

# All India Coordinated Research Project on Agrometeorology

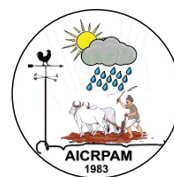
**Annual Report  
2021-22**



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

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### Foreword



Weather continues to play a dominant role in agricultural production despite of technological advances. In India, erratic rainfall distribution during southwest monsoon season and heatwaves during summer season affect the food grain production significantly. In addition, our country is experiencing extreme weather events such as drought, flood, cold waves, hailstorms, cyclones etc. every year causing heavy losses to agriculture and allied sectors. It is projected that occurrence of extreme weather events are likely to increase further.

All India Coordinated Research Project on Agrometeorology (AICRPAM) is playing a significant role in identifying regions vulnerable to climate variability and change, development of adaptation strategies to counter the negative effects. Towards achieving this goal, AICRPAM is carrying out research on impacts of higher temperature and change in rainfall patterns on major crops through developing crop-weather relationships, crop growth modeling studies, preparation of contingency crop plans for different rainfall situations, quantifying optimum weather requirements at different growth stages of major crops, development of weather insurance products, decision support systems for crop management and forewarning of pests and diseases through its network centres located in different agroclimatic zones of the country. The output of the AICRPAM research is also being used for improving the content and supporting the weather-based agro advisories being prepared and disseminated to the farmers through GKMS, a collaborative program of ICAR and IMD.

The efforts of the cooperating centres of AICRPAM in pursuing the assigned research programs are commendable. Cooperating centres are expected to develop user friendly products, integrated approaches to assess meteorological hazards and also to record positive & negative impacts of climate variability and change on agriculture. Strong linkages between ICAR Research Institutes and SAUs engaged in managing crop production is desirable to minimize the risks associated with weather variability for sustainable production. The Annual Progress Report of 2021-22 includes the prominent research results of the experiments conducted during *kharif* 2021 and *rabi* 2021-22 at 25 centres of AICRPAM. I take this opportunity to congratulate Dr. Santanu Kumar Bal, Project Coordinator (I/c) and his team in the coordinating unit and also the scientific staff of all 25 coordinating centres for their efforts in the compilation of this excellent report. I hope, the information presented in this report will be useful for several ministries for formulating strategies and policy implementation to minimize the effects of weather aberrations.

V. K. SINGH

Director

ICAR-CRIDA, Hyderabad



## Acknowledgement

I wish to place deep sense of gratitude to Indian Council of Agricultural Research for its continuous and generous support during the year 2021-22. The encouragement and guidance received from Hon'ble Secretary, DARE & Director General, Dr. Trilochan Mohapatra and Deputy Director General (NRM), Dr. Suresh Kumar Chaudhari is gratefully acknowledged. The constant guidance extended by Dr. S. Bhaskar, Assistant Director General (AAFCC) to the project is highly appreciable. The help and encouragement received from Dr. Vinod Kumar Singh, Director, ICAR-CRIDA for the effective functioning of the project is acknowledged with sincere thanks.

The sincere efforts of the scientists and other staff of all 25 Cooperating centres are highly acknowledged for carrying out the research experiments as per the technical program and bringing out valuable results that made it possible to complete a comprehensive report.

Help rendered by Dr. A.V.M. Subba Rao, Shri. N. Manikandan and Dr. M.A. Sarath Chandran for the compilation of this report are greatly acknowledged. My appreciation and thanks to Mr. A. Mallesh Yadav, Dr. V.M. Sandeep, Dr. V.P. Pramod, Dr. Deepti Verma, Mr. Sravan Kumar, Mr. Chandrakant, Ms. Manisha and Mrs. Vijayalakshmi for their contribution to this report.



**Santanu Kumar Bal**  
Project Coordinator (Ag. Met.)



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# 1. Introduction

The All India Coordinated Research Project on Agrometeorology (AICRPAM) was initiated by ICAR in May 1983 with the establishment of coordinating cell at the Central Research Institute for Dryland Agriculture, Hyderabad with 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 enhanced the Cooperating Centres to additional 13 Agricultural Universities of the country w.e.f. April 1995. The 25 Cooperating Centres of the AICRPAM network are: Akola, Anantapuramu, Anand, Bengaluru, Bhubaneswar, Chatha, Dapoli, Faizabad, Hisar, Jabalpur, Jorhat, Kanpur, Kovilpatti, Ludhiana, Mohanpur, Palampur, Parbhani, Raipur, Ranchi, Ranichauri, Samastipur, Solapur, Thrissur, Udaipur and Vijayapura (Fig. 1.1). The Quinquennial Review Team has reviewed the research progress of the project in 1992, 1998-99, 2006, 2011 and 2017. In the last QRT Report, the performance of AICRPAM was adjudged as **Very Good**.

## 1.1 Objectives

- To study the agricultural climate in relation to crop planning and assessment of crop production potentials in different agroclimatic regions
- To establish crop-weather relationships for major rainfed and irrigated crops in different agroclimatic regions
- To study the influence of weather on the incidence and spread of pests and diseases of field crops
- To evaluate adaptation strategies in crops against weather aberrations
- To provide research support for the agromet advisory services in India

## 1.2 Technical Program for 2018-22

The Technical Program for the years 2018 to 2022 for different centres of the project and a common core program decided for all the centres with emphasis on location-specific research needs is given below.

### 1) Agroclimatic Characterization (All centres)

- Development of databases (Block/Tehsil/Mandal level) on climate and crop data (district level)

## **Agroclimatic Analysis**

- Rainfall probability analysis
- Dry and wet spells
- Characterization of onset of crop season 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
- Preparation of crop-wise manuals for weather-based decisions in crop management
- Documentation of extreme weather events and their impacts on agriculture

## **2) Crop Weather Relationships**

- Development of weather-based crop yield prediction models
- Pooled analysis of crop weather data across multiple locations under AICRPAM
- Estimation of heat unit requirement of crops
- Effect of growing environment on yield and yield attributing parameters
- Estimation of Heat Use Efficiency (HUE), Consumptive Use of Moisture (CUM), Moisture Use Efficiency (MUE) and Radiation Use Efficiency (RUE) for various crops
- Interaction effect of the growing environment with crops/varieties

## **3) Crop Growth Modeling**

- Calibration and validation of crop weather simulation models with new genotypes
- Exploring management options for better resource management
- Climate change impact assessment
- Development and evaluation of adaptation strategies for reducing yield losses under future climates

## **4) Weather Effects on Pests and Diseases**

The technical program as finalized in the workshop for the themes 2, 3 and 4 are given in Table 1.1.

### 5) Agromet Advisory Services (All Centres)

- Monitoring of crop and weather situation, twice a week and its updation on the 'cropweatheroutlook' website
- Development of crop contingency plans for the 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 of agromet advisory services

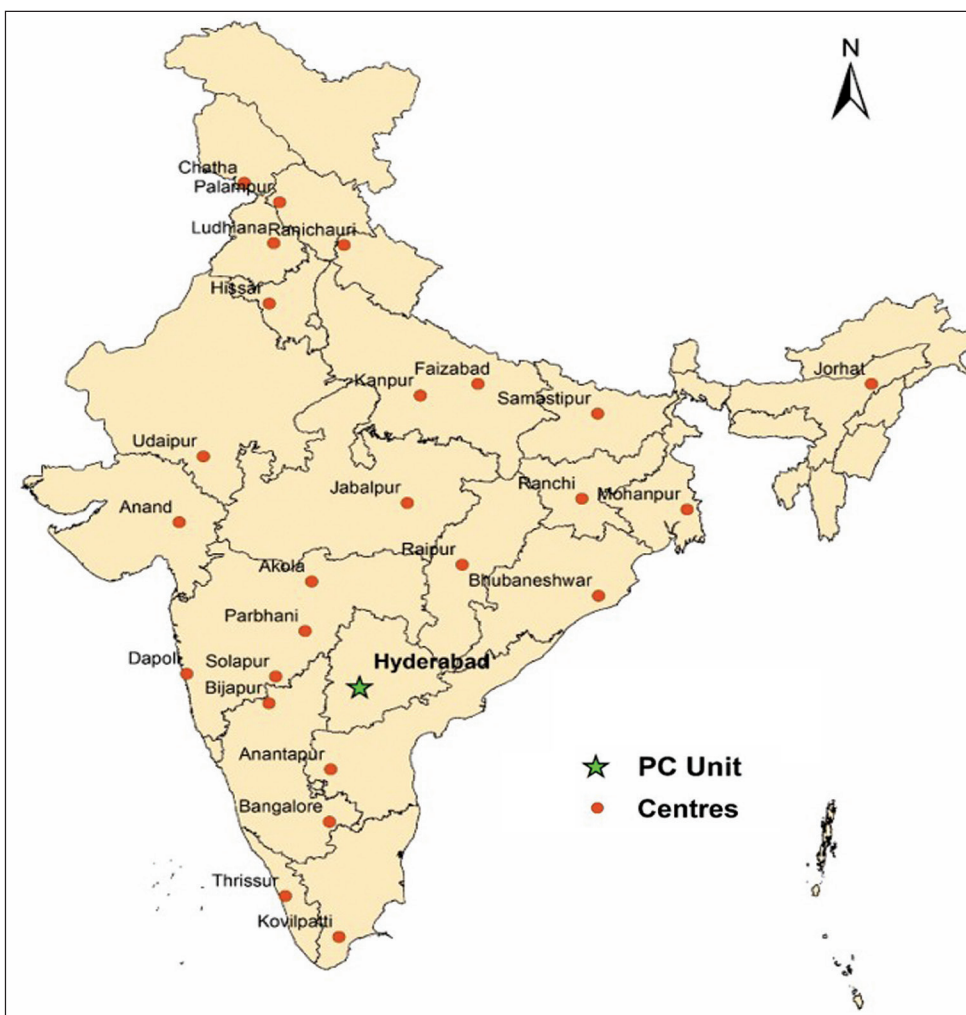


Fig. 1.1: Location map of Project Coordinating Unit and 25 cooperating centers of AICRPAM

**Table 1.1: Zone-wise technical program of AICRPAM centers for three different themes during 2018-22**

| S. No. | Zones                                  | Centre     | Crop Weather Relationship Studies                                                              |                                                                                           | Crop Growth Modeling | Weather Effects on Pests & Diseases                                                                 |
|--------|----------------------------------------|------------|------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|----------------------|-----------------------------------------------------------------------------------------------------|
|        |                                        |            | Khari/Varieties                                                                                | Rabi Varieties                                                                            |                      |                                                                                                     |
| 1      | Arid and Semi Arid: Black soil         | Akola      | Soybean: JS 335, JS 9305, TAMS 9821                                                            | Chickpea: Vijay, JAKI 9218, Akash                                                         | Soybean              | Soybean: Spodoptera / Semilooper                                                                    |
|        |                                        | Parbhani   | Soybean: JS-335, MAUS- 158, MAUS-71                                                            | Fallow                                                                                    | Cotton               | Cotton: Mealy bug, Sucking pest                                                                     |
|        |                                        | Solapur    | Pearl millet: Dhanshakti, ICTP-8203, Mahyco hybrid<br>Sunflower: MSFH-17, Bhanu, Phule Bhaskar | Sorghum: M-35-1, Phule Yeshoda, Phule Revati<br>Chickpea: Vijay, Digvijay, Virat          |                      | Sunflower: Thrips, Bud necrosis                                                                     |
|        |                                        | Kovilpatti | Fallow                                                                                         | Maize: S-6850, NK-6240, RMH- 3033 COH-(M) 6<br>Sorghum: CSV-20, K-8, K-12                 | Maize                | Maize: Aphid, Leaf hopper<br>Black gram: Powdery mildew                                             |
|        |                                        | Vijayapura | Soybean: JS-335, DSB-23-2, DSB-21                                                              | Chickpea: Vijay, JG-11, BG-11-05                                                          |                      | Grapes/Pomegranate: Powdery mildew, Downy mildew, Anthracnose, BLB                                  |
| 2      | Arid and Semi Arid: Red soil           | Anantapur  | Pigeon pea: PRG 176, LRG 41, LRG 52                                                            | Chickpea: JG 11, NBEG-47, NBEG-3                                                          | Groundnut            | Groundnut: Leaf miner (DSS)<br>Pigeon pea: Spotted Pod Borer                                        |
|        |                                        |            | Groundnut: K6, Kadri- Harithandhra, Dharani & Anantha                                          |                                                                                           |                      |                                                                                                     |
|        |                                        | Bengaluru  | Pigeon pea: PRG-176, TTB-7, BRG-1                                                              | Mango: Malika                                                                             |                      | Groundnut: Leaf miner, Tikka Disease, Pod borer, Spotted pod borer<br>Pigeon pea: Spotted boll worm |
| 3      | Western Arid and Semi Arid: loamy soil | Anand      | Groundnut: Chintamani-2, JL-24, K-6<br>Pearl millet: GHB 558, GHB 744, GHB 538                 | Mustard: Bio 902, GM-3, GDM-4                                                             | Pearl millet         | Mustard: Aphid                                                                                      |
|        |                                        | Hisar      | Pearl millet: GHB 558, HSB-67, HHB-272,<br>Guava: Hisar Safeda                                 | Barley: BH 393, BH 902, BH 946, BH 885<br>Potato: Kufri Surya, Kufri Bahar, Kufri Pushkar | Pearl millet         | Mustard: Aphid<br>Wheat: Yellow rust                                                                |
|        |                                        | Udaipur    | Soybean: JS-335, Pratap Soya, RKS-45                                                           | Mustard: Bio-902, Giriraj, Swarna Jyoti                                                   | Mustard              | Mustard: Aphid                                                                                      |

| S. No. | Zones                                                               | Centre      | Crop Weather Relationship Studies                            |                                                             | Crop Growth Modeling | Weather Effects on Pests & Diseases                                                           |
|--------|---------------------------------------------------------------------|-------------|--------------------------------------------------------------|-------------------------------------------------------------|----------------------|-----------------------------------------------------------------------------------------------|
|        |                                                                     |             | Kharif Varieties                                             | Rabi Varieties                                              |                      |                                                                                               |
| 4      | Sub-Humid alluvium-IGP                                              | Faizabad    | <b>Maize:</b> PMH 4, Naveen, UMC-1, Gaurav                   | <b>Mustard:</b> NDR-8501, NDRS-2001-1, Narendra Ageti Rai-4 | Rice                 | <b>Chickpea:</b> Pod borer                                                                    |
|        |                                                                     | Kanpur      | <b>Maize:</b> PMH 4, Azad Hy-brid-2, Malviya-2, DKC-7044     | <b>Wheat:</b> HD-2967, HD-2733, K-307, K-9107               | Rice, Wheat          | <b>Maize:</b> Stem borer<br><b>Wheat:</b> Blight                                              |
|        |                                                                     | Ludhiana    | <b>Maize:</b> PMH 4, PMH 1, PMH 2                            | <b>Wheat:</b> HD 2967, PBW 725, PBW 677                     | Wheat                | <b>Cotton:</b> Sucking pests                                                                  |
|        |                                                                     | Samastipur  | <b>Maize:</b> Bio-9637, Shaktiman-4, Shaktiman-5             | <b>Rabi Maize:</b> Bio-9637, Shaktiman-4, Shaktiman-5       | Maize                | <b>Maize:</b> Stem borer                                                                      |
| 5      | Central India- Sub Humid (Dry): Black and red soils                 | Jabalpur    | <b>Rice:</b> MTU 1010, Kranti, Sahbhagi                      | <b>Chickpea:</b> JG-14, JG-1 & JG-1                         | Rice, Soybean        | <b>Chickpea:</b> Pod borer                                                                    |
|        |                                                                     | Raipur      | <b>Rice:</b> MTU-1010, Chhattisgarh Sugandhit Dhan, IGKV R-1 | <b>Chickpea:</b> JG-14, Indira Chana-1, Vaibhav             | Rice                 | <b>Rice:</b> Yellow Stem Borer, Leaf folder, Brown Plant Hopper<br><b>Chickpea:</b> Pod borer |
| 6      | East and NE- Hot Sub Hu- mid (Moist): Deep loamy to clayey alluvium | Ranchi      | <b>Rice:</b> MTU 1010, Naveen, Sahbhagi                      | <b>Chickpea:</b> JG 14, Birs Channa 3, GNG 1581             | Rice                 | <b>Rice:</b> BLB (Bacterial Leaf Blight), Brown spot                                          |
|        |                                                                     | Bhubaneswar | <b>Rice:</b> Swarna, Satabdi, Bina-11                        | <b>Green gram:</b> Samrat, TARM-1, PDM-54                   | Rice                 | <b>Rice:</b> Sheath Blight, Blast                                                             |
|        |                                                                     | Jorhat      | <b>Rice:</b> Swarna, TTB-404, Mahsuri                        | <b>Green gram:</b> Samrat, Pratap, SGC- 16                  | Rice                 | <b>Rice:</b> Stem borer                                                                       |
|        |                                                                     | Mohampur    | <b>Rice:</b> Swarna, Satabdi, Nayanmoni                      | <b>Green gram:</b> Samrat, Pant Moong-5, Meha (IPM-99-125)  | Rice                 | <b>Rice:</b> Stem borer                                                                       |

| S. No. | Zones                                                                                 | Centre     | Crop Weather Relationship Studies                           |                                                                                   | Crop Growth Modeling | Weather Effects on Pests & Diseases                                       |
|--------|---------------------------------------------------------------------------------------|------------|-------------------------------------------------------------|-----------------------------------------------------------------------------------|----------------------|---------------------------------------------------------------------------|
|        |                                                                                       |            | <i>Kharij</i> Varieties                                     | <i>Rabi</i> Varieties                                                             |                      |                                                                           |
| 7      | Sub Himalayan-<br>Warm Sub Humid:<br>Deep loam forest soils                           | Chatha     | <b>Rice:</b> Basmati- 370, Pusa- 1121, R.S. Pura local      | <b>Wheat:</b> HD-2967, Raj-3077, RSP - 561<br><b>Mustard:</b> ONK-1, GSL-1, DGS-1 | Wheat                | <b>Wheat:</b> Yellow Rust<br><b>Mustard:</b> Aphid                        |
|        |                                                                                       | Palampur   | <b>Rice:</b> Basmati- 370, Pusa- 1121, Kasturi Basmati      | <b>Wheat:</b> HD-2967, HS-490, VL-907<br><b>Mustard:</b> ONK-1, GSL-1, HPN-1      | Wheat                | <b>Rice:</b> Blast                                                        |
|        |                                                                                       |            |                                                             |                                                                                   |                      | <b>Wheat:</b> Yellow Rust                                                 |
|        |                                                                                       | Ranichauri | <b>Finger Millet:</b> PRM - 2, VL Mandua 149, VL Mandua 324 | <b>Wheat:</b> HD 2967, VL Gehun 892, UP 2572                                      | Wheat                | <b>Finger millet:</b> Blast<br><b>Wheat:</b> Yellow Rust                  |
| 8      | Coastal<br>(Western Ghats)<br>– Hot humid to per humid: Laterite and coastal alluvium | Dapoli     | <b>Rice:</b> Jaya, Karjat-5, Palghar-1, Swarna, Karjat-2    | <b>Spice: Black Pepper:</b> Panniyur-1, Shakti, Thevram                           | Rice                 | <b>Rice:</b> Stem borer, Blue Beetle, BPH                                 |
|        |                                                                                       | Thrissur   | <b>Rice:</b> Iyothi, Kanchana and Jaya                      | <b>Spice: Black Pepper:</b> Panniyur 1 to Panniyur 8 (8 varieties)                | Rice                 | <b>Rice:</b> Stem borer, Leaf roller<br><b>Black Pepper:</b> Pollu Beetle |

## 2. Weather during 2021

A brief account of onset, progress and withdrawal of southwest monsoon (Jun-Sep) along with rainfall distribution details of northeast monsoon season (Oct-Dec) of 2021 for southern part of the country and annual rainfall of 25 centers of AICRPAM are presented hereunder:

### Onset of southwest monsoon

The southwest monsoon was set in over Kerala on 03 June 2021, a delay by two days compared to the normal date for onset (01 June) and covered the entire country on 13 July 2021; 05 days after its normal date (08 July).

### Rainfall distribution during monsoon season

The seasonal rainfall (Jun-Sep) over the country as a whole was 99% of its Long Period Average (LPA 1961-2010), *i.e.* 870 mm rainfall against the LPA (881 mm). The seasonal rainfall was normal over Northwest India (96% of LPA) and Central India (104% of LPA). It was below normal over East & Northeast (NE) India (88% of LPA) and above normal over South Peninsula (111% of LPA).

The seasonal rainfall received over 36 meteorological sub-divisions of the country during the southwest monsoon season along with respective LPA values and deviations from LPA (%) of 2021 are given in Table 2.1. Out of 36 meteorological subdivisions, 10 subdivisions received excess rainfall, 20 subdivisions received normal rainfall and 6 subdivisions received deficient rainfall during the season.

A total of 15 systems including 1 Cyclonic Storm, 1 Deep Depression, 4 Well Marked Low Pressure Areas, 7 Low Pressure Areas and 2 Surface Low Pressure Areas were formed during this period. A Deep Depression was formed during 12-15 September 2021 over Bay of Bengal. The first cyclonic storm of the season “**GULAB**” was formed during 24-28 September over Bay of Bengal. On September 26, cyclonic storm “**GULAB**” made landfall in over Andhra Pradesh and lost its energy over land, before degenerating into a remnant low on September 28.

### Withdrawal of southwest monsoon

The withdrawal of monsoon commenced on 28 September from some parts of west Rajasthan and Punjab, against its normal date of 17 September, and withdrew from the entire country on 25 October.

