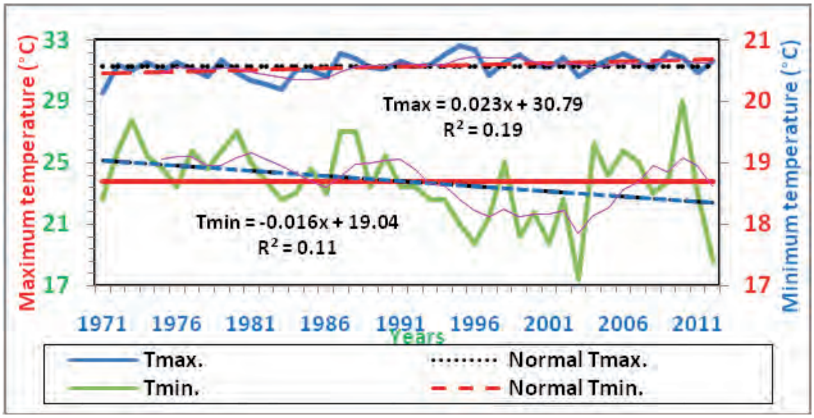



**Fig. 3.9:** Trends in annual maximum and minimum temperatures during 1971 to 2012 period at Kanpur

## Onset and withdrawal of monsoon

The onset and withdrawal of monsoon for different zones of central U.P. was analyzed and presented in Table 3.6. The data showed that southwest monsoon sets in three days later over southwest semi-arid zone as compared to central plain zone (20th June) and has high variability (4.58%) as compared to other two zones. Normal date of withdrawal of monsoon from Central plain and Bundhelkhand zone was 26th September which is one day later than southwest semi-arid zone and length of rainy season for this region is three days more than southwest semi-arid.

**Table 3.6: Onset and withdrawal pattern of monsoon over central Uttar Pradesh**

| Agroclimatic zone | Onset of monsoon | SD | CV% | Withdrawal of monsoon | SD | CV% | Length of rainy season | SD | CV% |
|---|---|---|---|---|---|---|---|---|---|
| Central plain | 20 June | 9.19 | 5.38 | 26 Sept. | 11.95 | 4.55 | 98 | 12.80 | 13.16 |
| Bundhelkhand | 21 June | 7.81 | 4.55 | 26 Sept. | 10.45 | 3.90 | 97 | 14.83 | 15.33 |
| Southwest Semi-arid | 23 June | 7.97 | 4.58 | 25 Sept. | 9.88 | 3.68 | 95 | 14.01 | 14.82 |

## Kovilpatti

Rainfall recorded at different locations of Tirunelveli district was analyzed to study its pattern during NE monsoon as well as on annual basis. LGP worked out for these locations along with rainfall and number of rainy days are presented in Table 3.7. Average rainfall of the district is 815.9 mm over 43.7 mean rainy days. On an annual basis, Ayykudi receives lowest (304.7 mm) and Shenkottai receives highest (2939.8 mm) rainfall. Places like Ambasamuthiram, Gatana nadhi, Kannadian Anaicut, Manimuthar, Panagudi, Ramanadhi, Shenkottai and Sivagiri receives rainfall above the district average. During NE monsoon season, the district on an average receives 472.7 mm with Shenkottai receiving highest (686.1 mm) and Pazhavoor receiving lowest (322.6 mm). Length of growing period in the district ranges from 7 to 45 weeks with a mean value of 12.9 weeks. LGP is highest at Shenkottai and lowest at Ayykudi.

**Table 3.7: Rainfall pattern and LGP at different locations of Tirunelveli district**

| S. No. | Place | Annual rainfall (mm) | | | Annual rainy days | NE monsoon (mm) | Growing period (weeks) |
|---|---|---|---|---|---|---|---|
| | | Lower | Mean | Higher | | | |
| 1. | Azhagiyapandi-yapuram | 386.6 | 712.61 | 1142.2 | 38.25 | 468.85 | 13 |
| 2. | Alankulam | 515.0 | 768.12 | 1255.8 | 45.53 | 464.35 | 13 |
| 3. | Ambasamuthiram | 524.0 | 936.53 | 1594.0 | 50.73 | 580.82 | 12 |
| 4. | Ayykudi | 304.7 | 652.66 | 1372.3 | 40.86 | 370.2 | 7 |
| 5. | Cheranmahadevi | 370.7 | 727.43 | 1348.1 | 39.17 | 448.27 | 10 |
| 6. | Gatana nadhi | 692.3 | 1066.18 | 1491.0 | 60.52 | 653.13 | 11 |
| 7. | Kalakadu | 484.6 | 788.2 | 1103.2 | 47.00 | 508.99 | 9 |
| 8. | Kannadian Anaicut | 429.3 | 830.88 | 1255.7 | 45.1 | 555.09 | 11 |
| 9. | Karuppanadhi | 340.0 | 638.77 | 1288.0 | 42.76 | 353.47 | 9 |
| 10. | Manimuthar | 528.7 | 982.07 | 1786.8 | 50.14 | 633.4 | 11 |
| 11. | Nanguneri | 370.2 | 651.6 | 1147.6 | 39.24 | 400.24 | 11 |
| 12. | Palayankottai | 447.6 | 706.25 | 1054.4 | 40.24 | 418.21 | 11 |
| 13. | Panagudi | 560.8 | 1106.07 | 2311.3 | 47.78 | 621.28 | 39 |
| 14. | Pazhavoor | 375.0 | 747.33 | 1042.0 | 35.45 | 322.58 | 10 |
| 15. | Radhapuram | 306.6 | 712.61 | 1594.0 | 33.66 | 379.83 | 8 |
| 16. | Ramanadhi | 409.0 | 828.91 | 1705.5 | 48.83 | 497.04 | 9 |
| 17. | Sankarankovil | 322.8 | 676.4 | 1335.2 | 37.41 | 422.28 | 8 |
| 18. | Shenkottai | 854.4 | 1515.51 | 2939.8 | 72.48 | 686.10 | 45 |
| 19. | Sivagiri | 364.8 | 903.68 | 1696.3 | 44.55 | 520.59 | 12 |
| 20. | Tenkasi | 425.0 | 778.61 | 1395.5 | 51.03 | 368.55 | 9 |
| 21. | Thiruvenkadam | 411.2 | 689.52 | 1520.5 | 20.25 | 365.14 | 8 |
| 22. | Tirunelveli | 409.0 | 564.74 | 987.0 | 35.83 | 328.87 | 9 |
| 23. | Vasudevanallur | 577.8 | 782.21 | 1204.6 | 37.94 | 503.73 | 11 |
| | **District average** | **264.4** | **815.9** | **1459.6** | **43.68** | **472.65** | **12.9** |

## Ludhiana

Using long-term daily data of pan evaporation of different locations of Punjab, seasonal and annual trends were worked out and presented in Table 3.8. Pan evaporation showed a decreasing trend in the past four decades. Annual, *kharif* season and *rabi* season pan evaporation rates were decreased by 0.06, 0.09 and 0.03 mm/year, respectively at Ballowal Saunkhri; 0.02, 0.03 and 0.01 mm/year, respectively at Ludhiana; and 0.01, 0.06 and 0.007 mm/year, respectively at Bathinda.

**Table 3.8: Trends in Open pan evaporation for different time periods at different locations in Punjab**

| Station | Annual | $R^2$ | *Kharif* | $R^2$ | *Rabi* | $R^2$ |
|---|---|---|---|---|---|---|
| Open pan evaporation (slope of regression = mm /calendar year) | | | | | | |
| Ballowal Saunkhri (1984-2011) | Y = -0.0635x + 131.41 | 0.87* | Y = -0.0914x + 188.32 | $R^2$ = 0.90* | Y = -0.0306x + 64.48 | 0.61* |
| Ludhiana (1970-2011) | Y = -0.0237x + 51.934 | 0.51* | Y = -0.0319x + 69.72 | $R^2$ = 0.61* | Y = -0.0168x + 36.668 | 0.30* |
| Bathinda (1977-2011) | Y = -0.0155x + 36.218 | 0.17* | Y = -0.0656x + 138.42 | 0.63* | Y = -0.0079x + 19.369 | 0.02 |

The decade wise analysis of number of rainy days revealed that a decreasing trend over the past four decades at the locations studied was observed (Table 3.9). During 1990-99 and 2000-09, Ballowal Saunkhri experienced maximum number of rainy days compared to Amritsar. The current decade witnessed lowest number of rainy days at all locations studied.

**Table 3.9: Decadal frequency distribution of rainy days at different locations of Punjab**

| Period | Ballowal Saunkhri | Amritsar | Jalandhar | Ludhiana | Patiala | Bathinda |
|---|---|---|---|---|---|---|
| 1970-79 | - | 388 | 415 | 363 | 362 | - |
| 1980-89 | - | 400 | 388 | 391 | 377 | 268 |
| 1990-99 | 559 | 458 | 539 | 429 | 409 | 314 |
| 2000-09 | 473 | 347 | 397 | 371 | 323 | 245 |

## Mohanpur

Spatial distribution of monthly reference crop evapotranpiration ($ET_0$) estimated by employing FAO Penman - Monteith method for the month of January, April, July and October 2012 are presented in Fig. 3.10. In southern West Bengal, the highest $ET_0$ was observed in April, followed by October month. In July, $ET_0$ is relatively low. The magnitude of $ET_0$ varied from 5.5 to 6.4 mm per day on monthly average basis. It was observed that Northern Bengal experiences low $ET_0$ rates even during summer and monsoon season.

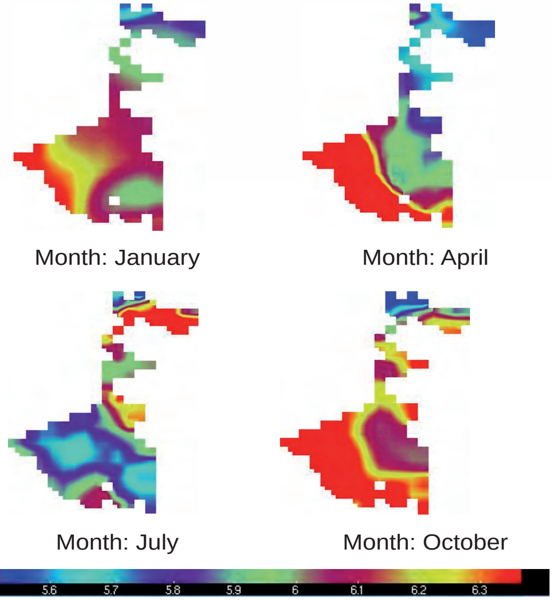



**Fig. 3.10:** Spatial variation of reference crop evapo-transpiration (mm per day) for various months over West Bengal

## Raipur

### Temperature trends

The district level mean maximum and minimum temperature data for the period 1971-2000 of Chattisgarh state were analyzed and the spatial distribution of mean temperatures is depicted in Fig. 3.11. It was found that both maximum and minimum temperatures followed similar pattern across the state. Highest mean maximum (32-33°C) and minimum (20-21°C) were observed over districts in the central part of the state. Relatively low temperature prevails over northern and southern parts of the state. The maximum temperatures range between 30 to 33°C and minimum temperature between 18 and 21°C across the state.

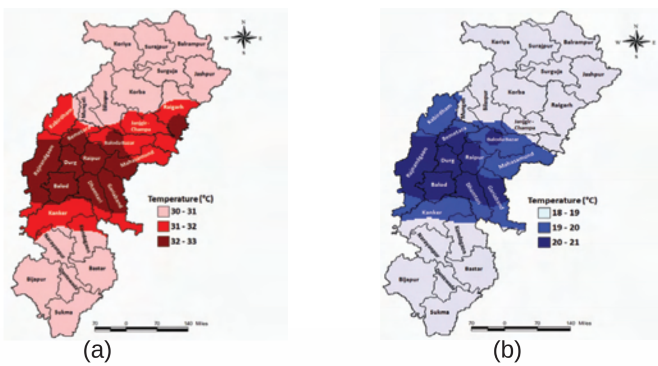



**Fig. 3.11:** Spatial distribution of mean annual (a) maximum (b) minimum temperature over Chhattisgarh State (1971-2000)

## Length of growing period

The length of growing period (LGP) in different districts of Chhattisgarh was computed using monthly rainfall and PET for the period of 1971-2010 by employing FAO method and the spatial distribution is presented in Fig. 3.12. In general, LGP is higher in southern parts of state (Bastar and part of Kongaon and Bijapur district). It may be attributed to low temperatures as evident from figure 3.11 (hence low PET) and this region is under the influence of both the SW and NE monsoons. The districts like Narayanpur, Dantewada, Sukma and parts of Kondagaon and Bijapur are having a growing season in the range of 151-160 days. The LGP is about 141-150 days in the northern parts comprising Koria, Surajpur, Surguja, Balrampur, Jashpur and parts of the districts *viz.*, Kanker, Rajnandgaon, Dhamtari, Gariaband. Lowest LGP (131-140 days) is noticed over central parts of the state.

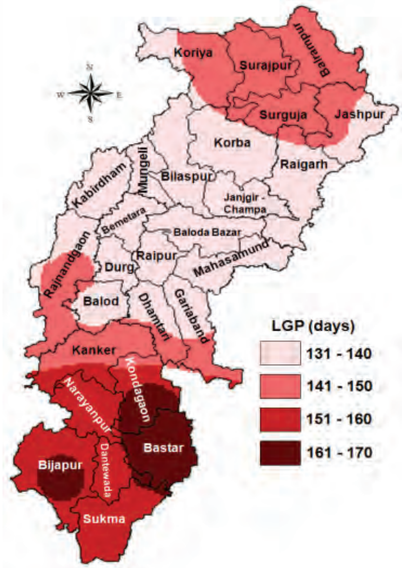



**Fig. 3.12:** Length of growing season in different districts of Chhattisgarh State

## Maximum one-day rainfall

Inter-annual variation in one day highest rainfall at Raipur and its trend over the period of 1971-2012 revealed that there is large variation in highest amount of rainfall in 24 hours and it is increasing over the years (Fig. 3.13). One day heavy rainfall of this kind would increase soil erosion and inflict damage to crops. This is also supporting the opinion that due to climate change the one day heavy rainfall events are increasing.

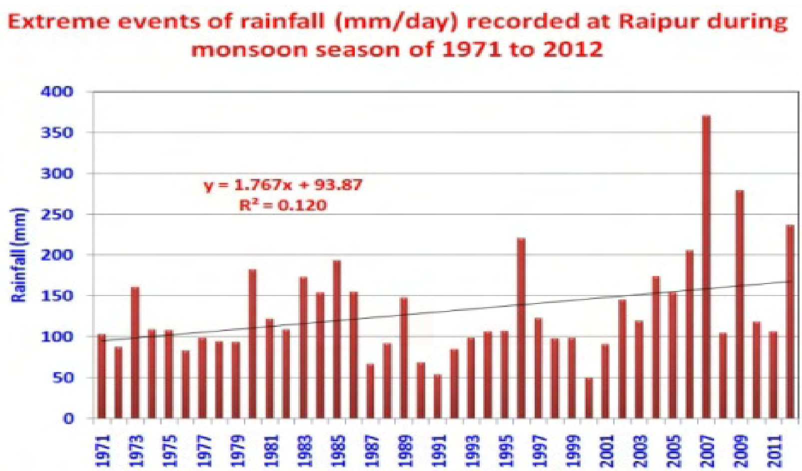



**Fig. 3.13:** Temporal variability in maximum one-day rainfall at Raipur

## Climatic shifts

In order to know variations/change in climate type at district level across the century (1901-2010) at the time scales of 30 years, climatic types based on moisture index (Thornthwaite and Mather, 1955) were computed and spatial distribution of climatic types for the periods 1901-1930, 1931-1960, 1961-1990 and 1991-2010 were depicted in Fig. 3.14. Results revealed that most of the districts in the state are falling under dry sub-humid climate. There is a clear evidence that the number of districts under moist sub-humid are declining and number of districts under semi-arid are increasing from 1901-1930 to 1991-2010.

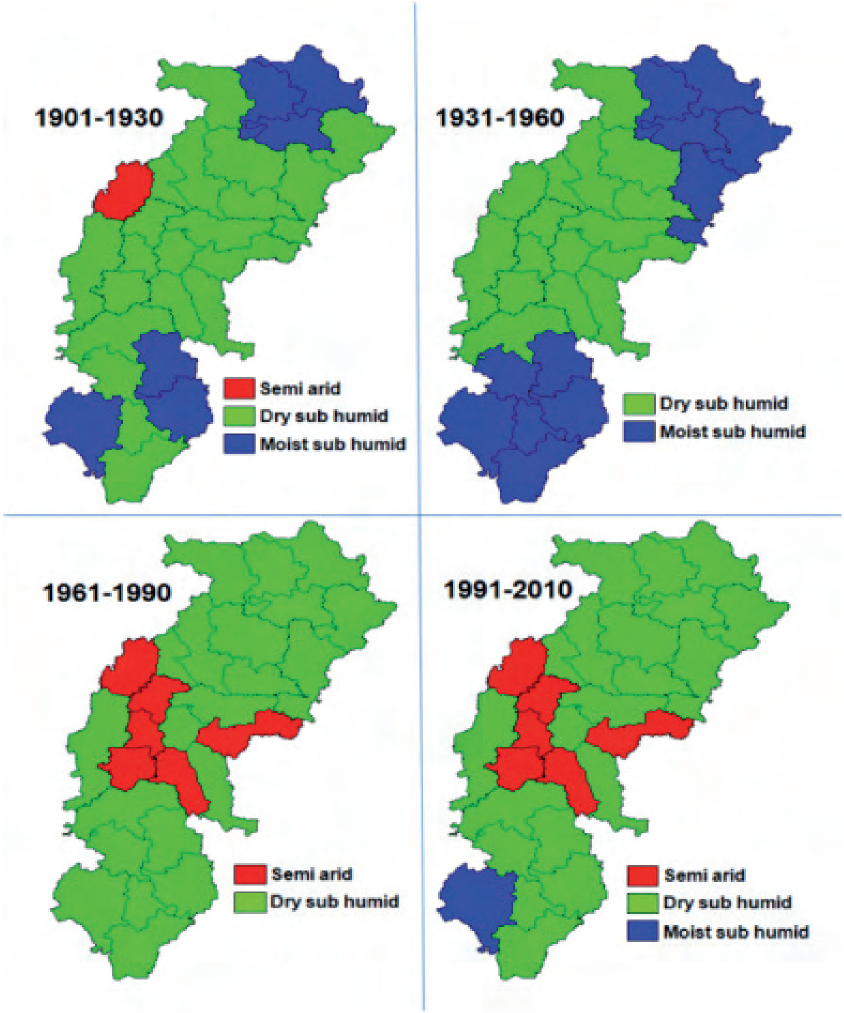



**Fig. 3.14:** Changes in climatic type of different districts of Chhattisgarh State during 1901-2010

## Ranchi

Long term annual rainfall data of four different regions of Jharkhand *viz.*, Santhal Pargana (1991-2012), North Chhotanagpur (1956-2012), Palamu (1976-2012) and Kolhan (1989-2012) were analyzed using regression technique to quantify changes in rainfall pattern (Fig. 3.15 a to d). There is an increasing trend in North Chhotanagpur (6.7 mm/ year) and Santhal Pargana regions (16.35 mm/year). In Palamu region, there is a decreasing trend in annual rainfall (-11.53 mm/year) over last 36 years. In recent decade, Palamu region received below normal rainfall. Kolhan region received more or less consistent rainfall over the period of 1989-2012 and showed almost no trend in annual rainfall. In recent decade, more fluctuations in rain were noticed and the year 2011 received maximum rain. The zone faced mild to medium drought on a number of occasions (2003, 2004, 2005, 2009 & 2010) during the last decade.

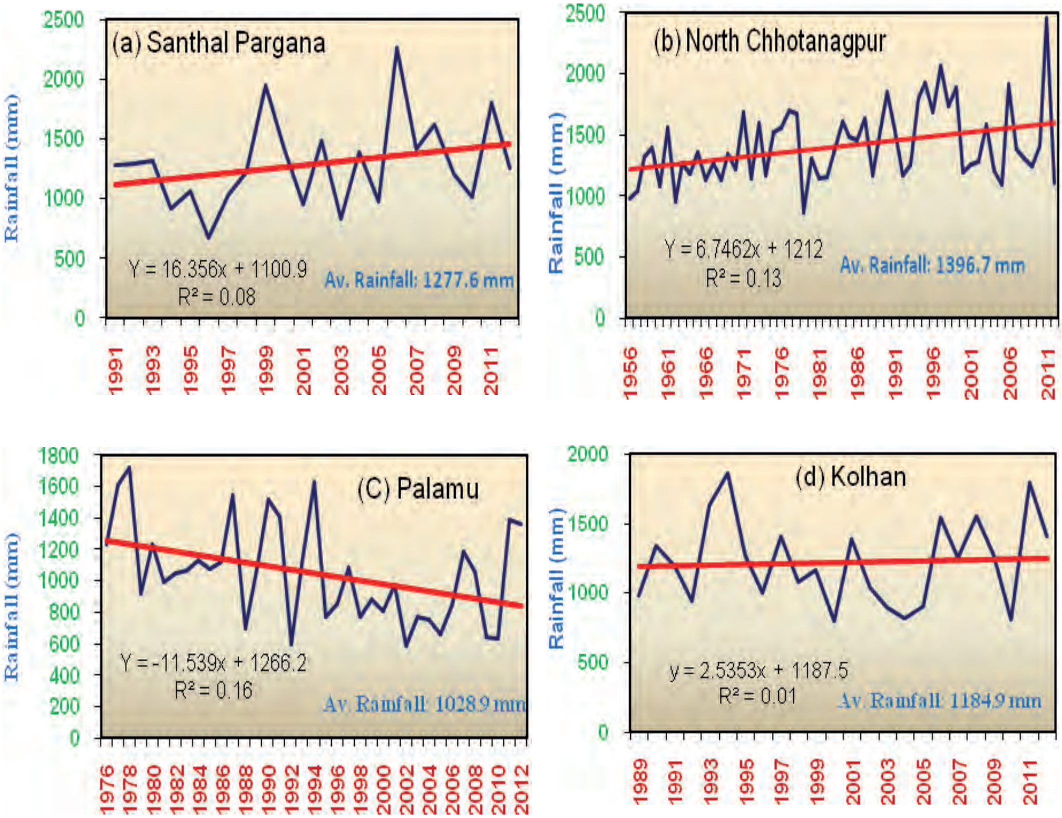



**Fig. 3.15:** Trends in annual rainfall in (a) Santhal Pargana (b) North Chhotanagpur (c) Palamu and (d) Kolhan regions of Jharkhand

## Samastipur

### Water balance

Components of water balance on a weekly basis were computed using the long-term data (1968-2012) at Samastipur and are presented in Fig. 3.16. Weekly rainfall exceeds 50 mm per week during 25-37 SMW and could be identified as ideal period for growing low land rice crop of less than 120 days duration.

Weekly total PET exceeds 20 mm during 10 to 46 SMW, while it exceeds 30 mm per week during 14 to 31 SMW. During December to February, PET values were lower than 20 mm per week. Water surplus conditions which includes runoff and deep drainage were found to prevail from 24 to 43 SMW and this information should be utilized for selecting low land rice varieties under average rainfall conditions. The total annual surplus was computed as 487.3 mm during 24 to 43 SMW as against the total water deficit 75.4 mm during the corresponding period. However, annual deficit remained at 591.4 mm. The available water holding capacity considered for the study was 140 mm per meter depth and 50 per cent of this comes to be 70 mm, occurs during 26 to 43 SMW. This indicates that under average rainfall conditions, crops grown during this period would be able to produce reasonably well. Soil moisture index also exhibited similar pattern with SMI values exceeding 0.5 during 26 to 43 SMW.

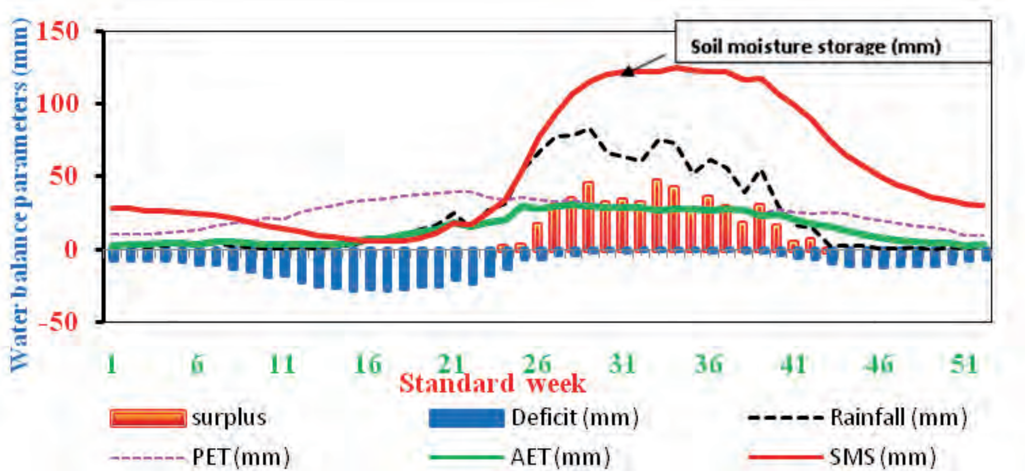



**Fig. 3.16:** Mean weekly water balance parameters at Samastipur

### Length of growing period

Length of growing period was determined on the basis of weekly moisture adequacy index thresholds (MAI $\geq$ 0.75 for start and MAI < 0.25 for termination) for the period of 1968-2012 and presented in Fig. 3.17. In the year 1977, LGP started as early as 16$^{th}$ week and in 1972 delayed up to 27 SMW. Growing season got terminated by 43 SMW during 2004-05 and extended up to 13 SMW during 1979-80. The lowest LGP of 154 days was recorded in 1988-89 as against the highest LGP of 350 days in 1977-78. When averaged over the period 1968-2012, mean LGP would become 217± 46 days with a CV of 21 per cent indicating high variability in the commencement and end of growing seasons. Out of 45 years, 48.9 percent years recorded LGP above the mean and 51.1 percent showed below average LGP. In about 60 per cent of the years LGP exceeded 200 days, thus facilitating double cropping with maize in the *kharif* season followed by short duration rapeseed in *rabi* season under rainfed conditions. It can also be inferred from the present analysis that sowing window of Samastipur district is 19 to 23 SMW, which can be a valuable input for Agromet advisory.

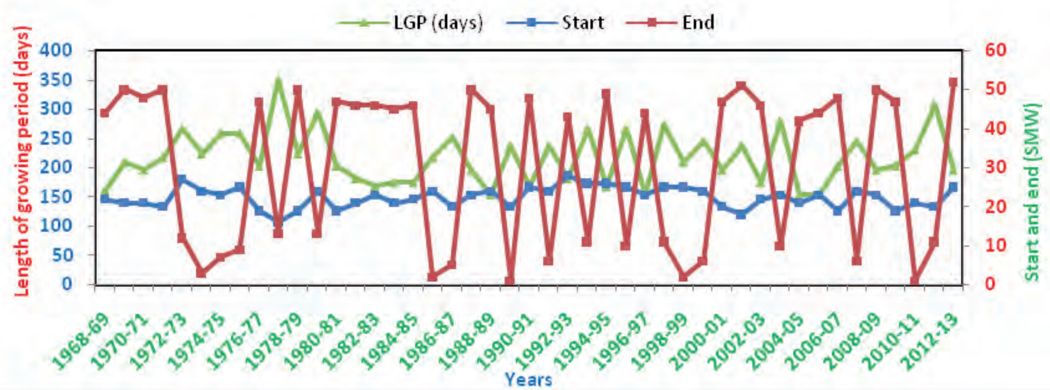



**Fig. 3.17:** Temporal behaviour in the start, end of growing period and LGP during 1968-2012 at Samatipur

## Solapur

The district wise daily rainfall data of Maharashtra for the period 1901-2006 during winter, pre-monsoon, monsoon and post monsoon seasons were analyzed and normal rainfall with coefficient of variation are depicted in Fig. 3.18 & 3.19. During the winter season (January- February) all the districts of central and western parts of the state receives very low rainfall (< 10 mm). The districts in the eastern parts received rainfall around 20 to 30 mm with maximum value of 35.9 mm over Bhandara district. During the pre-monsoon season (March-May) season maximum rainfall zone gets shifted from eastern parts to south western parts. Kolhapur district receives maximum rainfall (87.0 mm). Mean rainfall figures for most of the districts range between 20 to 30 mm during this season. Ratnagiri district receives highest rainfall during monsoon and post-monsoon seasons. Maximum rainfall zone which was initially over eastern parts gets shifted to southern parts in pre-monsoon and exhibits a slightly northern movement during monsoon season and remains there during post-monsoon season, as could be noticed from figures 3.18 a to d. The spatial distribution of CV values for the four seasons (Fig 3.19) shows that very less rainfall is received during the winter season with an associated high variability in all the districts of Maharashtra. Maximum variability (420.8%) is noticed in Ahmednagar and lowest (106.1) over Nagpur. During monsoon season despite very high rainfall, coefficient of variability of monsoon rainfall is very high in Mumbai (>35%).