**Table 2.1: Rainfall in 36 meteorological subdivisions during 2021 southwest monsoon season**

| S. No. | Region                 | Sub Division                       | Actual (mm) | Normal (mm) | Deviation (%) |
|--------|------------------------|------------------------------------|-------------|-------------|---------------|
| 1      | East & Northeast India | Arunachal Pradesh                  | 1298.8      | 1726.6      | -25           |
| 2      |                        | Assam & Meghalaya                  | 1387.3      | 1773.7      | -22           |
| 3      |                        | Nagaland-Manipur-Mizoram-Tripura   | 971.5       | 1426.7      | -32           |
| 4      |                        | Sub-Himalayan West Bengal & Sikkim | 1794.4      | 1970.8      | -9            |
| 5      |                        | Gangetic West Bengal               | 1548.5      | 1181.5      | 31            |
| 6      |                        | Jharkhand                          | 1043.4      | 1054.7      | -1            |
| 7      |                        | Bihar                              | 1044.3      | 1017.2      | 3             |
| 8      | Northwest India        | East Uttar Pradesh                 | 867.8       | 839.4       | 3             |
| 9      |                        | West Uttar Pradesh                 | 572.6       | 721.3       | -21           |
| 10     |                        | Uttarakhand                        | 1152.9      | 1176.9      | -2            |
| 11     |                        | Haryana-Chandigarh-Delhi           | 576.7       | 444.0       | 30            |
| 12     |                        | Punjab                             | 436.8       | 467.3       | -7            |
| 13     |                        | Himachal Pradesh                   | 690.1       | 763.5       | -10           |
| 14     |                        | Jammu & Kashmir                    | 401.6       | 566.0       | -29           |
| 15     |                        | West Rajasthan                     | 317.5       | 265.3       | 20            |
| 16     |                        | East Rajasthan                     | 696.7       | 602.9       | 16            |
| 17     | Central India          | Odisha                             | 1046.0      | 1155.3      | -9            |
| 18     |                        | West Madhya Pradesh                | 980.9       | 857.7       | 14            |
| 19     |                        | East Madhya Pradesh                | 891.6       | 1048.4      | -15           |
| 20     |                        | Gujarat Region                     | 788.8       | 922.9       | -15           |
| 21     |                        | Saurashtra & Kutch                 | 626.6       | 507.2       | 24            |
| 22     |                        | Konkan & Goa                       | 3559.8      | 2875.3      | 24            |
| 23     |                        | Madhya Maharashtra                 | 872.6       | 751.2       | 16            |
| 24     |                        | Marathwada                         | 988.5       | 668.8       | 48            |
| 25     |                        | Vidarbha                           | 968.9       | 943.1       | 3             |
| 26     |                        | Chhattisgarh                       | 1107.7      | 1142.1      | -3            |

| S. No.                 | Region          | Sub Division               | Actual (mm) | Normal (mm) | Deviation (%) |
|------------------------|-----------------|----------------------------|-------------|-------------|---------------|
| 27                     | South Peninsula | A & N Island               | 2025.0      | 1653.8      | 22            |
| 28                     |                 | Coastal Andhra Pradesh     | 704.0       | 586.9       | 20            |
| 29                     |                 | Telangana                  | 1044.2      | 751.9       | 39            |
| 30                     |                 | Rayalaseema                | 488.2       | 411.6       | 19            |
| 31                     |                 | Tamil Nadu & Puducherry    | 393.4       | 336.1       | 17            |
| 32                     |                 | Coastal Karnataka          | 2784.5      | 3095.1      | -10           |
| 33                     |                 | Karnataka (North Interior) | 607.3       | 497.1       | 22            |
| 34                     |                 | Karnataka (South Interior) | 699.0       | 681.8       | 3             |
| 35                     |                 | Kerala                     | 1719.1      | 2049.3      | -16           |
| 36                     |                 | Lakshadweep                | 790.9       | 1013.1      | -22           |
| East & Northeast India |                 |                            | 1298.0      | 1410.3      | -8            |
| Northwest India        |                 |                            | 635.0       | 599.5       | 6             |
| Central India          |                 |                            | 1183.0      | 976.5       | 21            |
| South Peninsula        |                 |                            | 1113.0      | 726.2       | 53            |
| Country as a whole     |                 |                            | 870.0       | 880.6       | -1            |

## Northeast monsoon

The northeast monsoon (NEM) rains commenced on 25 October, over Peninsular India against the normal date of 20 October. Five meteorological subdivisions viz., Coastal Andhra Pradesh (CAP), Tamil Nadu including Puducherry & Karaikal (TN), Kerala (KER), Rayalaseema (RYS) and South Interior Karnataka (SIK) receives significant rainfall due to the influence of northeast monsoon. During NEM 2021, four meteorological subdivisions viz., TN, KER, RYS and SIK received excess to large excess rainfall with KER, SIK, RYS recording more than 100% excess (large excess) rainfall. Whereas, normal rainfall received over CAP meteorological subdivision. During this season, 10 low pressure systems (2 Cyclonic Storms, 3 Depressions, 2 Well Marked Low and 3 Low Pressure Area) were formed. One Severe Cyclonic storm “**SHAHEEN**” (30 September - 4 October) was formed over Arabian Sea and three low pressure areas (One each over Bay of Bengal, Arabian Sea and over land) were formed. A cyclonic storm “**JAWAD**” (2-6 December) was formed over Bay of Bengal and brought heavy rainfall and strong winds in the states like Andhra Pradesh, Odisha and West Bengal and caused major disruptions.

## Rainfall at cooperating centers

During the year 2021, two centres of AICRPAM, viz., Parbhani (95%) and Hisar (67%) received large excess rainfall, while 11 centres received excess rainfall (+20 to +59% more than normal rainfall). Normal rainfall (-19 to +19%) was received in 10 coordinating centres while deficient rainfall (-20 to -59%) condition was experienced at Jorhat (-37%) and Jabalpur (-33%). The yearly rainfall of 25 AICRPAM centres during the year 2021 is furnished in Table 2.2.

**Table 2.2: Annual rainfall received at AICRPAM centers during 2021**

| S. No. | AICRPAM Centre | Actual (mm) | Normal (mm) | Departure (%) |
|--------|----------------|-------------|-------------|---------------|
| 1      | Akola          | 1148.3      | 799.0       | 44            |
| 2      | Anand          | 941.9       | 853.0       | 10            |
| 3      | Anantapuramu   | 931.4       | 590.0       | 58            |
| 4      | Bengaluru      | 1328.4      | 916.0       | 45            |
| 5      | Bhubaneswar    | 1929.4      | 1502.0      | 28            |
| 6      | Chatha         | 1202.6      | 1124.0      | 7             |
| 7      | Dapoli         | 5421.4      | 3529.0      | 54            |
| 8      | Faizabad       | 1047.0      | 1002.0      | 4             |
| 9      | Hisar          | 793.4       | 474.0       | 67            |
| 10     | Jabalpur       | 842.8       | 1253.0      | -33           |
| 11     | Jorhat         | 1204.2      | 1924.0      | -37           |
| 12     | Kanpur         | 1025.6      | 869.0       | 18            |
| 13     | Kovilpatti     | 914.7       | 714.0       | 28            |
| 14     | Ludhiana       | 881.6       | 733.0       | 20            |
| 15     | Mohanpur       | 1770.2      | 1539.0      | 15            |
| 16     | Palampur       | 2332.1      | 2332.0      | 0             |
| 17     | Parbhani       | 1719.3      | 881.0       | 95            |
| 18     | Raipur         | 1279.0      | 1145.0      | 12            |
| 19     | Ranchi         | 2204.3      | 1398.0      | 58            |
| 20     | Ranichauri     | 1371.1      | 1270.0      | 8             |
| 21     | Samastipur     | 1882.9      | 1235.0      | 52            |
| 22     | Solapur        | 763.6       | 721.0       | 6             |
| 23     | Thrissur       | 3477.1      | 2757.0      | 26            |
| 24     | Udaipur        | 840.2       | 601.0       | 40            |
| 25     | Vijayapura     | 632.8       | 594.0       | 7             |

### 3. Agroclimatic Characterization

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

#### Anand

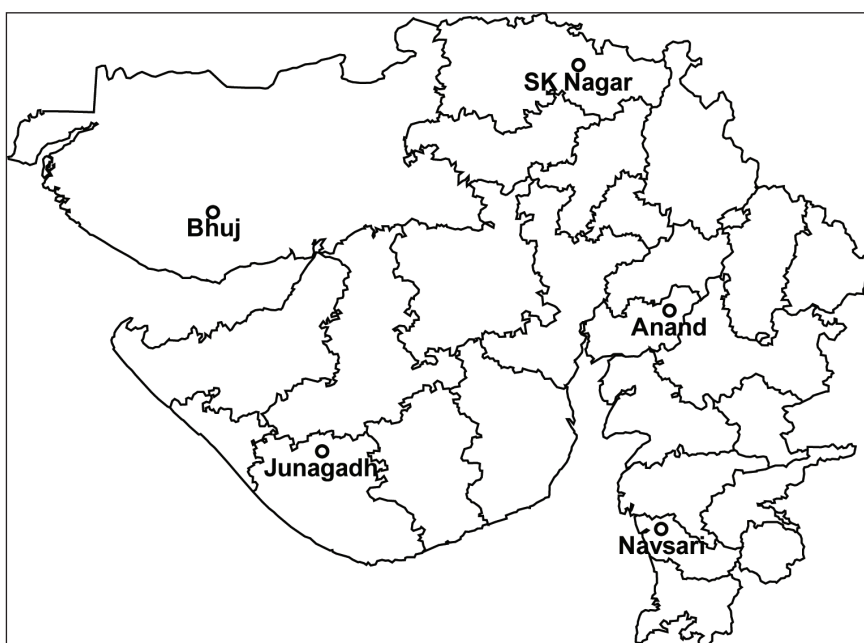
##### **Vegetation responses to meteorological drought at different stations of Gujarat**

For this study, five stations were chosen to represent different climatic conditions of Gujarat state and availability of long (30+ years) and continuous time series weather record was considered (Table 3.1 and Fig. 3.1). Daily temperatures (maximum and minimum) and rainfall data for these stations were converted into monthly scale and monthly PET was computed using Thornthwaite method. Standardized Precipitation Evapotranspiration Index (SPEI) was calculated as per procedure described by Vicente-Serrano *et al.* (2010) and was computed on 1-3 months scale for July to September months.

At present, crop condition during *kharif* was assessed using Vegetation Condition Index (VCI) based on Normalized Difference Vegetation Index (NDVI) of September month in seasonal drought assessment of Gujarat as per the drought manual of India. As the moisture availability for *rabi* season is also indirectly depends on rainfall receipt during monsoon, crop condition during post monsoon and winter season can also be affected by meteorological drought.

**Table 3.1: Coordinates, elevation, climate, soil type, length of used weather records of selected meteorological stations of Gujarat state**

| Station  | Latitude (°N) | Longitude (°E) | Elevation AMSL(m) | Climate   | Soil type             | Weather data period |
|----------|---------------|----------------|-------------------|-----------|-----------------------|---------------------|
| Anand    | 22.58         | 72.92          | 45                | Semi-arid | Sandy loam to sandy   | 1958-2019           |
| Bhuj     | 23.25         | 69.66          | 82                | Arid      | Sandy and saline soil | 1969-2014           |
| Junagadh | 21.52         | 70.46          | 61                | Semi-arid | Shallow medium black  | 1987-2019           |
| Navsari  | 20.95         | 72.92          | 10                | Sub-humid | Deep black clayey     | 1980-2019           |
| SK Nagar | 24.32         | 72.32          | 154               | Arid      | Sandy loam to sandy   | 1982-2019           |

**Fig. 3.1: Location of meteorological stations considered for study in Gujarat state**

Time series NDVI during post monsoon and winter months were considered to explore the association with different time scales of SPEI from July to September. The NDVI of September to February months was assumed to represent crop condition of *kharif* (September-October) and *rabi* (November-February) seasons.

**Table 3.2: Correlation between SPEI (1 to 3) of July-September months and NDVI of September-February months for selected meteorological stations of Gujarat state**

| NDVI and Months | SPEI-Time scale | Anand |       |       | Bhuj  |       |        | Junagadh |        |        | Navsari |       |        | SK Nagar |       |       |
|-----------------|-----------------|-------|-------|-------|-------|-------|--------|----------|--------|--------|---------|-------|--------|----------|-------|-------|
|                 |                 | Jul   | Aug   | Sep   | Jul   | Aug   | Sep    | Jul      | Aug    | Sep    | Jul     | Aug   | Sep    | Jul      | Aug   | Sep   |
| Sep             | 1m              | 0.20  | -0.29 | 0.44  | -0.15 | 0.28  | 0.66** | -0.35    | 0.09   | 0.35   | 0.16    | -0.19 | 0.11   | 0.25     | 0.03  | 0.41  |
|                 | 2m              | 0.02  | -0.08 | 0.03  | -0.28 | 0.04  | 0.61*  | -0.31    | -0.15  | 0.23   | 0.01    | 0.00  | -0.15  | 0.00     | 0.19  | 0.29  |
|                 | 3m              | -0.04 | -0.17 | 0.12  | -0.32 | -0.03 | 0.31   | -0.37    | -0.13  | 0.02   | 0.00    | -0.09 | 0.07   | 0.01     | 0.05  | 0.41  |
| Oct             | 1m              | 0.15  | -0.05 | 0.37  | -0.24 | 0.28  | 0.81** | 0.06     | 0.28   | 0.60*  | -0.12   | -0.41 | 0.68** | -0.15    | 0.23  | 0.33  |
|                 | 2m              | 0.13  | 0.04  | 0.17  | -0.34 | 0.02  | 0.75** | 0.03     | 0.22   | 0.53*  | -0.11   | -0.31 | 0.19   | 0.07     | -0.14 | 0.28  |
|                 | 3m              | 0.10  | 0.07  | 0.17  | -0.35 | -0.04 | 0.40   | -0.03    | 0.24   | 0.45   | -0.13   | -0.26 | 0.05   | 0.15     | 0.06  | -0.04 |
| Nov             | 1m              | -0.03 | 0.26  | -0.12 | -0.05 | 0.57* | 0.72** | 0.49*    | 0.41   | 0.55*  | 0.02    | -0.03 | 0.57*  | -0.03    | 0.15  | -0.21 |
|                 | 2m              | 0.03  | 0.13  | 0.13  | -0.13 | 0.31  | 0.88** | 0.63**   | 0.57*  | 0.60** | 0.01    | 0.01  | 0.36   | 0.19     | 0.01  | -0.10 |
|                 | 3m              | -0.02 | 0.16  | 0.02  | -0.16 | 0.26  | 0.62*  | 0.56*    | 0.72** | 0.75** | -0.01   | 0.01  | 0.31   | 0.29     | 0.14  | -0.17 |
| Dec             | 1m              | -0.27 | 0.26  | -0.29 | 0.07  | 0.48  | 0.67** | 0.54*    | 0.35   | 0.53*  | 0.15    | -0.09 | 0.56*  | 0.29     | 0.10  | 0.10  |
|                 | 2m              | -0.29 | -0.05 | 0.02  | -0.01 | 0.29  | 0.81** | 0.65**   | 0.56*  | 0.59*  | 0.08    | 0.07  | 0.30   | 0.00     | 0.38  | 0.17  |
|                 | 3m              | -0.31 | -0.11 | -0.15 | -0.07 | 0.25  | 0.59*  | 0.61**   | 0.68** | 0.76** | 0.06    | 0.02  | 0.36   | -0.01    | 0.17  | 0.44  |
| Jan             | 1m              | -0.03 | 0.17  | -0.07 | 0.08  | 0.30  | 0.66** | 0.31     | 0.44   | 0.59*  | 0.34    | -0.13 | 0.41   | 0.24     | 0.13  | 0.30  |
|                 | 2m              | -0.06 | 0.10  | 0.10  | -0.04 | 0.19  | 0.67** | 0.36     | 0.48   | 0.66** | 0.18    | 0.17  | 0.12   | -0.08    | 0.31  | 0.29  |
|                 | 3m              | -0.08 | 0.06  | 0.07  | -0.11 | 0.13  | 0.49   | 0.28     | 0.54*  | 0.69** | 0.18    | 0.08  | 0.40   | -0.10    | 0.10  | 0.46  |
| Feb             | 1m              | -0.11 | 0.00  | 0.47  | 0.04  | 0.25  | 0.75** | 0.07     | 0.47   | 0.55*  | 0.03    | -0.40 | 0.64** | -0.08    | -0.12 | 0.02  |
|                 | 2m              | -0.23 | -0.07 | 0.29  | -0.08 | 0.17  | 0.66** | 0.09     | 0.36   | 0.64** | 0.06    | -0.23 | 0.14   | 0.12     | -0.28 | -0.14 |
|                 | 3m              | -0.34 | -0.14 | 0.12  | -0.15 | 0.10  | 0.50   | 0.00     | 0.39   | 0.55*  | 0.06    | -0.14 | 0.10   | 0.12     | -0.13 | -0.29 |

\*Significant at 5% level, \*\*Significant at 1% level, n=17

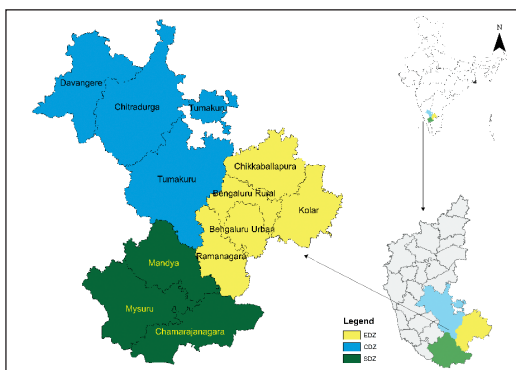
The combined 16-day NDVI values for years 2000 to 2016 were generated using MODIS/006/MCD43A4 dataset. NDVI of 12.5 km<sup>2</sup> uniform agricultural land closest to meteorological observatory were extracted and mean of month for the area computed. Correlation analysis between 1-3 months' time scales SPEI (SPEI1, SPEI2 and SPEI3) of July to September months and NDVI of September to February months was carried out. Results indicated that no significant association between SPEI and NDVI for Anand was noticed, which suggests crop conditions have low dependency on monsoon wetness. At Bhuj, vegetation condition of crop fields found to be significantly responsive to wetness of September (SPEI1 and SPEI2) for post monsoon and winter months. This shows agricultural crop conditions during *kharif* and *rabi* seasons near Bhuj are largely dependent on wetness of August and September months. It shows low rainfall after July may lead to drought condition in the arid region of Bhuj. Vegetation condition at Bhuj in November also had significant positive association with SPEI1 of August month. Wetness of September month based on one and two months (SPEI1 and SPEI2) is associated with crop condition with time lag of one month (October) and more. The crop condition during November and December months in Junagadh showed significant associations with wetness of July to September months in most time scales. SPEI values of September in 1-3 months scales have significant association with NDVI of post monsoon and winter which reveals dependency of *kharif* and *rabi* seasons on the wetness during and end of the monsoon (Table 3.2). SPEI1 of September has significant correlation with NDVI of October, November, December and February months at Navsari station indicating the importance of wetness at end of monsoon for *kharif* and following *rabi* season. Like Anand station, crop conditions in *kharif* and *rabi* seasons has no significant association at SK Nagar station.

## Bengaluru

### Drought characterization in south Karnataka

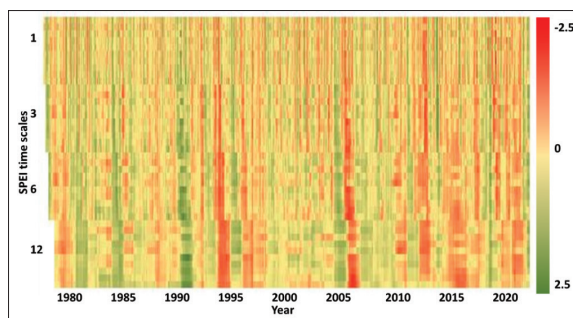
A comprehensive drought analysis based on Standardized Precipitation Evapotranspiration Index (SPEI) with various time scales using long-term meteorological data was carried out to find out its spatial variability over three dry zones of south Karnataka viz., Southern Dry Zone (Chamrajnagara, Mandya, Mysuru and part of Tumakuru), Central Dry Zone (Chitradurga, Davanagere and part of Tumakuru) and Eastern Dry Zone (Bengaluru Rural, Bengaluru Urban, Chikkaballapura, Kolar, Ramanagara and part of Tumakuru) (Fig. 3.2). These zones fall under tropical dry climate, receives an average annual precipitation of around 770 mm. Around 52 per cent of its annual rainfall is received during southwest

monsoon (June-Sept.) period while 28 per cent received during northeast monsoon period (Oct-Dec) and 20 per cent in winter and pre-monsoon period (Jan-May).



**Fig. 3.2: Location map of three dry zones of south Karnataka**

The temporal variability of SPEI during 1980-2020 under different time scales is furnished in Fig. 3.3. It shows a sharp contrast before and after 1995 and increasing trend of SPEI at four-time scales over south Karnataka.



**Fig. 3.3: Temporal variability of SPEI (1, 3, 6 and 12 month scales) from 1980 to 2020 in south Karnataka**

Before 1995, the study area was mainly characterized by normal and wet moisture conditions whereas frequent droughts of various time scales appeared after 1995. Though, the region experienced a wet period up to 2005, more frequent droughts were observed after 2015 in the region. Even though these are of moderate to severe category, their repeated occurrence caused aggravated crop productivity losses after 2005. Analysis of frequency distribution of drought types over different districts indicated most of the months fall around 'near normal' drought conditions (65.58%) together with 'moderate drought' (10.83%) and 'moderate wet' (10.70%) events, the area can be assessed as less affected by severe drought and wet events (Table 3.3).

**Table 3.3: Frequencies of different drought events in south Karnataka**

| District                 | Extreme drought | Severe drought | Moderate drought | Near normal  | Moderately wet | Severely wet | Extremely wet |
|--------------------------|-----------------|----------------|------------------|--------------|----------------|--------------|---------------|
| <b>Eastern Dry Zone</b>  |                 |                |                  |              |                |              |               |
| Bengaluru Rural          | 0.77            | 5.08           | 11.49            | 64.57        | 11.43          | 5.13         | 1.54          |
| Bengaluru Urban          | 0.46            | 3.95           | 13.44            | 63.02        | 11.79          | 6.00         | 1.33          |
| Chikkaballapur           | 0.77            | 5.65           | 10.57            | 64.77        | 10.71          | 6.31         | 1.23          |
| Kolar                    | 0.97            | 5.24           | 9.47             | 66.16        | 11.13          | 5.69         | 1.33          |
| Ramanagara               | 1.54            | 4.15           | 11.38            | 65.49        | 10.16          | 5.59         | 1.69          |
| <b>Central Dry Zone</b>  |                 |                |                  |              |                |              |               |
| Chitradurga              | 1.18            | 5.28           | 9.93             | 66.23        | 9.57           | 6.01         | 1.80          |
| Tumakuru                 | 1.65            | 4.82           | 10.71            | 66.12        | 9.84           | 4.92         | 1.95          |
| Davanagere               | 1.54            | 4.62           | 9.47             | 67.56        | 10.35          | 4.71         | 1.75          |
| <b>Southern Dry Zone</b> |                 |                |                  |              |                |              |               |
| Chamarajnaraga           | 0.92            | 4.42           | 11.90            | 64.35        | 11.81          | 5.07         | 1.54          |
| Mandya                   | 2.05            | 4.57           | 9.32             | 67.81        | 10.76          | 3.43         | 2.05          |
| Mysore                   | 0.97            | 5.09           | 11.44            | 65.27        | 10.16          | 5.49         | 1.59          |
| <b>South Karnataka</b>   | <b>1.17</b>     | <b>4.81</b>    | <b>10.83</b>     | <b>65.58</b> | <b>10.70</b>   | <b>5.30</b>  | <b>1.62</b>   |

In districts like Mandya, Tumakuru, Ramanagara, Davanagere and Chitradurga, drought events with higher magnitude (SPEI 2.05, 1.65, 1.54, 1.54 and 1.18, respectively) was observed when compared to other districts. The occurrence of extreme drought events in these districts are attributed to lower rainfall (901.6, 806.2, 717.7, 608.1 and 589.0 mm annually in Mandya, Tumakuru, Ramanagara, Davanagere and Chitradurga, respectively) and higher coefficient of variation (27-32 per cent).

## Bhubaneswar

Percentage frequency of meteorological drought was computed using 30 years (1991-2020) rainfall data at block level for the districts of Kalahandi and Nuapada which comes under Western Undulating agroclimatic zone of Odisha. Results revealed that different intensity of drought was experienced in different years and their percentage occurrence is presented in Table 3.4. Occurrence of moderate drought was found to be a common feature in both the district.

The probability for severe drought was observed in six blocks viz. Bhawanipatna, Dharamgarh, Golamunda, Kalampur, Karlamunda and Koksara with the maximum probability of occurrence in Dharmagarh (3 years) followed by Golamunda (2 years) in 30

years. Probabilities of occurrence of moderate droughts at different blocks of Kalahandi district was ranging from 7 to 27%. Among the blocks, Thuamul Rampur block of Kalahandi district was highly affected by moderate drought, which occurred in 8 years (1992, 1996, 1998, 2002, 2011, 2016, 2017, 2020) during the study period of 1991-2020 (Table 3.4). The probability of occurrence of no droughts was varied between 70 and 90%.

**Table 3.4: Frequency of occurrence of meteorological drought Kalahandi and Nuapada districts, Odisha**

| Block            | No drought   |            | Moderate drought |            | Severe drought |            |
|------------------|--------------|------------|------------------|------------|----------------|------------|
|                  | No. of years | % of years | No. of years     | % of years | No. of years   | % of years |
| <b>Kalahandi</b> |              |            |                  |            |                |            |
| Bhawanipatna     | 27           | 90         | 2                | 7          | 1              | 3          |
| Dharmagarh       | 21           | 70         | 6                | 20         | 3              | 10         |
| Golamunda        | 23           | 77         | 5                | 17         | 2              | 7          |
| Jaypatna         | 25           | 83         | 5                | 17         | 0              | 0          |
| Junagarh         | 24           | 80         | 6                | 20         | 0              | 0          |
| Kalampur         | 26           | 87         | 3                | 10         | 1              | 3          |
| Karlamunda       | 24           | 80         | 5                | 17         | 1              | 3          |
| Kesinga          | 23           | 77         | 7                | 23         | 0              | 0          |
| Koksara          | 23           | 77         | 6                | 20         | 1              | 3          |
| Lanjigarh        | 26           | 87         | 4                | 13         | 0              | 0          |
| M. Rampur        | 24           | 80         | 6                | 20         | 0              | 0          |
| Narla            | 24           | 80         | 6                | 20         | 0              | 0          |
| T. Rampur        | 22           | 73         | 8                | 27         | 0              | 0          |
| <b>Nuapada</b>   |              |            |                  |            |                |            |
| Boden            | 24           | 80         | 5                | 17         | 1              | 3          |
| Khariar          | 25           | 83         | 4                | 13         | 1              | 3          |
| Komna            | 26           | 87         | 4                | 13         | 0              | 0          |
| Nuapada          | 23           | 77         | 5                | 17         | 2              | 7          |
| Sinapali         | 26           | 87         | 3                | 10         | 1              | 3          |

In Nuapada district, Nuapada block was the worst affected by severe drought, which occurred in 2 years (2000 and 2002). Probability of severe drought was also observed in four blocks viz. Boden, Khariar, Nuapada, Sinapali with the probability of once in 30 years. In case of moderate drought, it was ranging from 10 to 17% in different blocks (Table 3.4). Boden and Nuapada block were highly affected by moderate drought, which occurred in 5 years (17%). The probability of occurrence of no drought was 77 to 87%.

## Chatha

### Annual and seasonal rainfall and temperature trend

Jammu region falls under sub-tropical to intermediate climate with warm summers and cold winters. A linear trend analysis through regression model was carried out to find out the in annual and seasonal (*kharif* and *rabi*) rainfall and temperature in different districts of Jammu region. It is inferred from the results that the annual rainfall found to be decreasing non-significantly during the last 40 years. The highest declining trend in rainfall was found at Samba location (7.33 mm per year) followed by Batote (4.99 mm per year) and lowest rate of decreasing in rainfall rate (0.56 mm per year) (Table 3.5).

**Table 3.5: Trend in annual and seasonal rainfall (mm) at various locations of Jammu region**

| Location                   | Annual rainfall (mm) |                | <i>Kharif</i> rainfall (mm) |                | <i>Rabi</i> rainfall (mm) |                |
|----------------------------|----------------------|----------------|-----------------------------|----------------|---------------------------|----------------|
|                            | Regression Equation  | R <sup>2</sup> | Regression Equation         | R <sup>2</sup> | Regression Equation       | R <sup>2</sup> |
| <b>Subtropical Region</b>  |                      |                |                             |                |                           |                |
| Jammu                      | $Y = -0.561x + 1186$ | 0.001          | $Y = 0.742x + 849.8$        | 0.001          | $Y = -1.259x + 298.4$     | 0.009          |
| Samba                      | $Y = -7.329x + 1221$ | 0.085          | $Y = 0.383x + 876.9$        | 0.0001         | $Y = -3.305x + 259.3$     | 0.051          |
| Kathua                     | $Y = -1.553x + 1238$ | 0.001          | $Y = 2.995x + 935.5$        | 0.012          | $Y = 1.683x + 238.9$      | 0.014          |
| <b>Intermediate Region</b> |                      |                |                             |                |                           |                |
| Rajouri                    | $Y = -1.408x + 1031$ | 0.002          | $Y = -0.064x + 611.3$       | 0.00001        | $Y = 2.025x + 356.4$      | 0.013          |
| Katra                      | $Y = -1.347x + 1201$ | 0.001          | $Y = -1.401x + 1505.0$      | 0.002          | $Y = -0.456x + 545.2$     | 0.0001         |
| Banihal                    | $Y = -0.869x + 1316$ | 0.001          | $Y = -0.662x + 443.4$       | 0.002          | $Y = 1.288x + 882.2$      | 0.006          |
| Batote                     | $Y = -4.995x + 1722$ | 0.037          | $Y = -0.212x + 504.3$       | 0.0001         | $Y = -5.594x + 1108.0$    | 0.070          |
| Bhaderwah                  | $Y = -4.333x + 1388$ | 0.051          | $Y = 0.985x + 503.3$        | 0.008          | $Y = -4.575x + 870.7$     | 0.061          |

The crop season (*kharif* and *rabi*) wise trends in rainfall revealed that the *kharif* season rainfall showed the decreasing trend over the all locations of intermediate region and increasing over sub-tropical region of Jammu region. The maximum increase in the *kharif* rainfall was observed in Kathua at the rate of 2.99 mm per year and under adjoining district at Samba at the rate of 0.38 mm per year (Table 3.5). While the *rabi* season rainfall was recorded decreasing trends in Jammu, Samba, Katra, Batote and Bhaderwah at the rate of 1.26, 3.31, 0.46, 5.59 and 4.56 mm per year, respectively and no significant increasing trends found at Kathua, Rajouri and Banihal with the rate of 1.68, 2.03 and 1.29 mm per year, respectively.

Trend in annual mean temperatures over different locations of Jammu region in the last 40 years showed a significant warming at 0.21-0.28 °C per decade in intermediate region (except Rajouri). The observed warming and cooling in mean temperature has observed unevenly distributed across Jammu region. At the same time, in sub-tropical region non-significant decrease at the rate of 0.013 & 0.014 °C per year in the mean annual temperature was observed in Jammu and Samba, respectively (Table 3.6).

**Table 3.6: Trend in annual mean, maximum and minimum temperature (°C) at various locations of Jammu region**

| Location                   | Annual mean temperature (°C) |                | Annual mean maximum temperature (°C) |                | Annual mean minimum temperature (°C) |                |
|----------------------------|------------------------------|----------------|--------------------------------------|----------------|--------------------------------------|----------------|
|                            | Regression Equation          | R <sup>2</sup> | Regression Equation                  | R <sup>2</sup> | Regression Equation                  | R <sup>2</sup> |
| <b>Subtropical Region</b>  |                              |                |                                      |                |                                      |                |
| Jammu                      | $Y = -0.014x + 23.22$        | 0.078          | $Y = -0.021x + 30.08$                | 0.105          | $Y = -0.008x + 16.36$                | 0.015          |
| Samba                      | $Y = -0.013x + 23.36$        | 0.039          | $Y = -0.032x + 30.26$                | 0.085          | $Y = 0.005x + 16.45$                 | 0.004          |
| Kathua                     | $Y = 0.011x + 22.81$         | 0.039          | $Y = -0.001x + 29.51$                | 0.001          | $Y = 0.025x + 16.11$                 | 0.091          |
| <b>Intermediate Region</b> |                              |                |                                      |                |                                      |                |
| Rajouri                    | $Y = -0.022x + 19.08$        | 0.026          | $Y = -0.132x + 28.76$                | 0.410          | $Y = 0.088x + 9.403$                 | 0.193          |
| Katra                      | $Y = 0.024x + 20.43$         | 0.203          | $Y = -0.002x + 26.66$                | 0.001          | $Y = 0.051x + 14.20$                 | 0.385          |
| Banihal                    | $Y = 0.027x + 14.13$         | 0.331          | $Y = 0.031x + 20.54$                 | 0.268          | $Y = 0.022x + 7.730$                 | 0.336          |
| Batote                     | $Y = 0.021x + 14.92$         | 0.186          | $Y = 0.012x + 20.42$                 | 0.066          | $Y = 0.030x + 9.430$                 | 0.196          |
| Bhaderwah                  | $Y = 0.028x + 14.43$         | 0.173          | $Y = -0.006x + 22.58$                | 0.009          | $Y = 0.062x + 6.285$                 | 0.436          |

The largest increase was found over Banihal in the annual mean temperature of more than 0.27 °C per decade (Table 3.6). The warming is much weaker in the sub-tropical region lesser or equal with 0.1 °C per decade, with mean temperature increase as compared to the intermediate region, where increase was more than 0.2 °C per decade. The mean maximum temperatures showed a non-significant decreasing trends over Jammu, Samba, Kathua (Sub-tropical region) while significant declining trend in Rajouri, Katra and Bhaderwah in intermediate region with the rate of 0.021, 0.032, 0.001, 0.132, 0.002 and 0.006 °C per year, respectively. While, at Banihal and Batote locations, the annual mean maximum temperature increasing at the 0.031 and 0.012 °C per year, respectively (Table 3.6).

In case of minimum temperature, the significant (in intermediate region) and non-significant (Sub-tropical region) warming trend was observed in all locations except Jammu during the period 1982-2021. The rate of warming of night time temperature was found in the range of 0.05-0.88 °C per decade in various locations of Jammu region. The highly significant

increase in minimum temperature was noticed in Katra ( $R^2=0.39$ ) and Banihal ( $R^2=0.34$ ) with a rate of 0.051 and 0.022 °C per year, respectively (Table 3.6).

## Faizabad

### Decadal variation of frost

The variation of frost occurrence at Faizabad on monthly basis was computed for the periods 1986-1995, 1996-2005, 2006-2015 and 2016-2021. The total number of frost occurrence during the decade 1986-2005 was 29 days. January month recorded maximum 20 days of frost occurrence, followed by December (8 days), while February month had frost free period during the decade. During 1996-2005 (Table 3.7), a total of 48 frost events was observed against 29 days occurred in previous decade. Highest number of frost events (41 days) was reported in the month of January. November month was frost free period during this decade.

**Table 3.7: Decadal variation in frost occurrence at Faizabad**

| Period    | Nov | Dec | Jan | Feb | Total |
|-----------|-----|-----|-----|-----|-------|
| 1986-1995 | 1   | 8   | 20  | 0   | 29    |
| 1996-2005 | 0   | 5   | 41  | 2   | 48    |
| 2006-2015 | 0   | 18  | 36  | 3   | 57    |
| 2016-2021 | 0   | 18  | 29  | 0   | 47    |

57 frost days was experienced during Nov-Feb period against 48 days in previous decade (1995-2005) and 29 days during the decade 1986-1995. Highest (36) number of frost days was reported in January followed by December month (18) while November was frost free month in the decade. In the recent period (2016 -2021), also frost days was recorded in the months of January and December whereas no frost days was recorded in November and February months at Faizabad. From the analysis, it is understood that maximum number of frost days is experienced in the month of January, followed by February month and hence frost preventing measures to be disseminated through agromet advisory services to avoid yield loss due to frost.

## Jorhat

### Drought severity assessment using Standardized Precipitation Index

An analysis was carried out to assess the drought severity through computation of SPI with two-time scales (annual and southwest monsoon) for the period of 28 years (1988-2015).

Different categories of droughts were classified based on the SPI value as proposed by McKee *et al.* (1993). SPI values on annual basis showed that, normal to moderate drought occurred in Karbi Anglong (-0.9 to -1.3), N. C. Hills (-0.1 to -1.0), Nalbari (-0.5 to -1.0), Kamrup Metro (-0.9 to -1.4) and Golaghat (-0.5 to -1.0) district of the state during 1988 to 2015. Moderate to severe drought was observed in Darrang (-1.6), Nagaon (-1.3 to -1.7) and Morigaon (-1.4 to -1.8) districts of the state (Table 3.8). On the other hand, normal to moderately wet condition occurred in Dhubri (0.3 to 1.4), Baksa (0.3 to 1.2), Cachar (-0.7 to 1.1), Tinsukia (-0.4 to 1.1) and Dibrugarh (-0.4 to 1.1). Similarly, moderately wet to extremely wet condition recorded in Kokrajhar (1.0 to 2.0), Chirang (1.8 to 2.7) and Karimganj (-0.1 to 2.5) districts of the state during 1988-2015 (Table 3.8). Overall normal SPI value was observed in Goalpara, Kamrup, Barpeta, Sonitpur, Udalguri, Sivasagar and Jorhat districts.

**Table 3.8: Average annual SPI in different districts of Assam (1988-2015)**

| S. No. | District           | Avg. annual SPI | S. No. | District  | Avg. annual SPI |
|--------|--------------------|-----------------|--------|-----------|-----------------|
| 1      | Karbi Anglong      | -1.14           | 15     | Cachar    | -0.06           |
| 2      | North Cachar Hills | -0.76           | 16     | Karimganj | 0.92            |
| 3      | Darrang            | -1.46           | 17     | Sonitpur  | -0.31           |
| 4      | Goalpara           | 0.29            | 18     | Dhemaji   | 0.90            |
| 5      | Kamrup             | -0.65           | 19     | Udalguri  | -0.42           |
| 6      | Barpeta            | -0.34           | 20     | Lakhimpur | 1.20            |
| 7      | Dhubri             | 0.79            | 21     | Sivasagar | 0.21            |
| 8      | Kokrajhar          | 1.41            | 22     | Golaghat  | -0.82           |
| 9      | Nalbari            | -0.79           | 23     | Jorhat    | 0.02            |
| 10     | Bongaigaon         | 1.20            | 24     | Tinsukia  | 0.50            |
| 11     | Baksa              | 0.69            | 25     | Dibrugarh | 0.44            |
| 12     | Chirang            | 2.17            | 26     | Nagaon    | -1.59           |
| 13     | Kamrup (Metro)     | -1.16           | 27     | Marigaon  | -1.70           |
| 14     | Hailakandi         | 0.19            |        |           |                 |

SPI values computed for four months of monsoon season revealed that normal to moderate drought condition was noticed in Karbi Anglong (-1.1 to -0.7), N. C. Hills (0.0 to -1.0), Nalbari (-1.2 to -0.6), Baksa (0.2 to 1.1), Kamrup Metro (-0.6 to -1.2), Hailakandi (-0.7 to 1.4), Golaghat (-0.6 to -1.1) districts of the state Assam. Darrang, Bongaigaon, Nagaon and Morigaon districts experienced moderate drought to severe drought was observed. At the same time, moderately wet to extremely wet level condition was experienced in Kokrajhar (1.4 to 2.2), Chirang (1.9 to 2.8) and Karimganj (-0.3 to 2.1) districts (Table 3.8). It is

understood from the analysis that extremely drought condition (SPI less than -2.0) was not witnessed in any districts of the state during the study period. However, extremely wet condition was prevailed in three districts viz., Kokrajhar, Chirang and Karimganj on both annual as well as seasonal basis.

## Ludhiana

### Characterization of changing pattern of agricultural crops vis-a-vis their effect on climatic entities in Punjab state

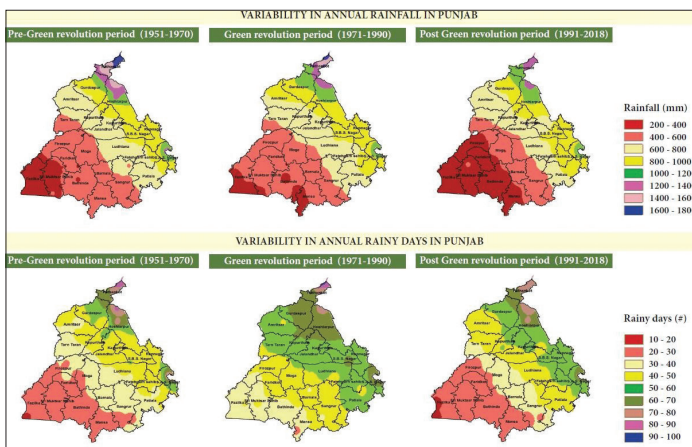
Punjab state has been pivotal in ushering the country towards self-sufficiency in food grains through the green revolution in India since 1960s. In Punjab, prior to green revolution highly diversified agriculture scenario was observed with crops like rice, wheat, maize, millets, barley, groundnut, chickpea, cotton, mustard, sugarcane, pulses, vegetables, etc. With the introduction of high yielding varieties of rice, wheat and development in the agro-technology including better crop production practices, irrigation and mechanization of farm operations during green revolution, the state gained the title of “Food Basket of the country”. In the present times, the major crops cultivated in the state are rice in *kharif* and wheat in *rabi*. Though in the north eastern parts of the state crops like maize and in south western parts crops like cotton and mustard are also cultivated, the area under these crops has declined compared to 1960s.

**Table 3.9: Changing pattern of cropped area in Punjab**

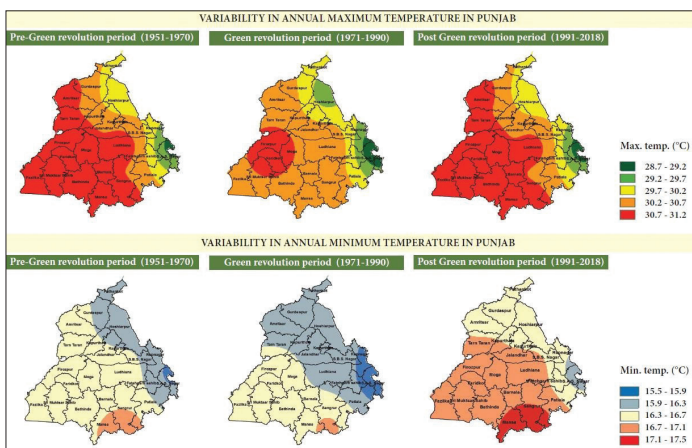
| Crop                       | Area ('000 ha)                      |                                          | Trend                 |
|----------------------------|-------------------------------------|------------------------------------------|-----------------------|
|                            | Green Revolution period (1971-1990) | Post Green Revolution period (1991-2018) |                       |
| <i>Kharif season crops</i> |                                     |                                          |                       |
| Rice                       | 17-175*                             | 40-309                                   | Increase              |
| Maize                      | 8-79                                | 0-66                                     | Decrease              |
| American cotton            | 0-167                               | 0-147                                    | Decrease              |
| Desi cotton                | 1-47                                | 0-11                                     | Decrease              |
| Pulses                     | 0-4                                 | 0-2                                      | Decrease              |
| <i>Rabi season crops</i>   |                                     |                                          |                       |
| Wheat                      | 70-344                              | 75-347                                   | No significant change |
| Mustard                    | 1-31                                | 1-11                                     | Decrease              |
| Pulses                     | 0-44                                | 0-2                                      | Decrease              |

\* Range represents the area of crop from lowest to highest in different districts of Punjab

In order to find the changes in area under different crops, *i.e.* rice, maize, cotton and pulses during *kharif* season and wheat, mustard and pulses during *rabi* season in the state have been taken during two major time periods *viz.*, green revolution period (1971-90) and post green revolution period (1991-2018). Likewise, the changes in climatic parameters on annual and seasonal (*kharif* and *rabi*) have been considered for three major time periods *viz.*, pre-green revolution period (1951-1970), green revolution period (1971-1990) and post green revolution period (1991-2018). The changes in land use and land cover pattern has a direct bearing on the climate entities such as temperature, rainfall, relative humidity, etc. One of major change in cropping pattern observed in the state was with the cultivation of transplanted rice. The area under rice has undergone an extensive jump by 850 %, *i.e.* from 0.36 Mha during 1970-71 to 3.06 Mha in 2017-18 has changed the agro-climatic scenario in the state (Table 3.9). The study showed no significant change in maximum temperature during pre-green revolution and post-green revolution time scales. At the same time, decrease in annual rainfall (Fig. 3.4) and increase in annual, *kharif* and *rabi* season minimum temperature (Fig. 3.5) was noticed during above mentioned time scales in the state of Punjab.