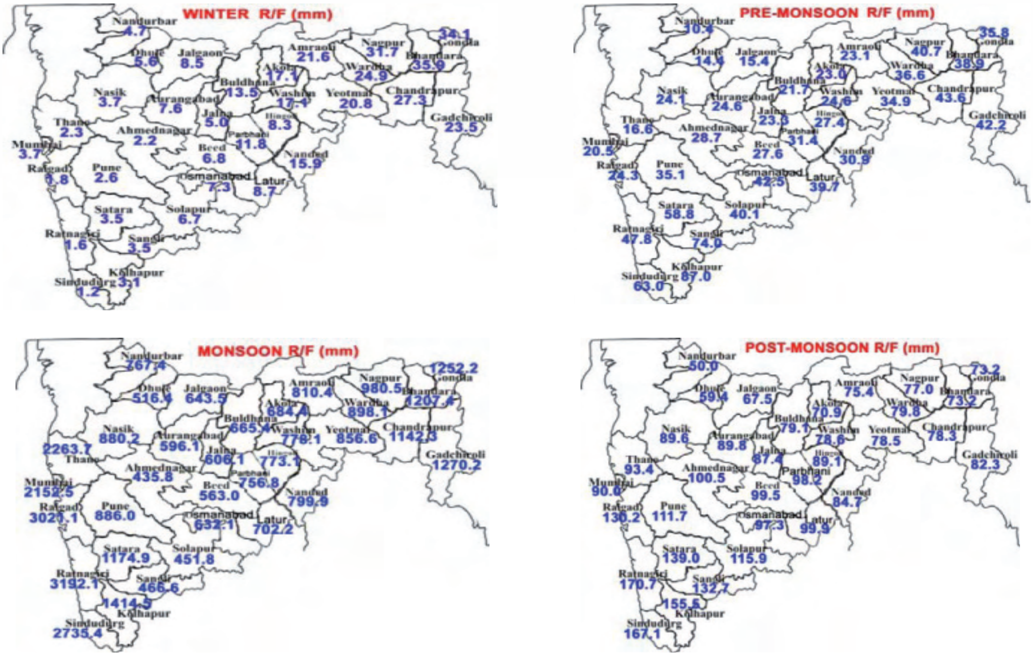



**Fig. 3.18:** Mean seasonal rainfall (mm) over different districts of Maharashtra

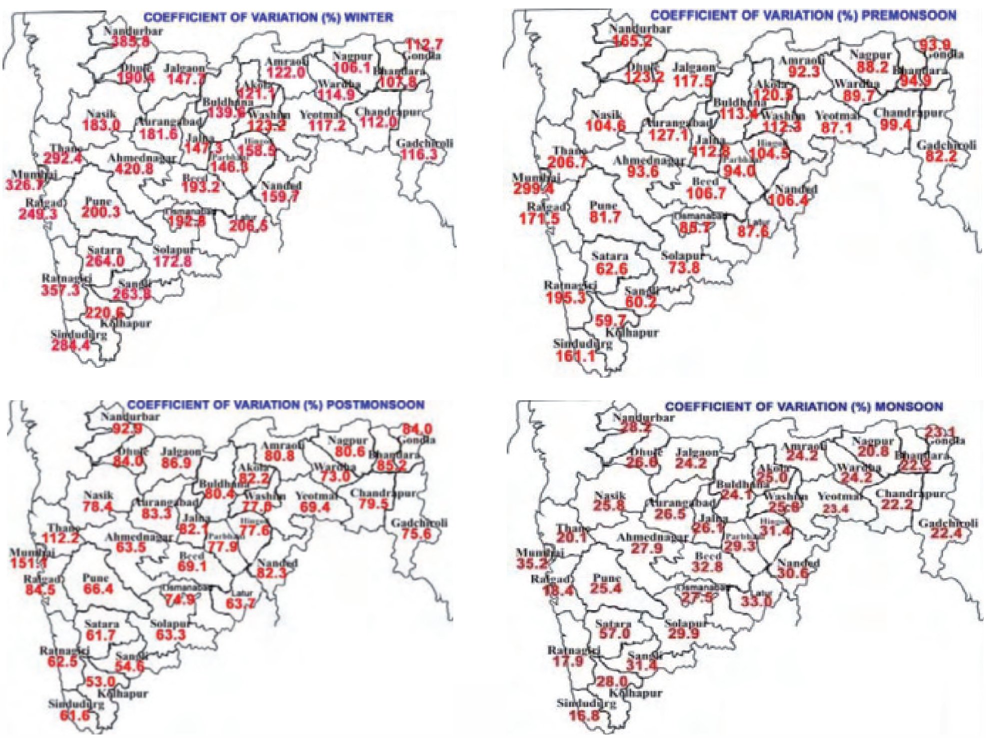



**Fig. 3.19:** Distribution of CV (%) of rainfall over the districts of Maharashtra during the four seasons

## Changes in the seasonality index

Analysis of seasonality index (SI) helps to have idea about the distribution of the rainfall among the months and categorize the districts in different rainfall regimes. Changes in seasonality index during the period 1951-2000 over 1901-50 was computed for all the districts of Maharastra and are presented in Fig. 3.20. The SI has increased in all the districts except Satara, Osmanabad, Nanded, Wardha and Bhandara.

SI values showed significant increasing trends (95%) in Mumbai, Pune, Buldhana and Amraoti districts (Fig. 3.21). SI values showed non-significant increasing trend for the districts of Thane, Nandurbar, Dhule, Jalgaon, Nasik, Ahmednagar, Solapur, Satara, Sangli, Kolhapur, Ratnagiri, Sindhudurg, Akola, Wahim, Yeotmal, Nanded and Gadchiroli. Significant decreasing trend (p=0.05) was noticed in Jalna and Nasik districts which is an indication of the increase in even distribution of rainfall over months. Though the districts, Raigad, Aurangabad, Beed, Osmanabad, Parbhani, Hingoli, Wardha, Nagpur, Bhandara, Gondia and Chandrapur showed decreasing trend, it is non-significant.

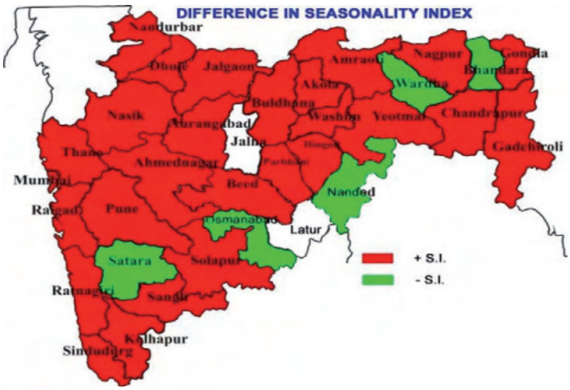



**Fig. 3.20:** Changes in the Seasonality Index over districts of Maharashtra during the period 1951-2000 over 1901-1950

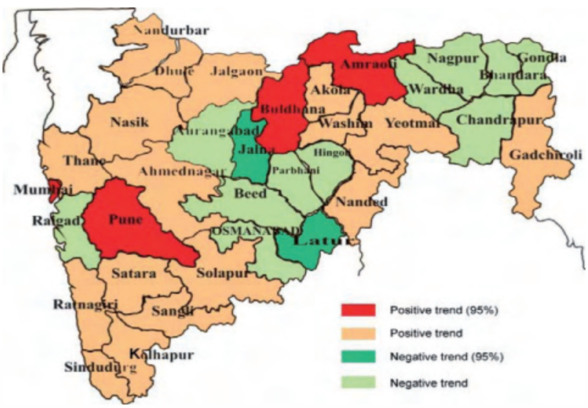



**Fig. 3.21:** Trends in the Seasonality Index over districts of Maharashtra during the period 1951-2000 over 1901-1950

## Thrissur

### Trend in annual rainfall over Kerala

Temporal variation in annual and seasonal rainfall during the period from 1871 to 2012 was analyzed using linear trend test. The mean annual rainfall of the State is 2824 ± 41 mm with a coefficient of variation of 14.26%, indicating a highly stable and dependable rainfall. Mean annual rainfall over Kerala showed a long-term non-significant decreasing trend (Fig. 3.22a). Rainfall during 1871 to 1975 showed an increasing trend (Fig 3.22b) and during 1975 to 2012 showed a decreasing trend (Fig. 3.22c).

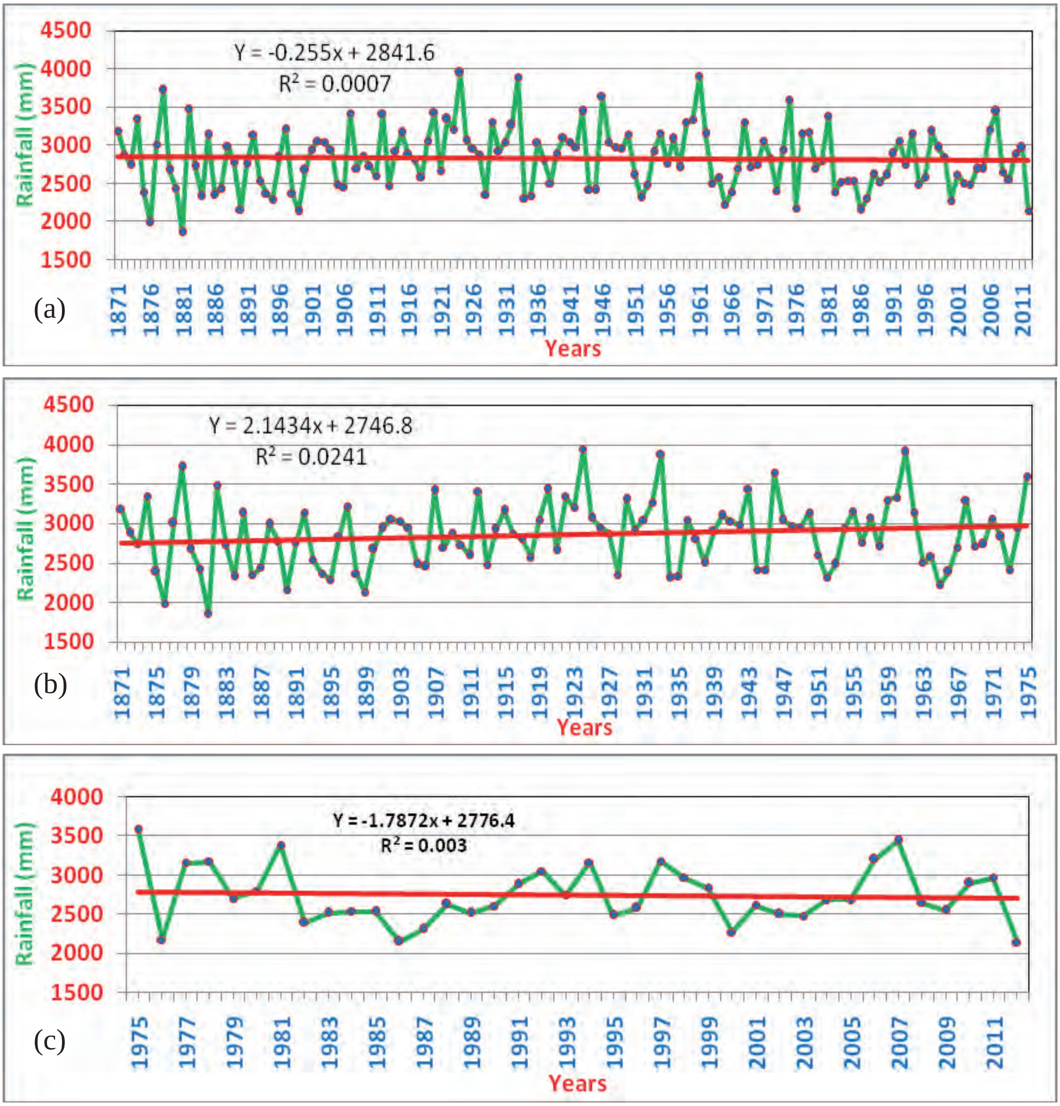



**Fig. 3.22:** Annual rainfall trends over Kerala for
(a) 1871-2012 (b) 1871- 1975 and (c) 1975-2012 periods

## Seasonal rainfall trend over Kerala

The linear trend test indicated that there is a declining tendency in the southwest monsoon rainfall over Kerala @ 1.22 mm per year during 1871 to 2012 (Fig. 3.23a). Post monsoon rainfall showed an increasing trend which was more evident beyond 1975 and it was increasing @ 0.72 mm per year (Fig. 3.23b). Winter rainfall showed an increasing trend. Increase in rainfall during the season is beneficial to the plantation crops. However, high variability of rainfall during this season will lead to uncertainty and the crops need assured irrigation (Fig. 3.23c). There was an overall increasing trend in summer rainfall which is statistically insignificant.

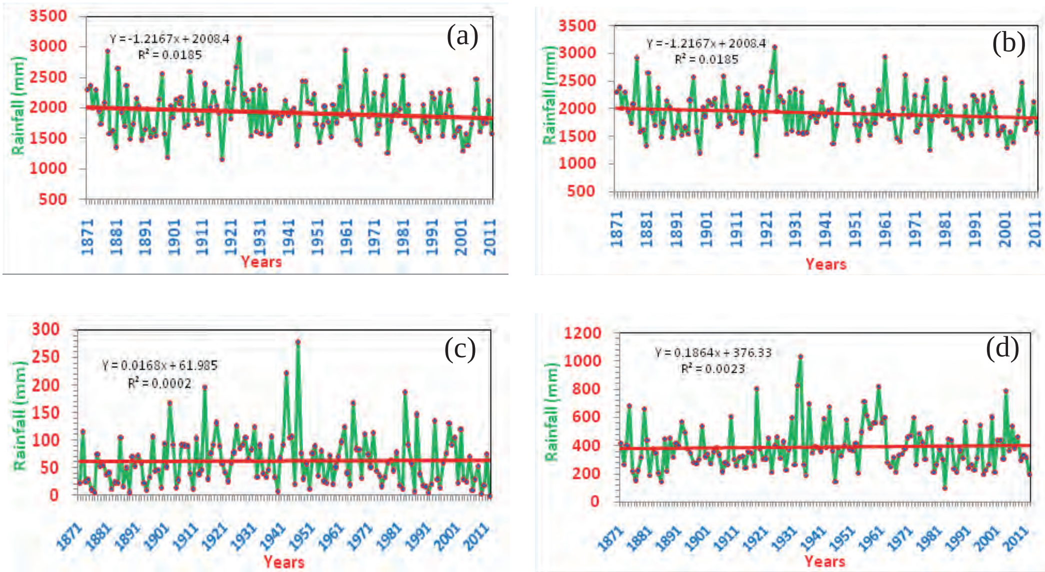



**Fig. 3.23:** Rainfall trends over Kerala during (a) Southwest monsoon, (b) Post-monsoon, (c) winter and (d) summer seasons

## Udaipur

The long-term annual rainfall data (1960-2012) of Rajasthan and its deviation from normal rainfall were analyzed to detect any changes in rainfall pattern during SW monsoon. Analysis showed that there were 10 deficit rainfall years (< 20% of the normal) and same number of excess rainfall years (> 20% of normal). In 16 years, rainfall though less than normal rainfall was placed under normal category as the deviation was <20 % (Fig. 3.24b). The five year moving average rainfall pattern for the period 1960-2012 showed a cyclic pattern (Fig. 3.24a). Decadal monsoon season rainfall presented in Fig 3.25a showed that maximum rainfall of 596.7 mm was received during 1970-79 followed by 1990-99 (566.0mm) and 2000-2011(496.2 mm). The lowest monsoon season rainfall of 427.8 mm was recorded during 1980-89 in last five decades. Further, Fig. 3.25b indicated that during the recent period (1990-2012) monsoon season rainfall increased by 7.1 mm compared to the early period of 1960-1989 (498.1 mm).

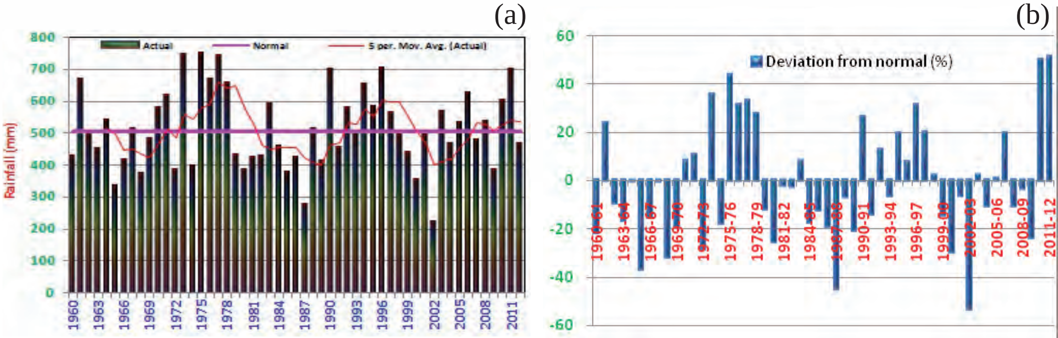



**Fig. 3.24:** (a) Monsoon season rainfall trends and (b) deviations from normal rainfall in Rajasthan (1960-2012)

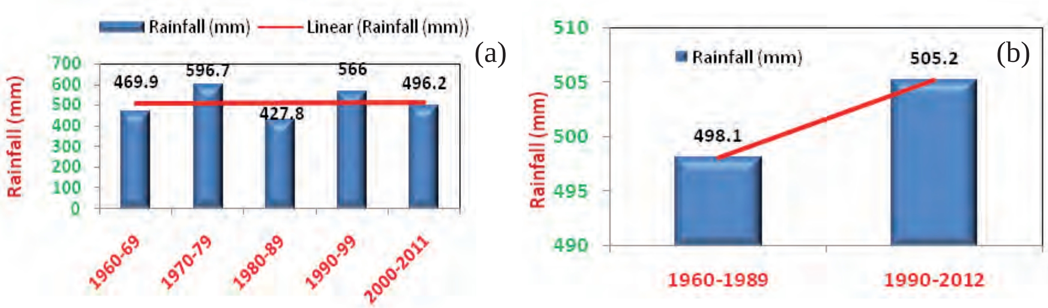



**Fig. 3.25:** (a) Decadal monsoon seasonal rainfall pattern and (b) change in rainfall during 1960-89 over 1990-2012 period in Rajasthan

# 4. Crop-weather relationships

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

## *Kharif*

### Rice

#### Kanpur

Productivity of three rice cultivars (NDR-359, CSR-27 and Sarjoo-52) under three environmental conditions imposed by staggered transplanting (13$^{th}$ Jul, 23$^{rd}$ Jul and 2$^{nd}$ Aug 2012) was studied using correlation analysis. The correlation between the weather variables at different phenophases and rice yields indicated that high rainfall at tillering stage was detrimental for crop growth whilst high temperature (maximum and minimum) and more sunshine hours were more conducive (Table 4.1).

**Table 4.1: Pearson's correlation coefficients between rice yields and different weather parameters prevailed during different crop growth stages at Kanpur**

| Growth stage | Tmax | Tmin | Tmean | STmean (5 cm) | $RH_I$ | $RH_{II}$ | RH mean | SSH | WS | RF | Eva. | AGDD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tillering | 0.83 | 0.88 | 0.83 | 0.83 | -0.81 | -0.81 | -0.81 | 0.87 | 0.78 | -0.80 | 0.84 | 0.95 |
| Anthesis | -0.40 | 0.68 | 0.40 | -0.18 | 0.45 | 0.55 | 0.54 | -0.56 | 0.51 | -0.28 | 0.87 | 0.96 |
| Grain filling | -0.37 | 0.57 | 0.48 | -0.49 | 0.36 | 0.52 | 0.51 | -0.37 | 0.53 | 0.72 | 0.90 | 0.97 |
| Maturity | 0.39 | 0.45 | 0.45 | 0.36 | -0.55 | 0.60 | 0.06 | 0.07 | 0.45 | 0.72 | 0.89 | 0.94 |

#### Ludhiana

Rice crop is stated to be prone to rise in temperatures. To determine the extent of its sensitivity and to evolve management strategies, rice crop was subjected to heat stress at different growth stages and salicylic acid application was considered as an ameliorative measure. In the field experiments heat stress was imposed at six stages for whole of the season (Hw); stress free ($H_0$); during tillering (Ht); during panicle initiation (Hpi); during anthesis (Ha) and during grain development (Hgd). The heat stress treatments were applied by placing the pots in the polyhouse constructed for this purpose. The western side of the poly house was kept open during the day to reduce the increase in temperature and during the night all sides were kept closed. The role of salicylic acid as ameliorative measure was assessed by spraying at concentration of 50 ppm at 5 days before transplanting.

The per cent deviation in yields in different treatments from the control treatment presented in Table 4.2 indicated that highest yield reduction occurred (-37%) due to heat stress at anthesis in the unsprayed plot and the stress was negated by spraying salicylic acid and the yields realized were +4% compared to control. However, the mitigating effect of salicylic acid could not be noticed at grain development stage.

**Table 4.2: Grain yield of rice under heat stress at different stages and mitigating effect of salicylic acid at Ludhiana**

| Heat stress treatments | Per cent change in rice yields from control | |
|---|---|---|
| | No spray | Spray |
| Heat stress for the entire crop season | 15.4 | 17.2 |
| Heat stress free | 0.0 | 7.5 |
| Heat stress during tillering | 8.8 | 7.2 |
| Heat stress during panicle initiation | 1.5 | 12.1 |
| Heat stress during anthesis | -37.0 | 4.0 |
| Heat stress during grain development | -17.1 | -12.4 |

## Samastipur

Influence of temperature and rainfall on three rice cultivars (RAU 3055, Rajendra Bhagawati and Saroj) was assessed by planting at 31 May, 15 June, 30 June and 16 July 2012. Crop sown on 15$^{th}$ June recorded highest yield (30.61 q/ha) (Table 4.3) which could be due to favourable temperature during 50 per cent flowering to maturity. Crop sown on 16$^{th}$ July yielded lowest due to no rainfall during crop season. The percentage of unfilled grains or chaffy grains per panicle increased when sowing was delayed beyond 15$^{th}$ June.

**Table 4.3: Effect of rainfall and temperature on yield of rice during *kharif 2012* at Samastipur**

| Date of sowing | Temperature (°C) | | Duration of 50 per cent flowering to milk stage (days) | Rainfall (mm) | Percentage of unfilled grains per panicle | Yield (q/ha) |
|---|---|---|---|---|---|---|
| | 50 % ear head to maturity | Mean Temp (°C) | | | | |
| 31 May | 32.1-24.3 | 28.2 | 34 | 281.3 | 22.0 | 24.93 |
| 15 June | 32.3-24.0 | 28.2 | 32 | 156.5 | 15.0 | 30.61 |
| 30 June | 31.4-19.8 | 25.6 | 31 | 124.5 | 18.5 | 28.90 |
| 16 July | 30.3-16.2 | 23.3 | 33 | 0.0 | 38.2 | 20.45 |

## Maize

### Jammu

Utility of Canopy-Air Temperature differential (CATD) and transpiration relationships in either irrigation management or yield assessment is governed by ambient atmospheric conditions (VPD); and edaphic (mainly available soil moisture) and crop characteristics (canopy size, canopy architecture and leaf adjustment to water deficit). The transpiration (TRN) and CATD relationship was established utilizing the data collected from fully matured healthy top leaves of maize variety Kanchan-517 sown on three different sowing dates viz., 22nd Jun, 2nd Jul and 12th Jul 2012. There is an inverse relationship between the two variables (Fig. 4.1) and the model fitted for the data accounted for 74% of the variability. The applicability of this model for field applications need to be tested in the ensuring crop seasons.

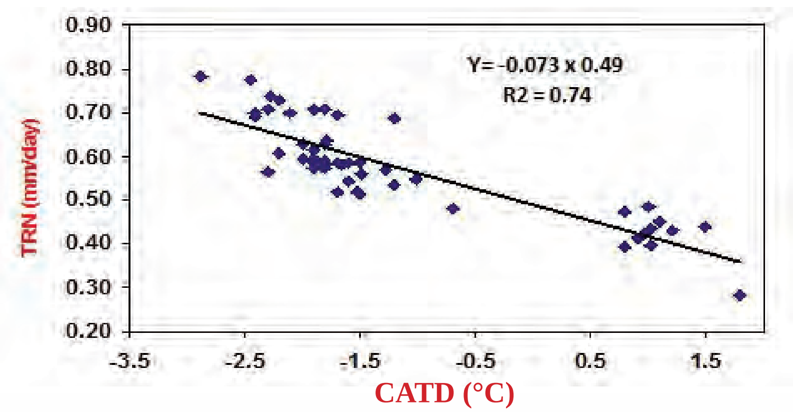



**Fig 4.1:** Canopy–air temperature differential (°C) and transpiration (mm/day) relationship in maize at Jammu.

## Pearl millet

### Solapur

Response of three pearl millet cultivars (Shanti, Mahyco hybrid and ICTP-8203) to varied weather conditions, created through staggered sowings (26, 30 and 33 SMW) from a three year experimentation was assessed through correlation studies. Pearl millet responded positively to minimum temperatures at all growth stages (Table 4.4). Bright sunshine hours had negative correlation at all the growth stages except sowing to emergence. Morning RH had negative influence on the crop growth from emergence to flowering, while evening RH favoured during flowering to dough stage.

**Table 4.4: Pearson's correlation coefficients between grain yield and different weather parameters prevailed during different phenophases of pearl millet at Solapur (2010-12)**

| Phase | T max | Tmin | RH1 | RH2 | SS | Epan | RF |
|---|---|---|---|---|---|---|---|
| Sowing to emergence | 0.72* | 0.70* | -0.74* | -0.74* | 0.60 | 0.78* | 0.90** |
| Emergence to 3 leaf | 0.53 | 0.80** | -0.66* | -0.20 | -0.65 | 0.56 | 0.75* |
| 3 leaf to panicle initiation | 0.40 | 0.84** | -0.71* | 0.23 | -0.79* | 0.70* | 0.39 |
| Panicle initiation to flowering | 0.18 | 0.86** | -0.28 | 0.59 | -0.85** | 0.71* | 0.61 |
| 50 % flowering to soft dough | 0.09 | 0.85** | 0.51 | 0.75* | -0.86** | 0.72* | 0.85** |
| Soft dough to hard dough | -0.19 | 0.81** | 0.80** | 0.85** | -0.86** | 0.70* | 0.86** |
| Hard dough to physiological maturity | 0.24 | 0.85** | 0.00 | 0.64 | -0.87** | 0.61 | 0.78* |

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

## Pigeon pea

### Faizabad

Relationship between leaf area index (LAI) and radiation use efficiency (RUE) in three pigeonpea cultivars (Narendra.Arhar-1, Narendra.Arhar-2, Bahar) raised under different growing environments (D1-July 6, D2-July 16 and D3-July 26) was studied. A linear relationship was found between these two variables (Fig 4.2) which accounted for 82 per cent variability. The relationship indicated that with a unit increase in LAI, the RUE would increase by 0.48g/MJ.

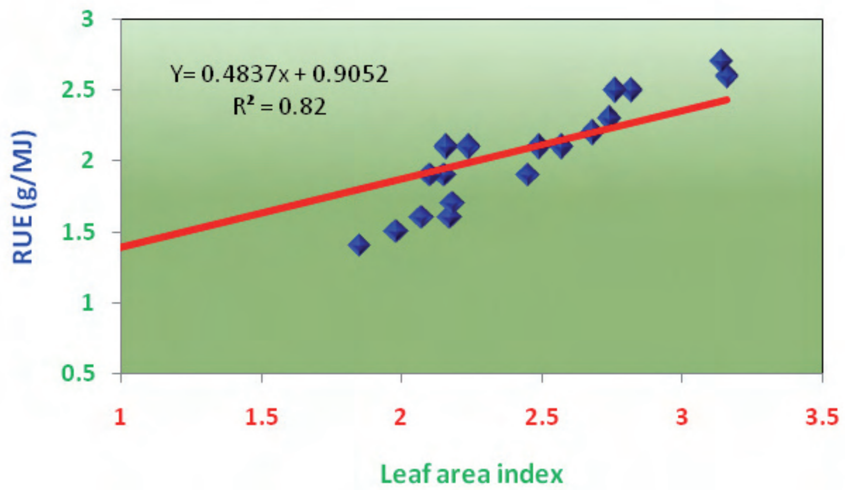
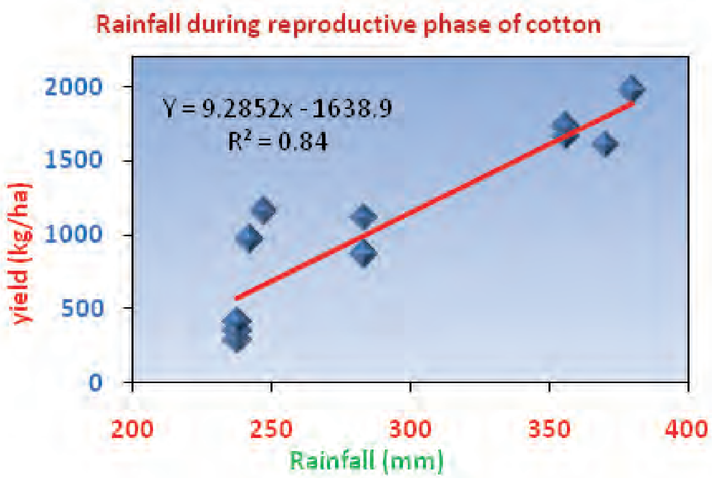



**Fig. 4.2:** Relationship between LAI and RUE in pigeonpea at Faizabad

# Cotton

## Akola

Impact of rainfall and temperature during sensitive growth stages of cotton hybrid (Ankur-651) was studied by sowing at different intervals. A positive impact of maximum and minimum temperatures during vegetative phase and rainfall as well as minimum temperature during reproductive phase on fiber yields was noticed (Fig 4.3). A rise in maximum temperature during reproductive phase was found detrimental. The best fit equations showed that a 10 mm rainfall increment during reproductive phase increases yield by about 93 Kg/ha while, 1°C rise in maximum temperature during reproductive phase would decrease yield by 1734 Kg/ha.



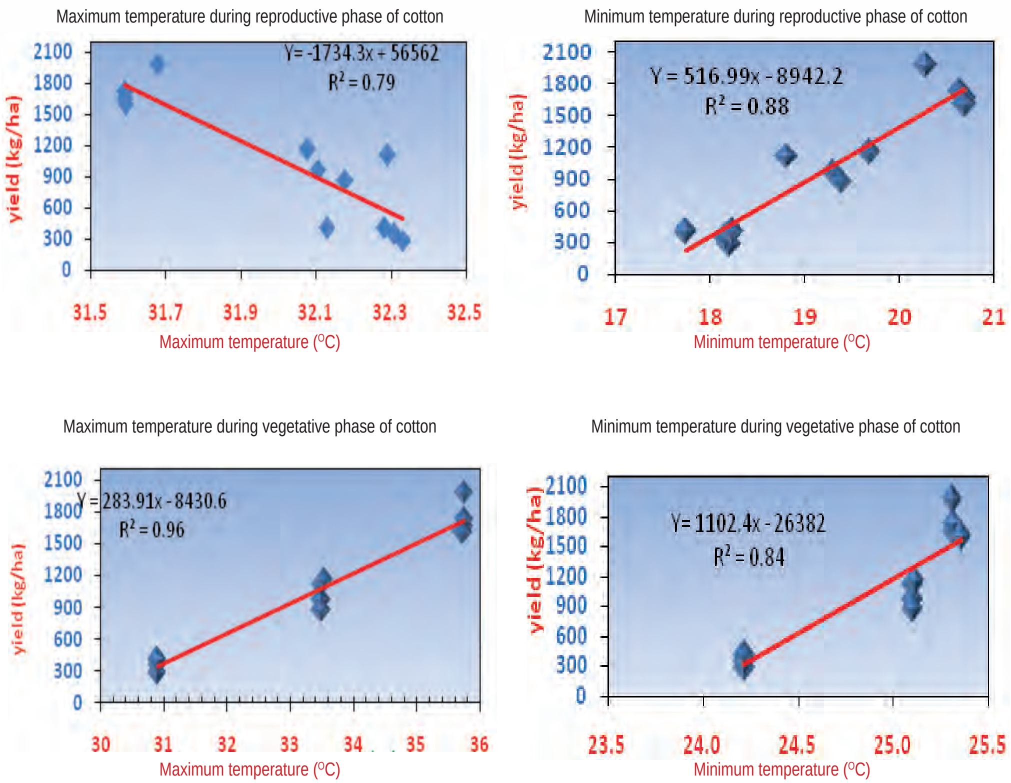



**Fig 4.3:** Influence of rainfall and temperatures prevailed during vegetative and reproductive phase on cotton yields at Akola

## Parbhani

Response of cotton to varied weather was assessed in three varieties viz., Ankur, Rashi-2 and Mallika grown under four environments (22nd Jun, 29th Jun, 6th Jul and 13th July 2012) using correlation studies. Temperature played a favourable role for crop emergence while high rainfall and humidity delayed the emergence. As cotton is a heliophyte, all the varieties responded positively to temperature at all growth stages (Table 4.5). Rainfall and relative humidity during square formation to flowering stage showed a negative influence. Hours of bright sunshine had a positive influence only during initial stage.