**Fig. 3.4: Change in annual rainfall pattern of Punjab**

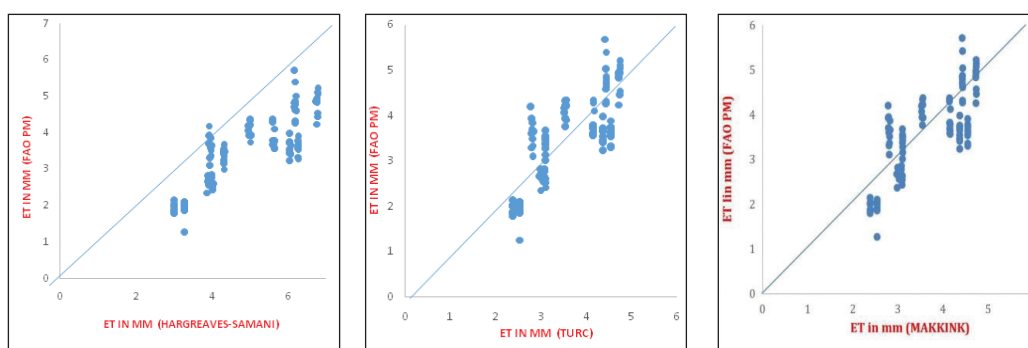


**Fig. 3.5: Changes in annual maximum and minimum temperature of Punjab**

## Mohanpur

### Evaluating PET methods (Hargreaves-Samani, Turc and Makkink) against FAO 56 Penman-Monteith method

An attempt was made to find the accuracy and reliability of PET methods proposed by Hargreaves-Samani, Turc and Makkink against the PET estimation by FAO Penman-Monteith (FAO PM) method which is considered as standard one. Error in PET estimation by these three methods with reference to FAO PM method was quantified using statistical indices like Mean Bias Error (MBE), Root Mean Square Error (RMSE) and Pearson correlation coefficients. The results showed that the PET estimation by Hargreaves-Samani (HS) was higher for all stations while lowest estimation was obtained for Makkink method (Fig. 3.6).



**Fig. 3.6: The 1:1 line between daily PET values as estimated by (a) HS, (b) Turc and (c) Makkink methods against the FAO PM method**

Table 3.10 shows the error statistics and correlation values of the three PET methods (Hargreaves-Samani, Turc and Makkink) used in the study against the FAO PM method. The correlation coefficient of Hargreaves-Samani method was slightly higher than the other two methods. However, the MBE and RMSE was found to be lowest in Makkink method and highest for Hargreaves-Samani method (Table 3.10). Small value of RMSE and MBE depicts that the discrepancy is less between FAO PM and empirical method under consideration. The best model was selected first based on their orientation along the 1:1-line (Fig. 3.6), the lowest value of MBE and RMSE and then coefficient of determination ( $R^2$ ). Considering the cumulative performance for 11 years (2010-2011), it is inferred that the Makkink method could efficiently reconstruct the actual ET pattern with simulated data input with least error and deviation. The Hargreaves-Samani method mainly overestimated the PET values whereas Turc method showed intermediate results. The factor responsible

for such overestimation by Hargreaves-Samani method could be the high difference between maximum and minimum temperature which forms an essential component in the Hargreaves-Samani equation.

**Table 3.10: Error statistics and correlation between the estimated PET (Hargreaves-Samani, Turc and Makkink methods) and FAO PM method**

| PET methods       | Mean Bias Error (MBE) | Root Mean Square Error (RMSE) | Pearson's correlation Coefficient (r) |
|-------------------|-----------------------|-------------------------------|---------------------------------------|
| Hargreaves-Samani | 1.30                  | 1.60                          | 0.84                                  |
| Turc              | 0.84                  | 1.01                          | 0.83                                  |
| Makkink           | 0.12                  | 0.56                          | 0.82                                  |

## Palampur

### Occurrence of hail, fog, frost and snowfall at Palampur

An attempt was made to document the extreme weather events like hailstorm, fog, frost and snowfall at CSK HP Agricultural University Palampur from 2008 to 2021. The days of occurrence and total number of events of hailstorm, fog, frost and snowfall during the above-mentioned period are presented in following Table 3.11.

**Table 3.11: Number of hailstorms, fog, frost and snowfall events, CSK HP Agricultural University Palampur during 2008-2021**

| Year | Number of events of |     |       |          |
|------|---------------------|-----|-------|----------|
|      | Hailstorm           | Fog | Frost | Snowfall |
| 2008 | 17                  | -   | 20    | 4        |
| 2009 | 4                   | 2   | 17    | 2        |
| 2010 | 7                   | 6   | 38    | 4        |
| 2011 | 5                   | 1   | 27    | 3        |
| 2012 | -                   | -   | 10    | -        |
| 2013 | 10                  | -   | 17    | -        |
| 2014 | 6                   | 2   | 11    | 1        |
| 2015 | 3                   | 3   | 12    | -        |
| 2016 | 6                   | 2   | 11    | 1        |
| 2017 | 11                  | 6   | 22    | 4        |
| 2018 | 6                   | 1   | 38    | 3        |
| 2019 | 6                   | 13  | 25    | 3        |
| 2020 | 5                   | 5   | 24    | 4        |
| 2021 | 7                   | 11  | 18    | 4        |

It can be seen that the hail events varied from no event in 2012 to as many as 17 events in 2008 per year at Palampur while 5 to 7 events are of common occurrence. Frost frequented for as small as 10 days (2012) to as large as 38 days (2018) during the season out of which it stretched from 2 days to 15 days in one go. A superficial look on frost events since 2001

indicates that the events were on rise during recent years *i.e.*, after 2004 onwards and the highest number of events were observed during 2010 & 2018 (38) and 2011 (27) followed by 24 during 2005 (Fig. 3.7). Snow occurred for 2 continuous days at least twice during past 15 years at and around the station.

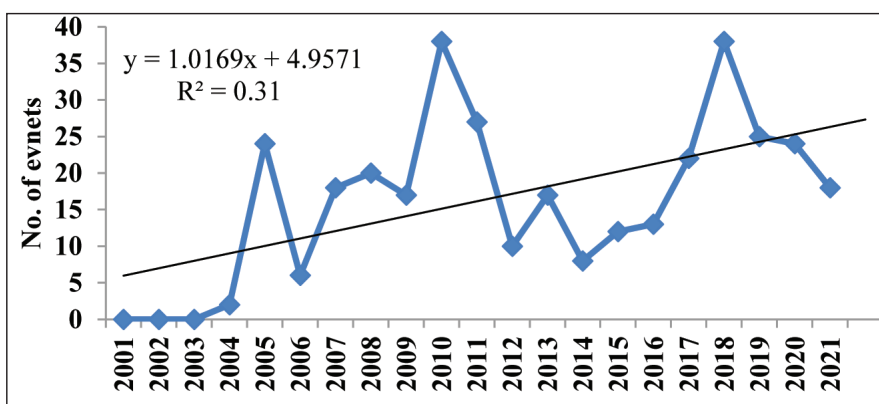
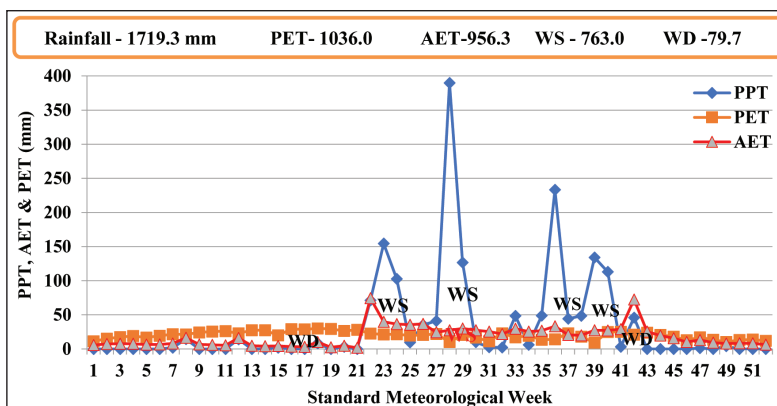


Fig. 3.7: Number of frost events recorded at Palampur

## Parbhani

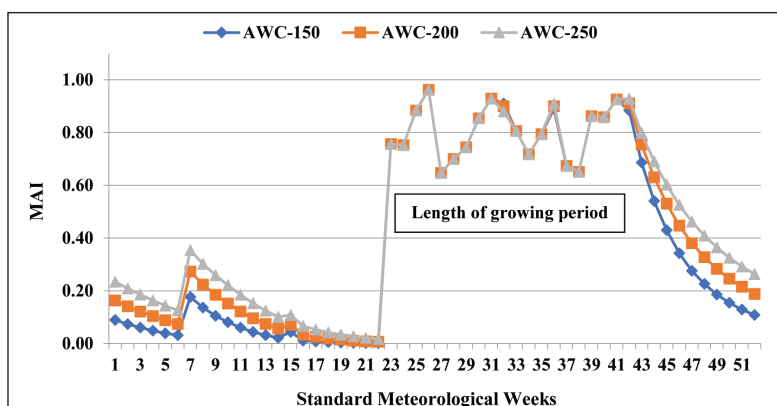
### Water Balance and Moisture Availability Index (MAI) at Parbhani

Climatic water balance was estimated for Parbhani on weekly basis for the year 2021. For this purpose, Potential Evapotranspiration (PET) was estimated using maximum and minimum temperature data. Using weekly rainfall and PET, climatic water balance was computed and Actual Evapotranspiration (AET) and Moisture Availability Index (MAI) were estimated for Parbhani. Available water holding capacity (AWHC) of 150, 200 and 250 mm are considered to represent the shallow, medium and deep soils, respectively. The weekly data of Precipitation, Potential Evapotranspiration, and Actual Evapotranspiration are presented in Fig. 3.8. The data showed that onset of monsoon was on 23 Standard Meteorological Week (SMW) and withdrawal of monsoon was during 42 SMW. Dry spell was occurred during the 31 & 32 SMW. Total annual rainfall, PET and AET recorded was 1719.3 mm, 1036.0 mm and 956.3 mm, respectively.



**Fig. 3.8: Weekly Precipitation (PPT), Potential Evapotranspiration (PET) and Actual Evapotranspiration (AET) at Parbhani during 2021**

The crop growth period referred as the period during which, the MAI was more than 0.5 at the time of sowing and active vegetative growth periods and more than 0.4 at the time of maturity. Total period during active vegetative growth for which MAI was less than 0.5 were considered as stress periods. Crop planning as per soil moisture storage, efficient moisture conservation and fertilizer use coupled with better management inputs lead to increase and stabilize yields of crops in dry lands. The data of MAI was depicted in Fig. 3.9 and it indicates that MAI began to increase from 24 SMW and started decreasing from 42 SMW. The total length of growing period was 19 weeks *i.e.* from 24 to 42 SMW at Parbhani.



**Fig. 3.9: Weekly Moisture Availability Index (MAI) at available soil moisture holding capacity of 150 mm, 200 mm & 250 mm at Parbhani during 2021**

## Samastipur

### Tracking climate change/variability through dry spell analysis

An analysis was done to find out the number of dry spells of different intensities *viz.* 5-7, 8-10 and 11-15 days duration during *kharif* season (June-September) for Pusa, Samastipur of Zone I, Purnia of Zone II, Bhagalpur of Zone IIIA and Patna of Zone IIIB. The analysis revealed sharp increase in dry spell during the month of June, August and September in the recent period (1999-2018). Dry spell in the month of July has remained almost similar during two periods *viz.* 1979-1998 and 1999-2018 for Pusa and Purnia (Table 3.12). However, 5-7 days dry spell has declined in the months of July and August, while long dry spell (11-15 days) has increased over Sabour. From this analysis, it is understood that short (5-7 days) as well as long (11-15 days) dry spells during June-September months were found to increase in the recent period at all study locations when compared to earlier period.

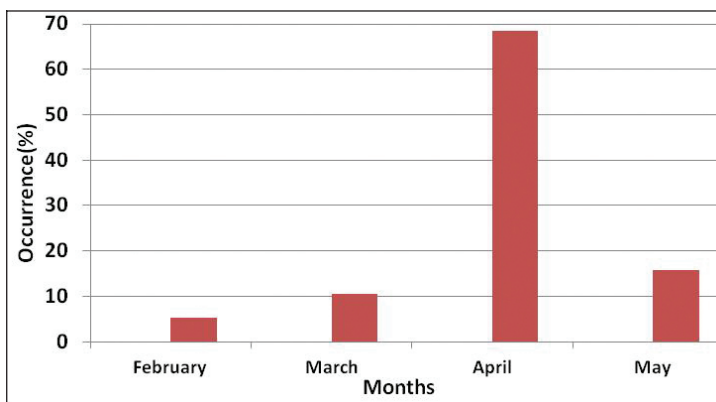
**Table 3.12: Frequency of dry spells at selected locations in Bihar during 1979-1998 and 1999-2018**

| Period                    | June     |           |            | July     |           |            | August   |           |            | September |           |            |
|---------------------------|----------|-----------|------------|----------|-----------|------------|----------|-----------|------------|-----------|-----------|------------|
|                           | 5-7 Days | 8-10 Days | 11-15 Days | 5-7 Days | 8-10 Days | 11-15 Days | 5-7 Days | 8-10 Days | 11-15 Days | 5-7 Days  | 8-10 Days | 11-15 Days |
| <b>Pusa (Zone I)</b>      |          |           |            |          |           |            |          |           |            |           |           |            |
| 1979-1998                 | 20       | 7         | 10         | 14       | 1         | 0          | 6        | 5         | 1          | 15        | 4         | 2          |
| 1999-2018                 | 25       | 11        | 8          | 13       | 2         | 0          | 16       | 5         | 0          | 21        | 9         | 5          |
| <b>Purnia (Zone II)</b>   |          |           |            |          |           |            |          |           |            |           |           |            |
| 1979-1998                 | 12       | 8         | 6          | 6        | 2         | 2          | 14       | 4         | 0          | 19        | 5         | 1          |
| 1999-2018                 | 25       | 10        | 7          | 6        | 3         | 2          | 18       | 6         | 1          | 20        | 8         | 4          |
| <b>Sabour (Zone IIIA)</b> |          |           |            |          |           |            |          |           |            |           |           |            |
| 1979-1998                 | 11       | 10        | 4          | 9        | 3         | 0          | 17       | 3         | 0          | 15        | 4         | 2          |
| 1999-2018                 | 18       | 10        | 7          | 7        | 4         | 4          | 12       | 6         | 2          | 23        | 12        | 2          |
| <b>Patna (Zone IIIB)</b>  |          |           |            |          |           |            |          |           |            |           |           |            |
| 1979-1998                 | 12       | 8         | 10         | 8        | 5         | 1          | 14       | 1         | 2          | 12        | 6         | 6          |
| 1999-2018                 | 23       | 9         | 11         | 13       | 5         | 5          | 11       | 4         | 2          | 16        | 11        | 5          |

### Hailstorm events in north Bihar

The agriculture in Bihar is besieged by all sorts of weather hazards and one of the most devastating climatic hazards that Bihar is witnessing in recent years is hailstorm. The occurrence of hailstorm in Bihar is observed during the period from February to May. It causes widespread damage to wheat, maize, potato, banana, mango, litchi and vegetables

crops affecting the livelihood of farmers and rural economy. Over an area, the extent of damage to the standing crops by hail storm depends on the size and density of hailstones that fall per unit area and wind velocity.



**Fig. 3.10: Probability of occurrence of hailstorm in different months over north Bihar (Database 2001-2020)**

Probability of occurrence of hailstorm in north Bihar is presented in Fig. 3.10, which showed that the month of April tends to experience almost 70 per cent of total hailstorm events. The frequency of occurrences have been observed to be higher in the recent few years. Of the 19 hailstorm events, 12 were observed during the last five years (2016-2020). East Champaran, Sitamarhi, Gopalganj, Muzaffarpur, Samastipur, Drabhanga and Vaishali districts were severely affected. Hailstroms accompanied by high velocity winds severely damaged standing wheat, maize, vegetables, banana, mango and litchi. Almost 50 per cent of wheat crop in these districts were completely damaged. In Muzaffarpur and Vaishali districts, almost all standing wheat crop in many blocks was totally devastated.

## 4. Crop Weather Relationship Studies

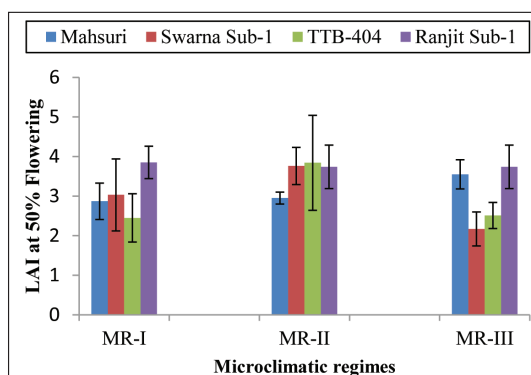
Weather plays a significant role in the crop production and productivity. It affects crops in every phenophase of their growth cycle, either directly or indirectly. Crop development and final productivity are the consequence of numerous physical and physiological processes, each of which is separately or in combination influenced by environmental conditions. Rainfall, temperature, moisture content in air as well as soils, duration and quality of light/solar radiation, wind, and cloudiness are the main weather variables that have a significant impact on crop development and production. Despite the fact that the climate is the least manageable natural resource, its interaction with agricultural factors has been found to be a potent tool for creating climate/weather-based management strategies in agriculture that will maximise the benefits from positive interactions and minimise the losses from negative ones. This chapter describes the results of field experiments conducted by AICRPAM cooperating centres as per technical program for characterizing crop weather relationships.

### *Kharif 2021*

#### Rice

#### Jorhat

The field experiment consisted of four different *Sali* rice varieties (Mahsuri, Swarna Sub-1, TTB-404 and Ranjit Sub-1) and three microclimatic regimes (transplanted on 26 June, 11 July and 27 July 2021) created by manipulating the transplanting dates. Leaf area index as influenced by the treatments is presented in Fig. 4.1.



**Fig. 4.1: Leaf Area Index recorded at 50% flowering stage under three different microclimatic regimes during kharif 2021**

The range of Leaf area Index (LAI) at 50% flowering stage was 2.17 to 3.85 with standard deviation of ( $\pm$ ) 0.15 to ( $\pm$ ) 1.20. Overall LAI was found to be maximum in Ranjit Sub-1 irrespective of planting dates. Correlation between grain yield and phasic mean meteorological parameters was also carried out and the result is presented in Table 4.1.

**Table 4.1: Correlation between grain yield and phasic mean meteorological parameters in *kharif* rice at Jorhat**

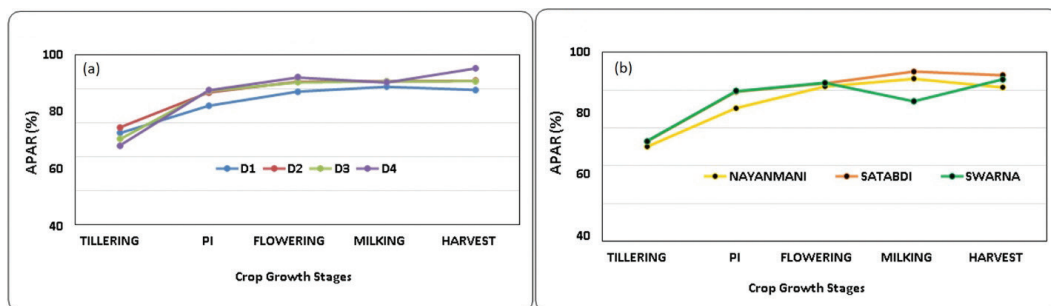
| Weather parameters           | Phenological stages | Grain yield (kg ha <sup>-1</sup> ) | Max LAI | Effective tillers m <sup>-2</sup> |
|------------------------------|---------------------|------------------------------------|---------|-----------------------------------|
| Tmax (mean)                  | Transplanting to PI | -0.11                              | -0.10   | -0.14                             |
|                              | PI to 50% flowering | 0.21                               | -0.46   | 0.08                              |
|                              | 50% flowering to PM | -0.20                              | 0.34    | 0.01                              |
| Tmin (mean)                  | Transplanting to PI | -0.41                              | 0.51    | -0.26                             |
|                              | PI to 50% flowering | -0.11                              | -0.24   | -0.28                             |
|                              | 50% flowering to PM | -0.19                              | 0.28    | 0.01                              |
| Bright Sunshine Hours (mean) | Transplanting to PI | 0.74                               | -0.25   | -0.01                             |
|                              | PI to 50% flowering | 0.35                               | -0.41   | 0.26                              |
|                              | 50% flowering to PM | -0.01                              | 0.13    | -0.06                             |
| Rainfall (cumulative)        | Transplanting to PI | 0.28                               | 0.28    | 0.49                              |
|                              | PI to 50% flowering | -0.01                              | 0.28    | 0.18                              |
|                              | 50% flowering to PM | 0.14                               | 0.07    | 0.01                              |
| RH (mean)                    | Transplanting to PI | -0.05                              | 0.03    | -0.01                             |
|                              | PI to 50% flowering | -0.37                              | 0.40    | -0.31                             |
|                              | 50% flowering to PM | -0.08                              | 0.05    | 0.02                              |
| Evaporation (cumulative)     | Transplanting to PI | 0.52                               | 0.27    | 0.73**                            |
|                              | PI to 50% flowering | -0.09                              | 0.35    | -0.07                             |
|                              | 50% flowering to PM | 0.33                               | 0.10    | 0.35                              |

\* and \*\* significant at 5 and 1 per cent levels, respectively

The results indicated that during vegetative (Transplanting to PI), reproductive (panicle initiation to 50% flowering) and maturity stages (50% flowering to physiological maturity); no significant association was observed among different weather parameters and grain yield. However, cumulative pan evaporation during vegetative stage showed a significant positive association with effective tillers per square meter with correlation coefficient 0.73\*\*. Number of effective tillers per square meter showed a positive association with cumulative rainfall throughout the different growth stages although the association was non-significant. Similarly, in case of maximum LAI; non-significant positive association was observed with cumulative rainfall, mean relative humidity and cumulative evaporation.

## Mohanpur

Field experiment was conducted with four dates of transplanting (DOTs) [23 June ( $D_1$ ), 07 July ( $D_2$ ), 20 July ( $D_3$ ) and 04 August 2021 ( $D_4$ )] and three varieties [Nayanmani ( $V_1$ ), Satabdi ( $V_2$ ) and Swarna ( $V_3$ )] at Mohanpur. Effect of growing environments and varieties on Absorbed Photosynthetically Active Radiation (APAR) was studied and the results are presented in Fig. 4.2.



**Fig. 4.2: Effect of (a) growing environments and (b) varieties on absorbed PAR of rice in Mohanpur**

It was observed that the absorption percentage of APAR increased (~25%) from tillering to panicle initiation stage for all the growing environments except  $D_1$  (Fig. 4.2a). For  $D_1$ , the rate of change of absorption percentage of APAR was lesser when compared to other transplanting dates. At the harvesting stage, maximum and minimum APAR was observed with  $D_4$  and  $D_1$ , respectively. Among the varieties, Satabdi and Swarna showed a similar trend of APAR. The lowest APAR was recorded in Swarna during milk stage (Fig. 4.2b). At the end of the crop growing period, Nayanmani recorded lowest APAR. The effect of growing environments and varieties on grain yield and radiation use efficiency (RUE) was also studied and the result is presented in Table 4.2.

**Table 4.2: Effect of dates of transplanting and varieties on total absorbed PAR, grain yield and radiation use efficiency of rice at Mohanpur**

| Treatments                   | APAR (MJ) | Yield (kg ha <sup>-1</sup> ) | RUE (g MJ <sup>-1</sup> ) |
|------------------------------|-----------|------------------------------|---------------------------|
| <b>Date of transplanting</b> |           |                              |                           |
| $D_1$                        | 410.5     | 5110.0                       | 1.24                      |
| $D_2$                        | 397.9     | 3621.1                       | 0.91                      |
| $D_3$                        | 385.8     | 3686.1                       | 0.96                      |
| $D_4$                        | 363.8     | 1685.6                       | 0.46                      |
| <b>Variety</b>               |           |                              |                           |
| $V_1$                        | 297.3     | 4730.8                       | 1.59                      |
| $V_2$                        | 378.7     | 3275.0                       | 0.86                      |
| $V_3$                        | 492.4     | 2571.3                       | 0.52                      |

Among the growing environments, crop transplanted on 23 June recorded the highest grain yield and RUE, followed by crop transplanted on 20 July. Among the varieties, highest yield and RUE was recorded by Nayanmani followed by Satabdi and Swarna.

## Raipur

A field experiment was conducted with three growing environments [01 June ( $D_1$ ), 15 June ( $D_2$ ) and 30 June ( $D_3$ )] and three rice varieties [MTU-1010 ( $V_1$ ), Rajeshwari ( $V_2$ ) and CG Sugandhit Bhog ( $V_3$ )] during *kharif* 2021. The effect of growing environments and varieties on Radiation Use Efficiency (RUE) of rice was studied and presented in Table 4.3.

The highest RUE at physiological maturity was recorded for cv. Rajeshwari transplanted on 15 June, followed by MTU1010 transplanted on 01 June. The reason for highest RUE in the case of Rajeshwari may be the fact that 15 June is the normal, recommended transplanting time for rice. The lowest RUE at maturity was recorded by Rajeshwari variety transplanted on 30 June.

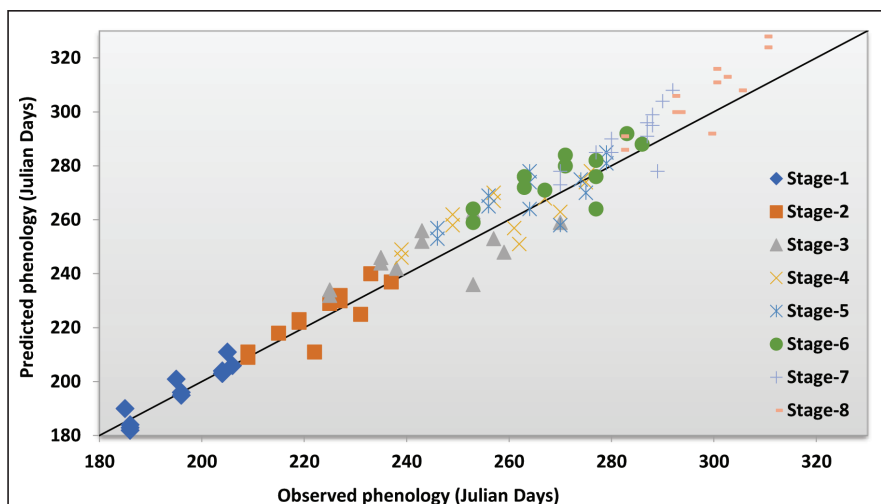
**Table 4.3: Effect of different growing environments on RUE ( $\text{g MJ}^{-1}$ ) of different rice varieties during *kharif* 2021 at Raipur**

| Treatments | Days after transplanting |      |      |      |      |      |          |
|------------|--------------------------|------|------|------|------|------|----------|
|            | 15                       | 30   | 45   | 60   | 75   | 90   | Maturity |
| $D_1V_1$   | 0.12                     | 0.28 | 0.96 | 1.79 | 2.04 | 2.85 | 2.41     |
| $D_1V_2$   | 0.14                     | 0.24 | 1.04 | 1.92 | 2.01 | 2.57 | 2.19     |
| $D_1V_3$   | 0.10                     | 0.26 | 0.88 | 1.64 | 1.74 | 2.62 | 2.40     |
| $D_2V_1$   | 0.11                     | 0.44 | 1.32 | 1.77 | 2.96 | 2.66 | 2.21     |
| $D_2V_2$   | 0.11                     | 0.45 | 1.32 | 2.05 | 3.47 | 3.30 | 2.69     |
| $D_2V_3$   | 0.10                     | 0.37 | 1.04 | 1.30 | 2.82 | 2.59 | 2.26     |
| $D_3V_1$   | 0.23                     | 0.78 | 1.26 | 2.23 | 2.84 | 2.51 | 2.13     |
| $D_3V_2$   | 0.21                     | 0.80 | 1.32 | 2.13 | 2.93 | 2.58 | 2.09     |
| $D_3V_3$   | 0.19                     | 0.66 | 1.07 | 1.62 | 2.31 | 2.27 | 2.12     |

$V_1$ : MTU1010 (ZC),  $V_2$ : Rajeshwari,  $V_3$ : CG Sugandhit Bhog;

$D_1$ -01/06/2021,  $D_2$ -15/06/2021,  $D_3$ -30/06/2021

The same variety (Rajeshwari) recorded highest and lowest RUE when transplanted with a gap of just 15 days. This indicates the influence of weather parameters and importance of optimum transplanting date. In addition to this, Raipur centre had used the dynamic crop weather calendar DSS for rice using past experiment data. It was used to validate the crop phenology during *kharif* 2021 and the result is presented in Fig. 4.3.



Stage-1: Nursery; Stage-2: Tillering; Stage-3: Panicle initiation; Stage-4: Heading; Stage-5: Anthesis; Stage-6: Beginning of grain filling; Stage-7: End of grain filling; Stage-8: Physiological maturity

**Fig. 4.3: Validation of dynamic crop weather calendar for rice in phenology prediction at Raipur**

The predicted phenology by DCWC for rice showed good agreement with the observed values as indicated by Fig. 4.3. This can be used in deciding the timing of various crop management activities in consideration with the weather forecast.

## Ranchi

Impact of growing environments and varieties on heat and radiation use efficiencies on rice was studied using a field experiment with three growing environments [Early (05 June), Normal (15 June) and Late (25 June)] and three varieties (Sahbhagidhan, Naveen and MTU 1010). The result of pooled data analysis of 5 years (2017-2021) is presented in Table 4.4.

In the case of HUE, late-sown crop recorded slightly higher values (2.22) than early sown crop. Among the varieties, Naveen recorded highest HUE (2.39), and Sahbhagidhan recorded the lowest (2.02). However, the difference in HUE between dates of sowing and varieties were not statistically significant. The highest RUE was recorded by late sown crop (2.22 g MJ<sup>-1</sup>) and the lowest was recorded by normal sown crop (2.14 g MJ<sup>-1</sup>). Among the varieties, Naveen recorded highest RUE (2.34 g MJ<sup>-1</sup>) and Sahbhagidhan recorded the lowest (2.07 g MJ<sup>-1</sup>).

**Table 4.4: Heat Use Efficiency (HUE) and Radiation Use Efficiency (RUE) of rice varieties under different growing environments at Ranchi (Pooled data 2017-2021)**

| Treatments            | HUE (kg ha <sup>-1</sup> °C day <sup>-1</sup> ) | RUE (g MJ <sup>-1</sup> ) |
|-----------------------|-------------------------------------------------|---------------------------|
| <b>Date of sowing</b> |                                                 |                           |
| Early                 | 2.22                                            | 2.18                      |
| Normal                | 2.16                                            | 2.14                      |
| Late                  | 2.23                                            | 2.22                      |
| SEm                   | 0.07                                            | 0.06                      |
| CD at 5%              | NS                                              | NS                        |
| <b>Variety</b>        |                                                 |                           |
| Sahbhagidhan          | 2.02                                            | 2.07                      |
| Naveen                | 2.39                                            | 2.34                      |
| MTU1010               | 2.19                                            | 2.12                      |
| SEm                   | 0.07                                            | 0.06                      |
| CD at 5%              | 0.21*                                           | 0.18*                     |
| <b>Interaction</b>    |                                                 |                           |
| SEm                   | 0.12                                            | 0.11                      |
| CD at 5%              | NS                                              | NS                        |

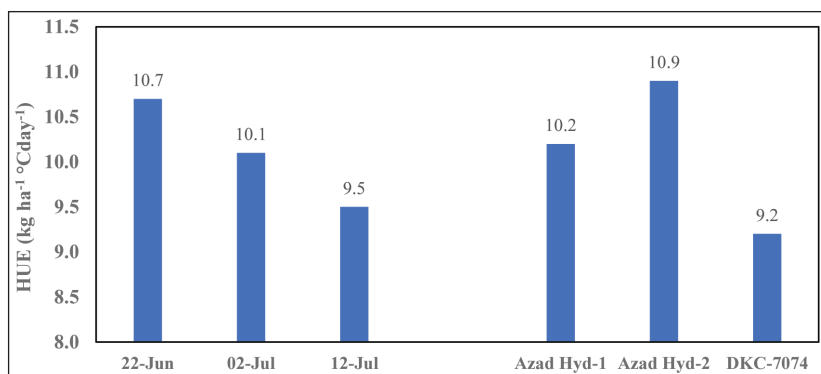
## Kanpur

Crop weather relationship studies were undertaken using three growing environments (22 June, 02 July and 12-July) and three varieties/hybrids (Azad hybrid-1, Azad hybrid-2 and DKC-7074). Dry matter accumulation, growing degree days (GDD) and HUE as affected by growing environments and varieties/hybrids was studied and the result is presented in Table 4.5 and Fig. 4.4.

The result indicated that growing degree days and heat use efficiency during whole crop season was recorded higher for crop sown on 22 June. The progressive decrease in total dry matter per hectare was observed with delayed sowings. A reason for this could be exploitation of weather and soil moisture at important growth stages by early sown crop and higher leaf area index which might have provided more photosynthetic area and contributed more dry matter (20886 kg ha<sup>-1</sup>).

**Table 4.5: Dry matter accumulation and GDD as influenced by different growing environment and cultivars in maize during *kharif* 2021 at Kanpur**

| Treatment                     | Dry matter (kg ha <sup>-1</sup> ) | GDD (°C day) |
|-------------------------------|-----------------------------------|--------------|
| <b>Growing environments</b>   |                                   |              |
| D <sub>1</sub>                | 20886.7                           | 1955         |
| D <sub>2</sub>                | 18943.3                           | 1881         |
| D <sub>3</sub>                | 16816.7                           | 1759         |
| <b>Variety/hybrid</b>         |                                   |              |
| V <sub>1</sub>                | 19053.3                           | 1871         |
| V <sub>2</sub>                | 20933.3                           | 1916         |
| V <sub>3</sub>                | 16660.0                           | 1808         |
| <b>Interaction</b>            |                                   |              |
| D <sub>1</sub> V <sub>1</sub> | 21250                             | 1961         |
| D <sub>1</sub> V <sub>2</sub> | 23330                             | 1998         |
| D <sub>1</sub> V <sub>3</sub> | 18080                             | 1906         |
| D <sub>2</sub> V <sub>1</sub> | 18300                             | 1893         |
| D <sub>2</sub> V <sub>2</sub> | 21340                             | 1934         |
| D <sub>2</sub> V <sub>3</sub> | 17190                             | 1814         |
| D <sub>3</sub> V <sub>1</sub> | 17610                             | 1759         |
| D <sub>3</sub> V <sub>2</sub> | 18130                             | 1815         |
| D <sub>3</sub> V <sub>3</sub> | 14710                             | 1703         |

**Fig. 4.4: Effect of growing environments and cultivars/hybrids on HUE of maize at Kanpur**

Higher growing degree days (1955 °C days) and heat use efficiency (10.7 g m<sup>-2</sup> °C day<sup>-1</sup>) was recorded by crop sown on 22 June when compared to 02 July (10.1 g m<sup>-2</sup> °C day<sup>-1</sup>) and 12 July (9.5 g m<sup>-2</sup> °C day<sup>-1</sup>), sowing. The HUE was influenced by varietal difference and varying thermal environment. Azad hybrid-2 recorded highest HUE (10.9 g m<sup>-2</sup> °C day<sup>-1</sup>) followed by Azad hybrid-1 (10.2 g m<sup>-2</sup> °C day<sup>-1</sup>) and DKC-7074 (9.2 g m<sup>-2</sup> °C day<sup>-1</sup>) during whole crop growing period.

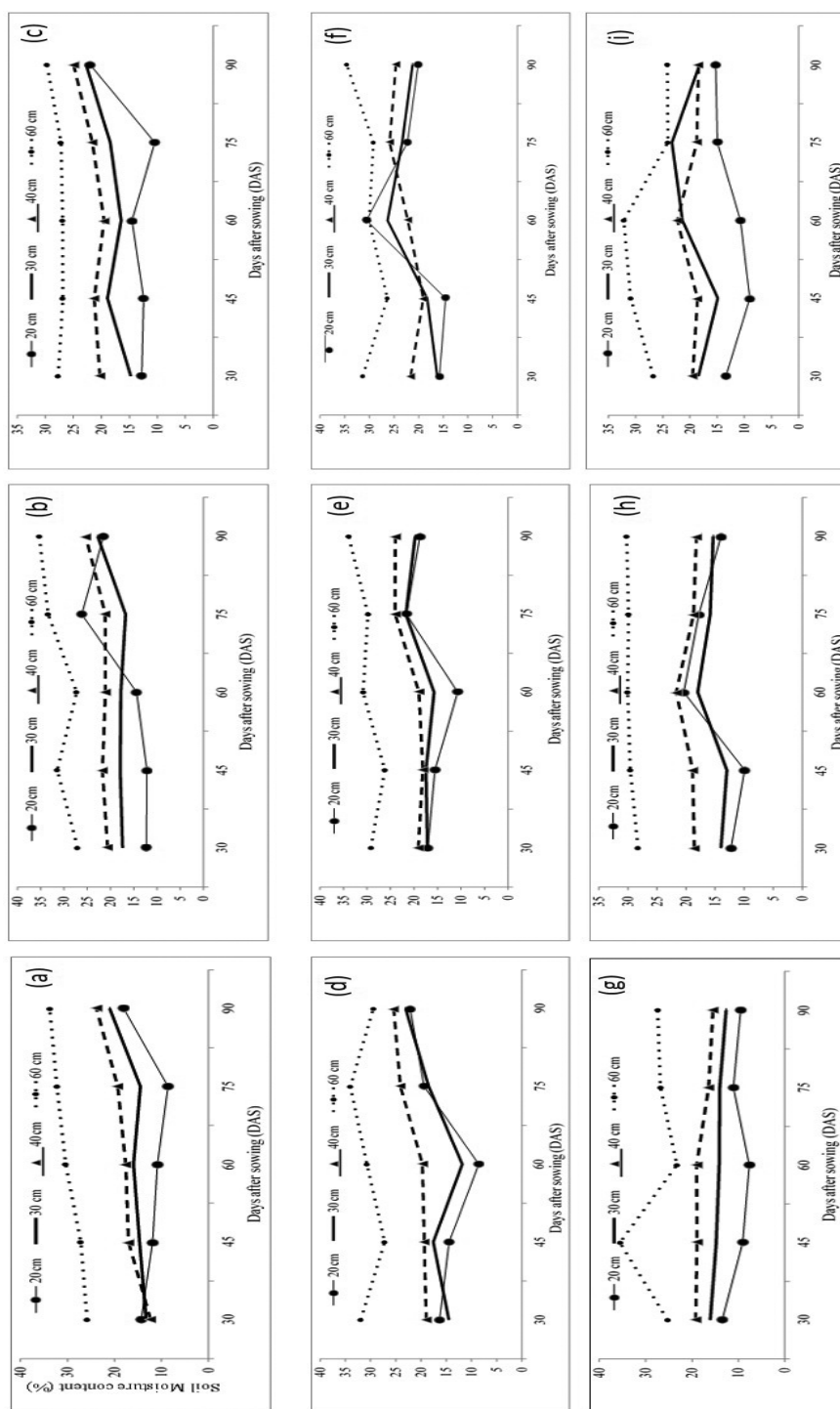
## Ludhiana

Field experiment consisted of three growing environments (01 June, 15 June and 01 July 2021) and three varieties (PMH13, JH-19014 and P-3396). The variation in soil moisture content in the three varieties grown under three growing environments was studied and the result is presented in Fig. 4.5a-i. Among the soil layers, the moisture content was higher in the deepest layer across different sowing dates and varieties. Among the varieties, soil moisture content was comparatively higher for JH-19014, especially when sown on 15 June. The yield and yield attributes of rice cultivars grown under different growing environments is presented in Table 4.6.

**Table 4.6: Plant height, yield and yield attributes of maize during *kharif* 2021 at Ludhiana**

| Treatments             | Perimeter of cobs (cm) | 100 grain weight (g) | No of grains per cob | Cob length (cm) | Grain yield (kg ha <sup>-1</sup> ) | Biomass (kg ha <sup>-1</sup> ) | Harvest index (%) |
|------------------------|------------------------|----------------------|----------------------|-----------------|------------------------------------|--------------------------------|-------------------|
| <b>Dates of sowing</b> |                        |                      |                      |                 |                                    |                                |                   |
| 1 June                 | 13.1                   | 28.6                 | 345                  | 16.5            | 6029                               | 17939                          | 33.6              |
| 15 June                | 13.3                   | 29.2                 | 369                  | 17.0            | 6392                               | 18672                          | 34.3              |
| 1 July                 | 12.8                   | 26.9                 | 316                  | 15.6            | 5680                               | 17744                          | 32.0              |
| CD (0.05)              | 0.4                    | 1.9                  | 18                   | 0.7             | 346                                | 626                            | NS                |
| <b>Varieties</b>       |                        |                      |                      |                 |                                    |                                |                   |
| PMH-13                 | 13.0                   | 28.3                 | 334                  | 16.2            | 5913                               | 17947                          | 33.0              |
| JH-19014               | 13.4                   | 30.1                 | 370                  | 16.9            | 6291                               | 18681                          | 33.7              |
| P-3396                 | 12.9                   | 26.3                 | 326                  | 16.0            | 5897                               | 17726                          | 33.3              |
| CD (0.05)              | 0.4                    | 1.9                  | 18.3                 | 0.7             | 346                                | 626                            | NS                |

The yield attributes like cobs perimeter, 100 grain weight, number of grains per cob, length of cob, was found to be higher in JH 19014 as compared to other varieties. Among the dates of sowing higher values of these parameters were noticed in D<sub>2</sub> (15 June) as compared to other dates of sowing. Averaged over cultivars biomass and grain yield was maximum in D<sub>2</sub> date of sowing (15 June 2021) as compared to other two dates of sowing. Averaged over dates of sowing, the biomass and grain yield of JH-19014 was higher as compared to rest of the cultivars. It is clear from the Table that the sowing on 15 June, 2021 of JH 19014 resulted in highest yield and it decreased on subsequent late sowing.



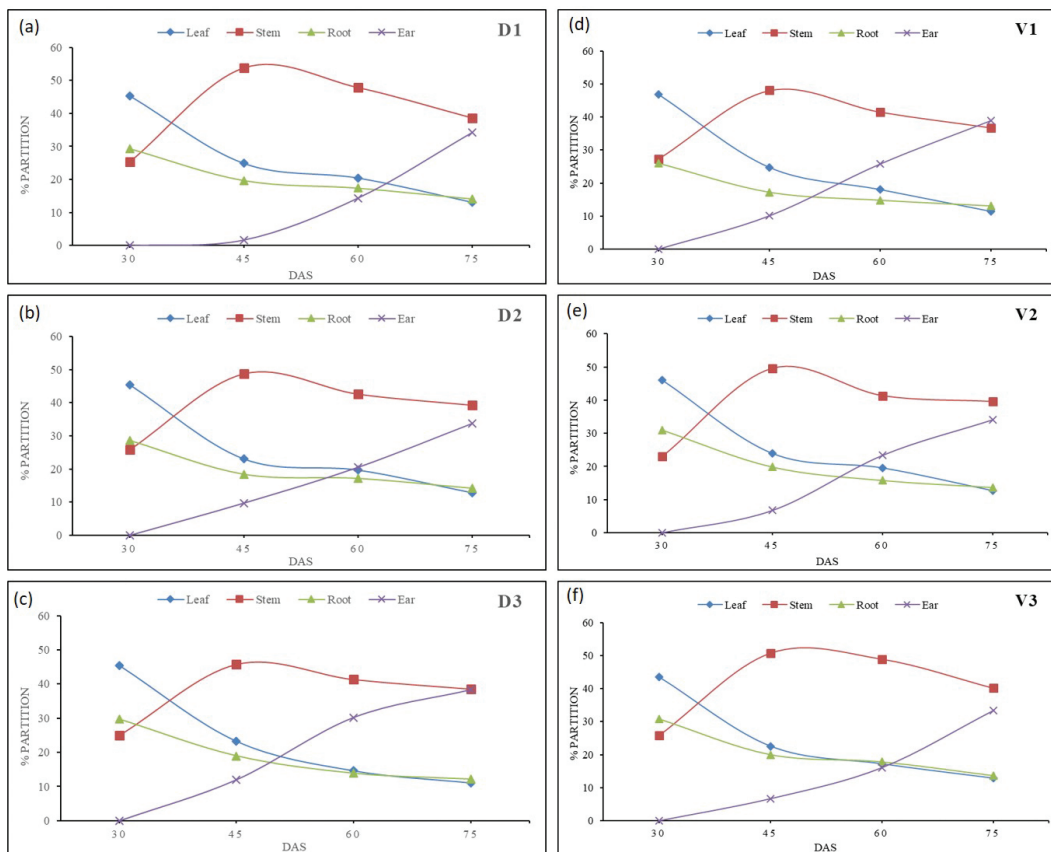
a-c: PMH-13 sown on 01 June, 15 June and 01 July; d-f: JH-19014 sown on 01 June, 15 June and 01 July; g-i: P-3396 sown on 01 June, 15 June and 01 July

**Fig. 4.5: Temporal variation in soil moisture content in three maize varieties cultivated under three growing environments at Ludhiana**

## Pearl millet

### Anand

Crop weather relationship studies in pearl millet was undertaken during *kharif* 2021 with three dates of sowing (22 June, 02 July and 12 July) and three varieties (GHB-538, GHB-558 and GHB-744). Effect of growing environments and varieties on biomass partitioning at various growth stages of the crop was studied and the result is presented in Fig. 4.6.