**Table 4.5: Pearson's correlation coefficients between weather parameters prevailed during different phenophases and cotton yield at Parbhani (2012-13).**

| Weather parameter | Sowing to emergence | Emergence to seedling | Seedling to square formation | Square formation to flowering | Flowering to boll setting | Boll setting to boll bursting | Boll bursting to 1st picking | 1st picking to 2nd picking | Pooled |
|---|---|---|---|---|---|---|---|---|---|
| Rainfall (mm) | -0.863** | 0.868** | 0.238 | -0.731** | -0.507* | 0.909** | 0.060 | 0.584** | 0.035 |
| Rainy days (No.) | -0.945** | 0.517* | 0.388 | -0.786** | -0.285 | 0.910** | 0.349 | 0.413 | 0.031 |
| Maximum temperature (°C) | 0.851** | 0.681** | -0.380 | -0.019 | -0.099 | -0.420 | 0.715** | -0.437 | 0.177** |
| Minimum Temperature (°C) | 0.283 | -0.149 | 0.848** | -0.244 | -0.337 | 0.842 | 0.603** | 0.237 | 0.060 |
| Mean Temperature (°C) | 0.862** | 0.534* | -0.060 | -0.170 | -0.195 | 0.840** | 0.715** | 0.043 | 0.086 |
| Temperature range (°C) | 0.267 | 0.728** | -0.661** | 0.213 | 0.073 | -0.799** | 0.337 | -0.458 | -0.011 |
| Morning RH (%) | -0.864** | -0.655** | 0.529* | -0.728** | -0.474 | 0.860** | -0.379 | 0.528* | -0.071 |
| Evening RH (%) | -0.743** | -0.341 | 0.123 | -0.635** | -0.204 | 0.858** | -0.111 | 0.245 | -0.037 |
| Mean RH (%) | -0.791** | -0.420 | 0.347 | -0.774** | -0.335 | 0.869** | -0.268 | 0.512* | -0.052 |
| $RH_{range}$ | 0.583** | 0.095 | 0.112 | 0.124 | -0.043 | -0.810** | -0.340 | 0.337 | 0.001 |
| Evaporation (mm) | 0.581** | 0.733** | -0.281 | 0.601** | 0.603** | -0.702** | 0.435 | -0.131 | 0.177 |
| Bright Sunshine hours (hrs) | 0.731** | 0.734** | -0.749** | -0.394 | -0.403 | -0.816** | 0.272 | -0.577** | -0.019 |
| Growing Degree Days | -0.020 | -0.015 | -0.016 | -0.017 | -0.020 | -0.010 | 0.007 | 0.007 | -0.004 |

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

# Groundnut

## Bengaluru

### Water Use

Water use pattern of three groundnut cultivars (TMV-2, K-134 and JL-24) grown under two environments was studied using FAO Water balance model and crop coefficients for different phenophases were worked out. In the 16th July sown crop, the model derived water requirement was 325 mm but available water was only 202 mm indicating a deficit of 123 mm. In the late sown crop the deficit was 230 mm. The model indicated soil moisture deficit conditions during pod formation and pod initiation in 16th July and 6th August sown crop, respectively. The corresponding Kc values were lower at both stages (Fig. 4.4).

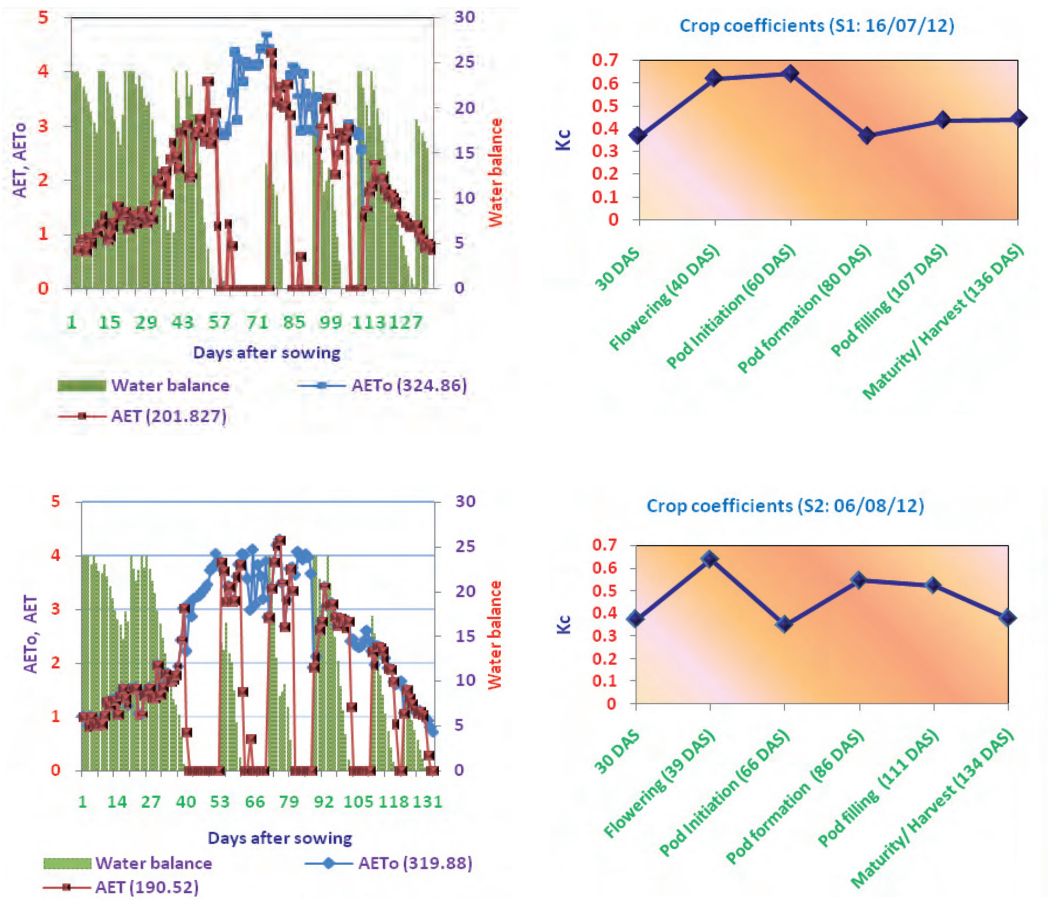



**Fig 4.4:** Water balance and crop coefficients for groundnut crop sown on two dates at Bengaluru

# Sunflower

## Solapur

Resource use efficiency of sunflower was studied in terms of moisture use efficiency (MUE) and radiation use efficiency (RUE) by creating variable environments through three different sowings. The MUE of 4.50 to 5.00 kg /ha/mm was found to be optimum for getting higher seed yield (Fig. 4.5). The relation between radiation interception and grain yield showed that if RUE increases linearly from 0.8 to 1.7 g $MJ^{-1}$ it would result in concurrent increase in seed yield from 600 to 1300 k/ ha. Thus every increase of 0.1 RUE there will be an increase of 50 k/ ha in seed yield. Optimum temperature ranges were determined by regressing seed yield on seasonal temperatures. Sunflower is found to be sensitive to both maximum and minimum temperatures and seed yield increased as the maximum and minimum temperature increased up to 32°C and 21.2°C, respectively. Thereafter, there was a negative impact of both temperature regimes.

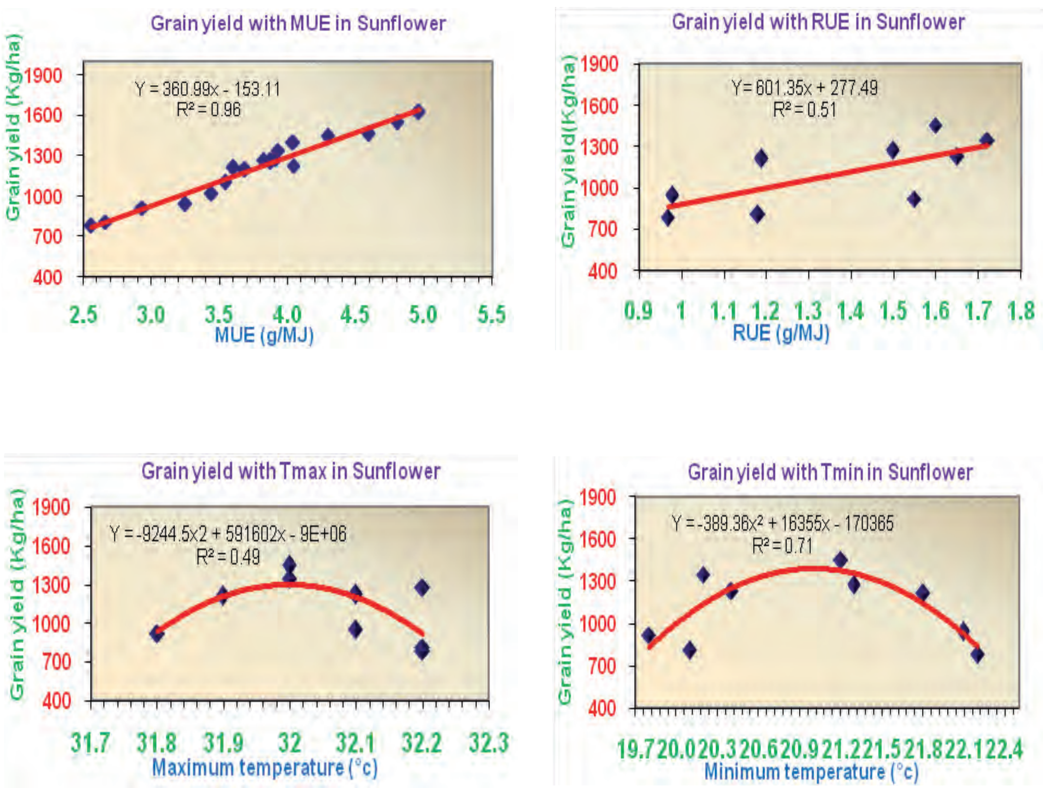



**Fig 4.5:** Relation between grain yield of sunflower with different agrometeorological indices.

# Soybean

## Akola

Influence of day and night temperatures prevailed during vegetative and reproductive phase on seed yield of soybean were studied using regression analysis. The analysis showed that maximum and minimum temperature prevailed during vegetative and reproductive phase is positively associated with soybean yield except with maximum temperature during reproductive phase (Fig. 4.6). The maximum and minimum temperature of 32.3°C and 24.4°C, respectively during vegetative phase were found to be favourable for growth, development and yield of soybean. Similarly, 28.4°C (Tmax) and 23.2°C (Tmin) during flowering phase were found to be optimum for seed yield.

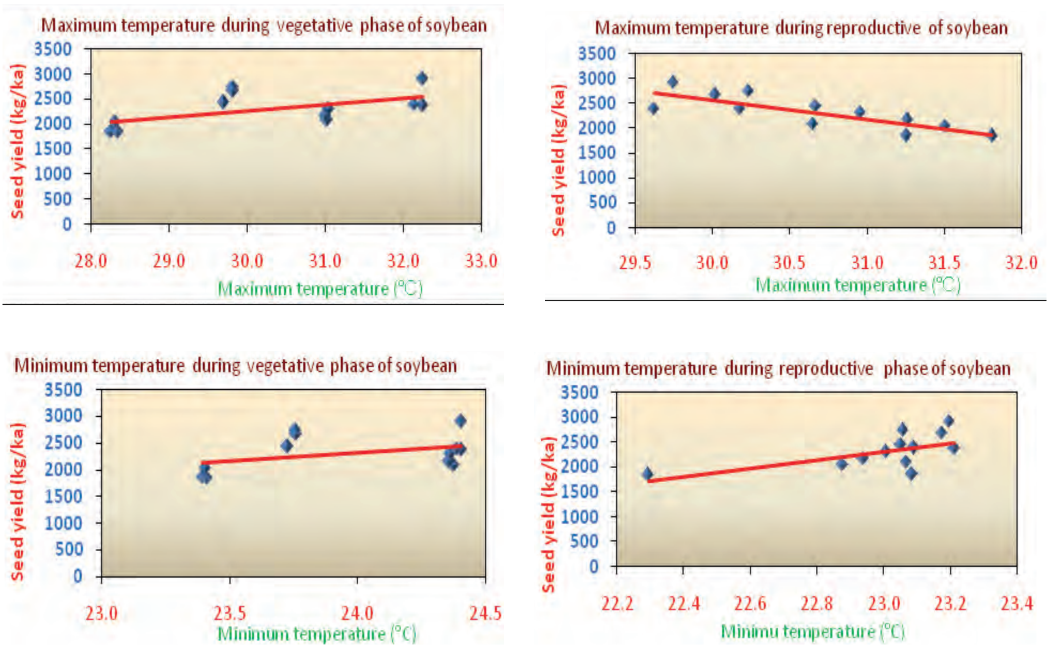



**Fig 4.6:** Influence of temperature during vegetative and reproductive phase on seed yield of soybean at Akola

## Parbhani

Weather influence on the performance of six soybean varieties *viz.,* MAUS-158, JS 93-05, MAUS-47, MAUS-71, MAUS-81 and JS-335 were studied by growing under four different environmental conditions. Crop performance was evaluated by relating weather that prevailed during different phenophases with crop yields (Table 4.7). Temperature (maximum, minimum and their range) during grain formation and rainfall during pod development stages showed positive influence whereas, rainfall and relative humidity showed adverse effect during grain development stage.

**Table 4.6: Pearson's correlation coefficient between grain yield and weather variables prevailed in different phenophases of Soybean at Parbhani (2012)**

| Parameters | Pod formation | Seed formation | Pod development | Seed development | Mean |
|---|---|---|---|---|---|
| Rainfall (mm) | 0.304 | 0.229 | 0.390* | -0.767** | 0.062 |
| Rainy days (No.) | 0.191 | 0.295 | 0.173 | -0.743** | 0.031 |
| Maximum temperature (°C) | 0.249 | 0.466** | -0.395* | -0.132 | 0.161* |
| Minimum Temperature (°C) | 0.274 | 0.735** | -0.305 | -0.229 | 0.158* |
| Mean Temperature (°C) | 0.290 | 0.601** | -0.396* | -0.350* | 0.206** |
| Temperature range (°C) | 0.035 | -0.055 | -0.268 | 0.077 | 0.035 |
| Morning RH (%) | 0.371* | 0.363* | 0.370* | -0.488** | 0.128 |
| Evening RH (%) | -0.367* | 0.187 | 0.150 | -0.630** | -0.071 |
| Mean RH (%) | -0.302 | 0.261 | 0.227 | -0.840** | -0.000 |
| RH range | 0.421** | 0.030 | -0.002 | 0.017 | 0.089 |
| Bright Sunshine hours (hrs) | 0.128 | -0.040 | -0.092 | 0.098 | 0.130 |
| Evaporation (mm) | 0.391* | 0.194 | 0.026 | -0.727** | 0.024 |
| Soil moisture content (%) | 0.023 | 0.491** | -0.025 | -0.399* | 0.100 |

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

## *Rabi*

## Sunflower

### Bijapur

Critical values of weather variables influencing the sunflower yield at different phenological stages were identified using eight year experimental data. Critical limits for each weather variable to obtain average and above average yields were identified for phenophase that was sensitive to the respective weather variable (Table 4.7).

**Table 4.7: Critical values of weather variables influencing the crop yield and the percent occurrence in the eight year experimentation at Bijapur**

| Weather Parameter | Crop Stage | Average to below average yield | | Average to above average yield | |
|---|---|---|---|---|---|
| | | Condition | Criteria satisfaction | Condition | Criteria satisfaction |
| Maximum Temperature | Seedling | > 30.0 °C | 100 % | < 30.0 °C | 92 % |
| Minimum Temperature | Seedling | < 21.0 °C | 75 % | > 21.0 °C | 100 % |
| | Vegetative | < 21.0 °C | 75 % | > 21.0 °C | 87 % |
| | FBI* | < 19.0 °C | 77 % | > 19.0 °C | 80 % |
| | Flowering | < 18.0 °C | 91 % | > 18.0 °C | 83 % |
| Morning Vapour Pressure | Seedling | < 18.5 mm Hg | 100 % | > 18.5 mm Hg | 86 % |
| | FBI | < 15.0 mm Hg | 100 % | > 17.0 mm Hg | 81 % |

| Weather Parameter | Crop Stage | Average to below average yield | | Average to above average yield | |
|---|---|---|---|---|---|
| | | Condition | Criteria satisfaction | Condition | Criteria satisfaction |
| Afternoon Vapour Pressure | Seedling | < 18.5 mm Hg | 84 % | > 18.5 mm Hg | 100 % |
| | Vegetative | < 17.0 mm Hg | 100 % | > 17.0 mm Hg | 86 % |
| | FBI | < 14.0 mm Hg | 100 % | > 14.0 mm Hg | 80 % |
| | Flowering | < 15.0 mm Hg | 91 % | > 15.0 mm Hg | 83 % |
| Morning Relative humidity | FBI | < 90 % | 72 % | > 90 % | 84 % |
| Afternoon Relative Humidity | Seedling | < 60 % | 88 % | > 60 % | 86 % |
| | Vegetative | < 55-60 % | 81 % | > 55-60 % | 84 – 100 % |
| | Flowering | < 49 % | 92 % | > 49 % | 90 % |
| Relative Humidity Range | Seedling | > 30 % | 88 % | < 30 % | 80 % |
| | Vegetative | > 30-35 % | 78 – 87 % | < 30-35 % | 81 – 90 % |
| Afternoon cloud cover | Seedling | < 6 Octa | 75 % | > 6 Octa | 81 % |
| | FBI | < 5 Octa | 90 % | > 5 Octa | 92 % |
| | Flowering | < 3 Octa | 80 % | > 5 Octa | 85 % |
| Bright Sunshine duration | Seedling | > 5 hours | 87 % | < 5 hours | 81 % |
| | Vegetative | > 5-6 hours | 75 % | < 5-6 hours | 87 – 90 % |
| Growing Degree Days | FBI | < 325 °days | 73 % | > 325 °days | 88 % |
| | Flowering | < 200 °days | 76 % | > 200 °days | 81 % |

*FBI: Flower bud initiation

## Wheat

### Anand

Water requirement and water use efficiency of four wheat cultivars (GW-322, GW-496, GW-366 and GW-1139) grown under four environments (1st Nov, 15th Nov, 30th Nov and 15th Dec, 2012) were assessed (Table 4.8). Wheat cultivar GW-322 sown on 1st November required more water and cultivar GW-1139 sown on 30th Nov and 15th Dec was the least water requiring variety. Wheat cv. GW-366 was the most efficient in water use across the sowings.

**Table 4.8:** Crop water requirements (mm) and WUE (kg/ha.mm) of wheat cultivars

| Variety | 1st Nov. | | 15th Nov. | | 30th Nov. | | 15th Dec. | | Average | |
|---|---|---|---|---|---|---|---|---|---|---|
| | CWR | WUE | CWR | WUE | CWR | WUE | CWR | WUE | CWR | WUE |
| GW-322 | 217 | 23.4 | 208 | 27.8 | 205 | 27.2 | 177 | 26.0 | 201.75 | 26.1 |
| GW-496 | 206 | 23.3 | 204 | 26.0 | 193 | 26.4 | 192 | 25.2 | 198.75 | 25.2 |
| GW-366 | 211 | 23.5 | 196 | 29.5 | 190 | 29.8 | 189 | 26.3 | 196.5 | 27.3 |
| GW-1139 | 194 | 16.8 | 193 | 22.2 | 186 | 25.7 | 186 | 22.9 | 189.75 | 21.9 |
| **Average** | 207 | 21.7 | 200 | 26.4 | 194 | 27.3 | 186 | 25.1 | | |

## Hisar

Sensitivity of wheat to weather prevailed during vegetative and reproductive phases was analyzed by correlation studies which revealed that maximum and minimum temperatures, evaporation and sunshine during reproductive stage have a positive influence and the influence became negative during vegetative stage (Table 4.9). The positive influence of temperature, evaporation and sunshine might be due to a enhanced photosynthetic activity. Negative influence of temperature during vegetative stage might be a reflection of increased respiration rate leading to poor sink development. Increased number of tillers per plant was noticed with a concurrent increase in rainfall. Number of tillers per plant and 1000 seed weight were found to be positively correlated with Tmin, Tmax, sunshine hour, evaporation and rainfall during the vegetative phase and negatively correlated with Tmin, Tmax, sunshine hours and evaporation during the reproductive phase.

**Table 4.9: Pearson's correlation coefficients (r) for seed yield and yield attributes with weather parameters during different stages of wheat**

| Weather parameters | Seed yield (Kg ha$^{-1}$) | Straw yield (Kg ha$^{-1}$) | No. of Tillers/ plant | 1000 seed weight (g) |
|---|---|---|---|---|
| **Vegetative stage** | | | | |
| Maximum temperature (°C) | -0.76* | -0.73* | 0.74* | 0.75* |
| Minimum Temperature (°C) | -0.75* | -0.68* | 0.75* | 0.78* |
| Morning RH (%) | 0.73* | 0.68* | -0.63* | -0.68* |
| Evening RH (%) | 0.65* | 0.73* | -0.76* | -0.74* |
| Bright Sunshine hours (hrs) | -0.72* | -0.68* | 0.74* | 0.72* |
| Evaporation (mm) | -0.65* | -0.62* | 0.73* | 0.75* |
| Rainfall (mm) | -0.77* | -0.65* | 0.67* | -0.65* |
| **Reproductive stage** | | | | |
| Maximum temperature (°C) | 0.65* | 0.74* | -0.72* | -0.75* |
| Minimum Temperature (°C) | 0.68* | 0.65* | -0.75* | -0.67* |
| Morning RH (%) | -0.64* | -0.75* | 0.74* | 0.75* |
| Evening RH (%) | -0.62* | -0.71* | 0.73* | 0.73* |
| Bright Sunshine hours (hrs) | 0.67* | 0.77* | -0.77* | -0.70* |
| Evaporation (mm) | 0.65* | 0.71* | -0.71* | -0.72* |
| Rainfall (mm) | -0.65* | -0.68* | 0.65* | -0.68* |

## Kanpur

A negative influence on rainfall and relative humidity during tillering stage of three wheat varieties (HD-2733, K-307 and K-9107) sown under three different dates (23rd Nov, 8th Dec and 23rd Dec, 2012) was noticed from correlation analysis (Table 4.10). On the other hand, humidity during anthesis and maturity showed positive influence. Barring tillering stage, at all other stages temperature and sunshine had a negative influence.

**Table 4.10:** Pearson's Correlation coefficients between wheat yield and weather at different stages

| Growth stage | Tillering | Anthesis | Grain filling | Maturity |
|---|---|---|---|---|
| Maximum temperature (°C) | 0.92 | -0.94 | -0.92 | -0.97 |
| Minimum Temperature (°C) | 0.91 | -0.94 | -0.95 | -0.96 |
| Mean Temperature (°C) | 0.92 | -0.94 | -0.94 | -0.97 |
| Mean soil temperature (5 cm) | 0.91 | -0.94 | -0.93 | -0.96 |
| Morning RH (%) | -0.86 | 0.65 | 0.85 | 0.97 |
| Evening RH (%) | -0.87 | -0.44 | 0.85 | 0.95 |
| Mean Relative humidity (%) | -0.87 | -0.12 | 0.85 | 0.97 |
| Bright Sunshine hours (hrs) | 0.83 | -0.92 | -0.88 | -0.41 |
| Wind speed (km/hr) | 0.36 | -0.87 | 0.12 | -0.91 |
| Rainfall (mm) | -0.76 | -0.83 | 0.77 | 0.66 |
| Evaporation (mm) | 0.89 | 0.77 | 0.61 | -0.13 |
| Accumulated Growing degree days (°Cd) | 0.85 | -0.85 | -0.92 | -0.23 |

## Ludhiana

Response of wheat varieties to temperature rise @ 0.4°C was studied by growing the crop in a temperature gradient tunnel (TGT). Wheat response presented in Fig. 4.7 showed that all varieties are sensitive to a rise in temperature and yields decreased gradually as the temperature increased from 1°C to 2.2°C. The cultivar DBW-17 was the most sensitive to temperatures with an yield reduction of 44% at a temperature rise of 2.2°C followed by PBW-621 (-36%), PBW-550 (-30%) and PBW-343 (-25%).

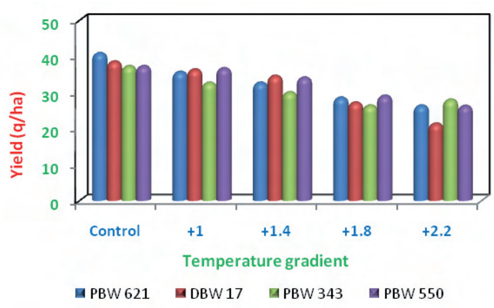



**Fig. 4.7:** Response of wheat varieties to a rise in temperature at Ludhiana

## Palampur

Optimum thresholds for minimum temperature and maximum temperatures during reproductive phase to attain an yield level of >3t/ha were determined from a six year experimentation. The optimum in case of minimum temperature was 10.9 and maximum temperature was 23.4°C. A rise in both temperatures above the threshold were found to be detrimental for wheat yields (Fig. 4.8 a and b). The impact became more pronounced as the duration of the temperatures above the threshold became large.

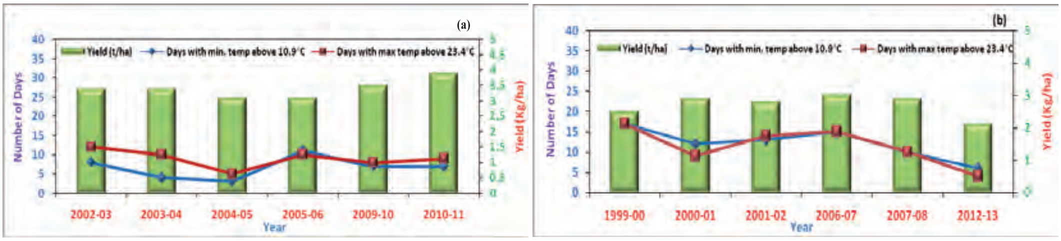



**Fig. 4.8:** Impact of duration of temperatures above threshold during reproductive phase for (a) high yield (>3 t/ha) and (b) low yield (2-3 t/ha) group of wheat at Palampur

## Ranchi

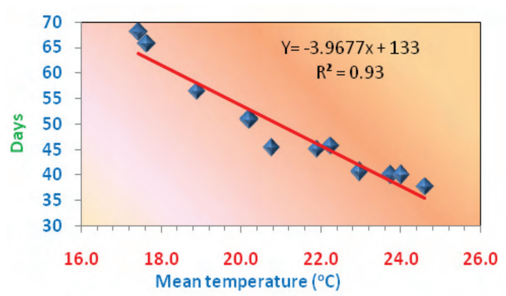
Sensitiveness of three wheat cultivars (HUW468, K9107 and BG 3) to air temperature was assessed by exposing them to seventeen sets of different micro environments by sowing on different dates in five years (2007-2012). Correlation analysis of the pooled data showed significant negative correlation between wheat yields and average maximum and minimum temperatures at most of the critical stages (Table 4.11). The period from anthesis to milking was found to be most sensitive stage to temperature rise, and BG 3 was most susceptible to increased minimum temperature at boot to anthesis stage. Among the varieties, BG 3 was found to be relatively temperature tolerant. Wheat cultivar K9107 was the most temperature sensitive.

**Table 4.11: Pearson's correlation coefficients between temperature during different phenophases and grain yield of wheat varieties**

| Variety | Temperature/ Stages | Vegetative | Boot-Anthesis | Anthesis-Milking | Milking-Maturity |
|---|---|---|---|---|---|
| K9107 | Maximum temperature (°C) | -0.50 | -0.78* | -0.85** | -0.74* |
| | Minimum Temperature (°C) | -0.17 | -0.68* | -0.76** | -0.68* |
| HUW468 | Maximum temperature (°C) | -0.53 | -0.59* | -0.59* | -0.28 |
| | Minimum Temperature (°C) | -0.27 | -0.44 | -0.52* | -0.29 |
| BG 3 | Maximum temperature (°C) | -0.38 | -0.50 | -0.56* | -0.43 |
| | Minimum Temperature (°C) | 0.02 | -0.60* | -0.51 | -0.40 |

### Udaipur

Impact studies on temperature during reproductive phase on yield of wheat variety Raj 4037 revealed that an increase in mean temperature during reproductive period by 1ºC reduces the reproductive period by about 4 days (Fig 4.9a). Heat stress during reproductive phase was found to be more pronounced than at vegetative stage. A mean temperature of 17.5 to 19.5ºC during reproductive phase was found to be optimum and pooled data (2007-08 to 2012-13) analysis revealed that higher grain yields can be realized during the years with mean temperature hovering around this optimum (Fig. 4.9b). Any increase in temperature beyond this optimum resulted in yield reductions ranging from 10.5 to 34.4 per cent.



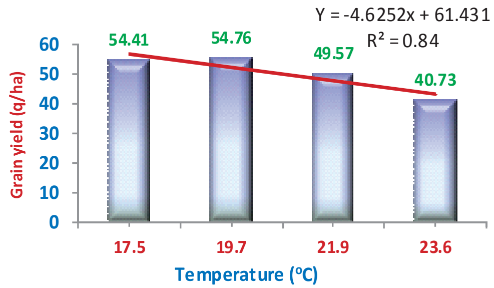




**Fig: 4.9:** Influence of mean temperature on (a) duration of reproductive phase and (b) grain yield of wheat at Udaipur

## Mustard

### Hisar

Energy balance studies were carried out over three mustard varieties (Kranti, RH-30, RH-406, RH 0749 and Laxmi) at different phenophases as well as at maximum LAI by recording energy partitioning on diurnal basis and compared with that of a bare field (Fig. 4.10). On a clear sunny day, most of the Net Radiation (Rn) was expended as Latent Energy (LE). In general, around 25 to 85 per cent of Rn was used as LE at different phenophases. Component of LE varied with the crop growth stage and date of sowing, whereas the values of LE over bare soil was more than 50 per cent of Rn. The increase in LE in the 1$^{st}$ to 3$^{rd}$ date of sowing was mainly due to variation in crop stage as well as LAI. The sensible heat flux (A) was less than LE irrespective of the sowing dates and date of observation. Among the varieties RH 0749 used higher fraction of Rn as LE compared to other varieties because it has more dense, green and erect canopy as compared to other varieties.