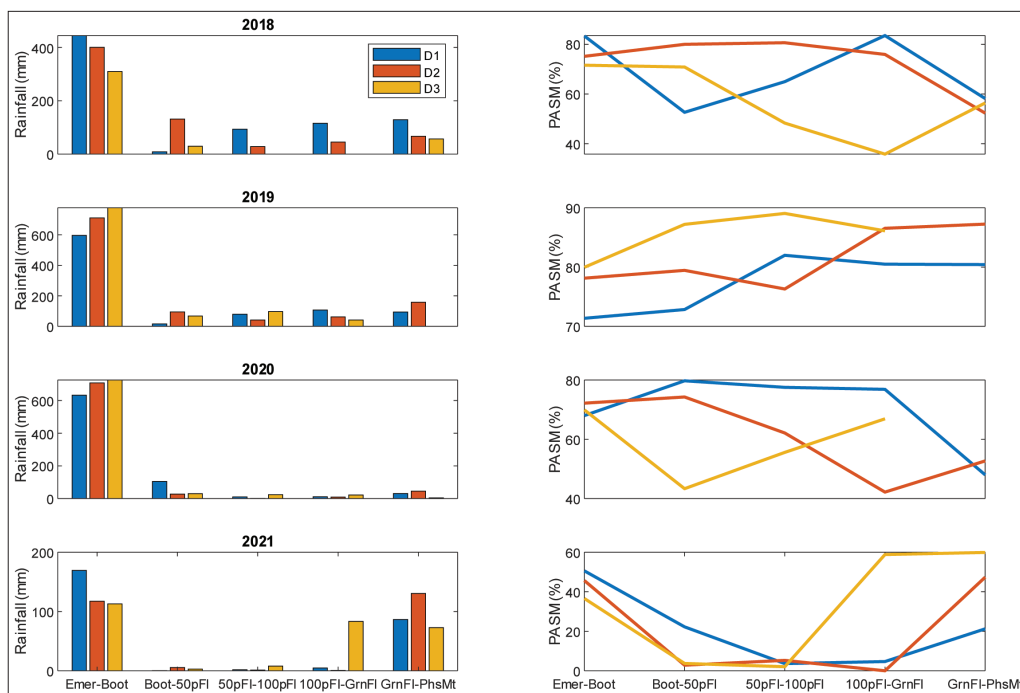


**Fig. 4.6: Effect of growing environments (a-c) and varieties (d-f) on biomass partitioning of pearl millet at Anand**

Leaf partitioning was recorded higher during early vegetative state (30 DAS) in all the dates of sowing and varieties, which declined during later phases. Highest stem partitioning was observed at 45 DAS in all three sowing and in all cultivars and gradually decrease with time. Highest root partitioning was recorded at 30 DAS and decrease gradually with time in all sowing and in all cultivar. Partitioning of ear head development was observed after 35 days.

### Impact of rainfall and soil moisture on grain yield of pearl millet

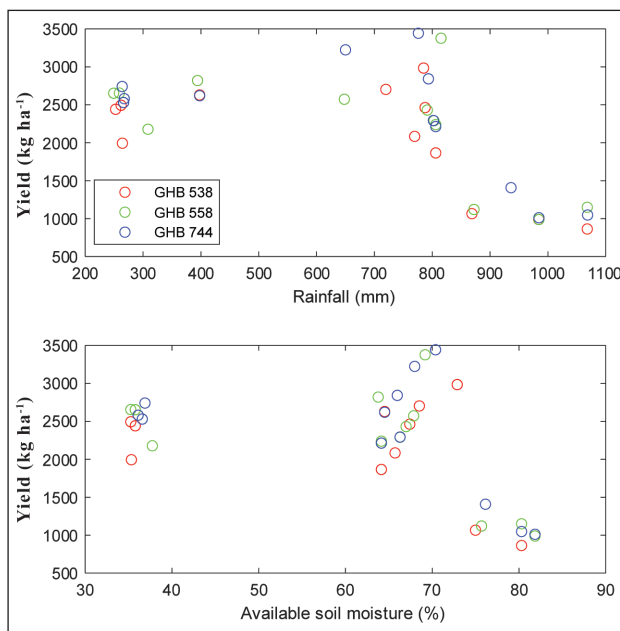
As the experiment was conducted in rainfed conditions, rainfall and soil moisture are determining factors to support the crop life. A pooled analysis of experiments conducted during 2018-2021 was carried out and crop phenophases-wise rainfall and per cent available soil moisture is depicted in Fig. 4.7.



**Fig. 4.7: Phenophase-wise rainfall and available soil moisture during different phenophases of pearl millet at Anand**

In all three crop growing seasons, rainfall receipts were higher during emergence to booting for all the growing environments ( $n=12$ ). In monsoon 2018, due to dry spells, late sowings resulted in continuous depletion in available soil moisture. In very late sowing, 100% flowering to grain filling phase had moisture stress condition where as in the year 2019, rainfall quantum and temporal distribution were good. Soil moisture status improved with time and remained above 70% during all phases of growing environments. There were relatively low soil moisture conditions during booting to 50% flowering of very late sowing and 100% flowering to grain filling phases of late sowing during *kharif* 2020. There was mid-season drought like condition during *kharif* 2021. There was very low available soil moisture during booting to grain filling in first two growing environments

and during booting to 100% flowering. The associations of yield with seasonal rainfall and mean available soil moisture shows that very high rainfall and moisture status affects crop performance (Fig. 4.8).



**Fig. 4.8: Association of seasonal rainfall and average available soil moisture with pearl millet productivity (2018-2021) at Anand**

Seasonal rainfall of about 700-800 mm and 65-70% available moisture are optimum for maximum productivity. Rainfall higher than 800 mm during the season with more than 70% mean available moisture reduce the production of pearl millet drastically.

## Hisar

Field experiment was taken up in Factorial RBD with three growing environments (15 July, 23 July and 07 August 2021) and three varieties (GHB 558, HHB 67 and HHB 272). Effect of growing environments on leaf area index of pearl millet varieties is presented in Table 4.7. The station received 268 mm rainfall during 23-25 September which proved detrimental to the crop sown on 7 August. The crop attained maximum Leaf Area Index (LAI) at 35 DAS at flag leaf stage and decreased thereafter. The maximum LAI was recorded by D<sub>2</sub> (5.68) followed by D<sub>1</sub> (5.51) and D<sub>3</sub> (4.45). Among varieties, maximum LAI was recorded by HHB-272 (5.50) followed by GHB-558 (5.38) and HHB 67 improved (4.76). The interaction between sowing dates and pearl millet varieties was non-significant.

**Table 4.7: Effect of sowing dates on LAI in pearl millet varieties during year 2021**

| Treatments                  | Days After Sowing |      |      |      |       |        |        |
|-----------------------------|-------------------|------|------|------|-------|--------|--------|
|                             | 21                | 28   | 35   | 42   | 49    | 56     | PM     |
| D <sub>1</sub> (15 July)    | 1.54              | 2.54 | 5.51 | 4.75 | 3.85  | 2.75   | 2.19   |
| D <sub>2</sub> (23 July)    | 1.72              | 2.72 | 5.68 | 5.30 | 4.31  |        |        |
| D <sub>3</sub> (07 Aug)     | 1.52              | 2.51 | 4.45 | 4.17 |       |        |        |
| SE(m)                       | 0.10              | 0.10 | 0.24 | 0.16 |       |        |        |
| CD @ 5%                     | NS                | NS   | 0.69 | 0.46 |       |        |        |
| V <sub>1</sub> (GHB 558)    | 1.71              | 2.71 | 5.38 | 4.77 | 4.47* | 3.13** | 2.39** |
| V <sub>2</sub> (HHB 67 Imp) | 1.48              | 2.48 | 4.76 | 4.35 | 3.66* | 2.22** | 1.95** |
| V <sub>3</sub> (HHB 272)    | 1.59              | 2.58 | 5.50 | 5.10 | 4.10* | 2.90** | 2.24** |
| SE (m)                      | 0.10              | 0.10 | 0.24 | 0.16 |       |        |        |
| CD @ 5%                     | NS                | NS   | NS   | 0.46 |       |        |        |
| A x B                       | NS                | NS   | NS   | NS   |       |        |        |

\*Average values of D<sub>1</sub> and D<sub>2</sub>\*\*values of D<sub>1</sub> only

## Solapur

Crop weather relationship studies in pearl millet at Solapur was started in 2016 with three growing environments [II fortnight of June (S<sub>1</sub>), II fortnight of July (S<sub>2</sub>) and II fortnight of August (S<sub>3</sub>)] and three varieties [ICTP-8203 (V<sub>1</sub>), Mahyco hybrid (V<sub>2</sub>) and Dhanshakti (V<sub>3</sub>)]. The number of days taken to achieve different growth stages of the crop under different growing environments were characterized using experimental data during 2016-2021 and presented in Table 4.8.

The total duration of three varieties varied according to the growing environment. For ICTP-8203, Mahyco hybrid and Dhanshakti, the mean total crop duration varied in the range 89-94, days 89-98 and 90-98 days, respectively. The third growing environment (II fortnight of August) recorded lowest crop duration for all the varieties, except for ICTP-8203. These changes in crop duration for same variety across the growing environments can be attributed the variation in the thermal regime and hence, the differences in accumulated growing degree days. Further, the mean radiation use efficiency (RUE) of pearl millet varieties under three growing environments were also characterized by pooling the results during 2016-21 and the result is presented in Table 4.9.

**Table 4.8: Mean number of days required to attain phenological stages as influenced by growing environments and varieties in *kharif* pearl millet (2016 to 2021) at Solapur**

| Sowing Time                   | Phenological stage |        |                    |           |               |            |            |               |
|-------------------------------|--------------------|--------|--------------------|-----------|---------------|------------|------------|---------------|
|                               | Emergence          | 3 leaf | Panicle initiation | Flag leaf | 50% flowering | Soft Dough | Hard Dough | Phy. Maturity |
| S <sub>1</sub> V <sub>1</sub> | 6                  | 6      | 11                 | 24        | 9             | 12         | 12         | 9             |
| Cumulative                    |                    | 12     | 23                 | 47        | 56            | 68         | 80         | 89            |
| S <sub>1</sub> V <sub>2</sub> | 8                  | 6      | 13                 | 26        | 9             | 10         | 13         | 9             |
| Cumulative                    |                    | 14     | 27                 | 53        | 62            | 72         | 85         | 94            |
| S <sub>1</sub> V <sub>3</sub> | 6                  | 7      | 14                 | 20        | 9             | 14         | 16         | 8             |
| Cumulative                    |                    | 13     | 27                 | 47        | 56            | 70         | 86         | 94            |
| S <sub>2</sub> V <sub>1</sub> | 6                  | 7      | 14                 | 20        | 9             | 14         | 16         | 8             |
| Cumulative                    |                    | 13     | 27                 | 47        | 56            | 70         | 86         | 94            |
| S <sub>2</sub> V <sub>2</sub> | 7                  | 7      | 14                 | 23        | 9             | 14         | 16         | 8             |
| Cumulative                    |                    | 14     | 28                 | 51        | 60            | 74         | 90         | 98            |
| S <sub>2</sub> V <sub>3</sub> | 8                  | 7      | 14                 | 29        | 10            | 11         | 12         | 8             |
| Cumulative                    |                    | 15     | 29                 | 58        | 68            | 79         | 93         | 98            |
| S <sub>3</sub> V <sub>1</sub> | 7                  | 7      | 13                 | 22        | 9             | 12         | 13         | 9             |
| Cumulative                    |                    | 14     | 27                 | 49        | 58            | 70         | 83         | 92            |
| S <sub>3</sub> V <sub>2</sub> | 6                  | 6      | 11                 | 24        | 9             | 12         | 12         | 9             |
| Cumulative                    |                    | 12     | 23                 | 47        | 56            | 68         | 80         | 89            |
| S <sub>3</sub> V <sub>3</sub> | 7                  | 9      | 13                 | 24        | 9             | 10         | 10         | 8             |
| Cumulative                    |                    | 16     | 29                 | 53        | 62            | 72         | 82         | 90            |

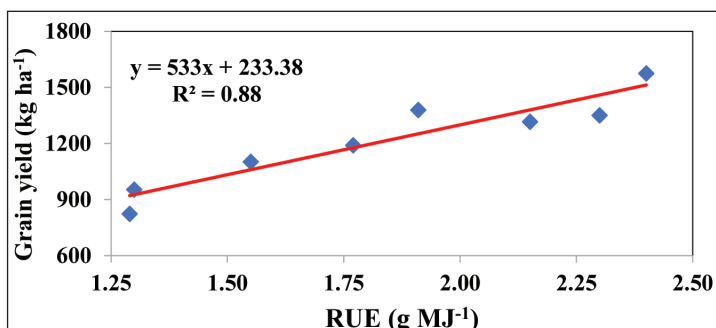
II fortnight of June (S<sub>1</sub>), II fortnight of July (S<sub>2</sub>) and II fortnight of August (S<sub>3</sub>), ICTP-8203 (V<sub>1</sub>), Mahyco hybrid (V<sub>2</sub>) and Dhanshakti (V<sub>3</sub>)

**Table 4.9: Mean Radiation Use Efficiency (g MJ<sup>-1</sup>) as influenced by sowing windows and varieties in *kharif* pearl millet (2016 to 2021) at Solapur**

| Sowing Time                   | Phenological stages wise RUE (g MJ <sup>-1</sup> ) |                    |           |                |            |            |                        |
|-------------------------------|----------------------------------------------------|--------------------|-----------|----------------|------------|------------|------------------------|
|                               | Emergence                                          | Panicle initiation | Flag leaf | 50 % flowering | Soft dough | Hard Dough | Physiological maturity |
| S <sub>1</sub> V <sub>1</sub> | 0.12                                               | 0.18               | 0.77      | 1.55           | 1.08       | 0.88       | 0.98                   |
| S <sub>1</sub> V <sub>2</sub> | 0.14                                               | 0.24               | 1.09      | 1.77           | 1.26       | 1.09       | 1.26                   |
| S <sub>1</sub> V <sub>3</sub> | 0.16                                               | 0.31               | 1.30      | 1.91           | 1.32       | 1.18       | 1.29                   |
| S <sub>2</sub> V <sub>1</sub> | 0.13                                               | 0.35               | 1.29      | 2.15           | 1.30       | 1.07       | 1.27                   |
| S <sub>2</sub> V <sub>2</sub> | 0.16                                               | 0.41               | 1.50      | 2.30           | 1.36       | 1.28       | 1.29                   |
| S <sub>2</sub> V <sub>3</sub> | 0.17                                               | 0.48               | 1.69      | 2.40           | 1.46       | 1.39       | 1.55                   |
| S <sub>3</sub> V <sub>1</sub> | 0.10                                               | 0.26               | 0.99      | 1.29           | 1.08       | 0.91       | 1.05                   |
| S <sub>3</sub> V <sub>2</sub> | 0.12                                               | 0.28               | 1.09      | 1.30           | 1.16       | 1.01       | 1.15                   |
| S <sub>3</sub> V <sub>3</sub> | 0.12                                               | 0.31               | 1.28      | 1.60           | 1.25       | 1.08       | 1.29                   |

II fortnight of June (S<sub>1</sub>), II fortnight of July (S<sub>2</sub>) and II fortnight of August (S<sub>3</sub>), ICTP-8203 (V<sub>1</sub>), Mahyco hybrid (V<sub>2</sub>) and Dhanshakti (V<sub>3</sub>)

The RUE linearly increased till 50% flowering, at which it recorded the highest value and then decreased. Among the treatments, Dhanshakti sown during second fortnight of July recorded highest RUE at 50% flowering (2.4 g MJ<sup>-1</sup>), followed by Mahyco hybrid (2.3 g MJ<sup>-1</sup>). At physiological maturity also, Dhanshakti sown during second fortnight of July recorded highest RUE (1.55 g MJ<sup>-1</sup>). It can be concluded that varieties sown during second fortnight of July recorded highest RUE. The relationship between RUE and grain yield is presented in Fig. 4.9, which indicated that yield increased linearly with RUE.



**Fig. 4.9: Relationship between RUE at physiological maturity and grain yield in pearl millet at Solapur**

### Ranichauri

A field experiment was taken up in factorial RBD with three growing environments (31 May, 10 June and 23 June 2021) and three varieties (VLM-324, PRM-2 and VLM-347) during *kharif* 2021. The number of days taken to achieve various growth stages of the crop under different growing environments was studied and the results are presented in Table 4.10.

**Table 4.10: Crop phenology of finger millet under different growing environments at Ranichauri during *kharif* 2021**

| Stage/Growing environment | D <sub>1</sub> (31 May) | D <sub>2</sub> (10 June) | D <sub>3</sub> (23 June) |
|---------------------------|-------------------------|--------------------------|--------------------------|
| S-E                       | 10                      | 16                       | 12                       |
| E-TL                      | 23                      | 34                       | 25                       |
| TL-JN                     | 18                      | 15                       | 21                       |
| JN-PI                     | 20                      | 15                       | 13                       |
| PI-FL                     | 13                      | 14                       | 12                       |
| FL-BGF                    | 9                       | 6                        | 9                        |
| BGF-EGF                   | 19                      | 7                        | 11                       |
| EGF-PM                    | 14                      | 21                       | 16                       |
| Total                     | 126                     | 128                      | 119                      |

*S: sowing, E: emergence, TL: tillering, JN: jointing, PI: panicle initiation, FL: 50% flowering, BGF: beginning of grain filling, EGF: end of grain filling, PM: physiological maturity*

Results indicated that the total crop duration was almost same in the case of crop sown on 31 May and 10 June. However, the crop duration shortened by nine days under late-sown conditions (23 June). This may be due to higher temperature faced by the late-sown crop which might have led to faster accumulation of growing degree days. The effect of growing environments on yield and yield attributes of finger millet varieties is described in Table 4.11.

**Table 4.11: Yield attributes, yields and harvest index (%) of finger millet as influenced by growing environments and varieties at Ranichauri during *kharif* 2021**

| Treatment                | Finger per plant | 1000-seed weight | Grain yield (kg ha <sup>-1</sup> ) | Biological yield (kg ha <sup>-1</sup> ) | Harvest index (%) |
|--------------------------|------------------|------------------|------------------------------------|-----------------------------------------|-------------------|
| <b>Date of sowing</b>    |                  |                  |                                    |                                         |                   |
| D <sub>1</sub> (31 May)  | 6.3              | 2.7              | 1,278                              | 4,134                                   | 31.5              |
| D <sub>2</sub> (10 June) | 6.6              | 2.9              | 1,135                              | 3,629                                   | 31.3              |
| D <sub>3</sub> (23 June) | 7.3              | 3.1              | 1,601                              | 4,607                                   | 34.6              |
| SEm±                     | 0.2              | 0.1              | 101                                | 322                                     | 1.3               |
| CD(P=0.05)               | 0.6              | NS               | 304                                | NS                                      | NS                |
| <b>Varieties</b>         |                  |                  |                                    |                                         |                   |
| V <sub>1</sub> (VLM-324) | 6.9              | 2.9              | 1,332                              | 4,171                                   | 32.3              |
| V <sub>2</sub> (PRM-2)   | 6.7              | 2.9              | 1,368                              | 4,201                                   | 32.2              |
| V <sub>3</sub> (VLM-347) | 6.7              | 2.8              | 1,314                              | 3,998                                   | 32.9              |
| SEm±                     | 0.2              | 0.1              | 101                                | 322                                     | 1.3               |
| CD (P=0.05)              | NS               | NS               | NS                                 | NS                                      | NS                |

Among the growing environments, crop sown on 23 June recorded the highest grain yield of 1601 kg ha<sup>-1</sup>. Similar result was observed in the case of fingers per plant, 1000 seed weight, biological yield and harvest index. The yield of crop sown on 23 June was significantly higher compared to that of 31 May and 10 June sown crops ( $p < 0.05$ ). Among the varieties, PRM-2 recorded slightly higher yield compared to VLM-324 and VLM-347, but there was no significant difference.

## Jabalpur

Crop weather relationship studies in soybean was taken up during *kharif* 2021 with three growing environments (22 June, 07 July and 22 July 2021) and three varieties (JS-20-98, JS-20-34 and JS-20-69). Correlation of weather parameters with seed yield at different phenological stages in soybean was estimated and the results are presented in Table 4.12. The results suggested that a negative correlation exhibited between maximum and minimum temperatures and bright sunshine hours with seed yield at vegetative stage and pod development stages. The relative humidity exhibited a negative association with seed yield during emergence, branching and flower stages. Rainfall is also associated in a similar manner thereby exhibiting a negative relation with seed yield if occurred during emergence and flower stage in soybean.