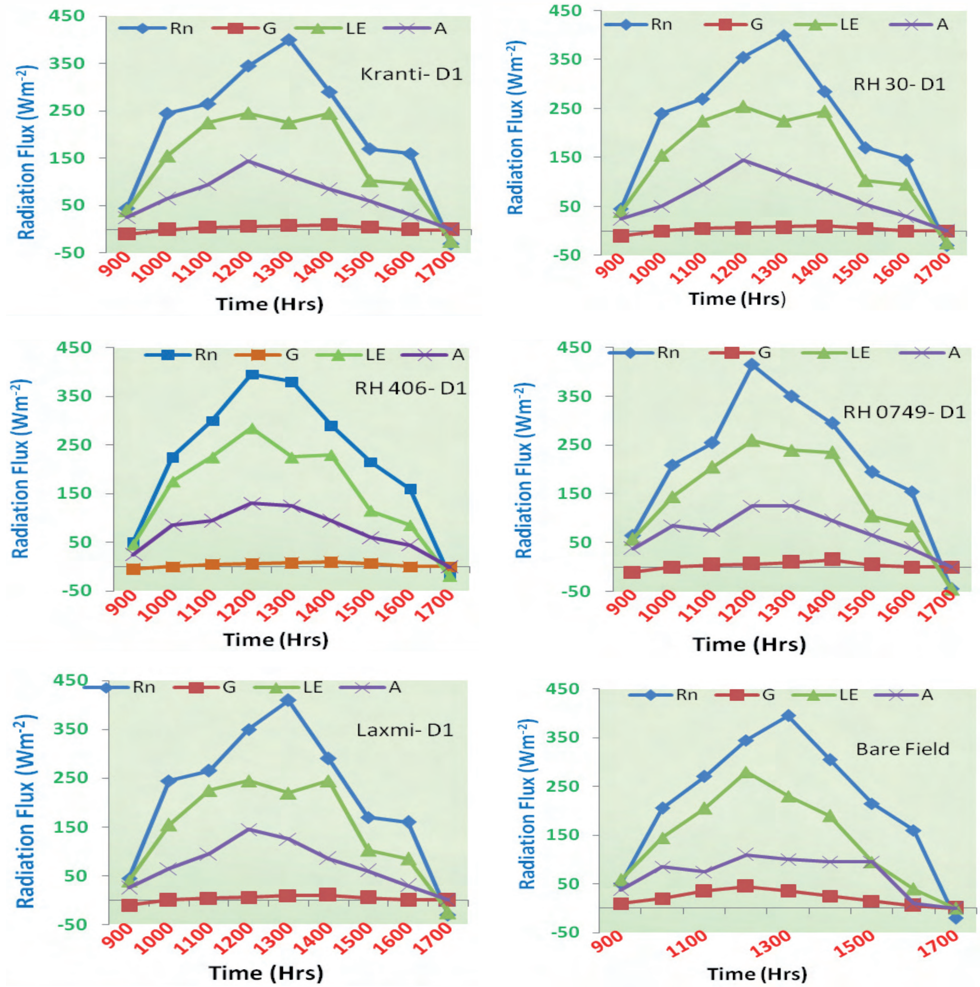



**Fig 4.10:** Partitioning of net radiant energy in different mustard varieties at Hisar

## Jammu

Relation between transpiration rate and Canopy Air Temperature Differential (CATD) in two mustard varieties (RL-1359 and RSPR-01) exposed to three different thermal regimes by sowing them on 22nd Oct, 30th Oct and 8th Nov 2012 was assessed and association between transpiration and CATD is presented in Fig 4.11. It was found that there was a decrease in transpiration with an increase in CATD. The model explains only 67% variation in transpiration due to CATD. The model can be used to detect water stress.

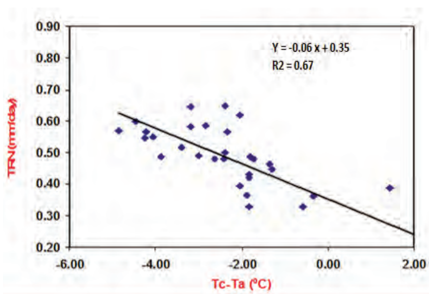



**Fig. 4.11:** Transpiration rate (mm/day) as a function of Canopy air temperature difference (°C) in mustard at Jammu

## Crop Coefficients

Crop Coefficients for mustard under sub-tropical condition of Jammu region were derived. The actual evapotranspiration (ETo) in different varieties of mustard for twelve seasons were measured with the help of lysimeter and mean weekly Kc values during crop growing season are presented in Fig. 4.12. The Kc value increases with crop age and reaches a maximum of 0.97 at 14th week after sowing and falls thereafter till maturity.

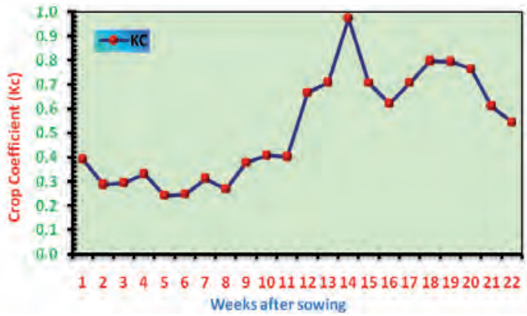



**Fig. 4.12:** Crop coefficient of mustard crop at different weeks after sowing (Mean of 12 seasons) at Jammu

# Chickpea

## Faizabad

Leaf Area Index (LAI) of any crop is an indicator of the growth and vigour of crop canopy and its ability to intercept PAR. Their relationship between LAI and APAR in chickpea was studied using experimental data of three cultivars (Radhey, Pusa 362 and Uday) and three sowing dates (25th Oct, 4th Nov and 14th Nov 2012) (Fig. 4.13). LAI and APAR showed a linear relationship with coefficient of determination of 95 per cent. The slope indicates that with a unit increase in LAI, the canopy is going to intercept 165 MJ of APAR more.

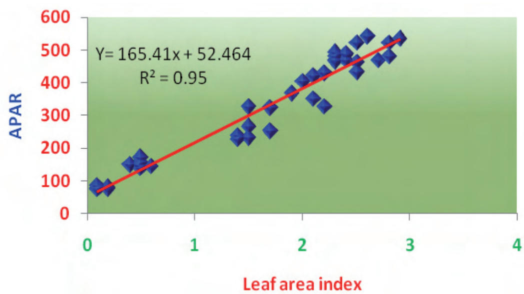



**Fig. 4.13:** Relation between LAI and APAR in chickpea at Faizabad

## Maximum temperature during reproductive stage

Maximum temperature during reproductive stage was found to have negative influence on chickpea yields as illustrated in Fig. 4.14. Yields decreased @ 0.29 q/ha for every 1°C rise in maximum temperature during reproductive stage in the temperature range of 27.2 to 33.2°C.

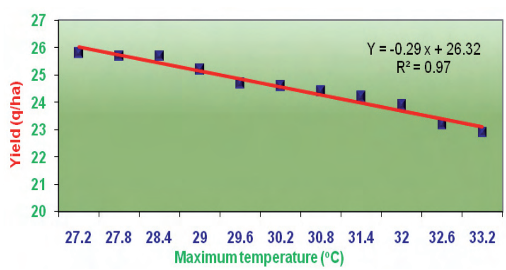



**Fig. 4.14:** Influence of maximum temperature prevailed during reproductive stage on the seed yield of Chickpea at Faizabad

## Jabalpur

Response of chickpea to weather at Jabalpur was assessed on seven varieties of chickpea (JGK-1, JG-315, JGK-3, JG-11, JGG-1, JG-322, JG-74) sown on three different dates (8th Nov, 23rd Nov, 8th Dec, 2012). Correlation coefficients between seed yield and weather parameters prevailed at different phenophases (Table 4.12) showed that during flowering stage crop responded positively to morning RH while during maturity both morning and evening RH were detrimental. During branching stage crop responded positively to evaporation. Sunshine hours and thermal units had positive relation during maturity stage.

**Table 4.12: Pearson's correlation coefficients between seed yield and weather parameters at different phenological stages in chickpea**

| Phenology | Branching | Flowering | Pod | Maturity |
|---|---|---|---|---|
| Maximum temperature (°C) | 0.06 | 0.45 | 0.38 | 0.42 |
| Minimum Temperature (°C) | -0.11 | 0.45 | 0.25 | 0.09 |
| Mean Temperature (°C) | -0.38 | 0.45 | 0.3 | 0.3 |
| Bright Sunshine hours (hrs) | 0.24 | -0.35 | 0.3 | 0.8** |
| Growing degree days (°Cd) | -0.73 | 0.22 | -0.36 | 0.44 |
| Helio thermal units (° Cd*hr) | 0.11 | -0.32 | 0.24 | 0.88** |
| Pheno thermal units (° Cd*hr) | 0.3 | -0.35 | 0.31 | 0.84** |
| Morning RH (%) | 0.56 | 0.73** | 0.24 | -0.61* |
| Evening RH (%) | -0.05 | -0.53 | 0.08 | -0.7* |
| Wind speed (km/hr) | 0.67* | -0.38 | -0.13 | -0.44 |
| Evaporation (mm) | 0.76* | -0.48 | 0.14 | 0.44 |
| Rainfall (mm) | 0.14 | -0.4 | 0.19 | 0.29 |

(* Significant at 5 percent level; ** Significant at 1 percent level)

## Solapur

Influence of weather prevailed during different phenophases on productivity of two chickpea varieties (Vijay and Dig Vijay) was assessed from four years of experimentation (2009-10 to 2012-13). It can be inferred from the correlation coefficients that crop requires higher minimum temperature for emergence (Table 4.13). Temperature (maximum and minimum) and rainfall favours the growth and development of chickpea crop. These significant weather parameters were used to develop following yield prediction model which explains about 75% variation in the chickpea yields.

Yield = -13285.7 + 382.9 *Tmax + 121.0* Tmin + 0.8*RF ............. ($R^2$= 0.75)

**Table 4.13: Pearson's correlation coefficients between seed yield and different weather parameters prevailed during different phenophases of chickpea at Solapur**

| Met. Indices | Phenophase | | | | |
|---|---|---|---|---|---|
| | Emergence | Branching | 50 % Flowering | Pod Formation | Pod maturity |
| Rainfall (mm) | 0.16 | 0.53* | 0.60* | 0.61* | 0.59* |
| Maximum temperature (°C) | 0.21 | 0.85** | 0.85** | 0.84** | 0.85** |
| Minimum Temperature (°C) | 0.63** | 0.64** | 0.68** | 0.76** | 0.79** |
| Morning RH (%) | 0.56* | 0.24 | 0.19 | 0.15 | 0.12 |
| Evening RH (%) | 0.50* | 0.36 | 0.31 | 0.29 | 0.25 |
| Wind speed (km/hr) | 0.07 | -0.47 | -0.01 | 0.06 | -0.31 |
| Bright Sunshine hours (hrs) | -0.27 | -0.07 | -0.09 | -0.18 | -0.10 |
| Evaporation (mm) | -0.10 | -0.05 | 0.14 | 0.12 | 0.22 |

(Significant at *0.05 and **0.01)

## Greengram

### Kovilpatti

Among the different sowing windows, crop sown during pre-monsoon and monsoon periods (39th and 41st std week) experienced lower atmospheric evaporation demands during reproductive stage of the crop (Table 4.14). The crop sown during the post-monsoon period (43rd std week) experienced higher evaporative demands at reproductive stage which might have affected the crop severely, thereby reflecting in the yields.

**Table 4.14: Rainfall and evaporation loss at different phenological stages of greengram as influenced by sowing dates at Kovilpatti**

| Stages / SMW | Germi-nation | | Vegetative and flower initiation | | Pod initiation | | 50% flowering | | 50 % Pod initiation | | Pod develop-ment | | Physio-logical maturity | | Yield (kg/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RF | Evp | RF | Evp | RF | Evp | RF | Evp | RF | Evp | RF | Evp | RF | Evp | |
| 39th | 20.4 | 3.0 | 189.3 | 3.3 | 0.0 | 4.6 | 1.4 | 3.6 | 0.2 | 2.2 | 0.2 | 4.0 | 15.4 | 2.7 | 263 |
| 41st | 20.4 | 3.0 | 189.3 | 3.3 | 0.0 | 4.6 | 1.4 | 3.6 | 0.2 | 2.2 | 0.2 | 4.0 | 15.4 | 2.7 | 269 |
| 43rd | 85.4 | 2.2 | 25.0 | 3.5 | 0.2 | 2.2 | 0.2 | 4.2 | 0.0 | 4.2 | 15.4 | 3.7 | 0 | 4.5 | 161 |

RF - Rainfall and Evp - Evaporation

# Potato

## Jorhat

Tuber yields of potato as influenced by weather at different phenophases were studied using correlation analysis which showed that both air and soil temperatures had a positive influence on crop growth and development during stolon formation (Table 4.15). During maturity stage, crop responded positively to bright sunshine hours.

**Table 4.15: Pearson's correlation coefficients between potato tuber yield and mean weather conditions at Jorhat**

| Growth stage | Maximum Temp. (°C) | Minimum Temp. (°C) | Mean Temp. (°C) | Morning RH (%) | Evening RH (%) | Bright Sunshine hours (hrs) | Soil Temp. |
|---|---|---|---|---|---|---|---|
| Stolon formation | 0.55 | 0.66 | 0.71 | 0.43 | 0.25 | 0.30 | 0.73 |
| Tuber formation | 0.09 | 0.03 | 0.02 | 0.19 | 0.14 | 0.03 | 0.21 |
| Tuber development | 0.36 | 0.44 | 0.45 | 0.20 | 0.34 | 0.35 | 0.14 |
| Maturity | 0.36 | 0.40 | 0.02 | 0.12 | 0.34 | 0.72 | 0.31 |

## Mohanpur

Water use in potato as influenced by sowing time, variety and irrigation showed that cv. Jyoti planted on 15th November under Alternate Furrow Irrigation (ALFI) system of irrigation has the highest WUE (Fig. 4.15). Lowest seasonal ET was recorded in cv. Surya planted on 29th November under All Furrow Irrigation (AFI) system of irrigation.

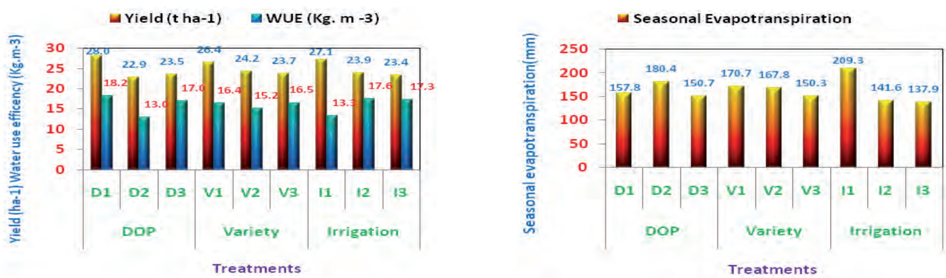



**Fig. 4.15:** Influence of date of planting, irrigation method and variety on (a) yield, WUE and (b) seasonal ET of potato at Mohanpur

# Cauliflower

## Thrissur

Influence of minimum temperature on duration of different phenophases and final curd yield in cauliflower was studied by planting under different dates. Curd yield was observed to be high when the duration of transplanting to curd initiation phase was short (Fig. 4.16). Duration of this growth stage varied between 50.9 days and 55.6 days. It was found that minimum temperature showed an overall negative influence on the duration from transplanting to curd initiation. But for the curd initiation to occur, the minimum temperature should be low in the preceding week.

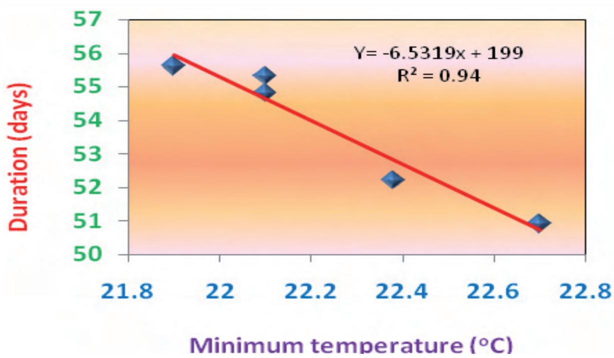



**Fig. 4.16:** Influence of minimum temperature on time taken from transplanting to curd initiation phase in cauliflower at Thrissur

## Prediction model

An yield prediction model was developed from mean weather conditions that prevailed from transplanting till curd initiation which is as follows:

Curd weight = 474.743 $T_{max}$ – 569.084 $T_{min}$ + 77.06 RH II – 418.844 BSS – 2547.22

The above model is helpful in predicting the curd yields well in advance and predicted curd yields agreed well with the actual yield (Fig. 4.17).

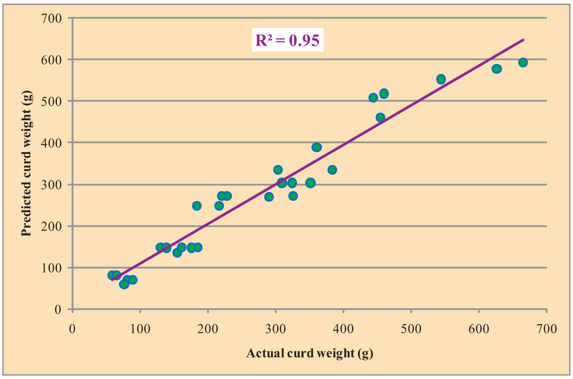



**Fig. 4.17:** Actual and predicted curd weight of cauliflower at Thrissur

# Mango

## Dapoli

A study on the flowering behaviour of Alphonso mango during 1997-98 to 2011-12 revealed that flowering commences during $48^{th}$ SMW and extends up to $2^{nd}$ SMW of the succeeding year. Weather conditions that prevailed during the week in question and that of preceding one to four weeks did not show any significant influence on the flower initiation (Table 4.16).

**Table 4.16: Pearson's correlation coefficients between weather parameters and flowering initiation in Alphonso mango at Dapoli**

| Statistic | Flowering | Weather parameters of present week | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Maximum Temp. (°C) | Minimum Temp. (°C) | Morning RH (%) | Evening RH (%) | Bright Sunshine hours (hrs) | Rainfall (mm) | Rainy days | Evaporation rate (mm/day) |
| Mean | 50.33 | 31.76 | 13.76 | 92.32 | 47.86 | 7.91 | 0.69 | 0.00 | 3.60 |
| C.V. | 3.38 | 1.21 | 7.09 | 14.02 | 127.60 | 1.16 | 6.24 | 0.00 | 0.93 |
| S.D. | 1.84 | 1.10 | 2.66 | 3.74 | 11.30 | 1.08 | 2.50 | 0.00 | 0.96 |
| Correlation | -- | 0.156 | 0.290 | 0.120 | 0.104 | -0.369 | 0.0956 | --- | 0.047 |
| Weather parameters of previous week | | | | | | | | | |
| Mean | 50.33 | 31.82 | 14.42 | 91.83 | 51.73 | 7.97 | 2.93 | 0.00 | 3.93 |
| C.V. | 3.38 | 1.70 | 6.62 | 20.56 | 127.13 | 0.36 | 120.46 | 0.00 | 0.80 |
| S.D. | 1.84 | 1.35 | 2.66 | 4.69 | 11.67 | 0.62 | 11.36 | 0.00 | 0.93 |
| Correlation | -- | -0.136 | -0.025 | 0.057 | 0.220 | -0.485 | 0.091 | --- | 0.265 |
| Weather parameters preceding two weeks | | | | | | | | | |
| Mean | 50.33 | 32.25 | 15.02 | 91.99 | 51.06 | 8.11 | 0.33 | 0.07 | 4.26 |
| C.V. | 3.38 | 0.53 | 6.86 | 34.17 | 148.92 | 0.71 | 1.31 | 0.06 | 0.92 |
| S.D. | 1.84 | 0.75 | 2.71 | 6.05 | 12.63 | 0.87 | 1.18 | 0.26 | 0.99 |
| Correlation | -- | 0.089 | 0.372 | -0.102 | 0.315 | -0.231 | 0.119 | 0.107 | 0.341 |
| Weather parameters preceding three weeks | | | | | | | | | |
| Mean | 50.33 | 32.53 | 17.02 | 93.07 | 55.20 | 7.60 | 0.77 | 0.07 | 4.08 |
| C.V. | 3.38 | 0.43 | 7.26 | 10.20 | 138.43 | 1.46 | 4.06 | 0.07 | 0.95 |
| S.D. | 1.84 | 0.68 | 2.79 | 3.31 | 12.18 | 1.25 | 2.09 | 0.27 | 1.01 |
| Correlation | -- | 0.188 | 0.463 | -0.068 | 0.062 | -0.033 | 0.092 | 0.073 | 0.051 |
| Weather parameters preceding four weeks | | | | | | | | | |
| Mean | 50.33 | 31.91 | 30.03 | 32.32 | 87.53 | 45.16 | 13.77 | 0.28 | 0.57 |
| C.V. | 3.38 | 2.49 | 29.68 | 948.8 | 125.58 | 462.03 | 599.58 | 0.59 | 1.44 |
| S.D. | 1.84 | 1.63 | 5.64 | 31.88 | 11.60 | 22.25 | 25.35 | 0.80 | 1.24 |
| Correlation | -- | -0.237 | 0.430 | -0.219 | 0.500 | 0.424 | 0.148 | 0.150 | -0.397 |

## Dairy milk production

### Palampur

Temperature-humidity index (THI) and milk production data of Research Dairy Farm at Palampur for a period of 13 years (2000-12) were used to analyse the heat stress effect on the milch animals. During different months the THI values ranged between 47 to 72 in the morning and 55 to 77 in the afternoon. Mild heat stress with THI ranging from 72-79 could be observed in the afternoon hours (between 12 to 4PM) during May to September only, whereas the stress was absent in the morning in these months except June (Table 4.17).

**Table 4.17: Milk production as influenced by weather parameters at Research Dairy Farm at Palampur**

| Months | Milk Prod. (Kg) | Change in milk production | $THI^*_I$ | Change in $THI_I$ | $THI^*_{II}$ | Change in $THI_{II}$ | Mean THI | Change in Mean THI |
|---|---|---|---|---|---|---|---|---|
| Jan | 21225.9 | | 47 | | 55 | | 51 | |
| Feb | 19640.9 | -1585 | 50 | 3 | 58 | 3 | 54 | 3 |
| Mar | 23175.4 | 3534.5 | 55 | 5 | 65 | 7 | 60 | 6 |
| Apr | 22714.8 | -460.6 | 62 | 7 | 71 | 6 | 66 | 6 |
| May | 24367.7 | 1652.9 | 67 | 5 | 76 | 5 | 71 | 5 |
| Jun | 22036.6 | -2331.1 | 72 | 5 | 77 | 1 | 75 | 4 |
| Jul | 21652.3 | -384.3 | 71 | -1 | 75 | -2 | 73 | -2 |
| Aug | 21026.8 | -625.5 | 70 | -1 | 74 | -1 | 72 | -1 |
| Sep | 19495.4 | -1531.4 | 67 | -3 | 75 | 1 | 71 | -1 |
| Oct | 19420 | -75.4 | 60 | -7 | 71 | -4 | 65 | -6 |
| Nov | 18431.6 | -988.4 | 53 | -7 | 65 | -6 | 59 | -6 |
| Dec | 19901.1 | 1469.5 | 50 | -3 | 61 | -4 | 55 | -4 |

* $THI_I$ and $THI_{II}$ are THI in morning and afternoon respectively.

The scatter plots between changes in milk production and changes in five month (June to Oct.) mean THI values during which the milk production is likely to be affected due to thermal stress are presented in Fig. 4.18. The scatter plot shows that there is significant change in milk production (-165.5 Kg) with unit change in afternoon time THI values. In order to dissipate the mild heat stress experienced by the dairy animals in the afternoons during the months of June to October in Palampur region, showers with plain water once or twice could be extremely useful along with proper ventilated improved housing. Temperature during October to May was largely hostile calling for better heat conserving housing as well as additional concentrates to be fed to the dairy animals for maintaining body temperature for higher productivity.

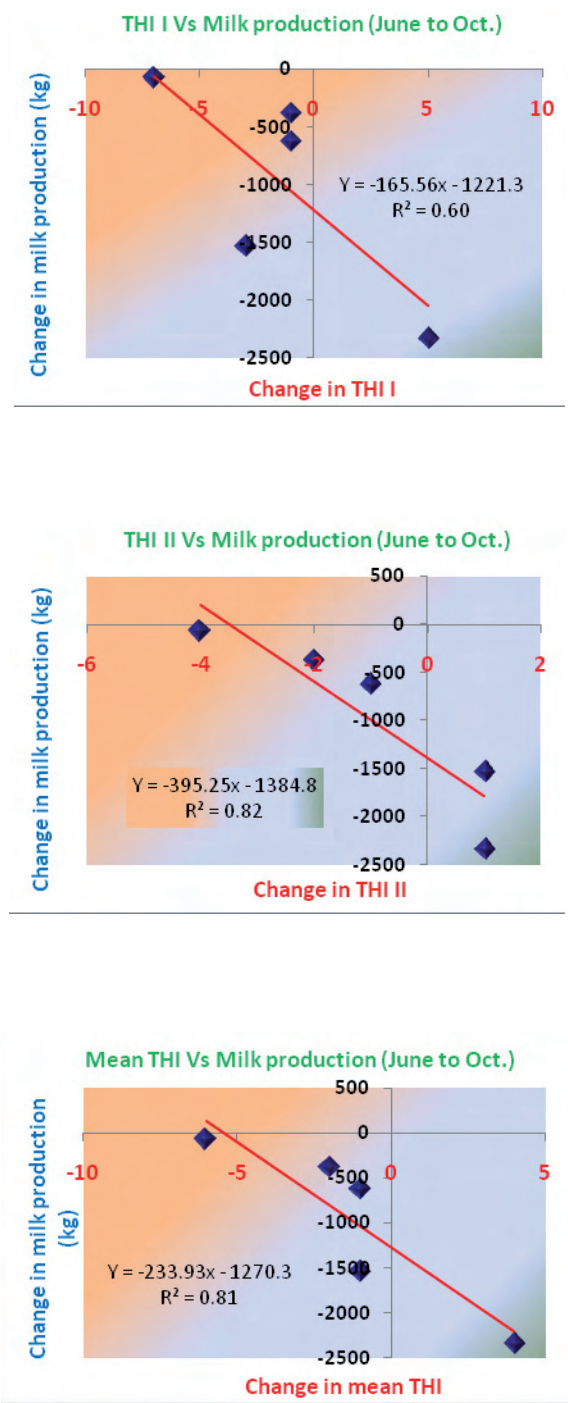



**Fig. 4.18:** Scatter plots between change in production in response to a change in THI values at different times of the day at Palampur

# 5. Crop growth modelling

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

## Groundnut

### Anand

Experimental data (2009-12) for a three year period were used to validate and calibrate PNUTGRO model for Anand conditions. Model performance in simulating days to anthesis, days to maturity, LAI and pod yields are presented in Fig 5.1. It can be inferred that model over-estimated periodic LAI and days to anthesis and under estimated days to maturity. However, the model simulated pod yields were close to the observed at most of the occasions.

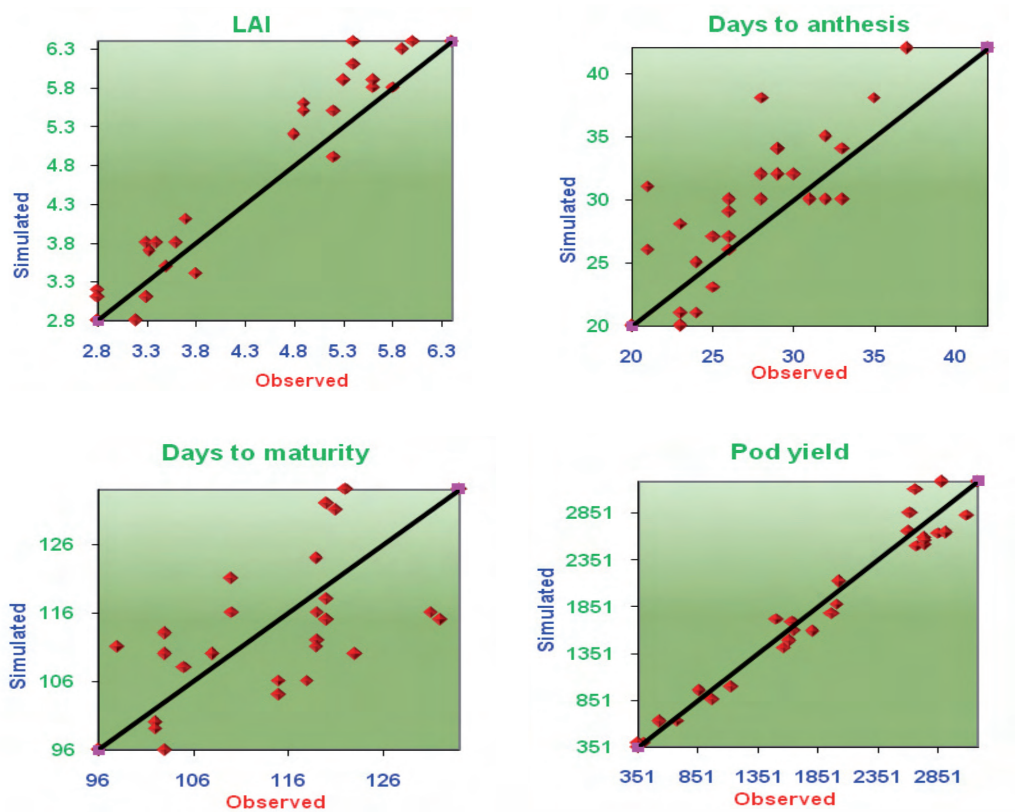



**Fig. 5.1:** Performance of PNUTGRO model in simulating growth and yield of groundnut at Anand

## Anantapur

Models to predict phenological stages like flowering, pod initiation and maturity in groundnut were developed using thermal time. Individual model's performance was evaluated against observed data of 2011 and 2012 and average values of two years are presented in Table 5.1. Model that predicts flowering performed with an accuracy of ± 1.0 day in all dates of sowing but model to predict maturity did not perform well and the error ranged from -2 to -8.5 days.

**Table 5.1: Validation of thermal time based models to predict phenological stages of groundnut at Anantapur**

| Phenological stage | Model used | predicted days | Actual days |
|---|---|---|---|
| **Early sowing** | | | |
| Flowering | Y = 0.0604 X – 2.3237 | 23.5 | 23 |
| Pod initiation | Y = 0.0526 X + 3.5424 | 54 | 54.5 |
| Maturity | Y = 0.0353 X + 39.716 | 114.5 | 116.5 |
| **Normal sowing** | | | |
| Flowering | Y = 0.0604 X – 2.3237 | 22 | 21.5 |
| Pod initiation | Y = 0.0526 X + 3.5424 | 54.5 | 55.5 |
| Maturity | Y = 0.0353 X + 39.716 | 112.5 | 121 |
| **Late sowing** | | | |
| Flowering | Y = 0.0479 X + 3.212 | 21.5 | 21.5 |
| Pod initiation | Y = 0.0495 X + 5.7102 | 51 | 52 |
| Maturity | Y = 0.0237 X + 59.227 | 106.5 | 115 |

(Variable X = Growing degree days)

## Bengaluru

Models developed from agrometeorological indices / variables like GDD, SSH and AET to predict drymatter accumulated at different phenophases of groundnut utilizing data collected during 200-2009 period were validated for the year 2012. The models tested are of the form:

$$T_i = T_{i-1}S_i + (A_iX_i + B_iY_i + C_iZ_i) \ldots\ldots\ldots\ldots(1)$$

Where Ti = Accumulated dry matter at the end of $i^{th}$ stage

S = Coefficient of previous stage accumulated biomass

X = GDD, Y = SSH, Z = AET

and

$$Yg = IT_1(O) + JT_2(O) + KT3(O) + LT_4(O) + MT_5(P) \ldots\ldots\ldots\ldots (2)$$

Where, Yg is pod yield, $T_1(O)$, $T_2(O)$, $T_3(O)$ and $T_4(O)$ are the observed total dry-matter at the end of first four stages and $T_5(P)$ is the predicted total dry-matter for 5th stage. I, J, K, L, M and N are the stage specific coefficients. Regression coefficients of different variables and coefficient of determination ($R^2$) for fitted models for drymatter accumulation for different stages are presented in Table 5.2. This model was found to be significant, accounting for 87.74% variation in the pod yields. However, the yield prediction model found to over-estimate the yields for two varieties but performed reasonably well in case of cv. K-134 with predicted yields very much close to the observed (Table 5.3).

**Table 5.2: Regression coefficients for different variables for different phenological stages**

| Stages of crops | | Initial TDM | GDD | SSH | AET | $R^2$ |
|---|---|---|---|---|---|---|
| 30 DAS | | | 0.0065 | 0.0119 | -0.0284 | 0.7724 |
| 50% flowering stage | | 1.8585* | 0.0013 | -0.0112 | 0.0668 | 0.9608 |
| Pod initiation stage | | 1.6820* | 0.0633 | 0.0066 | -0.1461 | 0.9353 |
| Pod filling stage | | 0.9036* | -0.0133 | 0.0561 | 0.0056 | 0.9433 |
| Harvesting stage | | 1.0541* | 0.0196 | -0.0515 | 0.0189 | 0.9795 |
| **Pod yield** | **TDM 1** | **TDM 2** | **TDM 3** | **TDM 4** | **Predicted TDM 5** | **$R^2$** |
| | 1.4275 | -0.0307 | -0.4205 | -0.0276 | 0.6358* | 0.8774 |

(* significant at 5% significance level)

**Table 5.3: Validation of Stocheometric crop weather model for year 2012**

| Variety | Actual (kg/ha) | Forecasted (kg/ha) | Percent deviation |
|---|---|---|---|
| TMV-2 | 522.9 | 619.2 | 15.6 |
| JL-24 | 414.6 | | 33.0 |
| K134 | 615.8 | | 0.6 |
| Mean | 517.8 | | 16.4 |

# Rice

## Faizabad

Performance of DSSAT-rice model for Sarjoo-52 was evaluated using a two year experimental data (2009-11). A comparison of observed and simulated values for phenological events and grain yield are presented in Table 5.4. Model slightly over-estimated days taken to anthesis under all transplanting dates with an error range of 0 to 5 days. However, the error was higher under late transplanted rice ($25^{th}$ July). Days to physiological maturity was under-estimated by model in early transplanting with error ranging from 0 to -19 days. Model under-estimated rice yields in July $5^{th}$ transplanted rice which may be due to higher number of days taken to anthesis and physiological maturity over simulated value. Due to delayed transplanting, the grain yield of rice decreased in accordance with observed values. It indicated the better sensitivity of DSSAT model.

**Table 5.4: Performance of DSSAT-rice in simulating phenology and yield of rice at Faizabad**

| Parameters | 5 July | | 15 July | | 25 July | |
|---|---|---|---|---|---|---|
| | Simulated | Observed | Simulated | Observed | Simulated | Observed |
| **2010** | | | | | | |
| Anthesis day | 91 | 90 | 91 | 87 | 90 | 85 |
| Phy. Maturity | 116 | 123 | 116 | 114 | 116 | 109 |
| Grain Yield | 4122 | 4168 | 4160 | 3964 | 4249 | 3782 |
| **2011** | | | | | | |
| Anthesis day | 93 | 93 | 92 | 90 | 90 | 85 |
| Phy. Maturity | 128 | 128 | 128 | 118 | 117 | 114 |
| Grain Yield | 4780 | 4132 | 4132 | 4691 | 4546 | 3615 |
| **2012** | | | | | | |
| Anthesis day | 89 | 93 | 90 | 90 | 90 | 88 |
| Phy. Maturity | 114 | 133 | 115 | 124 | 116 | 118 |
| Grain Yield | 4178 | 4224 | 4326 | 3975 | 4178 | 3952 |

## Jorhat

DSSAT-rice model's performance in simulating phenology and yield of cv. Ranjit was assessed using three years experimental data (1998, 1999, 2003) under different transplanting dates. Model could predict anthesis and physiological maturity within the reasonable limits compared to observed in all transplanting dates with a mean RMSE of

5.1 and 5.5, respectively (Table 5.5). Simulated yields were within ±16% of the observed for all the transplanting dates with a RMSE value of 401 kg/ha. The normalized RMSE value was below 10%. These results indicated that the DSSAT-Rice v4.5 model is capable of simulating growth and yield of rice cv. Ranjit grown in upper Brahmaputra valley with reasonable accuracy.

**Table 5.5: Validation of DSSAT-rice model in simulating phenology and yield of rice at Jorhat**

| Year | Date of transplanting | Days taken to anthesis (DAT) | | Days taken to physiological maturity (DAT) | | Grain yield (kg/ha) | |
|---|---|---|---|---|---|---|---|
| | | Observed | Simulated | Observed | Simulated | Observed | Simulated |
| 1998 | 22 June | 112 | 107 | 138 | 131 | 4795 | 4720 |
| | 07 July | 110 | 102 | 136 | 128 | 4380 | 4813 |
| | 22 July | 108 | 100 | 132 | 126 | 3960 | 4585 |
| 1999 | 20 June | 106 | 108 | 140 | 134 | 4204 | 4624 |
| | 05 July | 100 | 103 | 134 | 130 | 4387 | 4630 |
| | 20 July | 97 | 101 | 127 | 130 | 4150 | 4717 |
| 2003 | 24 June | 113 | 108 | 140 | 134 | 4550 | 4220 |
| | 22 June | 108 | 103 | 137 | 133 | 4230 | 4413 |
| | 07 July | 103 | 102 | 133 | 136 | 3980 | 4385 |
| RMSE | | | 5.1 | | 5.5 | | 401 |
| Normalized RMSE | | | 4.8 | | 4.1 | | 9.3 |

## Kanpur

DSSAT-rice model calibrated for rice cv. NDR-359 using two years' experimental data (2010-11) was used to project rice yields under climate change scenarios. The climate change scenarios were in turn obtained by running MARK sim weather generators. Simulation outputs of DSSAT-rice model with MARK sim average model input indicated that grain yield would decrease progressively from 2030 to 2050 and thereafter marginally increase by four per cent under late planted conditions. Simulations using MARK Sim MIROC3.2 model output predicted increasing trends in all three planting dates from 2020 to 2080. However, under late planting condition a decline in yields were projected @ 7% during 2020 to 2030 (Table 5.6). Model output of MARK Sim CSIRO –Mk-3.5 indicated that rice yields would increase by 0.2%, 7.0% and 10% from 2020 (6063 kg/ha) to 2040, 2050 and 2080, respectively, with an exception that yield would decrease by 2.4% in early plantings during 2020 to 2030.

**Table 5.6: DSSAT-rice simulated yields under different climatic scenarios at Kanpur**

| Climatic scenario | Time of transplanting | Grain yield (kg/ha) | | | | |
|---|---|---|---|---|---|---|
| | | Years | | | | |
| | | 2020 | 2030 | 2040 | 2050 | 2080 |
| MARK Sim Average model | Early | 5811 | 5932 | 5793 | 5872 | 6021 |
| | Timely | 5973 | 5998 | 6051 | 5931 | 5792 |
| | Late | 6063 | 5561 | 6014 | 5796 | 6089 |
| MARK Sim CNRM-CM3 model | Early | 5933 | 6120 | 5882 | 5691 | 5830 |
| | Timely | 5931 | 5975 | 6090 | 5936 | 6029 |
| | Late | 5536 | 5487 | 5502 | 5573 | 5491 |
| MARK Sim CSIRO-Mk3.5 model | Early | 6063 | 5917 | 6176 | 6491 | 6691 |
| | Timely | 6179 | 6157 | 6293 | 6325 | 6336 |
| | Late | 0 | 5831 | 5991 | 6124 | 6438 |
| MARK Sim ECHam5 model | Early | 6063 | 6134 | 6146 | 6362 | 0 |
| | Timely | 6179 | 6309 | 6069 | 6049 | 6373 |
| | Late | 0 | 5883 | 5999 | 6082 | 6046 |
| MARK Sim MIROC3.2 model | Early | 5301 | 5521 | 5851 | 6110 | 0 |
| | Timely | 5913 | 6227 | 6064 | 6206 | 6373 |
| | Late | 5484 | 5441 | 5855 | 5604 | 6046 |

## Mohanpur

DSSAT-rice model was validated for cv. Satabdi using data from three different planting dates (15th June, 29th June and 13th July). Model under-estimated grain yields for all the transplanting dates. The under-estimation ranged from 2.7 to 11.6% and the error range was more in the early transplanted crops (Fig 5.2).

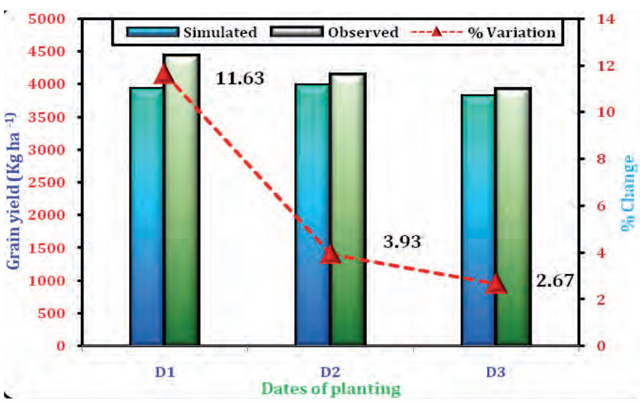



**Fig. 5.2:** Comparison of DSSAT-rice predicted and observed grain yields at Mohanpur

## Raipur

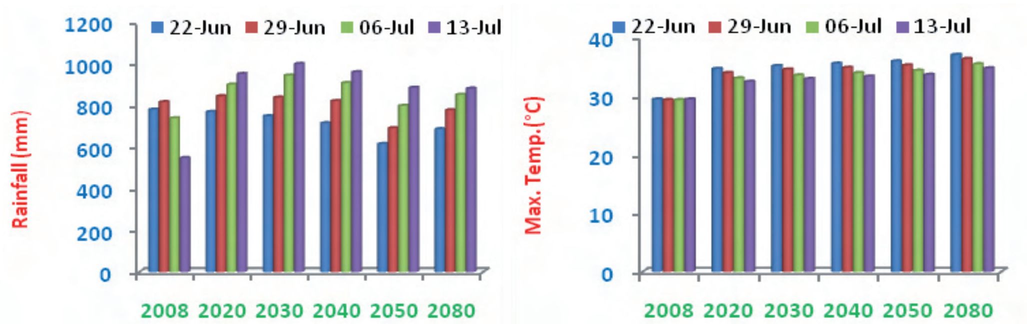
DSSAT-rice model calibrated for cv. Karma Masuri for present climatic conditions was used to assess the rice productivity in future climates. Sowing time criteria was used as a adaptation strategy and the results presented in Table 5.7 indicated that the sowing window of 21st June (2nd date of sowing in 2011) and 22nd June (3rd date of sowing in 2012) may be suitable in future climates as evident from projected positive change in yield as compared to corresponding current year yields.

**Table 5.7: Future changes in rice yields compared to yield under present climatic conditions at Raipur**

| Variety | Date of Sowing | Yield (kg/ha) | Yield difference compaired with present climate in | | | | |
|---|---|---|---|---|---|---|---|
| | | | 2020 | 2030 | 2040 | 2050 | 2080 |
| | | **2011** | | | | | |
| Karma Masuri | 11th June | 4849 | -3.73 | -18.83 | -30.52 | -56.75 | -3.73 |
| | 21st June | 5094 | 5.91 | 7.24 | 13.92 | 6.40 | 5.91 |
| | 29th June | 4000 | -2.20 | -5.80 | -7.03 | -5.13 | -2.20 |
| | | **2012** | | | | | |
| Karma Masuri | 10th June | 3486 | 32.21 | 9.84 | -7.75 | -39.62 | -72.29 |
| | 15th June | 3463 | 49.29 | 38.87 | 7.57 | -0.17 | -54.11 |
| | 22nd June | 4565 | 17.17 | 17.22 | 29.09 | 33.14 | -8.87 |

## Ranchi

Yield of upland rice variety Vandana for Ranchi region in future climates were projected using DSSAT-rice model and sowing dates were chosen as an adaptation strategy. Climate change scenarios of four different models were averaged to simulate the future climates at Ranchi for 2008, 2020, 2030, 2050, 2080. Projected rainfall and temperature conditions for four rice growing environments are presented in Fig. 5.3.



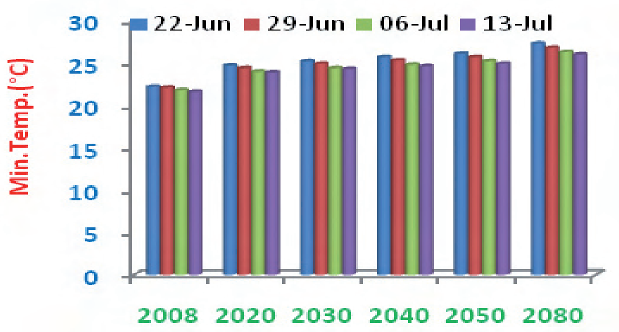



**Fig. 5.3:** Projected rainfall, maximum and minimum temperatures during four rice growing environments at Ranchi

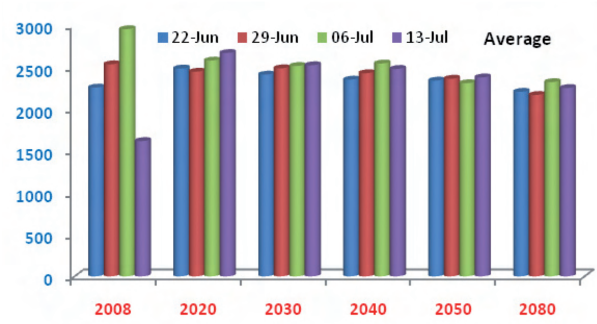



**Fig. 5.4:** DSSAT-rice predicted yields for different planting conditions

Reduced rice yields were projected with a reduction in rainfall coupled with an increasing maximum and minimum temperatures during the crop season (Fig 5.4). Weather output by different models indicated that predicted rainfall amount received during crop duration is increasing with delay in sowing and maximum amount would be received under late sown conditions (Fig. 5.3). Reduction in rainfall amount due to climate change under normal sowing conditions may lead to a reduction in yields. Rainfall amount decreased from 783.3 mm under present climate to 617.8 mm by 2050, whereas under late sown conditions it increased from 550 mm in present climate to 884.4 mm by the year 2080.

Average output of four models indicated an increasing trend in maximum and minimum temperatures but maximum temperature would increase for crops sown early compared to late sown crop. Mean minimum temperature also increased from 22.2, 22.1, 21.8 and 21.6°C to 27.3, 26.8, 26.3 and 26°C, respectively with delay in sowing time. Increase in mean maximum and minimum temperature was around 7.6 to 5°C for early sown crops and 5.3 to 4.4°C for late sown crop by the year 2080. This scenario is an indication of shifting or delayed onset of monsoon in future climates thereby calling for an adjustment in planting time and development of varieties which are heat tolerant and requiring less water.

## Wheat

### Faizabad

DSSAT-wheat model was used to simulate yields of wheat cv. HUW-234 under warming / cooling conditions ranging from ±0.5 to ±3.0°C. Data from a two years (2005-06) field experimentation were used to calibrate the model. A rise in temperature led to a decrease in days to maturity as well as yields across sowing dates. The magnitude of decline was high in early sown crop (Table 5.8). On the contrary, decreasing temperatures prolonged the crop duration across the sowing dates. Simulated crop yields progressively increased with decrease in temperature.

**Table 5.8: Simulated yields of wheat cv. HUW-234 under warm / cool environments at Faizabad**

| Sowing | Normal | | Percent deviation from normal | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | +0.5 °C | | +1.0 °C | | +1.5 °C | | +2.0 °C | | +2.5 °C | | +3.0 °C | |
| | M.D | Yield | M.D | Yield | M.D | Yield | M.D | Yield | M.D | Yield | M.D | Yield | M.D | Yield |
| 10 Nov. | 131 | 3291 | -2.29 | -1.76 | -3.82 | -5.99 | -6.11 | -7.99 | -8.40 | -11.76 | -9.92 | -13.52 | -12.21 | -16.74 |
| 25 Nov. | 127 | 3489 | -1.57 | -3.64 | -3.15 | -4.99 | -3.94 | -8.34 | -6.30 | -10.63 | -7.87 | -12.67 | -9.45 | -14.85 |
| 10 Dec. | 120 | 3326 | -0.83 | -0.93 | -0.83 | -1.56 | -2.50 | -4.06 | -4.17 | -6.16 | -5.83 | -7.28 | -7.50 | -9.68 |
| | Normal | | -0.5 °C | | -1.0 °C | | -1.5 °C | | -2.0 °C | | -2.5 °C | | -3.0 °C | |
| 10 Nov. | 131 | 3291 | 1.53 | 2.34 | 3.05 | 4.44 | 4.58 | 7.99 | 6.11 | 11.85 | 7.63 | 16.59 | 9.16 | 20.02 |
| 25 Nov. | 127 | 3489 | 0.79 | 1.61 | 1.57 | 1.89 | 2.36 | 4.56 | 3.94 | 6.33 | 4.72 | 8.40 | 5.51 | 7.51 |
| 10 Dec. | 120 | 3326 | 0.83 | 2.07 | 0.83 | 1.32 | 1.67 | 1.05 | 1.67 | 0.18 | 2.50 | -0.12 | 3.33 | -1.92 |

(M.D. - Maturity days)

### Jammu

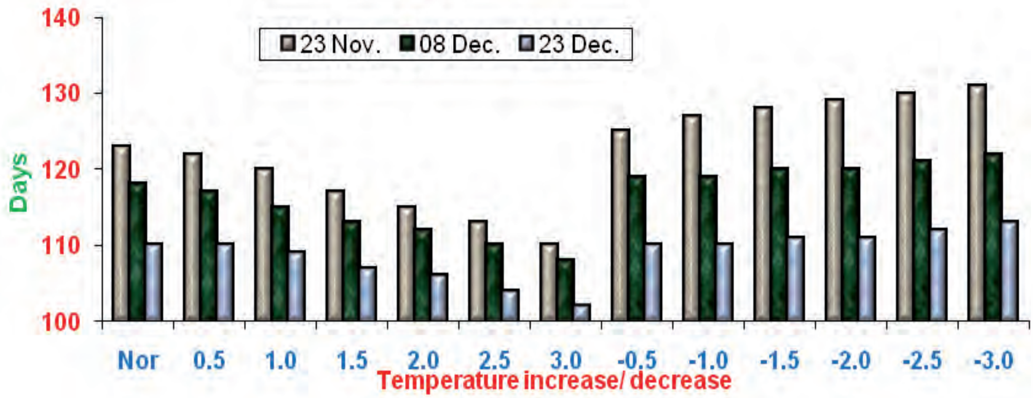
Wheat phenology simulated for cv. PBW-343 using DSSAT-wheat model was compared with the observed events from a field experimentation conducted for four years with two growing environments (1$^{st}$ fortnight and 2$^{nd}$ fortnight of Nov). Model simulated days to flowering and maturity were close to the observed in the early sown crop compared to the late sown. Leaf area index was also simulated reasonably well by the model and the per cent deviation ranged from -3.8 to -4.4 (Table 5.9). Drymatter and grain yields were simulated with an accuracy ranging from -3.8 to -10.8 in the early sown crop and from -4.4 to -11.9 in the late sown crop. Model under-estimated the crop phenology and growth on most of the occasions.

**Table 5.9: Simulated and observed phenology and yield attributes of Wheat cv. PBW-343 at Jammu**

| Crop Parameter | D1 : First date of sowing | | | D2 : Second date of sowing | | |
|---|---|---|---|---|---|---|
| | Sim | Obs | Deviation (%) | Sim | Obs | Deviation (%) |
| Anthesis date | 106 | 108 | -1.6 | 97 | 101 | -4.0 |
| Phy. Maturity | 155 | 153 | 1.2 | 141 | 145 | -2.8 |
| Grain Yd. (kg/ha) | 4699 | 4907 | -4.3 | 4008 | 4339 | -7.6 |
| Max. Leaf Area | 3.8 | 4.0 | -3.8 | 3.3 | 3.4 | -4.4 |
| Tops wt. at maturity (kg/ha) | 8932 | 10016 | -10.8 | 7421 | 8427 | -11.9 |

## Kanpur

Impact of changes in temperature on duration of wheat and its productivity was studied using DSSAT-wheat model. Simulations were carried out after calibrating the model using data from field experimentation involving three sowing environments (28th Nov, 3rd Dec and 23rd Dec). Temperature changes were assumed to either increase or decrease @ 0.5°C from the normal till ±3°C. Yields (simulated) were observed to decrease in early sown crop with a rise in temperature as well as with temperature falling beyond -1.5°C (Fig. 5.5). Productivity was found to increase with a temperature decline by 0.5 °C in early sown crop. Productivity of timely sown crop was found to increase with temperature up to +1.5 °C and falls beyond that temperature. Yields would also decline in normal sown crop for temperatures falling beyond -1.0 °C. Under late sown conditions, a temperature rise in the range of +0.5 to 2.0 °C was found to have a positive impact which turned to be negative for temperatures beyond +2.0 °C. Under late sown conditions, any decrease in temperature was found to be reducing the grain yields.



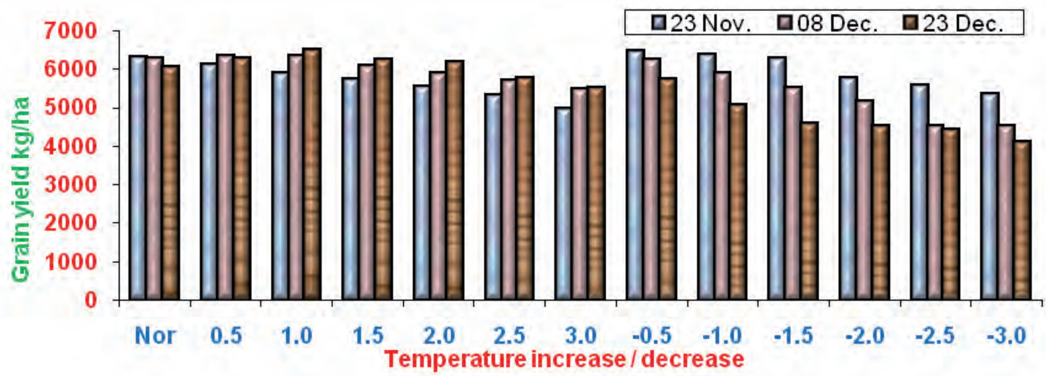



**Fig. 5.5:** Simulated changes in wheat crop phenology and yields with corresponding changes in temperature regimes at Kanpur

## Ludhiana

Performance of DSSAT-wheat model was evaluated for seven locations (Palampur, Ludhiana, Kanpur, Faizabad, Udaipur, Ranchi and Raipur) using different statistics. Results showed that (Table 5.10) model could predict days to anthesis with a mean difference of -6 to +14 days with a D-index value of above 0.6 at six locations. Days to maturity simualted by model were within the limit of -6 to +3 days and D-index value was more than 0.6 for all locations. The grain yields were also simulated reasonably well and deviations ranged from -498 to +754 Kg/ha. The D-index value for grain yields were above 0.6 for all locations except Faizabad (0.54).

**Table 5.10: Performance of DSSAT-Wheat V4.5 at seven wheat growing locations**

| Variable Name | Mean | | Std.Dev. | | r-Square | Mean Diff. | Mean Abs. Diff. | RMSE | d-Stat. | No. of Obs. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Obs | Sim | Obs | Sim | | | | | | |
| **Palampur (VL 829)** | | | | | | | | | | |
| Anthesis (DAS) | 130 | 124 | 14.24 | 11.97 | 0.84 | -6 | 7 | 7.79 | 0.91 | 4 |
| Yield (kg/ha) | 3284 | 3086 | 586.03 | 421.94 | 0.28 | -198 | 501 | 548.73 | 0.65 | 4 |
| Maturity (DAS) | 148 | 151 | 12.09 | 11.30 | 1.00 | +3 | 3 | 2.96 | 0.98 | 4 |
| **Ludhiana (PBW 343)** | | | | | | | | | | |
| Anthesis (DAS) | 113 | 117 | 4.63 | 4.93 | 0.62 | +4 | 4 | 4.95 | 0.77 | 12 |
| Yield (kg/ha) | 3971 | 4407 | 457.26 | 724.91 | 0.73 | +436 | 450 | 599.03 | 0.77 | 12 |
| Maturity (DAS) | 146 | 146 | 5.93 | 6.56 | 0.54 | 0 | 4 | 4.64 | 0.85 | 12 |
| **Kanpur (HD 2733)** | | | | | | | | | | |
| Anthesis (DAS) | 85 | 88 | 1.63 | 4.90 | 1.00 | +3 | 3 | 4.43 | 0.62 | 3 |

| Variable Name | Mean | | Std.Dev. | | r-Square | Mean Diff. | Mean Abs. Diff. | RMSE | d-Stat. | No. of Obs. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Obs | Sim | Obs | Sim | | | | | | |
| Yield (kg/ha) | 4817 | 5571 | 658.09 | 479.88 | 0.99 | +754 | 754 | 776.90 | 0.70 | 3 |
| Maturity (DAS) | 114 | 114 | 4.92 | 6.53 | 0.99 | 0 | 2 | 1.73 | 0.98 | 3 |
| **Faizabad (HVW 234)** | | | | | | | | | | |
| Anthesis (DAS) | 78 | 92 | 13.88 | 4.90 | 1.00 | +14 | 14 | 16.63 | 0.62 | 3 |
| Yield (kg/ha) | 3872 | 3374 | 216.72 | 387.83 | 0.97 | -498 | 498 | 528.63 | 0.54 | 3 |
| Maturity (DAS) | 122 | 120 | 8.65 | 6.13 | 0.99 | -3 | 3 | 3.74 | 0.94 | 3 |
| **Udaipur (Raj 4037)** | | | | | | | | | | |
| Anthesis (DAS) | 78 | 80 | 4.72 | 4.24 | 0.69 | +2 | 3 | 3.41 | 0.86 | 8 |
| Yield (kg/ha) | 5751 | 6132 | 1188.45 | 1108.69 | 0.79 | +381 | 524 | 663.36 | 0.91 | 8 |
| Maturity (DAS) | 116 | 111 | 8.98 | 5.88 | 0.67 | -6 | 6 | 7.68 | 0.76 | 8 |
| **Ranchi (K 9107)** | | | | | | | | | | |
| Anthesis (DAS) | 85 | 88 | 4.80 | 3.54 | 0.61 | +3 | 4 | 4.16 | 0.78 | 9 |
| Yield (kg/ha) | 4058 | 4196 | 549.51 | 477.06 | 0.54 | +137 | 324 | 404.71 | 0.84 | 9 |
| Maturity (DAS) | 122 | 117 | 6.27 | 5.37 | 0.75 | -5 | 5 | 5.81 | 0.80 | 9 |
| **Raipur (Kanchan)** | | | | | | | | | | |
| Anthesis (DAS) | 81 | 83 | 2.16 | 0.94 | 0.11 | +2 | 2 | 2.65 | 0.49 | 3 |
| Yield (kg/ha) | 3520 | 3800 | 198.83 | 420.06 | 1.00 | +279 | 279 | 356.43 | 0.72 | 3 |
| Maturity (DAS) | 109 | 108 | 4.03 | 1.70 | 0.98 | 0 | 2 | 2.38 | 0.83 | 3 |

## Palampur

Response of wheat cv. VL 829 to a rise in temperature was studied using DSSAT-wheat model. Simulations were made for temperature increments in the range of +0.5°C to 3.0°C from the normal. Adaptation strategies like sowing time adjustment, additional nitrogen and irrigation were also considered in the simulations. Results of the simulation are summarized in Table 5.11.