**Table 4.12: Correlation between weather parameters and seed yield at different phenological stages in soybean at Jabalpur during *kharif* 2021**

| Phenological stages                        | r-value             | T max  | Tmin   | Tmean  | SSH    | GDD   | HTU    | PTU   | RH-I   | RH-II   | WS     | Evp    | Rainfall | Rainy-days |
|--------------------------------------------|---------------------|--------|--------|--------|--------|-------|--------|-------|--------|---------|--------|--------|----------|------------|
| Sowing to Emergence                        | Pearson Correlation | 0.233  | 0.167  | 0.245  | 0.229  | 0.244 | 0.234  | 0.245 | -0.235 | -0.244  | -0.068 | 0.168  | -0.244   | -0.244     |
|                                            | Sig. (2-tailed)     | 0.546  | 0.669  | 0.526  | 0.553  | 0.527 | 0.544  | 0.525 | 0.542  | 0.527   | 0.862  | 0.666  | 0.528    | 0.527      |
| Emergence to Branching                     | Pearson Correlation | 0.166  | 0.147  | 0.154  | 0.21   | 0.293 | 0.265  | 0.29  | -0.132 | -0.155  | -0.228 | 0.172  | 0.256    | -0.038     |
|                                            | Sig. (2-tailed)     | 0.669  | 0.705  | 0.693  | 0.587  | 0.445 | 0.491  | 0.449 | 0.734  | 0.691   | 0.555  | 0.658  | 0.506    | 0.923      |
| Branching to Flowering                     | Pearson Correlation | -0.489 | -0.468 | -0.482 | -0.469 | 0.347 | -0.263 | 0.372 | 0.469  | 0.46    | 0.516  | -0.522 | 0.169    | 0.523      |
|                                            | Sig. (2-tailed)     | 0.182  | 0.204  | 0.189  | 0.203  | 0.361 | 0.494  | 0.324 | 0.203  | 0.213   | 0.155  | 0.149  | 0.664    | 0.149      |
| Flowering to pod Development               | Pearson Correlation | 0.348  | 0.533  | 0.426  | 0.21   | 0.421 | 0.244  | 0.479 | -0.522 | -0.699* | -0.249 | 0.241  | -0.631   | -0.547     |
|                                            | Sig. (2-tailed)     | 0.359  | 0.139  | 0.253  | 0.587  | 0.259 | 0.527  | 0.192 | 0.149  | 0.036   | 0.518  | 0.531  | 0.068    | 0.127      |
| Pod Development to Physiological Maturity  | Pearson Correlation | -0.042 | 0.118  | 0.234  | -0.158 | 0.45  | -0.063 | 0.324 | 0.395  | 0.736*  | -0.256 | -0.043 | 0.653    | 0.751*     |
|                                            | Sig. (2-tailed)     | 0.914  | 0.763  | 0.544  | 0.685  | 0.224 | 0.872  | 0.395 | 0.292  | 0.024   | 0.506  | 0.912  | 0.057    | 0.02       |
| Physiological maturity to Harvest maturity | Pearson Correlation | 0.475  | 0.158  | 0.521  | 0.426  | 0.553 | .826** | 0.511 | -0.322 | -0.409  | -0.255 | 0.104  | -0.508   | -0.488     |
|                                            | Sig. (2-tailed)     | 0.196  | 0.685  | 0.151  | 0.252  | 0.122 | 0.006  | 0.16  | 0.398  | 0.274   | 0.508  | 0.791  | 0.162    | 0.183      |

## Parbhani

Crop weather relationship studies in soybean was taken up during *kharif* 2021 with three growing environments (18 June, 25 June, 06 July and 15 July 2021) and three varieties (MAUS-158, MAUS-71 and JS-335). Correlation of weather parameters with seed yield at different phenological stages in soybean was estimated and the results are presented in Table 4.13. The rainfall has significant positive correlation with seed yield at P<sub>3</sub>, P<sub>9</sub> and P<sub>10</sub> stages and negatively correlated at P<sub>6</sub> and P<sub>7</sub> stages of MAUS-158, MAUS-71 and JS-335 varieties.

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

| Parameters           | P <sub>1</sub> | P <sub>2</sub> | P <sub>3</sub> | P <sub>4</sub> | P <sub>5</sub> | P <sub>6</sub> | P <sub>7</sub> | P <sub>8</sub> | P <sub>9</sub> | P <sub>10</sub> |
|----------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|-----------------|
| <b>V1 (MAUS 158)</b> |                |                |                |                |                |                |                |                |                |                 |
| Rainfall (mm)        | 0.19           | 0.39           | 0.58**         | 0.07           | -0.01          | -0.99**        | -0.45*         | 0.03           | 0.53*          | 0.60**          |
| Tmax (°C)            | 0.80**         | 0.71**         | -0.99**        | 0.17           | 0.17           | 0.63**         | -0.37          | -0.46*         | -0.78**        | 0.05            |
| Tmin (°C)            | -0.39          | 0.85**         | -0.32          | -0.26          | -0.63**        | -0.62**        | 0.93**         | -0.38          | 0.88**         | 0.99**          |
| RH-I (%)             | -0.59**        | -0.19          | 0.71**         | 0.05           | -0.86**        | -0.57**        | 0.18           | -0.95**        | 0.32           | 0.92**          |
| RH-II (%)            | -0.37          | -0.28          | 0.77**         | -0.16          | -0.30          | -0.25          | -0.17          | 0.37           | 0.67**         | 0.74**          |
| BSS (Hrs)            | -0.34          | 0.71**         | -0.81**        | 0.32           | 0.48*          | -0.07          | -0.57*         | 0.57*          | -0.57*         | -0.59*          |
| <b>V2 (MAUS 71)</b>  |                |                |                |                |                |                |                |                |                |                 |
| Rainfall (mm)        | -0.07          | 0.04           | 0.83**         | 0.42           | -0.20          | -0.96**        | -0.64**        | 0.29           | 0.20           | 0.84**          |
| Tmax (°C)            | 0.95**         | 0.87**         | -0.94**        | -0.08          | -0.14          | 0.71**         | -0.03          | -0.73**        | -0.63*         | -0.28           |
| Tmin (°C)            | -0.68**        | 0.86**         | -0.06          | -0.21          | -0.86**        | -0.73**        | 0.76**         | -0.07          | 0.92**         | 0.92**          |
| RH-I (%)             | -0.65*         | -0.50*         | 0.88**         | 0.40           | -0.66**        | -0.66**        | -0.17          | -0.79**        | -0.01          | 0.97**          |
| RH-II (%)            | -0.03          | 0.01           | 0.50*          | -0.43          | -0.46*         | 0.10           | 0.05           | 0.14           | 0.48*          | 0.49*           |
| BSS (Hrs)            | -0.39          | 0.44*          | -0.72**        | 0.64*          | 0.75**         | -0.37          | -0.53*         | 0.54*          | -0.34          | -0.42           |
| <b>V3 (JS-335)</b>   |                |                |                |                |                |                |                |                |                |                 |
| Rainfall (mm)        | -0.07          | 0.19           | 0.76**         | 0.26           | -0.27          | -0.98**        | -0.67**        | 0.30           | 0.32           | 0.77**          |
| Tmax (°C)            | 0.92**         | 0.87**         | -0.96**        | -0.10          | 0.07           | 0.80**         | -0.13          | -0.66**        | -0.79**        | -0.09           |
| Tmin (°C)            | -0.56*         | 0.94**         | -0.05          | -0.39          | -0.74**        | -0.57*         | 0.84**         | -0.28          | 0.84**         | 0.97**          |
| RH-I (%)             | -0.76**        | -0.43          | 0.87**         | 0.24           | -0.69**        | -0.75**        | 0              | -0.87**        | 0.18           | 0.99**          |
| RH-II (%)            | -0.18          | -0.21          | 0.65**         | -0.21          | -0.25          | -0.01          | -0.17          | 0.36           | 0.45*          | 0.66**          |
| BSS (Hrs)            | -0.21          | 0.61*          | -0.86**        | 0.52*          | 0.68**         | -0.34          | -0.40          | 0.41           | -0.33          | -0.62**         |

\* = Significant at 5 %

\*\* = Significant at 1 %

P<sub>1</sub>- Sowing to emergence; P<sub>2</sub>- Emergence to seedling; P<sub>3</sub>-Seedling to branching; P<sub>4</sub>-Branching to flowering  
P<sub>5</sub>-Flowering to pod formation; P<sub>6</sub>-Pod formation to grain formation; P<sub>7</sub>-seed formation to pod development  
P<sub>8</sub>-Pod development to pod containing full grain size; P<sub>9</sub>-Pod containing full grain size to dough stage;  
P<sub>10</sub>-Dough stage to maturity

The maximum temperature has significant positive correlation with seed yield at P<sub>1</sub>, P<sub>2</sub> and P<sub>6</sub> stages and negatively correlated at P<sub>3</sub>, P<sub>8</sub> and P<sub>9</sub> stages of MAUS-158, MAUS-71 and JS-335 varieties. The minimum temperature has significant positive correlation with seed yield at P<sub>2</sub>, P<sub>7</sub>, P<sub>9</sub> and P<sub>10</sub> stages and negatively correlated at P<sub>5</sub> and P<sub>6</sub> stages of MAUS-158, MAUS-71 and JS-335 varieties. The RH-I has significant negative correlation with seed yield at P<sub>1</sub>, P<sub>5</sub>, P<sub>6</sub> and P<sub>8</sub> stages and positively correlated at P<sub>3</sub> and P<sub>10</sub> stages of MAUS-158, MAUS-71 and JS-335 varieties. The RH-II was significantly positively correlated with seed yield at P<sub>3</sub>, P<sub>9</sub> and P<sub>10</sub> stages of MAUS-158 & MAUS-71 varieties and P<sub>3</sub>, P<sub>5</sub>, P<sub>9</sub> and P<sub>10</sub> stages of JS-335 variety. The bright sunshine hours had significant positive correlation with seed yield at P<sub>2</sub>, P<sub>5</sub> and P<sub>8</sub> stages of MAUS-158, P<sub>2</sub>, P<sub>4</sub>, P<sub>5</sub> and P<sub>8</sub> stages of MAUS-71 and P<sub>2</sub>, P<sub>4</sub> and P<sub>5</sub> of JS-335 and negatively correlated at P<sub>3</sub>, P<sub>7</sub>, P<sub>9</sub> and P<sub>10</sub> stages of MAUS-158, P<sub>3</sub> and P<sub>7</sub> stages of MAUS-71b and P<sub>3</sub>, P<sub>7</sub> stages of JS-335 varieties.

## Vijayapura

The crop weather relationship studies in soybean at Vijayapura was started in 2016. In *kharif* 2021, the treatments consisted of three growing environments (28 June, 06 July and 20 July) and three cultivars (JS 335, DSb 21 and DSb 23-2). The six-year data was analysed for establishing relationships between stage-wise meteorological variables and soybean yield through correlation studies, and the results are presented in Table 4.14.

**Table 4.14: Correlation between seed yield of soybean (all 3 varieties) and stage wise agrometeorological variables at Vijayapura (2016-21)**

| Parameter | Germination | Seedling | Vegetative | Flowering | Pod Development | Maturity |
|-----------|-------------|----------|------------|-----------|-----------------|----------|
| Tmax      | 0.60        | -0.01    | 0.26       | 0.00      | -0.13           | -0.44    |
| Tmin      | 0.57        | 0.13     | 0.45       | 0.42      | 0.63            | 0.52     |
| VP-I      | 0.48        | 0.23     | 0.11       | 0.32      | 0.60            | 0.58     |
| VP-II     | 0.02        | -0.36    | 0.25       | 0.29      | 0.68            | 0.69     |
| RH-I      | -0.22       | 0.08     | -0.10      | 0.22      | 0.57            | 0.60     |
| RH-II     | -0.54       | -0.03    | -0.06      | 0.07      | 0.53            | 0.69     |
| EVAP      | 0.44        | 0.05     | 0.09       | -0.25     | -0.43           | -0.45    |
| RF        | -0.41       | 0.37     | -0.07      | 0.05      | 0.15            | 0.22     |
| GDD       | 0.60        | 0.11     | 0.16       | 0.14      | 0.17            | 0.16     |

Level of Significance 5% in blue, 1% in red colour

The maximum temperature and GDD during germination stage (0.60), minimum temperature during vegetative stage (0.45), and afternoon relative humidity at maturity

stage (0.69) showed the highest and highly significant correlation. On the other hand, afternoon relative humidity during germination stage (-0.54), evaporation during pod development stage (-0.43) and temperature range during maturity stage (-0.59) showed highly non-significant association with soybean grain yield.

## Groundnut

### Anantapuramu

Field experiment was taken up with rainfed and irrigated conditions as main plot treatment, three growing environments as sub-plot treatment (10 July, 24 July and 11 August 2021) and four cultivars as sub-sub-plot treatment (K6, Kadiri Harithandhra, Dharani and Anantha) during *kharif* 2021. Effect of treatments on crop phenology, GDD and HUE was studied under rainfed and protective irrigated condition are presented in Tables 4.15 and 4.16, respectively.

**Table 4.15: Effect of growing environments on phenology, GDD and HUE of groundnut under rainfed condition during *kharif* 2021 at Anantapuramu**

| Phenophases                | DAS    | GDD | AGDD | HTU<br>(°C day hour) | HUE<br>(g m <sup>-2</sup> °C days <sup>-1</sup> ) |
|----------------------------|--------|-----|------|----------------------|---------------------------------------------------|
| 1 FN of July (10 July)     |        |     |      |                      |                                                   |
| Sowing - Emergence         | 0-7    | 137 | 137  | 280                  | 0.58                                              |
| Emergence- 50% Flowering   | 8-31   | 413 | 550  | 2395                 |                                                   |
| 50% Flowering - Pegging    | 32-38  | 128 | 677  | 342                  |                                                   |
| Pegging - Pod development  | 39-54  | 209 | 887  | 998                  |                                                   |
| Pod development - Maturity | 55-103 | 881 | 1768 | 4421                 |                                                   |
| 2 FN of July (24 July)     |        |     |      |                      |                                                   |
| Sowing - Emergence         | 0-9    | 167 | 167  | 1016                 | 0.52                                              |
| Emergence- 50% Flowering   | 10-32  | 432 | 598  | 2186                 |                                                   |
| 50% Flowering - Pegging    | 33-41  | 170 | 768  | 516                  |                                                   |
| Pegging - Pod development  | 42-53  | 207 | 975  | 851                  |                                                   |
| Pod development- Maturity  | 54-107 | 932 | 1907 | 4845                 |                                                   |
| 1 FN of August (11 August) |        |     |      |                      |                                                   |
| Sowing - Emergence         | 0-8    | 140 | 140  | 231                  | 0.47                                              |
| Emergence- 50% Flowering   | 9-33   | 448 | 588  | 1988                 |                                                   |
| 50% Flowering - Pegging    | 34-39  | 126 | 714  | 746                  |                                                   |
| Pegging - Pod development  | 40-55  | 214 | 929  | 1042                 |                                                   |
| Pod development – Maturity | 56-97  | 752 | 1681 | 3467                 |                                                   |

**Table 4.16: Effect of growing environments on phenology, GDD and HUE of groundnut under protective irrigated condition during *kharif* 2021 at Anantapuramu**

| Phenophases                | DAS    | GDD | AGDD | HTU<br>(°C day hour) | HUE<br>(gm <sup>-2</sup> °C days <sup>-1</sup> ) |
|----------------------------|--------|-----|------|----------------------|--------------------------------------------------|
| 1 FN of July (10 July)     |        |     |      |                      |                                                  |
| Sowing - Emergence         | 0-7    | 137 | 137  | 280                  | 0.62                                             |
| Emergence - 50% Flowering  | 8-31   | 413 | 550  | 2395                 |                                                  |
| 50% Flowering - Pegging    | 32-38  | 128 | 677  | 342                  |                                                  |
| Pegging - Pod development  | 39-54  | 209 | 887  | 998                  |                                                  |
| Pod development - Maturity | 55-106 | 928 | 1815 | 4421                 |                                                  |
| 2 FN of July (24 July)     |        |     |      |                      |                                                  |
| Sowing - Emergence         | 0-9    | 167 | 167  | 1016                 | 0.64                                             |
| Emergence - 50% Flowering  | 10-32  | 432 | 598  | 2186                 |                                                  |
| 50% Flowering - Pegging    | 33-41  | 170 | 768  | 516                  |                                                  |
| Pegging - Pod development  | 42-53  | 207 | 975  | 851                  |                                                  |
| Pod development - Maturity | 54-107 | 932 | 1907 | 4845                 |                                                  |
| 1 FN of August (11 August) |        |     |      |                      |                                                  |
| Sowing - Emergence         | 0-8    | 140 | 140  | 231                  | 0.48                                             |
| Emergence - 50% Flowering  | 9-33   | 448 | 588  | 1988                 |                                                  |
| 50% Flowering - Pegging    | 34-39  | 126 | 714  | 746                  |                                                  |
| Pegging - Pod development  | 40-50  | 214 | 929  | 1042                 |                                                  |
| Pod development - Maturity | 56-97  | 752 | 1681 | 3467                 |                                                  |

In the case of rainfed groundnut, crop sown during first fortnight of July recorded highest HUE (Table 4.15). However, the HTU, AGDD and total crop duration was highest for crop sown during second fortnight of July. Under protective irrigation, crop sown during second fortnight of July recorded highest HUE, HTU, AGDD and total crop duration (Table 4.16). The HUE was higher under protective irrigated condition compared to rainfed condition at Anantapur. The differences in phenology was observed only for the crop sown on first fortnight of July (07 July) where rainfed crop attained physiological maturity around 103 days after sowing, whereas crop raised with protective irrigation took 107 days for the same.

Correlation study between dry matter production and weather parameters during different phenophases of groundnut crop was carried out using field experimental data during 2015-20 and the results are presented in Table 4.17. Bright sunshine hours during emergence to flowering showed significant negative correlation with yield. Rainfall and AGDD during pod initiation to pod maturity showed significant positive correlation with pod yield.

**Table 4.17: Correlation between dry matter production and weather parameters during different phenophases of groundnut (2015-2020) at Anantapuramu**

| Growth stage                | TMax   | TMin  | TMean | RH-I  | RH-II | WS     | RF     | SSH     | EVP    | GDD    |
|-----------------------------|--------|-------|-------|-------|-------|--------|--------|---------|--------|--------|
| Sowing-Emergence            | -0.04  | 0.04  | -0.02 | -0.14 | 0.05  | 0.28   | -0.09  | -0.28   | 0.07   | -0.22  |
| Emergence-50% flowering     | 0.06   | 0.38  | 0.24  | -0.35 | -0.05 | 0.35   | -0.18  | -0.532* | 0.09   | -0.31  |
| 50% flowering - Pegging     | 0.12   | 0.30  | 0.22  | 0.09  | -0.12 | 0.0    | 0.18   | 0.36    | 0.06   | 0.22   |
| Pegging-Pod initiation      | 0.25   | 0.10  | 0.22  | 0.0   | -0.06 | -0.27  | 0.10   | 0.07    | 0.07   | 0.26   |
| Pod initiation-pod maturity | -0.267 | 0.438 | 0.128 | 0.40  | 0.415 | -0.266 | 0.570* | -0.237  | -0.134 | 0.482* |

## Cotton

### Akola

A field experiment was conducted in Akola with two growing environments (normal sowing on 28 June and late sowing on 13 July) with two planting densities (60 x 20 cm and 75 x 20 cm) and three genotypes [AKH-081 (*G. hirsutum*), AKA-7 (*G. arboreum*) and Balwan NCS 8899 BG-II (Bt Cotton)] was taken up during *kharif* 2021. Effect of treatments on seed cotton yield, stalk yield, harvest index and thermal use efficiency (TUE) was studied and result is presented in Table 4.18.

Significant higher seed yield (1018.94 kg ha<sup>-1</sup>) was obtained when crop was sown on 28 June (Monsoon sowing) than that of late sown crop. This was due to reduced soil moisture regime and less favourable weather variables encountered across late sown crop. Cotton stalk yield, biological yield and harvest index followed similar trend as that of seed cotton yield. The population density (P<sub>1</sub>) of 60 x 20 cm (83,333 plants ha<sup>-1</sup>) produced marginally more seed cotton yield (930.72 kg ha<sup>-1</sup>) than population density of 75 x 20 cm (66,666 plants ha<sup>-1</sup>) which yielded 833.72 kg ha<sup>-1</sup>.

All the cotton genotypes differed from each other for seed cotton yield ha<sup>-1</sup>. Genotype Bt cotton Balwan recorded significantly higher seed cotton yield (1019.75 kg ha<sup>-1</sup>) than hirsutum cotton AKH 081 (859.50 kg ha<sup>-1</sup>) and arboreum cotton AKA 7 (767.42 kg ha<sup>-1</sup>) Stalk yield and biological yield were significantly higher with Balwan followed by AKH 081 and AKA 7. Harvest index was significantly higher under Balwan (36.8%) followed by AKH 081 (36.7%) and least under AKA 7 (36.3%). Heat use efficiency was found to be higher for monsoon sown crop (D1) with respect to both seed cotton and biomass production and it decreased in subsequent late sowing (D2).

**Table 4.18: Seed cotton yield, cotton stalk yield, biological yield and harvest index as influenced by different treatments**

| Treatment                      | Seed cotton yield (kg ha <sup>-1</sup> ) | Cotton stalk yield (kg ha <sup>-1</sup> ) | Biological yield(kg ha <sup>-1</sup> ) | Harvest index (%) | Thermal use efficiency (kg ha <sup>-1</sup> °C day <sup>-1</sup> ) |
|--------------------------------|------------------------------------------|-------------------------------------------|----------------------------------------|-------------------|--------------------------------------------------------------------|
| <b>Weather variability</b>     |                                          |                                           |                                        |                   |                                                                    |
| D <sub>1</sub> -Monsoon sowing | 1019                                     | 1755                                      | 2774                                   | 36.7              | 0.43 (0.74)                                                        |
| D <sub>2</sub> - Late sowing   | 746                                      | 1293                                      | 2039                                   | 36.5              | 0.35 (0.61)                                                        |
| SE(m)±                         | 25.0                                     | 47.3                                      | 71.8                                   | --                | --                                                                 |
| CD (P=0.05)                    | 86.7                                     | 163.8                                     | 248.6                                  | --                | --                                                                 |
| CV%                            | 12.0                                     | 13.1                                      | 12.6                                   | --                | --                                                                 |
| <b>Population density</b>      |                                          |                                           |                                        |                   |                                                                    |
| P <sub>1</sub> - 60 x 20 cm    | 931                                      | 1595                                      | 2525                                   | 36.8              | 0.42 (0.71)                                                        |
| P <sub>2</sub> - 75 x 20 cm    | 834                                      | 1454                                      | 2288                                   | 36.4              | 0.37 (0.64)                                                        |
| SE(m)±                         | 25.0                                     | 47.4                                      | 71.9                                   | --                | --                                                                 |
| CD (P=0.05)                    | 86.6                                     | NS                                        | NS                                     | --                | --                                                                 |
| CV%                            | 12.0                                     | 13.2                                      | 12.6                                   | --                | --                                                                 |
| <b>Genotype</b>                |                                          |                                           |                                        |                   |                                                                    |
| V <sub>1</sub> -AKH 081        | 860                                      | 1480                                      | 2340                                   | 36.7              | 0.39 (0.67)                                                        |
| V <sub>2</sub> -AKA 7          | 767                                      | 1347                                      | 2114                                   | 36.3              | 0.34 (0.64)                                                        |
| V <sub>3</sub> -Balwan         | 1020                                     | 1745                                      | 2765                                   | 36.8              | 0.44 (0.75)                                                        |
| SE(m)±                         | 37.5                                     | 62.6                                      | 99.5                                   | --                | --                                                                 |
| CD (P=0.05)                    | 112.6                                    | 187.7                                     | 298.3                                  | --                | --                                                                 |
| CV%                            | 14.7                                     | 14.2                                      | 14.3                                   | --                | --                                                                 |
| <b>Interaction</b>             |                                          |                                           |                                        |                   |                                                                    |
| D x P                          | NS                                       | NS                                        | NS                                     | --                | --                                                                 |
| D x V                          | NS                                       | NS                                        | NS                                     | --                | --                                                                 |
| P x V                          | NS                                       | NS                                        | NS                                     | --                | --                                                                 |
| D x P x V                      | NS                                       | NS                                        | NS                                     | --                | --                                                                 |

Figures in parentheses indicate thermal use efficiency in terms of biomass

As of the different population densities, Heat use efficiency in terms of seed cotton yield and biomass production was higher with the population density of 60 x 20 cm (83,333 plants ha<sup>-1</sup>) followed by 75 x 20 cm (66,666 plants ha<sup>-1</sup>). Heat use efficiency was found to be higher in Balwan (V<sub>3</sub>) and AKH 081 varieties with respect to seed cotton and biomass production. It was followed by AKA-7 variety.