## Table 5.11: Summary of the impact of changes in intra-seasonal temperatures on wheat

| Temperature rise Impact | Early sowing | | Timely sowing | | Late sowing | | Remarks |
|---|---|---|---|---|---|---|---|
| | + ve | -ve | + ve | -ve | + ve | -ve | |
| 0.5 °C | | 1st fortnight March | Feb /1st fortnight March | 1st fortnight April | 2nd fortnight Jan/ March | | • More beneficial to **timely and late sown** wheat than early sown crop.<br>• Additional nitrogen: in **timely sown** wheat will reduce the impact during 1-15th April with 100kg/ha additional grain yield<br>• Additional irrigation: in **early sown** wheat will reduce the impact during 1-15th April with 600kg/ha additional grain yield |
| 1.0 °C | | 2nd fortnight March | 2nd fortnight of Jan/ 1st fortnight Feb | 2nd fortnight March | | 1st fortnight April | • **Timely sown** wheat will be more benefitted<br>• Additional nitrogen: **timely sown** will be marginally benefitted during first fortnight of January<br>• Additional irrigation: will have no effect |
| 1.5 °C | | 2nd fortnight March | 1st fortnight Jan /1st fortnight Feb/ 1st fortnight March | 2nd fortnight March | 1st fortnight Jan/2nd fortnight Feb/1st fortnight March | 1st fortnight April | • Temperature rise during 15th Feb-15th March in **late sown** wheat will be more benefitted<br>• Additional nitrogen: will be beneficial for **timely and late sown** during first fortnight of January<br>• Additional irrigation: no effect |
| 2.0 °C | | 2nd fortnight March | 2nd fortnight of Feb/1st fortnight March | 2nd fortnight March/1st Jan -14th Feb/15th Feb-15th March | | 1st Jan -14th Feb/ 2nd fortnight March /1st fortnight April | • Increase in temperature during 16-31st March will cause reduction in **all the dates** and reduction decreases with delay in sowing. **Timely sown** wheat is benefitted more if temperature rise is encountered during 1st Feb to 15th March<br>• Additional nitrogen: beneficial for **early and timely sown**<br>• Additional irrigation: no effect |
| 2.5 °C | Jan | 2nd fortnight March | Jan | 2nd fortnight March | Jan | 2nd fortnight March /1st fortnight April | • Increase in temperature during 16-31st March causes reduction in **all the dates** and reduction decreases with delay in sowing.<br>• **Timely sown** wheat is benefitted more if temperature rise is encountered during 1st Feb to 15th March. Rise in temperature during 1-31st Jan will be beneficial for all the three dates, one of which **late sown** wheat will be benefited the most.<br>• Additional nitrogen and additional irrigation will have no effect |
| 3.0 °C | 1st fortnight Jan & Feb | 2nd fortnight March/ 1st fortnight March | 1st Jan -first fortnight March | 2nd fortnight March | 1st Jan -1st fortnight March | 2nd fortnight March /1st fortnight April | • Additional nitrogen will be helpful to contain the effect of 3.0 °C rise in temperature during 1-15th January in timely sowing wheat.<br>• additional irrigation will have no effect |

## Ranchi

Changes in wheat phenology and yields with a change in intra-seasonal temperatures were simulated using DSSAT-wheat model (Fig. 5.6). Increase in seasonal temperature during anthesis period (2nd fortnight of January) for normal sown crop was found to be detrimental whereas a negative effect in late sown crop was noticed with a rise in temperatures during 2nd fortnight of February coinciding anthesis. Reduction in yield was more pronounced with a temperature rise by 2.5 to 3 °C under each sowing date. Increase in temperature during 2nd fortnight of December would increase the wheat yield under late sown condition and maximum increase likely to occur with a temperature rise of 1.5 °C. The results indicate that there is a need to develop heat resistant wheat variety to overcome the adverse impacts of climate change.

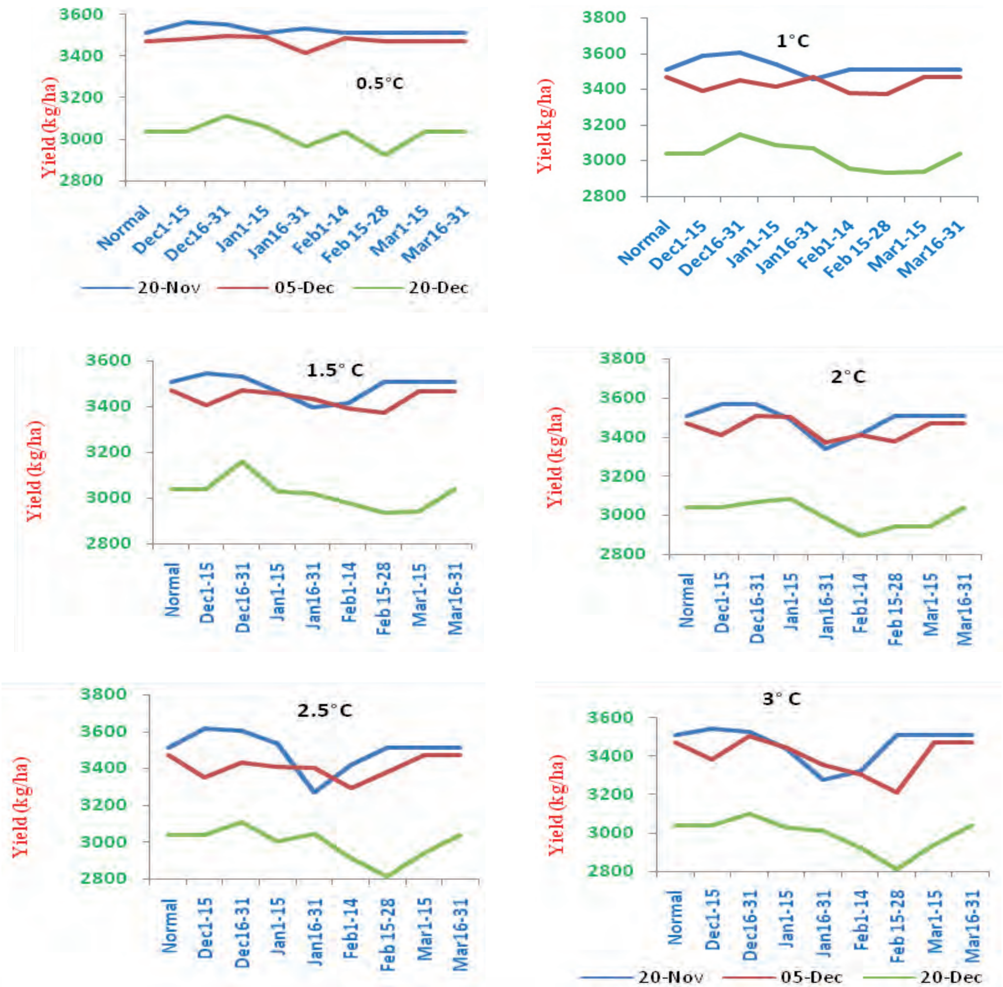



**Fig. 5.6:** Influence of changes in intra-seasonal temperatures on wheat yield (kg/ha) at Ranchi

## Udaipur

Data generated from a three-year field experimentation (2005-06, 2009-10 and 2010-11) with cv. Raj 4037 grown under four different dates of sowing (5th Nov, 20th Nov, 5th Dec, 20th Dec), two fertility and irrigation levels were used to simulate wheat yields under different temperature scenarios (Table 5.12). Simulations with a rise in seasonal temperatures from 0.5 to 3.0 °C showed that yield would decrease gradually under each sowing environment. Highest yield reduction of 1031 kg/ha was noticed at a temperature of +3.0 °C in the 5th November sown crop. Exactly opposite results were obtained with a decrease in temperatures from -1.0 to -3.0 °C. Adaptation strategies like enhanced nitrogen and irrigation levels did not show any ameliorative effect for temperature changes.

**Table 5.12: Simulated grain yields (kg/ha) of wheat cv. Raj 4037 under different temperature scenarios at Udaipur**

| Change in growing season temperature | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DOS | Observed | 0.50 | 1.00 | 1.50 | 2.00 | 2.50 | 3.00 | -0.5 | -1 | -1.5 | -2 | -2.5 | -3 |
| Recommended nitrogen and irrigation | | | | | | | | | | | | | |
| 05-Nov | 6933 | 6484 | 6259 | 5747 | 5589 | 5132 | 4902 | 7266 | 7590 | 7813 | 8397 | 8594 | 8389 |
| 20-Nov | 6983 | 6667 | 6520 | 6138 | 5939 | 5723 | 5409 | 7359 | 7511 | 7710 | 7756 | 7704 | 7150 |
| 05-Dec | 6799 | 6587 | 6509 | 6244 | 6136 | 5894 | 5734 | 7055 | 7065 | 6823 | 6081 | 5642 | 5842 |
| 20-Dec | 5871 | 5659 | 5420 | 5429 | 5417 | 5207 | 5169 | 5882 | 5573 | 5311 | 4768 | 4084 | 4493 |
| Fertilized with 25 % extra nitrogen | | | | | | | | | | | | | |
| 05-Nov | 6933 | 6701 | 6453 | 5937 | 5742 | 5229 | 4951 | 7519 | 7888 | 8120 | 8690 | 8665 | 8743 |
| 20-Nov | 6983 | 6667 | 6520 | 6138 | 5939 | 5723 | 5409 | 7359 | 7511 | 7710 | 7756 | 7704 | 7150 |
| 05-Dec | 6799 | 6587 | 6509 | 6244 | 6136 | 5894 | 5734 | 7055 | 7065 | 6823 | 6081 | 5642 | 5842 |
| 20-Dec | 5871 | 5659 | 5420 | 5429 | 5417 | 5207 | 5169 | 5882 | 5573 | 5311 | 4768 | 4084 | 4493 |
| Irrigated with one extra irrigation | | | | | | | | | | | | | |
| 05-Nov | 6933 | 6701 | 6453 | 5937 | 5741 | 5229 | 4951 | 7519 | 7888 | 8120 | 8690 | 8665 | 8743 |
| 20-Nov | 6983 | 6667 | 6520 | 6138 | 5939 | 5723 | 5409 | 7359 | 7511 | 7710 | 7756 | 7704 | 7150 |
| 05-Dec | 6799 | 6587 | 6509 | 6244 | 6136 | 5894 | 5734 | 7055 | 7065 | 6823 | 6081 | 5642 | 5842 |
| 20-Dec | 5871 | 5659 | 5420 | 5429 | 5417 | 5207 | 5169 | 5882 | 5573 | 5311 | 4768 | 4084 | 4493 |

## Wheat yields under A1B scenario

Projected wheat yields under A1B climate change scenario showed that productivity of cv. Raj 4037 would go down by 14.3 to 25.2% by the year 2055 and by 27.4 to 30.9% by the year 2099. Simulated yield reductions were moderate (3.1 to 9.3%) by the year 2030 (Fig. 5.7).

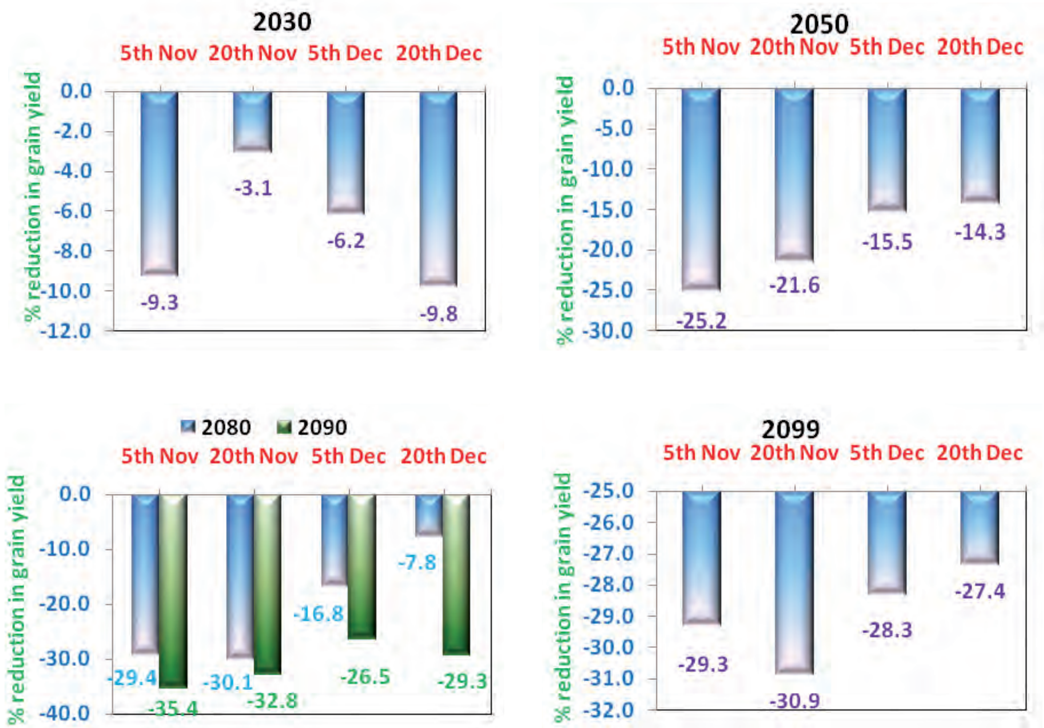



**Fig. 5.7:** Changes in wheat productivity under A1B scenario at different time periods at Udaipur

# 6. Effect of weather on pest and diseases

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

## Rice

### Kanpur

Stem borer infestation in three rice varieties (NDR-359, CSR-27 and Sarjoo-52) grown under variable environments created by staggered planting dates was studied in relation to weather conditions prevailed. Correlation analysis showed that (Table 6.1) stem borer larval population was positively associated with mean temperature, minimum temperature and humidity across planting dates and varieties. Maximum temperature and rainfall adversely affected larval population in the 13$^{th}$ July planted crop, maximum temperature and BSS in the other two plantings.

**Table 6.1: Pearson's correlation coefficients between weather parameters and stem borer population in rice varieties at Kanpur**

| Weather | Timely planting (13.07.2012) | | | Late planting (23.07.2012) | | | Very late planting (02.08.2012 ) | | |
|---|---|---|---|---|---|---|---|---|---|
| | NDR-359 | CSR-27 | Sarjoo-52 | NDR-359 | CSR-27 | Sarjoo-52 | NDR-359 | CSR-27 | Sarjoo-52 |
| Maximum temperature (°C) | -0.233 | -0.254 | -0.194 | -0.125 | -0.160 | -0.089 | 0.127 | 0.115 | 0.046 |
| Minimum Temperature (°C) | 0.426 | 0.420 | 0.427 | 0.400 | 0.309 | 0.341 | 0.365 | 0.361 | 0.362 |
| Mean Temperature (°C) | 0.349 | 0.334 | 0.372 | 0.393 | 0.270 | 0.341 | 0.395 | 0.386 | 0.363 |
| Morning RH (%) | 0.248 | 0.273 | 0.242 | 0.223 | 0.229 | 0.194 | 0.309 | 0.299 | 0.350 |
| Evening RH (%) | 0.358 | 0.365 | 0.349 | 0.332 | 0.268 | 0.270 | 0.300 | 0.296 | 0.316 |
| Mean Relative humidity (%) | 0.367 | 0.378 | 0.358 | 0.339 | 0.282 | 0.277 | 0.322 | 0.316 | 0.344 |
| Rainfall (mm) | -0.039 | -0.068 | -0.053 | 0.036 | 0.012 | 0.035 | 0.094 | 0.096 | 0.089 |
| Bright Sunshine hours (hrs) | -0.525 | -0.579 | -0.551 | -0.549 | -0.507 | -0.489 | -0.404 | -0.447 | -0.441 |

## Cotton

### Parbhani

Fluctuations in the sucking pests *viz.*, aphids and jassids population were studied in relation to weather conditions prevailed at different time periods of crop growth. All the weather parameters except BSS favored the incidence of jassids on cotton. Rainfall, rainy days, minimum temperature and RH significantly favored the jassids infestation while BSS significantly favored the aphid infestation and other weather parameters particularly Tmin and RH negatively influenced the aphid infestation in cotton (Table 6.2).

**Table 6.2: Pearson's correlation coefficients between aphids, jassids and weather parameters in cotton at Parbhani**

| Parameters | Aphids | Jassids |
|---|---|---|
| Rainfall | -0.233 | 0.537** |
| Rainy days | -0.292 | 0.408** |
| Maximum temperature (°C) | -0.247 | 0.270 |
| Minimum Temperature (°C) | -0.604** | 0.525** |
| Morning RH (%) | -0.439** | 0.488** |
| Evening RH (%) | -0.437** | 0.431** |
| Evaporation (mm) | 0.256 | 0.188 |
| Bright Sunshine hours (hrs) | 0.350* | -0.549** |
| Critical value(1-tail, .05) = ± 0.330 | Critical value(2-tail, .05) = ± 0.387 | |

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

## Soybean

### Akola

Population dynamics of semilooper in soybean in relation to weather were studied using tools like correlation and regression. Correlation studies indicated that semilooper incidence is controlled by temperature (maximum and mean) of the preceding 2 to 3 weeks (Table 6.3). Relative humidity (instant and lag) was found to encourage the buildup of semilooper population. Thus, lower temperatures and high humid conditions are congenial for semilooper incidence and development in soybean.

**Table 6.3: Pearson's correlation coefficient between semilooper population and weather parameters at different lag periods in soybean at Akola**

| Parameters | Lag phase (Week) | | | |
|---|---|---|---|---|
| | 0 | 1 | 2 | 3 |
| Maximum Temperature (°C) | -0.227 | -0.250 | -0.502** | -0.584** |
| Minimum Temperature (°C) | 0.420* | 0.315 | -0.128 | -0.222 |
| Mean Temperature (°C) | 0.091 | -0.206 | -0.472** | -0.520** |
| Morning RH (%) | 0.758** | 0.750** | 0.503** | 0.108 |
| Evening RH (%) | 0.358* | 0.362* | 0.595** | 0.677** |
| Mean Relative humidity (%) | 0.468** | 0.500** | 0.658** | 0.615** |

| Parameters | Lag phase (Week) | | | |
|---|---|---|---|---|
| | 0 | 1 | 2 | 3 |
| Rainfall (mm) | 0.459** | -0.162 | -0.229 | -0.205 |
| Rainy day | 0.447** | -0.009 | -0.168 | -0.061 |
| Bright Sunshine hours (hrs) | -0.228 | -0.247 | -0.491** | -0.716** |

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

Semilooper population data were regressed on different weather parameters that prevailed during different preceding time periods in order to identify optimum range for each variable and to develop a forewarning model, if possible. Relation with minimum temperature showed that pest had a narrow range of night time temperatures but fluctuates widely with day time temperatures (Fig. 6.1).

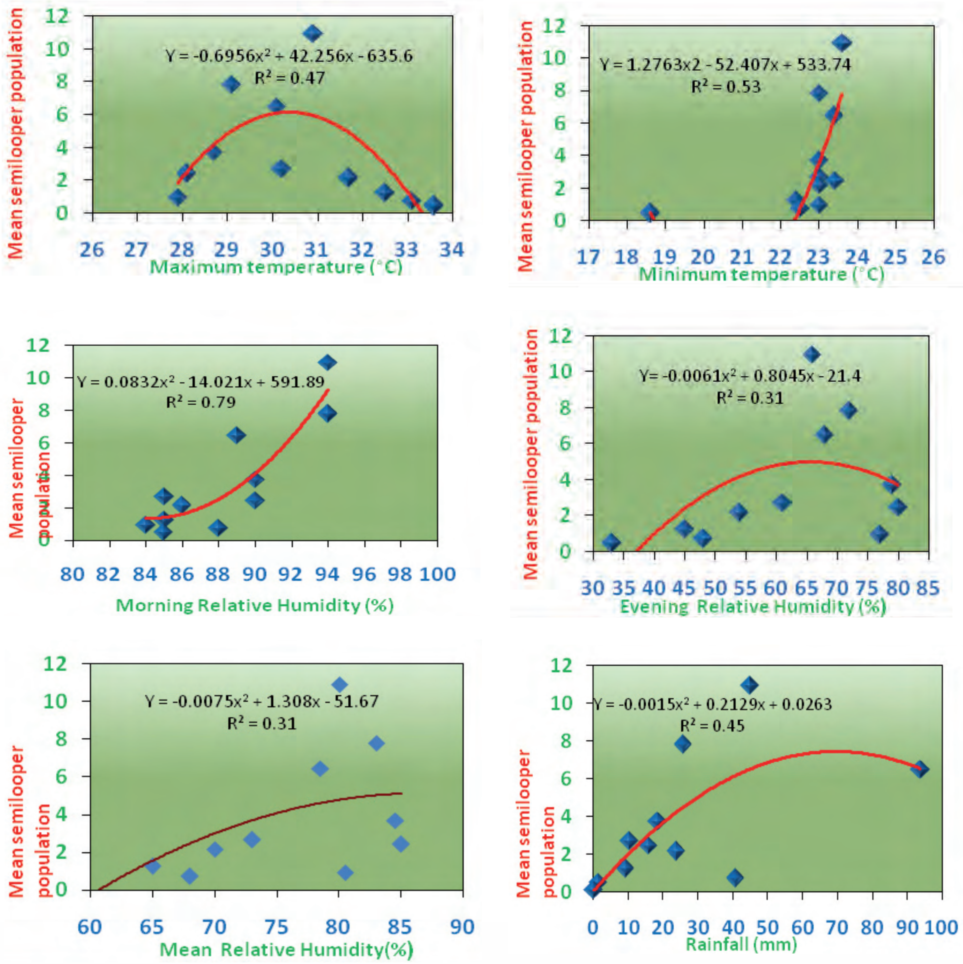



**Fig. 6.1:** Relationships between weather parameters and semilooper population in soybean at Akola

# Groundnut

## Anantapur

Role of weather in the incidence of leaf webber in groundnut was studied utilizing weather conditions with different lead periods. Correlation study was used as a criteria to identify critical weather parameters at different time periods (Table 6.4) and the identified parameters were used to develop forewarning models. The most significant weather parameters were identified by performing correlation between number of webs/ $m^2$ and individual weather parameters at different lead time and these significant weather parameters were used to develop regression models for predicting leaf webber incidence in groundnut.

**Table 6.4: Correlation coefficients between no. of webs per $m^2$ and weather parameters**

| Lead period | Maximum Temp. (°C) | Minimum Temp. (°C) | Morning RH (%) | Evening RH (%) | Bright Sunshine hours (hrs) | Rainfall (mm) | Rain free days | Rain fall total (mm) | Wind Speed (kmph) | Evapo-ration (mm) |
|---|---|---|---|---|---|---|---|---|---|---|
| *3 Days Lead Period* | -0.05 | -0.06 | 0.01 | -0.23 | 0.26* | -0.19 | 0.13 | -0.16 | -0.36 | -0.06 |
| *3 Days Lead Period Mean* | 0.04 | 0 | 0.21 | -0.34 | 0.42** | -0.18 | 0.12 | -0.14 | -0.43 | -0.03 |
| *7 Days Lead Period* | -0.01 | -0.26 | 0.20 | -0.17 | 0.22 | -0.15 | 0.31* | -0.35 | -0.26 | -0.04 |
| *7 Days Lead Period Mean* | 0.00 | -0.28 | 0.13 | -0.30 | 0.39** | -0.15 | 0.31* | -0.35 | -0.36 | -0.03 |

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

Backward and stepwise regression analysis showed that seven days lead period mean has shown highest $R^2$ value of 0.42 in backward regression but in step wise regression analysis it has shown $R^2$ value of 0.15 and only sunshine hours has influenced the population of webs per $m^2$. Whereas, 3 day lead period mean maintained the stability in backward and stepwise regression with $R^2$ value of 0.261 and the no. of webs per $m^2$ were influenced by both sunshine hours and wind velocity. Even though, the $R^2$ value for 3 day lead period mean of weather parameters was significant at P=0.05, the $R^2$ value is less and it explains only 26% variability in no. of webs per $m^2$. The model needs further improvement with more no. of observations (Table 6.5).

**Table 6.5: Regression models to predict leaf webber infestation in groundnut at different lead periods**

| Lead period | Regression equation | $R^2$ |
|---|---|---|
| | **Back ward** | |
| 7 Days Lead Period | No.of webs/$m^2$ = 69.768 + 41.932 * Rain free days– 9.036 * Wind speed | 0.22 |
| 7 Days Lead Period Mean | No.of webs/$m^2$ = - 443.464 + 94.060 * Tmin – 11.497 * RH 2 – 3.579 * RF total – 27.030* Wind speed – 86.644 * Evaporation | 0.42 |

| Lead period | Regression equation | $R^2$ |
|---|---|---|
| 3 Days Lead Period | No.of webs/$m^2$ = 680.66 - 4.392 * RH1 – 12.974 * Wind speed | 0.17 |
| 3 Days Lead Period Mean | No.of webs/$m^2$ = 172.036 + 15.86 * SSH – 8.704 * Wind speed | 0.26 |
| **Step wise** | | |
| 7 Days Lead Period | No.of webs/$m^2$ = 309.072 – 2.368 * RF total – 7.210 * Wind seed | 0.19 |
| 7 Days Lead Period Mean | No.of webs/$m^2$ = 6.249 + 28.986 * SSH | 0.15 |
| 3 Days Lead Period | No.of webs/$m^2$ = 297.092 – 10.034 * Wind Speed | 0.13 |
| 3 Days Lead Period Mean | No.of webs/$m^2$ = 172.036 + 15.86 * SSH – 8.704 * Wind speed | 0.26 |

## Grape

### Bijapur

Forewarning models developed for flea beetle, thrips and mealy bug using data collected during 2006-2010 were validated for the post rainy season of 2012-13. Using maximum temperature and rainfall of preceding week, the flea beetle was forecasted with minimum error (Table 6.6). Compared to the model for flea beetle, the model developed for thrips resulted in large errors. Minimum temperature based models with a lead period of 1 to 3 weeks resulted in marginal errors (Table 6.7). In case of mealy bug, the model developed was meant for estimating the pest population but not for forewarning purpose. Minimum temperature based models performed reasonably well for forewarning mealy bug incidence also (Table 6.8). Among the different models, the model for flea beetle performed better.

**Table 6.6: Forecast models for flea beetle on grapes during post rainy period and its error in estimation for 2012-13**

| Lead time | Model No. | Model | Error estimation |
|---|---|---|---|
| 3 | 1 | Y= 16.44 – 0.59 MinT(3) | -4.0 |
| | 2 | Y= 15.36 – 0.18 RH2(3) | -4.8 |
| 2 | 1 | Y= 14.91 – 0.50 MinT(2) | -4.1 |
| 1 | 1 | Y= 34.12 – 0.63 MaxT(1) – 0.51 MinT(1) | -4.9 |
| | 2 | Y= 37.31 – 0.75 MaxT(2) – 0.48 MinT(1) | -3.7 |
| | 3 | Y= 39.62 – 1.06 MaxT(2) – 0.06 RF(1) | -2.4 |
| 0 | 1 | Y= 40.07 – 0.49 MinT(0) – 0.83 MaxT(1) – 0.04 RF(3) | -4.7 |
| | 2 | Y= 51.22 – 0.10 RH2(0) – 1.13 MaxT(1) – 0.11 RH2(2) | -8.1 |
| | 3 | Y= 40.24 – 0.14 RH2(0) – 0.86 MaxT(1) – 0.02 RF(1) – 0.05 RF(3) | -7.0 |

The errors for thrips models were very high compared to the models of flea beetle. The smallest errors were noticed for models using minimum temperature at lead time of 1 to 3 weeks Similar to thrips, the estimation of mealy bug was also more accurate with minimum temperature. However in the case of mealy bug it was only estimation but not prediction Thus, the pest forecast models indicated that the models for Flea beetle were better than those for thrips and mealy bug.

**Table 6.7: Forecast models for thrips on grapes during post rainy period and its error in estimation for 2012-13**

| Lead time | Model No. | Model | Error estimation |
|---|---|---|---|
| 3 | 1 | Y= 81.2 – 3.22 MinT(3) | -17.7 |
| | 2 | Y= 186.25 – 1.87 RH1(3) | -23.1 |
| | 3 | Y= 80.44 – 1.09 RH2(3) | -21.9 |
| 2 | 1 | Y= 87.90 – 3.64 MinT(2) | -17.3 |
| 1 | 1 | Y= 87.07 – 3.60 MinT(1) | -18.5 |
| 0 | 1 | Y= 91.29 – 3.40 MinT(0) | -29.2 |
| | 2 | Y= 215.64 – 3.49 MinT(0) – 1.53 RH1(3) | -23.0 |
| | 3 | Y= 227.73 – 1.15 RH2(0) – 1.71 RH1(1) | -34.2 |
| | 4 | Y= 79.82 – 1.07 RH2(0) – 0.24 RF(1) | -31.8 |
| | 5 | Y= 200.38 – 1.44 RH1(0) – 2.99 MinT(1) | -24.3 |
| | 6 | Y= 200.78 – 1.59 RH1(0) – 0.77 RH2(1) | -25.8 |
| | 7 | Y= 195.40 – 1.92 RH1(0) – 0.34 RF(1) | -20.6 |
| | 8 | Y= 207.8 – 1.52 RH1(0) – 3.06 MinT(2) | -24.0 |
| | 9 | Y= 190.94 – 1.87 RH1(0) – 0.26 RF(2) | -32.2 |
| | 10 | Y= 216.48 – 1.66 RH1(0) – 2.81 MinT(3) | -25.4 |
| | 11 | Y= 355.62 – 1.94 RH1 (0) – 1. 89 RH1(3) | -33.1 |
| | 12 | Y= 234.88 – 1.82 RH1(0) – 1.05 RH2(3) | -31.8 |

**Table 6.8: Forecast models for mealy bug on grapes during post rainy period and its error in estimation for 2012-13**

| Lead time | Model No. | Model | Error estimation |
|---|---|---|---|
| 0 | 1 | Y= 38.44 – 1.21 MinT(0) | -13.4 |
| 0 | 2 | Y= 82.56 – 0.75 RH1(0) | -16.7 |
| 0 | 3 | Y= 37.22 – 0.40 RH2(0) | -16.9 |

# Chickpea

## Faizabad

Pod borer population in chickpea was monitored on a weekly basis and population dynamics in relation to weather were studied. Role of temperature in regulating larval population was assessed by regressing population data on the corresponding temperature values and the resultant relations are presented in Fig. 6.2 a and b. Larval population increased with increase in maximum temperature from 23 to 33°C and minimum temperature from 8 to 12°C. Large data base is however required to develop a temperature based prediction models.

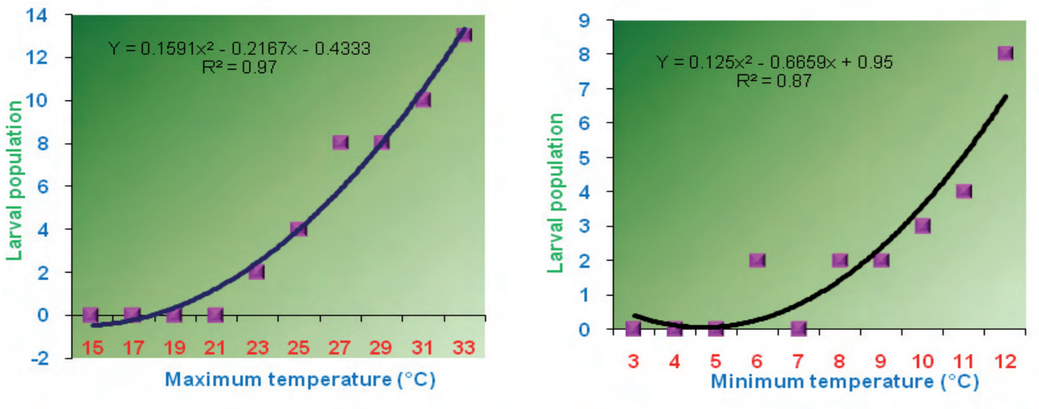



**Fig. 6.2 a & b:** Influence of temperature on larval population of chickpea pod borer at Faizabad

## Jabalpur

Influence of weather parameters on incidence of larval population of *Helicoverpa armigera* was studied using correlation analysis and the results are presented in Table 6.9. Rainfall, number of rainy days and temperature (maximum and minimum) were found to have a negative effect (statistically non-significant) on the larval population of pod borer.

**Table 6.9: Pearson's correlation coefficients between *H. armigera* and weather parameters at Jabalpur**

| Chickpea varieties | Maxi-mum Temp. (°C) | Mini-mum Temp. (°C) | Bright Sunshine hours (hrs) | Rainfall (mm) | Morn-ing RH (%) | Eve-ning RH (%) | Wind speed (km/hr) | Evapo-ration (mm) | Rainy days |
|---|---|---|---|---|---|---|---|---|---|
| Gulabi | -0.29 | -0.43 | 0.39 | -0.34 | 0.095 | -0.19 | -0.24 | -0.2 | -0.48 |
| Kabuli | -0.27 | -0.33 | 0.43 | -0.44 | -0.14 | -0.19 | -0.12 | -0.12 | -0.5 |
| Desi | -0.08 | -0.16 | 0.35 | -0.27 | 0.05 | 0.05 | 0.07 | -0.06 | -0.25 |

# Mustard

## Anand

Aphid incidence on mustard as influenced by weather conditions was studied using 11 years experimentation involving different sowing environments. Early and late sown crops were found to be relatively more sensitive than normal sown crop. Peak incidence was noticed generally during 2nd SMW in early and late sown crops while in the normal sown crops it was during 5th SMW (Fig 6.3 a). Negative impact of mean temperature on the aphid incidence was noticed in the late sown crop. The variations in aphid index during growing season and in relation to temperature in late sown crop is presented in Fig. 6.3 b.

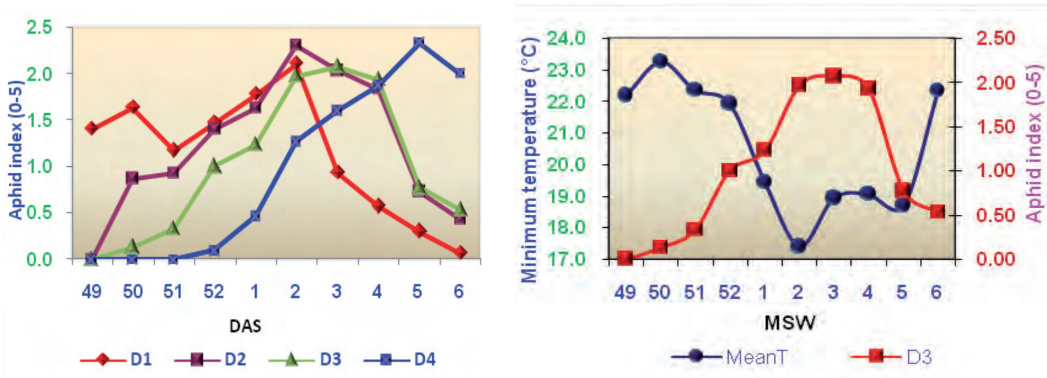



**Fig. 6.3:** (a) Variation in aphid index as a function of time under different dates of sowing and (b) its relation with mean temperature in late sown mustard at Anand

## Jammu

Incidence and development of aphid population on two mustard varieties (RL-1359 and RSPR-01) in relation to weather was studied using three years experimental data (2010-13), each with three sowing environments. Curve fit software was used to determine the best fit model for the data. Peak population of aphids generally attained during 90 to 110 days after sowing. From the relations presented in Fig 6.4 it can be deduced that a maximum temperature of 16.8 °C, mean temperature of 11.8 °C and Thermal Humidity Index (THI) of 7.7 were the most favorable environmental conditions for aphid population buildup beyond threshold level.

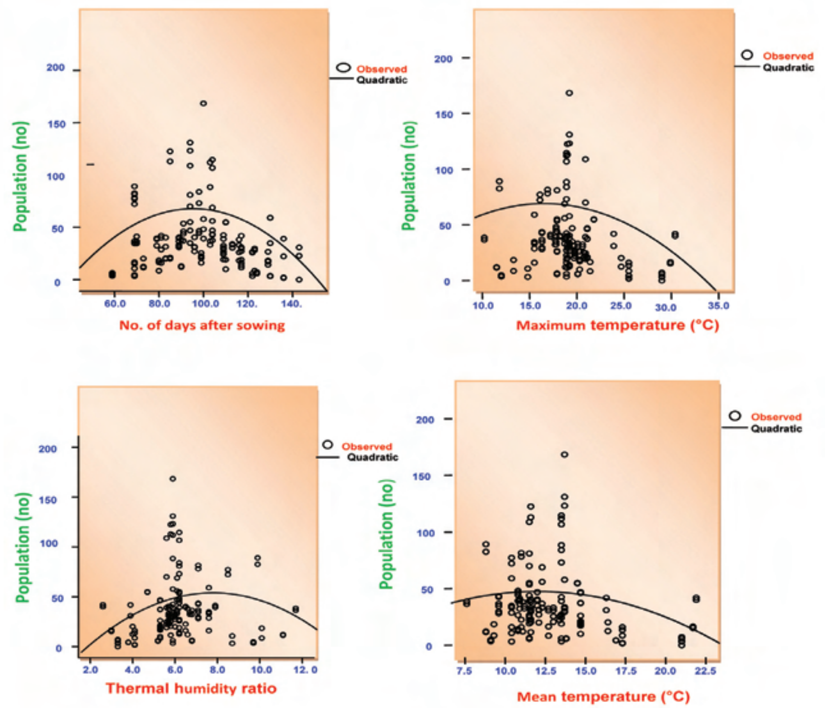



**Fig. 6.4:** Mustard aphid population fluctuations in relation to weather variables at Jammu

## Udaipur

Aphid incidence on the top 10 cm inflorescence of mustard cv. Bio-902 grown under three sowing environments *viz.*, 12th Oct., 27th Oct. and 11th Nov. 2012 (Table 6.10) was studied. The peak infestation of aphids was noticed at the green seed stage of the crop sown on 11th Nov. However, aphid population was below ETL across sowing environments. Aphid infestation was more in late sown crop as compared to early sown crop.

**Table 6.10: Mustard aphid population as influenced by sowing time at Udaipur**

| Standard Meteorological week | SMW 5 | SMW 6 | SMW 7 | SMW 8 | SMW 9 | SMW 10 | SMW 11 |
|---|---|---|---|---|---|---|---|
| 12th Oct. | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27th Oct. | 2 | 5 | 0 | 0 | 0 | 0 | 0 |
| 11th Nov. | 12 | 25 | 21 | 20 | 22 | 10 | 0 |
| Max. T. | 26.0 | 22.5 | 27.5 | 30.2 | 28.0 | 34.0 | 30.5 |
| Min T. | 11.0 | 4.0 | 13.0 | 13.2 | 7.0 | 13.0 | 15.0 |
| Mean T. | 18.5 | 13.0 | 20.0 | 21.7 | 17.5 | 23.5 | 22.8 |
| Mean RH | 56 | 56 | 52 | 53 | 42 | 42 | 56 |

## Mohanpur

Role of weather in the incidence of aphids on mustard was assessed from a three year experimentation (2010-13). Aphid population fluctuations in the individual years were plotted along with temperature and hours of sunshine in Fig. 6.5 a to c. There was a sudden surge in the aphid population if the temperature exceeds 20°C for a sufficiently longer period. It could be noticed from Fig. 6.5c that average temperatures though remained above 20°C on two occasions they did not led to a population built-up as the durations were shorter (2 to 3 days). Low hours of bright sunshine was found to be favouring low aphid population built-up.

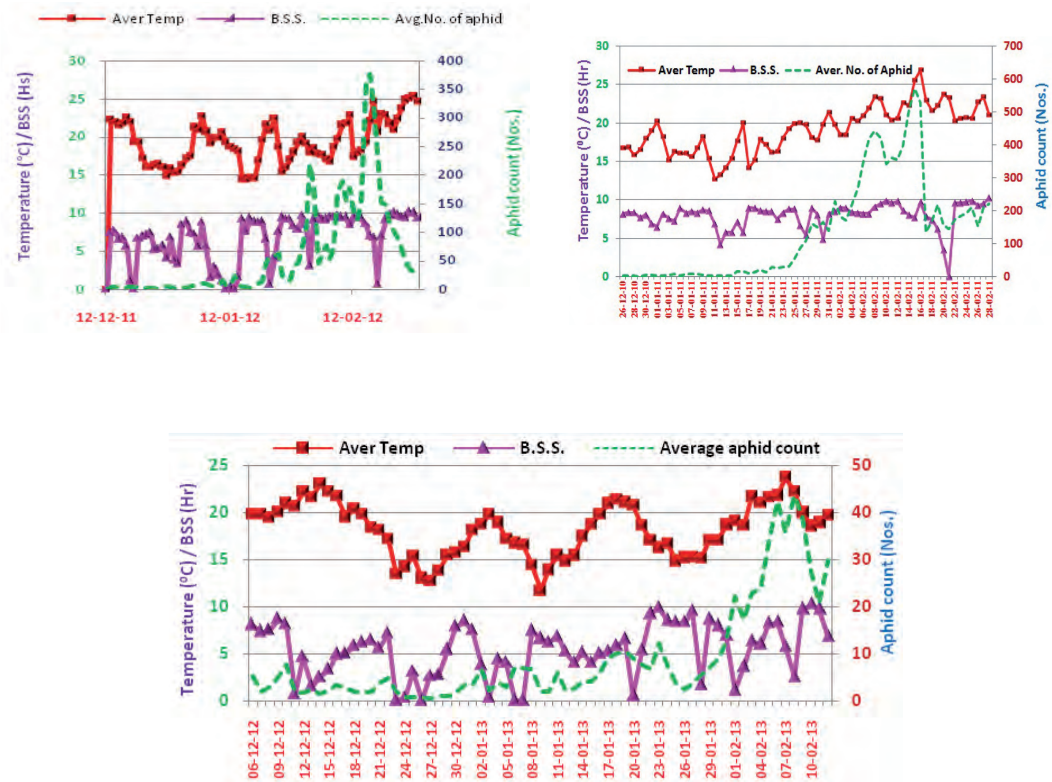



**Fig. 6.5:** Variations in mustard aphid population, mean temperature and bright sunshine hours at Mohanpur

# 7. Summary

## Agroclimatic characterization

- Spatial distribution of temperature of Gujarat showed that Vav, Thrad and Radhanpur blocks of Banaskantha district experience highest mean annual temperatures and parts of South Gujarat, coastal area of Saurashtra and Kutch experience cooler temperatures.
- Trend analysis of long term monthly rainfall data of Vidarbha region showed an increasing trend in August rainfall across all the districts except Bhandara and Gondia.
- Mean onset of monsoon was late by one week (25$^{th}$ SMW) in the northern dry zone, while it was earlier by one week (23$^{rd}$ SMW) in the districts of northern transition zone of Karnataka.
- Growing the crops during 28$^{th}$ to 48$^{th}$ SMW was found to be suitable for Bangalore location.
- Analysis of 39 years' rainfall data (1973-2012) at Dapoli revealed that the mean week of commencement of monsoon is 23$^{rd}$ SMW and the withdrawal date is 40$^{th}$ SMW.
- Historic data analysis (1980-2010) on weather events like frost, fog and dew at Hisar showed an increasing trend in frost as well as fog occurrences and a slight decreasing trend in dew occurrences.
- Spatial distribution of mean annual maximum, minimum temperatures and RH with isotherm and isohume prepared for Jammu province showed that south-west end of the province to be a high temperature zone with annual maximum temperature exceeding 28°C.
- Annual maximum temperature showed an increasing trend at the rate of 0.23 °C/ decade and annual minimum showed a decreasing trend at the rate of -0.16 °C/decade at Kanpur.
- Annual, *kharif* season and *rabi* season pan evaporation rates have decreased by 0.06, 0.09 and 0.03 mm/year, respectively at Ballowal Saunkhri; 0.02, 0.03 and 0.01 mm/year, respectively at Ludhiana; and 0.01, 0.06 and 0.007 mm/year, respectively at Bathinda.
- Spatial distribution of monthly reference $ET_0$ was estimated using FAO Penman-Monteith method for the month of Jan, Apr, Jul and Oct 2012 for West Bengal state which showed that Northern Bengal experience low $ET_0$ rates even during summer and monsoon season.
- Spatial distribution of climatic types of Chhattisgarh showed that number of districts under moist sub-humid are declining and number of districts under semi-arid are increasing from 1901-1930 to 1991-2010.
- LGP analysis was carried out at Samastipur (1968-2012) and the sowing window of Samastipur district was found to be 19-23 SMW.
- District-wise daily rainfall data of Maharashtra for the period 1901-2006 indicated that during pre-monsoon season (March-May), maximum rainfall zone got shifted from eastern parts to south western parts.

# Crop-weather relationships

## *Kharif* 2012

### Rice

- High temperature (both maximum and minimum) and SSH at tillering stage was found to be favourable and high rainfall was detrimental for crop growth at Kanpur.
- Sensitivity of rice to a rise in temperature was studied at Ludhiana which revealed that highest yield reduction would occurr (-37%) due to heat stress at anthesis.

### Maize

- Transpiration and CATD relationship showed an inverse relationship and the model fitted for the data accounted for 74% of the variability at Jammu.

### Pearl millet

- At Solapur, three pearl millet cultivars (Shanti, Mahyco hybrid and ICTP-8203) responded positively to minimum temperatures at all growth stages. Bright sunshine hours had a negative correlation at all the growth stages except sowing to emergence.

### Pigeon pea

- At Faizabad, a linear relationship between leaf area index (LAI) and radiation use efficiency (RUE) indicated that with a unit change in LAI, the RUE would increase by 0.48g/MJ.

### Cotton

- A 10 mm rainfall increment during reproductive phase increased yield by about 93 kg/ha while, 1$^{o}$C rise in maximum temperature during reproductive phase would decrease yield by 1734 kg/ha at Akola.
- At Parbhani, rainfall and relative humidity during square formation to flowering stage exerted a negative influence. Hours of bright sunshine had a positive influence only during initial stage.

### Groundnut

- Water use pattern of three groundnut cultivars (TMV-2, K-134 and JL-24) was studied using FAO Water balance model at Bangalore. The model indicated soil moisture deficit conditions during pod formation and pod initiation in 16$^{th}$ July and 6$^{th}$ August sown crop, respectively.

### Sunflower

- Critical values of weather variables influencing the sunflower yield at different phenological stages were identified at Bijapur.
- The Moisture Use Efficiency (MUE) of 3.50 to 4.00 kg ha/mm was found to be optimum for getting higher seed yield at Solapur. It was also found that for every increase of 0.1 RUE there would be an increase of 0.5 q ha$^{-1}$ in seed yield.

### Soybean

- The maximum and minimum temperatures of 32.3 °C and 24.4 °C, respectively during vegetative phase were found to be favourable for growth development and yield of soybean at Akola.
- Temperature (maximum, minimum and their range) during grain formation and rainfall during pod development stages showed positive influence whereas, rainfall and relative humidity showed adverse effect during grain development stage at Parbhani.

## *Rabi* 2012-13

### Wheat

- Water requirement and its' use efficiency of four wheat cultivars (GW-322, GW-496, GW-366 and GW-1139) grown under four environments (1st Nov, 15th Nov, 30th Nov and 15th Dec, 2012) at Anand showed that cv. GW-366 was the most efficient in water use.
- Maximum and minimum temperatures, evaporation and sunshine during reproductive stage have a positive influence and the influence became negative during vegetative stage at Hisar.
- At Kanpur, a negative influence of rainfall and relative humidity during tillering stage of three wheat varieties (HD-2733, K-307 and K-9107) sown under three different dates (23rd Nov, 8th Dec and 23rd Dec, 2012) was noticed from correlation analysis.
- Response of wheat varieties to temperature rise at Ludhiana by growing the crop in a temperature gradient tunnel (TGT) showed that cv. DBW-17 was the most sensitive to temperatures with an yield reduction of 44% at a temperature rise of 2.2 °C followed by PBW-621 (-36%), PBW-550 (-30%) and PBW-343 (-25%).
- Optimum thresholds for minimum temperature and maximum temperatures during reproductive phase to attain a yield level of >3t/ha were determined from a six year experimentation at Palampur. In case of minimum temperature, the optimum was 10.9 and in maximum temperature it was 23.4 °C.
- The period from anthesis to milking was found to be the most sensitive stage to temperature rise, and wheat variety BG 3 was most susceptible to increased minimum temperature at boot to anthesis stage at Ranchi. Among the varieties, BG 3 was found to be relatively temperature tolerant. Wheat cultivar K9107 was the most temperature sensitive.
- A mean temperature of 17.5 to 19.5 °C during reproductive phase was found to be optimum for the wheat cv. Raj 4037

### Mustard

- Among different varieties (Kranti, RH-30, RH-406, RH 0749 and Laxmi), RH- 0749 used higher fraction of Rn as LE compared to other varieties because it has denser, green and erect canopy.

- At Jammu, relation between transpiration rate and Canopy Air Temperature Differential (CATD) in two mustard varieties (RL-1359 and RSPR-01) revealed that there was a decrease in transpiration with an increase in CATD. The model could explain only 67% variation in transpiration.

### Chickpea

- At Faizabad, with an unit increase in LAI, the canopy would additionally intercept 165 MJ of APAR in chickpea varieties (Radhey, Pusa 362 and Uday).
- Crop-weather relationship studies in chickpea at Jabalpur showed that during flowering stage, crop responded positively to morning RH while during maturity both morning and evening RH were detrimental.

### Potato

- Crop-weather relationship studies at Jorhat revealed that both air and soil temperatures during stolon formation and bright sunshine hours during maturity stage had positive influences on crop growth and development.
- Water use in potato as influenced by sowing time, variety and irrigation was examined at Mohanpur, which indicated that cv. Jyoti planted on 15th November under ALFI system of irrigation has the highest WUE.

### Cauliflower

- It was found that minimum temperature had an overall negative influence on the duration from transplanting to curd initiation at Thrissur. Curd yield was observed to be high when the duration of transplanting to curd initiation phase was short (50-55 days).

### Dairy milk production

- Effect of heat stress on milch animals revealed that there was a change in milk production (-165.5 kg) with an unit change in afternoon Temperature Humidity Index (THI) values.

## Crop growth modeling

## *Kharif* 2012

### Groundnut

- PNUTGRO model simulated the pod yields with reasonable accuracy while it over-estimated periodic LAI and days to anthesis and under-estimated days to maturity at Anand.
- Thermal time based regression model could predict flowering with an accuracy of ± 1.0 day in all dates of sowing but model to predict maturity did not perform well and the error ranged from -2 to -8.5 days at Anantapur.
- Stocheometric model developed to predict groundnut yields at Bangalore performed better for cv. K-134 (+0.6%) than for cv. TMV-2 (+15.6%) and JL-24 (+16.4%).

### Rice

- DSSAT-rice model for cv. Sarjoo-52 slightly over-estimated days taken to anthesis under all transplanting dates (error range of 0 to 5 days) while under-estimated days to physiological maturity (error range of 0 to -19 days) and yields in early transplanted crop for Faizabad conditions.
- DSSAT-rice model predicted days taken to anthesis, physiological maturity and yields of cv. Ranjit with a mean RMSE of 5.1, 5.5 and 401 kg/ha, respectively under Jorhat conditions.
- DSSAT-rice simulation with average of four different climate scenarios of MARKsim revealed that grain yield would decrease progressively from 2030 to 2050 and thereafter marginally increase by four per cent under late planted conditions at Kanpur
- Simulation of DSSAT-rice model for cv. Karma Masuri indicated that sowing window of 21$^{st}$ - 22$^{nd}$ June as an adaptation strategy may be suitable in future climates for Raipur conditions
- DSSAT-rice model under-estimated grain yields of cv. Satabdi for all the transplanting dates with higher error range (-2.7 to -11.6%) in the early transplanted crops at Mohanpur.

## *Rabi* 2012-13

### Wheat

- At Faizabad, DSSAT-wheat model predicted a decrease in days to maturity as well as yields for cv. HUW-234 with a rise in temperature from +0.5 to +3.0 °C. On the contrary, decreasing temperatures prolonged the crop duration across the sowing dates.
- Validation of DSSAT-wheat model at Jammu resulted in under-estimation of crop phenology and yield on most of the occasions.
- DSSAT-wheat simulation with temperature change at Kanpur revealed that under late sown conditions, a seasonal temperature rise in the range of +0.5 to 2.0 °C was found to have a positive impact which turns to be negative for temperatures beyond +2.0 °C.
- At Ludhiana, performance of DSSAT-wheat model was evaluated for seven locations (Palampur, Ludhiana, Kanpur, Faizabad, Udaipur, Ranchi and Raipur) using different statistics. Model could predict phenology and yields with reasonable accuracy for all the location except at Faizabad.
- Increase in temperature during anthesis period for normal sown (2$^{nd}$ fortnight of January) and late sown crop crop (2$^{nd}$ fortnight of February) was found to be detrimental as simulated by DSSAT-wheat model at Ranchi.
- DSSAT-wheat simulations at Udaipur indicated that yield would decrease gradually under each sowing environment with a rise in seasonal temperatures from 0.5 to 3.0 °C. Adaptation strategies like enhanced nitrogen and irrigation levels did not show any ameliorative effect for temperature changes.

# Effect of weather on pest and diseases

## *Kharif* 2012

### Rice

- At Kanpur, stem borer larval population was positively associated with mean, minimum temperature and humidity across planting dates and varieties. Maximum temperature and rainfall adversely affected larval population in the $13^{th}$ July planted crop, maximum temperature and BSS in the other two plantings .

### Cotton

- Rainfall, rainy days, minimum temperature and RH significantly favored the jassids infestation while BSS significantly favored the aphid infestation and other weather parameters particularly minimum temperature and RH negatively influenced the aphid infestation in cotton at Parbhani.

### Soybean

- Lower temperatures (preceding 2 to 3 weeks) and high humid conditions (instant and with a lag of 3 weeks) are congenial for semilooper incidence and development in soybean at Akola.

### Grape

- Among the forewarning models developed for flea beetle, thrips and mealy bug, the model for flea beetle forecasted with minimum errors at Bijapur.

## *Rabi* 2012-13

### Chickpea

- Polynomial relation between pod borer and weather revealed that larval population increased with increase in maximum temperature from 23 to 33 °C and minimum temperature from 8 to 12 °C.
- Rainfall, number of rainy days and temperature (maximum and minimum) were found to have a non-significant negative effect on the larval population of pod borer at Jabalpur.

### Mustard

- Mean temperatures was found to be negatively influence the aphid incidence in the late sown crop at Anand.
- Maximum temperature of 16.8 °C, mean temperature of 11.8 °C and thermal humidity index of 7.7 were the most favorable environmental conditions for aphid population buildup beyond threshold level at Jammu.
- At Udaipur, the peak infestation of aphids was noticed at the green seed stage of the crop sown on $11^{th}$ Nov. Aphid infestation was more in late sown crop as compared to early sown crop.
- It was noticed that there was a sudden surge in the aphid population if the temperature exceeds 20 °C for sufficiently longer period at Mohanpur.

# Research Publications: 2012-13

## Co-ordinating Unit

### Peer reviewed research publications:


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., Triveni, U., Harisatyanarayana, N., Latha, P., Venugopala Rao, N., and Rao V.U.M., 2012. Influence of weather on fibre yield of mesta (Hibiscus sabdariffa) in North Coastal Zone of Andhra Pradesh, India. Archives of Agronomy and Soil Science (2012). DOI: 10.1080/03650340.2012.699675.

Bapuji Rao, B., Linitha Nair, Bhavani, B., and Rao, V.U.M., 2012. Weather and scale insect (Melanaspis glomerata) interactions in sugarcane. *International Sugar Journal*, 114: 668-672.

Bapuji Rao, B., Ramaraj, A.P., Chattopadhyay, C., Prasad, Y.G., and Rao, V.U.M., 2012. Predictive model for mustard aphid infestation for eastern plains of Rajasthan. *Journal of Agrometeorology*, 14(1): 60-62.

Bapuji Rao, B., Triveni, U., Linitha Nair, Harisatyanarayana, N., Latha P., and Rao, V.U.M., 2012. Assessment of influence of weather parameters on Mesta (Hibiscus sabdariffa) in North-Coastal zone of Andhra Pradesh. *Indian Journal of Dryland Agricultural Research and Development*, 27(2): 26-30.

B. Bapuji Rao, V.P. Pramod, P. Santibhushan Chowdary and V.U.M. Rao. (2013) Solar radiation estimation from limited meteorological parameters in a semi-arid environment, *Journal of Agrometeorology*, Vol.15, Spl.Issue-I, PP 63-70.

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Bapuji Rao, B., Sandeep, V.M., Santibhushan Chowdary, P., Pramod, V.P., and Rao, V.U.M., 2013. Reference crop evapotranspiration over India: A comparison of estimates from Open pan with Penman-Monteith method. *Journal of Agrometeorology*, 15(Special Issue - II) (In press).

B.M.K. Raju., K.V. Rao., B. Venkateswarlu., A.V.M.S. Rao., C.A. Rama Rao., V.U.M. Rao., M. Srinivasa Rao and K. Nagasree. (2013) Change in climate in India during last few decades, *Journal of Agrometeorology*, Vol.15, Spl.Issue-I, PP 30-36.

C.A. Rama Rao., B.M.K. Raju., A.V.M.S. Rao., V.U.M. Rao., K.V. Rao., Kausalya Ramachandran and B. Venkateswarlu. (2013) Climate change projections - A District-wise analysis for rainfed regions in India, *Journal of Agrometeorology*, Vol.15, Spl.Issue-I, PP 13-19.

Gouri, V., Bapuji Rao, B., Chitkala Devi, T., Kumari, M.B.G.S., and Ankaiah R., 2013. Thermal requirement of rabi maize in North Coastal Zone of Andhra Pradesh. *Journal of Agrometeorology,* 15(Special Issue - II) (In press).

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Kaushalya Ramachandran., Venkateshwarlu B., Ramarao CA., Rao VUM., Raju BMK., Rao AVMS., Saikia US., Thilagavathi N., Gayatri M., Satish J., 2013. Assessment of Vulnerability of Indian Agriculture to rainfall variability - Use of NOAA-AVHRR (8km) & MODIS (250m) Time-Series NDVI Product. Climate Change & Environmental Sustainability 1(1):37-52.

Patel, H.R., M.M. Lunagaria., B.I. Karande., Vyas Pandey., S.B. Yadav., A.V. Shah., V.U.M. Rao and S. Nareshkumar. (2013) Impact of projected climate change on groundnut in Gujarat, *Journal of Agrometeorology,* Vol.15, Spl.Issue-I, PP 41-44.

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Rao, K.V., Bhaskara Rao, I., Rao, V.U.M., Bapuji Rao, B., Prasad, J.V.N.S. and Mallikarjuna Reddy. 2013. Comparison of two weather generators for rainfall simulation: A case study for humid and semi arid environments. *Journal of Agrometeorology,* 15(Special Issue - II) (In press).

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Srinivasa Rao, M., P.C.M. Padmaja., D. Manimanjari., V.U.M. Rao., M. Maheswari., Abdul Khadar., M. Vanaja., K. Srinivas and B. Venkateswarlu. (2013) Response of Aphis craccivora Koch to elevated CO2 on cowpea, *Journal of Agrometeorology*, Vol.15, Spl.Issue-I, PP 51-56.

## Popular articles

Bapuji Rao, B., Rao, K.V., Rao, V.U.M. and Venkateswarlu, B., 2012. Kaalanugulanga varisagulo marpulu, Annadata (Monthly agricultural magazine in Telugu), August, 2012: 53-54.

## Technical Bulletins

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## Software developed

Bapuji Rao, B., Rao, V.U.M., Sandeep, V.M., Santibhushan Chowdary, P., Ramamohan, I. and Venkateswarlu, B. 2012. PET Calculator v2.0.

# AICRPAM Centres Publications

## Akola

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Anil Karunakar., M.M. Shitole., M.B. Nagdeve., M.M. Ganvir., S.B. Sakhare and V.V. Gabhane. 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.

Gabhane, V. V., Nagdeve, M. B., Ganvir, M. M., Anil Karunakar, Patode, R. S. and Sakhare, S. B. 2012. Sustainability of sorghum+pigeonpea intercropping system in rotation on vertisols under dryland conditions of Maharashtra. Abstracts, National symposium on "Climate change and Indian agriculture: slicing down the uncertainties" pp 103, 22-23 Jan. CRIDA, Hyderabad.

Ganvir, M.M., Nagdeve, M.B., Karunakar, A.P., Gabhane, V.V., Patode, R.S. and Sakhare, S. B. 2012. Productivity of cotton as influenced by land configuration and nutrient modules under dryland condition. Abstracts, National symposium on "Climate change and Indian agriculture: slicing down the uncertainties" pp 104-105, 22-23 Jan. CRIDA, Hyderabad.

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., Ramamohan Reddy, K., Gabhane, V.V., Ganvir, M.M., Karunakar, A. P. and Sakhare, S. B. 2012. Effect of continuous contour trenches on ground water recharge for small catchment in Vidarbha region of Maharashtra. Abstracts, National symposium on "Climate change and Indian agriculture: slicing down the uncertainties" pp 154-155, 22-23 Jan. CRIDA, Hyderabad.

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Mishra, S.K., Shekh, A.M., Patel, H.R., Patel, G.G., Karande, B.I. and Vyas Pandey. Effect of dates of sowing on thermal and radiation use efficiencies of wheat cultivars. Journal of Agrometeorology (Special issue). 14: 378-382.

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Patel, G.G., Patel, H.R., Pandey, V., Yadav, S.B. and Rao, V.U.M. 2013. Weather based forewarning models for mustard aphid under middle Gujarat agro climatic condition. National symposium on “Climate change and Indian agriculture: Slicing down the uncertainties” held at CRIDA, Hyderabad during 22-23 January 2013, pp 228.

## Anantapur

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Venkatachalapati, V., Mrudula, G., Narasimha Rao, S.B.S., Anitha, V., Madhan Mohan, M. and Vijay Sai Reddy, M. 2012. Growth and yield of chickpea as influenced by irrigation levels and dates of sowing, *Progressive Research- An International Journal* 8(1): 141-142.

### Book Chapters:

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## Bengaluru

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

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## Dapoli

### Peer reviewed research papers:

Thorat, S.T. Management of Protective irrigation for *rabi* crops. October 2012. Baliraja Masik, Page no. 73-75.

## Faizabad

### Peer reviewed research papers:

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Dhankhar, S.K., Chohan, P.K. and Surender Singh. 2012. Influence of weather parameters on incidence of yellow vein mosaic virus disease in okra. *Journal of Agrometeorology.* 14(1): 57-59.

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Kamlesh Kumar., Surender Singh and Diwan Singh. 2013. Seasonal climatic variability and its impact assessment on wheat productivity using crop modeling techniques in Haryana. *Journal of Agrometeorology* (Spl Issue-I). 15: 25-29.

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## Jabalpur

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### Papers presented in Symposium / Conference / Seminar / Workshop

Bhadauria, U.P.S., Jain, S. and Bhan, M. 2012. Analysis of extreme events of temperatures and rainfall in Madhya Pradesh. National Symposium on 'Frontiers of meteorology with special reference to the Himalayas'. TROPMET 2012, Nov. 20-22, 2012, Dehradun.

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Bhadauria, U.P.S., Jain, S. and Bhan, M. 2013. Analysis of extreme events of temperatures and rainfall in Madhya Pradesh. National symposium on climate change and Indian agriculture: slicing down the uncertainties, Jan 21-23, Hyderabad.

## Kanpur

### Peer reviewed research papers:

Tripathi, A.K., Dubey, A.P., Awasthi, U.D., Tripathi, B.N., Somendra Nath and Anand Kumar Tripathi. 2012. Growth and dry matter partitioning of winter maize (*Zea mays*) as influenced by intercropping. *Current Advances in Agriculture Science.* 4(1): 20-24.

## Kovilpatti

### Book Chapters:

Solaimalai, A., Subbulakshmi, S. and Jawahar, D. 2013. Climate change and its impact on Agriculture. AICRP on Agrometeorology, ARS, Kovilpatti, P. 32 (in Tamil).

### Technical Bulletins:

Solaimalai, A., Subbulakshmi, S., Jawahar, D., Rao, V.U.M. and Ashok kumar, G. 2012. Weather based decisions for growing Rabi Maize in Southern Agroclimatic zone of Tamil Nadu. Agricultural Research Station, Kovilpatti, Tamil Nadu. 40 p.

Solaimalai, A., Subbulakshmi, S., Jawahar, D., Rao, V.U.M. and Ashok kumar, G. 2012. Long term rainfall analysis for Tirunelveli District of Tamil Nadu. Agricultural Research Station, Kovilpatti, Tamil Nadu. 232 p.

### Popular articles:

Subbulakshmi, S., Suguna, S., Solaimalai, A., Selvarani, A. and Jawahar, D. 2012. Pairkalivukalai payanpaduthi cipikkalan valarthal. Kalathumedu, 1(12): 6-9.

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Subbulakshmi, S., Solaimalai, A. and Rao, V.U.M. 2013. Response of Bt cotton to different sowing windows and plant spacing under rainfed vertisol conditions. In: Proc. of National Symposium on “Climate change and Indian Agriculture: Slicing Down the Uncertainties” held at CRIDA, Hyderabad, January 22 & 23, 2013. P: 127-128.

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Bal, S.K., Mukherjee, J., Singh, G., Sood, A., Choudhury, B.V., Singh, H. and Prabhjyot Kaur. 2012. Agroclimatic resource inventory characterization of Punjab state in spatial domain. *Indian J of Ecology*. 39(1): 11-17.

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.

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Kamal Vatta., Prabhjyot Kaur., Harpreet Singh and Tinku Grover. 2012. Vulnerability of Punjab agriculture to climate change – A district wise analysis. Network Project on Climate change, ICAR, New Delhi. Punjab Agricultural University, Ludhiana. Pages 44.

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. AICRPAM, Dept. of Agricultural Meteorology, PAU, Ludhiana. pages 60.

Jalota, S.K. and Prabhjyot Kaur. 2013. Climate change in Punjab and crop yields. Punjab Agricultural University, Ludhiana. pages 22.

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Harpreet Singh., Prabhjyot Kaur., S S Sandhu., 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

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Gill, K.K., Prabhjyot Kaur., Ritu Babuta., Sandhu, S.S. and Deepak. 2013. Evaluating weather parameters for predicting wheat yield in central region of Punjab. In Proceedings of National Symposium on Climate Change and Indian Agriculture: Slicing Down the Uncertainties. held on 23-23 Jan 2013 at CRIDA Hyderabad. pp 110.

Prabhjyot Kaur. 2013. Climate Change in Punjab – A Critical Scrutiny of the past. In Brainstorming workshop on "Climate Change and Sustainability of Agriculture" held at PAU, Ludhiana on February 6, 2013.

Prabhjyot Kaur., Harpreet Singh and Amarinder Singh. 2013. Predicting climate change induced vulnerability to major cereal crops under various scenario in Punjab. In pp 53: Proceedings of International Conference on Agriculture and Climate Change held on January 29-30, 2013 at New Delhi.

Prabhjyot Kaur., Harpreet Singh., S S Sandhu., K.K. Gill and P.K. Gill. 2013. Recent trends in incidence of extreme weather events at different locations in Punjab. In Proceedings of National Symposium on Climate Change and Indian Agriculture: Slicing Down the Uncertainties. Held on 23-23 Jan 2013 at CRIDA Hyderabad. pp 20.

Prabhjyot Kaur., Ashu Bala, Singh, H., Sandhu, S.S. and Gill, K.K. 2013. Quantitative evaluation of yield gap in rice and wheat productivity in different agroclimatic zones of Punjab. In Proceedings of National Symposium on Climate Change and Indian Agriculture: Slicing Down the Uncertainties. Held on 23-23 Jan 2013 at CRIDA Hyderabad. pp 202.

Sandhu, S.S. and Prabhjyot Kaur. 2013. Mitigation of terminal heat stress in wheat through irrigation scheduling in Punjab. In: Proceedings of International Conference on Agriculture and Climate Change held on 29-30 Jan 2013 at New Delhi. Pp 102.

Sandhu, S.S., Prabhjyot Kaur., Gill, K.K. and Ashu Bala. 2013. Effect of inter and intra seasonal variability in meteorological parameters on rice productivity in central Punjab. In Proceedings of National Symposium on Climate Change and Indian Agriculture: Slicing Down the Uncertainties. held on 23-23 Jan 2013 at CRIDA Hyderabad. pp 80.

## Mohanpur

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Basu, B., Mondal, B.C., Mukherjee, A., Banerjee, S. and Rao, V.U.M. 2012. Weather based agro-advisories towards enhancing resilience of agriculture at Bongheri Village, West Bengal. *Journal of Agrometeorlogy*. (14): 252-255.

Biswas, S., Mukherjee, A. and Sarkar, S. 2012. Screening of suitable climatological model for estimation of reference evapotranspiration in New Alluvial Zone of West Bengal. *Journal of Agrometeorlogy*. (14): 292-298.

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.

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Das, S., Biswas, S., Mukherjee, A. and Banerjee, S. 2012. Evaluating performance of rice under elevated CO2 and temperature condition through DSSAT model. *Journal of Agrometeorlogy*. (14): 325-330.

Mukherjee, A., Banerjee, S., Chatterjee, S., Banerjee, S., Chakravarty, A.K. and Sarkar, S. 2012. Yield and water use pattern of wheat grown under different date of sowing and varying irrigation scheduling. *Journal of Agrometeorlogy*. (14): 285-291.

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Samanta, S., Banerjee, S. and Mukherjee, A. 2012. Rainfall variability study over Kalyani region, West Bengal. *Journal of Agrometeorlogy*. (14): 401-406.

## Palampur

### Peer reviewed research papers:

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.*

Prasad, R. 2013. Climate Change Studies in Agriculture under National Agricultural Research System in India and role of CSK Himachal Pradesh Agricultural University, Palampur. *International Journal of Agriculture and Biology. (In Press).*

Prasad, R., Kumari, V., Sharma, A. and Sehgal, S. 2013. A study on high incidence of mustard aphids, *Brevicoryne brassicae* (L.) and *Myzus persicae* (Sulzer) on Gobhi Sarson during warmer and drier winters at Palampur, Himachal Pradesh (India). *Journal of Agrometeorology. (In Press).*

Prasad, R., Kumar, S., Sehgal, S. and Sharma, A. 2013. Higher ambient temperature experienced during different phenophases and its impact on duration and yield of wheat crop (*Triticum aestivum* L.) in mid hill conditions of Himachal Pradesh. *Journal of Agrometeorology. (In Press).*

Prasad, R., Shekhar, J., Singh, G., Kumari, V., Sehgal, S. Sharma, A. and Kumar, S. 2013. District Level Contingency Plans- a sure way to slice down the impact of climatic uncertainties in hill and mountain Agriculture of Himachal Pradesh. *Journal of Agrometeorology. (Communicated).*

## Papers presented in Symposium / Conference / Seminar / Workshop:

Prasad, R., Sharma, A. and Sehgal, S. 2013. Higher ambient temperature experienced during different phenophases and its impact on yield and duration of wheat crop (*Triticum aestivum* L.). Oral presentation in National Symposium on "Climate Change and Indian Agriculture: Slicing Down the Uncertainties**"** held at CRIDA, Hyderabad on 22-23 Jan, 2013.

Prasad, R., Sharma, A. and Sehgal, S. 2013. A study on high incidence of mustard aphids, *Brevicoryne brassicae* (L.) and *Myzus persicae* (Sulzer) on Gobhi Sarson during warmer and drier winters at Palampur, Himachal Pradesh (India)". Abstract in National Symposium on "Climate Change and Indian Agriculture: Slicing Down the Uncertainties" held at CRIDA, Hyderabad on 22-23 Jan, 2013.

Prasad, R., Singh, G., Shekhar, J., Sehgal, S. and Sharma, A. 2013. District Level Contingency Plans- a sure way to slice down the impact of climatic uncertainties in hill and mountain Agriculture of Himachal Pradesh. Abstract in National Symposium on "Climate Change and Indian Agriculture: Slicing down the Uncertainties" held at CRIDA, Hyderabad on 22-23 Jan, 2013.

Prasad, R. 2013. Climate Change Studies in Agriculture under National Agricultural Research System in India and role of CSK Himachal Pradesh Agricultural University, Palampur. Abstract in International conference on "Crop Management in changing climate" held at the University of Agriculture, Faisalabad, Pakistan during February, 11-13, 2013.

## Parbhani

### Papers presented in Symposium / Conference / Seminar / Workshop:

Aher H.V., and Jadhav, M.G. 2013. Rainfall Variability and Pearl millet production in Aurangabad districts of Maharashtra. Paper presented in National Symposium on Climate Change and Indian Agriculture: Slicing down the Uncertainties held at CRIDA, Hyderabd during 22-23rd January 2013 PP.92.

Jadhav M.G. and Khandagale, G.B. 2013. Effect of weather parameters on grain and fodder yield of Kharif sorghum at Parbhani. Paper presented in National Symposium on Climate Change and Indian Agriculture: Slicing down the Uncertainties held at CRIDA, Hyderabd during 22-23rd January 2013 PP.45.

## Rakh Dhiansar

### Peer reviewed research papers:

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### Popular articles:

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

## Ranichauri

### Peer reviewed research papers:

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## Samastipur

### Peer reviewed research papers:

Sattar, A., Manish Kumar., Bobade, P. and Chandrawanshi, S. 2013. Assessing the length of growing season and drought incidence in Bihar. *Journal of Agrometeorology.* (Special Issue- 1) 15: 192-194.

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### Book Chapters

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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)

### Technical Bulletins:

Pandey, I.B., Manish Kumar., Bobade, P. and Chandrawanshi, S.K. 2013. *Jalbayu paribartan tatha badalte mausam me krishi, Bulletin* Vol 1.

### 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:

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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.

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Apotikar V.A., Solanki A.V., Jadhav J.D. and Hasure R.R.2012 (Jun) Effect of Leaf temperature and Air temperature on Graded yield of Potato. Asian Journal of Environmental Sciences 07 (01): 001-012.

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Palve D.K., Ghule P.L., Jadhav J.D. and Dahiphale V.V, 2012 (Oct) Gross monetary returns (Rs/ha), Net monetary returns (Rs/ha) and Benefit: cost ratio of Bt cotton in different treatments. International Journal of Commerce and Business Management. 05 (02): 269-273

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Kambale R.D., Jadhav J.D., Andhale R.P. and Pawar P.B. 2012 (Dec) Sowing dates and potash levels influences on yield of Chickpea. Advance research Journal of Crop Improvement. 03(02): 148-153

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## Book Chapters: Nil

### Technical Publications (Extended Summary):

Khadatare S.V., Shinde V.A., Jadhav J.D. and Kadam J.R, 2012 (Nov) Predict the Phenophases using Agro-Metrological Indices in Safflower. Indian Journal of Agronomy (Extended Summary). 2 : 89

Bhore, A.V., Jadhav J.D., Bavadekar V.R. and Kadam J.R, 2012 (Nov) Heat unit accumulation of safflower cultivars as influenced by different sowing windows. Indian Journal of Agronomy (Extended Summary).2:90

Kadam, J.R., Jadhav J.D., Bavadekar V.R. and Bhore A.V, 2012 (Nov) Impact of abiotic factors in relationship to growth and yield of safflower under dryland condition. Indian Journal of Agronomy (Extended Summary).2:254

Thorve, S.B., Upadhye, S.K., Jadhav J.D., Bhanavase D.B. and Kadam J.R. 2012 (Nov) Productivity Enhancement on farmers field in the of rabi sorghum (Sorghum bicolor L.) under scaracity situation by adopting in-situ moisture conservation practices. Indian Journal of Agronomy (Extended Summary),2:699

Apotikar V.A., J.D.Jadhav., A.V. Solanki. 2012 (Nov) Effect of Leaf temperature and Air temperature on Graded yield of Potato. Indian Journal of Agronomy (Extended Summary) 2:932

Gaikwad U.S., J.D. Jadhav., V.A. Shinde. and J.R. Kadam. 2012 (Nov). Integrated farming system for sustainability and livelihood security for dryland, Indian Journal of Agronomy (Extended Summary).2:949

Shinde V.A., J.D. Jadhav., S.V. Khadtare. and J.R. Kadam. 2012 (Nov) Economic analysis of existing farming systems in scarcity zone of Western Maharashtra. Indian Journal of Agronomy (Extended Summary).2:971

Patil, S.V., J.D. Jadhav. and J.R. Kadam. 2012 (Nov ) Agri-Horti System a solution For Income Generation under Climate Change. Indian Journal of Agronomy (Extended Summary). 2:1313

Jadhav J.D., V.A. Shinde., S.V. Khadatare. and J.R. Kadam, 2012 (Nov) Use the Knowledge of Nakshtra for analyzing rainfall under climate change situation to decide the contingent crop plan. Indian Journal of Agronomy (Extended Summary) 2:1328

Bavadekar V.R., J.D. Jadhav., V.A. Shinde and J.R. Kadam 2012 (Nov) Know the rainfall probability, Harvest rain water and decide the cropping pattern of drought prone areas. Indian Journal of Agronomy (Extended Summary),2:1330

## Technical Publications (Abstracts):

Kambale P.S., V.G. Maniyar and J.D Jadhav, 2013 (Jan) AET Measurement in Soybean and estimation of PET by various methods, Journal of Agrometeorology.11

Bavadekar V.R., J.D. Jadhav., A.V. Bhore and J.R. Kadam, 2013 (Jan) Variability and probability of rainfall during Nakshtras period for drought prone areas of Maharashtra. Journal of Agrometeorology. 16

Rathod R.K., J.D. Jadhav., A.V. Bhore., J.R. Kadam and V.R. Bavadekar, 2013 (Jan), Rainfall Variability of Selected Places and Decadal/Pentacle Analysis-A Case Study of Solapur. Journal of Agrometeorology, 16

Sanglikar R.V., P.B. Pawar., J.D. Jadhav., V.R. Bavdekar and J.R. Kadam, 2013 (Jan). Yearly, Monthly, Seasonal - Normal, Surplus and Drought Analysis of rainfall, Journal of Agrometeorology,17

Thorve S.B., J.D. Jadhav., P.B. Pawar., A.V. Bhore and J.R. Kadam, 2013 (Jan) District Variability of Rainfall in Solapur (MS). Journal of Agrometeorology.18

Upadhye S.K., J.D. Jadhav., P.B. Pawar., V.R. Bawdekar and JR Kadam, 2013 (Jan) Use of Models for Prediction of Rainfall. Journal of Agrometeorology.19

Jadhav J.D., P.B. Pawar., V.R. Bavdekar., A.V. Bhore and J.R. Kadam, 2013 (Jan) Identifying the Changes in Rainfall Trends Accordingly Suggest Cropping Pattern for the Districts of Western Maharashtra. Journal of Agrometeorology.24

Khadatare S.V., J.D. Jadhav., J.R. Kadam, and A.V. Bhore, 2013 (Jan). Safflower growth and yield relationship with meteorological parameters, Journal of Agrometeorology,47

Kambale P.S., V.G. Maniyar and J.D. Jadhav, 2013 (Jan) Meteorological week wise PET Estimation and AET Measurement in Soybean (Glycine max L.), Journal of Agrometeorology,55

Andhale R.P., R.D. kamble., Jadhav J.D. and Pawar P.B, 2013 (Jan), Growing degree days as influenced by sowing days and potash levels of chickpea, Journal of Agrometeorology. 88

Benke P.S., R.P. Andhale., V.A. Apotikar., J.D. Jadhav and A.V. Solanki, 2013 (Jan) Sowing Windows Effect on Radiation Interception in Potato. Journal of Agrometeorology, 89.

Dorkar D.P., P.S. Kambale., V.G. Maniyar and J.D. Jadhav, 2013 (Jan) Crop coefficient (Kc) of Soybean (Glycine max L.). Journal of Agrometeorology.90

Kamble R., P.R.P. Andhale., J.D. Jadhav and P. B. Pawar, 2013 (Jan) Radiation interception and light use efficiency by different sowing environments in chickpea, Journal of Agrometeorology.90

Pawar P.B., A.V. Solanki., V.A. Apotikar., J.D. Jadhav and V.A. Wadile, 2013 (Jan) Effect of leaf temperature and air temperature on graded yield of potato. Journal of Agrometeorology, 91.

Dhadge S.M., J.D. Jadhav., R.V. Sanglikar and J.R. Kadam, 2013 (Jan) Effect of integrated nutrient management on growth, yield and quality of summer groundnut (Aarchis hypogaea L.) under climate change situation, Journal of Agrometeorology,94

Deshmukh V.V., S.M. Dhadge., J.D. Jadhav and J.R. Kadam, 2013 (Jan), Cropping System of groundnut (Arachis hypogaea L.)-maize (Zea mays) A Case Study under climate change situation, Journal of Agrometeorology.94

Apotikar V.A., A.V. Solanki., J.D. Jadhav and P.B. Pawar, 2013 (Jan). Effect of Irrigation Levels on Rate of Photosynthesis in Potato, Journal of Agrometeorology.103

Shinde S.K., J.D. Jadhav., S.V. Khadatare and J.R. Kadam, 2013 (Jan), Phenophase prediction model for Safflower, Journal of Agrometeorology.107

Wadile V.A., V.A. Apotikar., J.D Jadhav and A.V. Solanki, 2013 (Jan), Studies on stomatal conductance and stomatal resistance in relation to haulum yield in potato, Journal of Agrometeorology, 108

Wakode A.R., C.N. Gangde., R.K. Rathod. and J.D. Jadhav, 2013 (Jan), Energy use and input: output analysis of cotton production, Journal of Agrometeorology,108

Shinde V.A., G.K. Bembalkar., J.D. Jadhav. and J.R. Kadam, 2013 (Jan), Integrated farming system research for sustainability and livelihood security of the farmers in the scarcity zone of Maharashtra, Journal of Agrometeorology,118

Bhore A.V., J.D. Jadhav., J.R. Kadam and V.R. Bavadekar, 2013 (Jan), Scarcity places of North, Central and Southern Maharashtra Rainfall Probabilities and Contingent crop planning, Journal of Agrometeorology,153

Munde P.A., R.K. Rathod., J.D. Jadhav and R.G. Nadre, 2013 (Jan), Precise Operations Using Tractor Drawn Inter-Row Rotary Weeder Under Climate Change Situation, Journal of Agrometeorology,154

Bembalkar G.K.,V.A. Shinde., J.D. Jadhav and J.R. Kadam, 2013 (Jan), Economic analysis of existing farming systems in scarcity zone of Western Maharashtra, Journal of Agrometeorology,169.

Kadam J.R., J.D. Jadhav, S.B. Thorve, S.K. Upadhye and D.B. Bhanvase, 2013 (Jan), Agro advisories and crop planning on weather basis in scaracity zone of Maharashtra, Journal of Agrometeorology,177

Akashe V.B., M.A. Gud., S.K. Shinde., J.D. Jadhav., V.R. Bavdekar and J.R. Kadam, 2013 (Jan), Weather based forewarning models for safflower aphid (Uroleuconcompositae T.) in the scarcity zone of Maharashtra, Journal of Agrometeorology,231.

Maniyar V.G,. P.S. Kambale. and J.D. Jadhav, 2013 (Jan), AET Measurement in Soybean and estimation of PET by various methods, Journal of Agrometeorology.

## Papers presented in Symposium / Conference / Seminar / Workshop:

Upadhye S.K., V.A. Sthool, and J.D. Jadhav, 2013 (Jan), Development of location specific constants in IFD equation for Solapur station, Journal of soil and water conservation Enggenering,155 Paper published in 47 th Annual Convention and International Symposium, on Bio-Energy, from Jan. 28-30,2013 at Hyderabad organized by NG Ranga Agril, Univ-Hyderabad.

## Symposium / Seminars / Meetings / Lectures attended:

Jadhav J.D., B.T. Jadhav, Aattended Biennial workshop of AICRP On Agrometeorology and NICRA project at Udaipur (Rajasthan), Oct 11-14 2012. At Udaipur.

Jadhav J.D., Attended Third Inter National Agronomy Congress on Agriculture, Diversification, Climate change Management and Livelihood, organized by Agronomy Journal, from Nov. 26-30, 2012 at New Delhi. Nov.26-30, 2012, At New Delhi.

Jadhav J.D, Attended National Symposium, Climate change and Indian agriculture: Slicing Down the Uncertainities, from Jan. 22-23, 2013 at Hyderabad organized by CRIDA-Hyderabad/AAM-Anand., Jan. 22-23,2013, At Hyderabad.

Jadhav J.D., V.R. Bawadekar, Attended training on Crop growrh simulation DSSAT-Modeling, Mar 11-15 2013, At Anand.

## Awards from recognized institute/ICAR institute

Jadhav J.D., Bhore A.V. and Bawadekar V.R. 11 BEST AICRPAM CENTRE AWARD In the Biennial workshop of AICRPAM at Udaipur (Raj) -14 , OCT., 2012

Kadam J.R., Jadhav J.D., Sanglikar R.V. BEST POSTER PRESENTATION AWARD In the Symposium on Climate change and Indian agriculture :Slicing Down the Uncertainities at Hyderabad (A P) 22-23, JAN, 2013.

### Radio Talks / TV Interview:

Every week Agro advisory Broad casted + 02 own programme

Regular weather forecasting on early morning and on every wednesday at 07:30 pm in Gaonkari mandal on AIR Solapur regarding Agro-Advisory Service.

## Thrissur

### Book Chapters:

Rao, G.S.L.H.V.P., 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.

### Papers presented in Symposium / Conference / Seminar / Workshop:

Karthika, V.P., Prasada Rao, G.S.H.L.V., Ajithkumar, B., Laly John, C. and Pradeepkumar, T. 2012. Influence of planting time on the curd weight of cauliflower (Brassica oleracea var. botrytis) in the central region of Kerala. 22nd Swadesi Science Congress (Kasargod). A16.

Rao, G.S.L.H.V.P., 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., 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.

Rao, G.S.L.H.V.P., Gopakumar, C.S. and Krishnakumar, K.N. 2012. Impact of climate change on monsoon onset and monsoon rainfall over Kerala from 1870 to In: Proceedings of OCHAMP 2012 held at IITM Pune during 21-25, February 2012.

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.

### Popular articles:

Karthika, V.P. and Ajith Kumar, B. 2012. Profitable Cauliflower Cultivation. Karshakan 2012, vol. 20, Pp.12-15.

Karthika, V.P., Prasada Rao, G.S.H.L.V., Ajithkumar, B., Laly John, C. and Pradeepkumar, T. 2013. Influence of weather variables on the curd yield of cauliflower (Brassica oleracea var. botrytis) in the central region of Kerala. In: Proceedings of National

Symposium on “Climate Change and Indian Agriculture: slicing down the uncertainties during 22-23 January 2013 S3-73.

Lincy Davis, P. and Ajith Kumar, B. 2013. Crop weather realationship studies in bitter gourd. : in. Proceedings of National Symposium on “Climate Change and Indian Agriculture: slicing down the uncertainties during 22-23 January 2013 S3-74.

## Udaipur

### Peer reviewed research papers:

Bahadur Singh., Kaushik, M.K., Mundra, S.L. and Solanki, N.S. 2012. Effect of seed rate and nitrogen on growth and yield of summer fodder sorghum (*Sorghum bicolor*) (L.) Moench). *International Journal of forestry and Crop Improvement*. 3(2): 109-111.

Meena, R.P., Meena, B.L. and Solanki, N.S. 2013. Effect of different sowing environments on dry matter accumulation, thermal indices at different growth stages and yield of fenugreek (*Trigonella foenum-graecum* L.). *Journal of Agrometeorology* (Special issue-I). 15: 198-200.

Pushendra Singh., Sumeriya, H.K., Solanki, N.S. and Upadhyay, B. 2012. Yield and economics of sorghum genotypes as affected by fertility levels. *Annals of Plant and Soil Research.* 14(1): 65-67.

Pushendra Singh., Sumeriya, H.K. and Solanki, N.S. 2012. Effect of Fertilizer Levels on Productivity and Economics of Elite sorghum (*Sorghum bicolor*) (L.) Moench) Genotypes. *Madras Agricultural Journal.* 99(7-9): 567-569.

Pushendra Singh., Sumeriya, H.K., Solanki, N.S. and Azad Murdia. 2012. Productivity, economics and quality of fodder sorghum under varying levels of nitrogen and phosphorus. *Annals of Plant and Soil Research.* 14(2): 127-129.

### Technical Bulletins:

Bulletin on “RAINFALL ATLAS OF SOUTH EAST RAJASTHAN” 2013 by Dr. N.S. Solanki and Ms. Bhavya Bandi.

# Staff position at cooperating centers during 2013

| Centre | Positions Sanctioned and Filled (F) / Vacant (V) | | | | | |
|---|---|---|---|---|---|---|
| | Agrometeo-rologist | Junior Agronomist | Senior Technical Assistant | Meteorological Observer | Field Assistant | Junior Clerk |
| Akola | F | – | – | F | F | – |
| Anand | F | F | F | F | F | F |
| Anantapur | V | F | F | F | F | F |
| Bengaluru | F | F | F | F | F | F |
| Bhubaneshwar | F | – | – | V | F | – |
| 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 | – | – | F | F | – |
| Kovilpatti | F | F | F | F | F | F |
| Ludhiana | F | F | F | F | F | F |
| Mohanpur | F | F | F | F | F | F |
| Palampur | F | – | – | F | F | – |
| Parbhani | F | – | – | F | V | – |
| Raipur | F | – | – | F | V | – |
| Rakh Dhiansar | F | – | – | F | F | – |
| Ranchi | F | F | F | F | F | F |
| Ranichauri | V | F | V | V | V | V |
| Samastipur | F | – | – | V | F | – |
| Solapur | F | F | F | V | V | V |
| Thrissur | F | – | – | V | F | – |
| Udaipur | F | – | – | F | V | – |
| **Total posts sanctioned** | **25** | **12** | **12** | **25** | **25** | **12** |
| **Total posts filled** | **21** | **12** | **10** | **19** | **19** | **9** |

# All India Coordinated Research Project on Agrometeorology

### Centre-wise and Head-wise RE allocation (Plan) for the year 2012-13

| S. No. | Name of the Centre | Pay & Allow. | TA | RC | NRC | IT | TSP (100%) works | Total ICAR Share |
|---|---|---|---|---|---|---|---|---|
| 1 | Akola | 1600000 | 18000 | 60000 | 100000 | 50000 | 0 | 1828000 |
| 2 | Anand | 2200000 | 22000 | 120000 | 100000 | 60000 | 0 | 2502000 |
| 3 | Anantapur | 3200000 | 12000 | 120000 | 100000 | 60000 | 0 | 3492000 |
| 4 | Bengaluru | 3800000 | 22000 | 120000 | 130000 | 60000 | 0 | 4132000 |
| 5 | Bhubaneswar | 1700000 | 18000 | 60000 | 0 | 40000 | 950000 | 2768000 |
| 6 | Bijapur | 1200000 | 18000 | 60000 | 100000 | 40000 | 0 | 1418000 |
| 7 | Dapoli | 1900000 | 18000 | 60000 | 100000 | 40000 | 0 | 2118000 |
| 8 | Faizabad | 2760000 | 18000 | 120000 | 100000 | 60000 | 0 | 3058000 |
| 9 | Hisar | 2100000 | 12000 | 120000 | 130000 | 60000 | 0 | 2422000 |
| 10 | Jabalpur | 1600000 | 12000 | 120000 | 0 | 60000 | 600000 | 2392000 |
| 11 | Jorhat | 2400000 | 60000 | 60000 | 0 | 40000 | 700000 | 3260000 |
| 12 | Kanpur | 1400000 | 18000 | 60000 | 100000 | 40000 | 0 | 1618000 |
| 13 | Kovilpatti | 2400000 | 22000 | 120000 | 110000 | 60000 | 0 | 2712000 |
| 14 | Ludhiana | 3300000 | 22000 | 120000 | 100000 | 60000 | 0 | 3602000 |
| 15 | Mohanpur | 2400000 | 22000 | 120000 | 100000 | 60000 | 0 | 2702000 |
| 16 | Palampur | 2500000 | 18000 | 60000 | 0 | 40000 | 950000 | 3568000 |
| 17 | Parbhani | 1600000 | 18000 | 60000 | 100000 | 40000 | 0 | 1818000 |
| 18 | Raipur | 1700000 | 18000 | 60000 | 0 | 40000 | 700000 | 2518000 |
| 19 | Rakh Dhiansar | 2000000 | 18000 | 60000 | 100000 | 40000 | 0 | 2218000 |
| 20 | Ranchi | 2500000 | 22000 | 120000 | 0 | 60000 | 700000 | 3402000 |
| 21 | Ranichauri | 3200000 | 18000 | 120000 | 100000 | 60000 | 0 | 3498000 |
| 22 | Samastipur | 1300000 | 16000 | 60000 | 100000 | 40000 | 0 | 1516000 |
| 23 | Solapur | 2500000 | 22000 | 120000 | 0 | 60000 | 650000 | 3352000 |
| 24 | Thrissur | 2000000 | 18000 | 60000 | 100000 | 40000 | 0 | 2218000 |
| 25 | Udaipur | 3000000 | 18000 | 60000 | 0 | 40000 | 750000 | 3868000 |
| | **TOTAL** | **562,60,000** | **5,00,000** | **22,20,000** | **17,70,000** | **12,50,000** | **60,00,000** | **680,00,000** |


XII Biennial Workshop
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All India Coordinated Research Project on Agrometeorology
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October 9-11, 2012
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