## Rabi 2021-22

### Wheat

#### Chatha

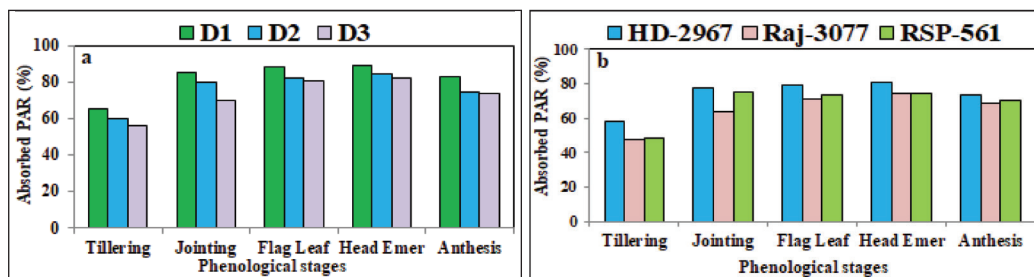
The field experiment was taken up with three growing environments (06 Nov, 22 Nov and 06 Dec 2021) and three cultivars (HD-2967, Raj-3077 and RSP-561) during *rabi* 2021-22. Effect of growing environments and varieties on radiation use efficiency was quantified and presented in Table 4.19

**Table 4.19: Radiation use efficiency ( $\text{g MJ}^{-1} \text{m}^{-2}$ ) at different growth intervals of wheat varieties sown under different growing environments during *rabi* 2021-22 at Chatha**

| Treatments                 | Days after sowing |      |      |      |      |      |      |      |
|----------------------------|-------------------|------|------|------|------|------|------|------|
|                            | 30                | 45   | 60   | 75   | 90   | 105  | 120  | 135  |
| <b>Dates of sowing</b>     |                   |      |      |      |      |      |      |      |
| D <sub>1</sub> - 06 Nov 22 | 0.35              | 0.40 | 0.42 | 0.49 | 0.54 | 0.91 | 1.08 | 0.94 |
| D <sub>2</sub> - 22 Nov 22 | 0.27              | 0.38 | 0.40 | 0.47 | 0.72 | 0.81 | 0.96 | 0.77 |
| D <sub>3</sub> - 06 Dec 22 | 0.26              | 0.37 | 0.38 | 0.42 | 0.45 | 0.66 | 0.71 | 0.68 |
| <b>Varieties</b>           |                   |      |      |      |      |      |      |      |
| V <sub>1</sub> - HD2967    | 0.31              | 0.41 | 0.45 | 0.54 | 0.64 | 0.87 | 1.04 | 0.90 |
| V <sub>2</sub> - Raj 3077  | 0.30              | 0.35 | 0.34 | 0.40 | 0.52 | 0.73 | 0.80 | 0.70 |
| V <sub>3</sub> - RSP561    | 0.29              | 0.39 | 0.40 | 0.43 | 0.54 | 0.77 | 0.88 | 0.77 |

The crop sown on 06 November recorded highest RUE ( $1.08 \text{ g MJ}^{-1} \text{m}^{-2}$ ) than 22 November ( $0.96 \text{ g MJ}^{-1} \text{m}^{-2}$ ) and 06 December ( $0.71 \text{ g MJ}^{-1} \text{m}^{-2}$ ) sown crop at 120 days after sowing. The RUE of wheat crop decreased with delayed sowing. The RUE of wheat increased with growth of the crop and recorded highest value at 120 days after sowing and decreased thereafter under all the dates of sowing. Among the varieties, RUE increased from 30 to 120 DAS and the variety HD-2967 recorded highest RUE ( $1.04 \text{ g MJ}^{-1} \text{m}^{-2}$ ) followed by RSP-561 ( $0.88 \text{ g MJ}^{-1} \text{m}^{-2}$ ) and Raj-3077 ( $0.80 \text{ g MJ}^{-1} \text{m}^{-2}$ ) at 120 days after sowing, after which it decreased. The reason for this decline in RUE after 120 DAS might be due to less dry matter accumulation by the crop because of decreased chlorophyll content at the later stages. The variety (HD 2967) has recorded highest radiation use efficiency at various growth interval of time followed by RSP561 and Raj 3077. Due to higher RUE, the more total above ground dry matter produced by the variety HD-2967 and recorded higher yield than the other two varieties.

A study on variation in absorbed photosynthetically active radiation (APAR) under different growing environments and varieties was also studied and the result is presented in Fig. 4.10a and b.



$D_1$  - 06 Nov 22,  $D_2$  - 22 Nov 22,  $D_3$  - 06 Dec 22

**Fig. 4.10: Effect of (a) growing environments and (b) varieties on APAR at various growth stages of wheat during rabi 2021-22 at Chatha**

The wheat crop sown on 06 November has utilized the maximum PAR as compared to crop sown on 22 November and 06 December. The per cent PAR absorptivity increased from tillering to hard dough stage and decreases thereafter due to the senescence of leaves in all sowing environments. The early sown wheat crop utilized maximum PAR and it ranged from 65 to 89 per cent of the total incident radiation, whereas in 22 November (normal) and 06 December (late) sown crop, the absorbed PAR ranged from 60 to 84 per cent and 56 to 82 percent, respectively. In early, normal and late sown crop, the maximum absorbed PAR recorded were 89, 84 and 82 percent, respectively at spike emergence stage. The variety HD 2967 utilized more absorbed PAR (80 per cent) and ranges from 58 to 80 per cent of the incident PAR, whereas in variety Raj-3077 and RSP-561 the absorbed PAR varies from 47 to 73 per cent and 48 to 74 per cent, respectively.

### Kanpur

Crop weather relationship study in wheat was taken up with three growing environments (30 Nov, 15 Dec and 30 Dec 2021) and four cultivars (HD-2733, K-307, K-9107 and HD-2967) to for eight years (2014-15 to 2021-22). The data was used to identify optimum temperature thresholds for obtaining various yield levels viz., above average, average and below average. The result is presented in Table 4.20.

The results indicated that above average yields were obtained when average maximum and minimum temperatures from jointing to maturity were lower, and vice-versa. Due to the highest per cent of yield loss, the variety HD-2967 was identified as the sensitive to heat stress.

**Table 4.20: Temperature (°C) during different phenological stages of four wheat cultivars for obtaining three different categories of yield**

| Yield category                                     | Emergence | CRI  | Tillering | Jointing | PI   | Flowering | Anthesis | Milking | Dough | Maturity | Yield (kg ha <sup>-1</sup> ) |
|----------------------------------------------------|-----------|------|-----------|----------|------|-----------|----------|---------|-------|----------|------------------------------|
| <b>Variety: HD-2733 - Maximum temperature (°C)</b> |           |      |           |          |      |           |          |         |       |          |                              |
| Above average                                      | 27.1      | 24.9 | 21.8      | 19.9     | 21.6 | 21.9      | 23.6     | 25.2    | 27.4  | 31.4     | 5106                         |
| Average                                            | 24.8      | 22.8 | 19.5      | 20.7     | 22.7 | 24.8      | 27.6     | 29.8    | 32.4  | 36.1     | 4488                         |
| Below average                                      | 21.9      | 19.9 | 20.6      | 23.5     | 26.1 | 27.1      | 29.3     | 31.1    | 33.9  | 35.6     | 3558                         |
| <b>Variety: HD-2733 - Minimum temperature (°C)</b> |           |      |           |          |      |           |          |         |       |          |                              |
| Above average                                      | 11.8      | 9.9  | 8.1       | 7.1      | 8.0  | 9.0       | 9.6      | 11.4    | 13.1  | 15.0     | 5106                         |
| Average                                            | 10.3      | 9.3  | 7.8       | 7.5      | 8.1  | 10.0      | 11.9     | 14.8    | 16.0  | 17.9     | 4488                         |
| Below average                                      | 9.0       | 7.4  | 8.2       | 9.8      | 11.4 | 13.2      | 14.6     | 16.0    | 17.4  | 18.2     | 3558                         |
| <b>Variety: K-307 - Maximum temperature (°C)</b>   |           |      |           |          |      |           |          |         |       |          |                              |
| Above average                                      | 27.3      | 25.3 | 21.5      | 20.0     | 21.7 | 22.2      | 23.8     | 26.5    | 27.5  | 32.3     | 4782                         |
| Average                                            | 25.3      | 23.0 | 20.8      | 21.0     | 23.3 | 24.5      | 27.5     | 28.2    | 31.0  | 34.5     | 4165                         |
| Below average                                      | 21.9      | 19.8 | 20.3      | 23.4     | 26.5 | 27.5      | 29.9     | 31.9    | 35.1  | 37.0     | 3379                         |
| <b>Variety: K-307 - Minimum temperature (°C)</b>   |           |      |           |          |      |           |          |         |       |          |                              |
| Above average                                      | 12.2      | 10.4 | 8.4       | 6.9      | 8.2  | 8.5       | 9.6      | 12.4    | 13.1  | 16.1     | 4782                         |
| Average                                            | 10.0      | 8.8  | 7.4       | 7.9      | 8.7  | 10.3      | 12.9     | 13.7    | 15.3  | 17.7     | 4165                         |
| Below average                                      | 9.1       | 7.5  | 8.3       | 9.8      | 11.5 | 13.5      | 14.8     | 16.4    | 17.7  | 18.9     | 3379                         |
| <b>Variety: K-9107 - Maximum temperature (°C)</b>  |           |      |           |          |      |           |          |         |       |          |                              |
| Above average                                      | 26.9      | 25.3 | 21.4      | 20.1     | 21.9 | 23.4      | 25.2     | 27.9    | 29.3  | 33.9     | 4284                         |
| Average                                            | 25.4      | 22.4 | 20.6      | 21.1     | 23.5 | 25.0      | 27.5     | 28.8    | 32.3  | 35.8     | 3813                         |
| Below average                                      | 21.5      | 19.5 | 20.5      | 24.2     | 27.6 | 28.0      | 30.6     | 33.1    | 35.5  | 37.2     | 3055                         |

| Yield category                                     | Emergence | CRI  | Tillering | Jointing | PI   | Flowering | Anthesis | Milking | Dough | Maturity | Yield<br>(kg ha <sup>-1</sup> ) |
|----------------------------------------------------|-----------|------|-----------|----------|------|-----------|----------|---------|-------|----------|---------------------------------|
| <b>Variety: K-9107 - Minimum temperature (°C)</b>  |           |      |           |          |      |           |          |         |       |          |                                 |
| Above average                                      | 11.6      | 10.6 | 8.1       | 7.3      | 8.1  | 8.7       | 10.9     | 13.3    | 14.4  | 16.8     | 4284                            |
| Average                                            | 10.7      | 8.2  | 7.6       | 7.9      | 9.5  | 10.3      | 13.1     | 14.0    | 15.8  | 18.0     | 3813                            |
| Below average                                      | 8.6       | 7.4  | 8.3       | 10.3     | 12.6 | 14.0      | 15.5     | 16.9    | 18.3  | 19.6     | 3055                            |
| <b>Variety: HD-2967 - Maximum temperature (°C)</b> |           |      |           |          |      |           |          |         |       |          |                                 |
| Above average                                      | 27.1      | 24.9 | 21.6      | 20.2     | 22.0 | 22.3      | 24.1     | 26.4    | 28.1  | 32.9     | 5330                            |
| Average                                            | 25.0      | 22.8 | 20.1      | 20.8     | 23.8 | 25.9      | 28.6     | 29.7    | 33.1  | 36.3     | 4690                            |
| Below average                                      | 21.8      | 19.8 | 20.6      | 23.8     | 27.0 | 27.4      | 30.1     | 32.3    | 34.9  | 36.6     | 3679                            |
| <b>Variety: HD-2967 - Minimum temperature (°C)</b> |           |      |           |          |      |           |          |         |       |          |                                 |
| Above average                                      | 11.8      | 9.8  | 8.0       | 7.3      | 8.4  | 8.9       | 10.2     | 12.2    | 13.4  | 11.8     | 5330                            |
| Average                                            | 10.8      | 9.0  | 8.1       | 7.6      | 8.7  | 10.5      | 13.3     | 14.9    | 16.9  | 18.1     | 4690                            |
| Below average                                      | 8.7       | 7.5  | 8.2       | 10.2     | 12.3 | 13.6      | 15.1     | 16.6    | 17.9  | 19.0     | 3679                            |
| <b>All varieties - Maximum temperature (°C)</b>    |           |      |           |          |      |           |          |         |       |          |                                 |
| Above average                                      | 26.7      | 24.7 | 21.4      | 19.6     | 21.8 | 22.8      | 24.8     | 27.1    | 29.3  | 33.2     | 5082                            |
| Average                                            | 25.5      | 23.2 | 20.3      | 20.8     | 23.3 | 24.5      | 27.2     | 28.9    | 31.4  | 35.3     | 4274                            |
| Below average                                      | 21.6      | 19.6 | 20.5      | 24.0     | 26.9 | 27.7      | 30.0     | 32.0    | 34.8  | 36.5     | 3347                            |
| <b>All varieties - Minimum temperature (°C)</b>    |           |      |           |          |      |           |          |         |       |          |                                 |
| Above average                                      | 11.7      | 9.9  | 8.1       | 7.1      | 7.7  | 8.9       | 10.6     | 12.8    | 14.4  | 16.3     | 5082                            |
| Average                                            | 10.7      | 8.9  | 7.8       | 7.7      | 9.1  | 10.1      | 12.2     | 14.1    | 15.5  | 17.6     | 4274                            |
| Below average                                      | 8.8       | 7.5  | 8.2       | 10.1     | 12.0 | 13.7      | 15.1     | 16.4    | 17.8  | 19.0     | 3347                            |

## Maize

### Kovilpatti

Crop weather relationship studies were taken up with four growing environments (39, 40, 41 and 42 SWMs) and four hybrids (S 6850, NK6240, RMH 3033 and COHM 6) during *rabi* 2021-22. Effect of growing environments and hybrids on plant height, LAI, yield and yield attributes of maize is presented in Table 4.21.

Crop sown during 39 and 42 SMWs recorded the highest and lowest crop height, respectively. It was observed that the mean crop height decreased up on subsequent delay in the sowing time from 39 SMW. Among hybrids, COH (M)6 was the tallest and S 6850 was the shortest. Similar result was observed in the case of LAI also, where crop sown during 39 SMW recorded the highest LAI at tasselling and it reduced as the crop sowing got delayed.

**Table 4.21: Influence of sowing environments on growth attributes and yield parameters of maize hybrids under rainfed condition during 2020 - 2021**

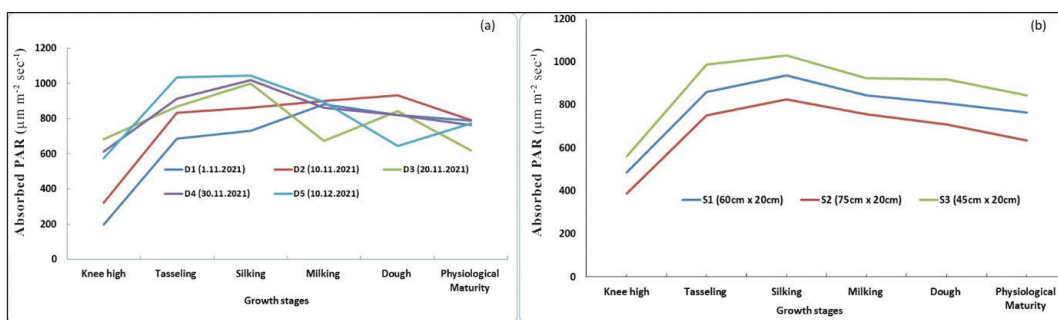
| Treat-ments                 | Plant height (cm) | LAI at tasseling | Cob length (cm) | Cob girth (cm) | Grain rows cob <sup>-1</sup> | Grains row <sup>-1</sup> | 100 seed weight (g) | Grain yield (kg ha <sup>-1</sup> ) | Stover yield (kg ha <sup>-1</sup> ) |
|-----------------------------|-------------------|------------------|-----------------|----------------|------------------------------|--------------------------|---------------------|------------------------------------|-------------------------------------|
| <b>Growing environments</b> |                   |                  |                 |                |                              |                          |                     |                                    |                                     |
| 39 SMW (26 Sep)             | 268.2             | 6.24             | 16.82           | 14.98          | 16.62                        | 28.84                    | 32.10               | 4864                               | 8926                                |
| 40 SMW (03 Oct)             | 245.8             | 6.04             | 15.86           | 12.93          | 15.40                        | 26.21                    | 31.60               | 4470                               | 8320                                |
| 41 SMW (10 Oct)             | 234.5             | 5.60             | 12.16           | 10.82          | 14.32                        | 24.30                    | 28.40               | 3860                               | 7025                                |
| 42 SMW (17 Oct 17)          | 218.4             | 4.92             | 11.6            | 9.43           | 11.86                        | 20.38                    | 24.36               | 3320                               | 6278                                |
| CD (5 %)                    | 5.2               | 0.18             | 0.38            | 0.43           | 0.41                         | 0.76                     | 0.28                | 148                                | 241                                 |
| <b>Hybrids</b>              |                   |                  |                 |                |                              |                          |                     |                                    |                                     |
| S 6850                      | 188.4             | 5.21             | 10.81           | 11.60          | 11.16                        | 22.1                     | 31.20               | 3420                               | 6725                                |
| NK6240                      | 208.6             | 5.82             | 12.48           | 14.12          | 13.86                        | 26.4                     | 32.18               | 4460                               | 8280                                |
| RMH 3033                    | 206.2             | 5.61             | 12.14           | 13.28          | 12.16                        | 24.3                     | 31.80               | 4052                               | 7650                                |
| COH (M) 6                   | 278.4             | 6.36             | 16.42           | 16.18          | 15.78                        | 28.6                     | 33.20               | 4928                               | 9115                                |
| CD (5%)                     | 6.3               | 0.14             | 0.28            | 0.41           | 0.32                         | 0.60                     | 0.38                | 146                                | 218                                 |

The grain and stover yields were also greatly influenced by the sowing windows on maize hybrids. The 39 SMW sown crop recorded the highest grain yield (4652 kg ha<sup>-1</sup>) and stover yield (7916 kg ha<sup>-1</sup>) than the other sowing windows. This was followed by 40 SMW sown

crop. The lowest grain yield ( $3120 \text{ kg ha}^{-1}$ ) and stover yield ( $5632 \text{ kg ha}^{-1}$ ) was registered by the 42 SMW sown crop. Maize hybrid COH (M) 6 recorded the highest grain yield ( $4123 \text{ kg ha}^{-1}$ ) and stover yield ( $8354 \text{ kg ha}^{-1}$ ) than other hybrids tested. This was followed by NK 6240 hybrid. Maize hybrid S6850 has given the lowest grain yield ( $4012 \text{ kg ha}^{-1}$ ) and stover yield ( $6750 \text{ kg ha}^{-1}$ ) under rainfed vertisols tract of Kovilpatti region. Early sown maize hybrids ( $D_{11}$ ) received higher amount of rainfall ( $498 \text{ mm}$ ) and even distribution (31 rainy days) throughout the crop growth period, which favoured the growth and higher yield than the other sowing environments.

## Samastipur

Impact of growing environments (01 Nov, 10 Nov, 20 Nov, 30 Nov and 10 Dec) and spacing ( $60 \times 20 \text{ cm}$ ,  $75 \times 20 \text{ cm}$  and  $45 \times 20 \text{ cm}$ ) on absorbed PAR of *rabi* maize was studied during *rabi* 2021-22 and presented in Fig. 4.11.



**Fig. 4.11: Effect of (a) growing environments and (b) spacing on absorbed PAR of maize at Samastipur during *rabi* 2021-22**

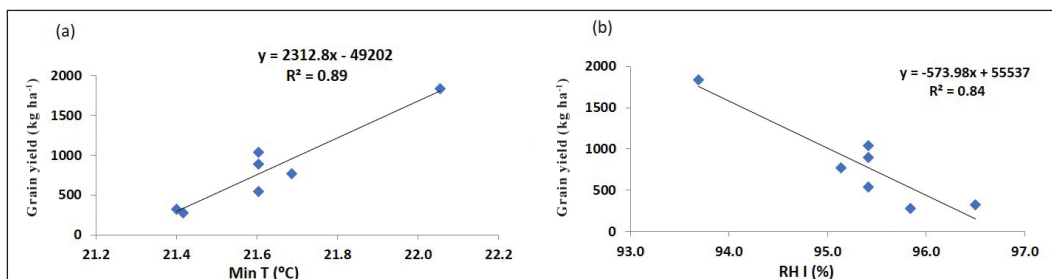
It was observed that silking stage of the crop absorbed the highest PAR ( $931.2 \mu\text{m}^2 \text{ sec}^{-1}$ ), followed by tasselling stage ( $867.0 \mu\text{m}^2 \text{ sec}^{-1}$ ). Varying plant densities significantly influenced PAR absorption by the crop. Densely planted crop ( $45 \times 20 \text{ cm}$ ) absorbed more PAR than other two wider spacing. The highest absorption was recorded by the crop sown on 30 November and the lowest by 1 November sown crop. The Interaction effect between dates of sowing and spacing on PAR absorption was found to be significant only in silking stage.

## Sorghum

### Kovilpatti

A field experiment was conducted with three growing environments (sown on 39 SMW, 41 SMW and 43 SMW) and four sorghum genotypes (K-12, K-8, CSV-20 and CO-30)

during *rabi* 2021-22. Effect of minimum temperature during grain development stage and minimum temperature during vegetative stage on grain yield of *rabi* sorghum is presented in Fig. 4.12.



**Fig. 4. 12: Effect of minimum temperature on grain yield of *rabi* sorghum during (a) grain development stage and (b) vegetative stage at Kovilpatti during 2021-22**

There was a linear relationship with increase in minimum temperature at grain development stage. Increase in minimum temperature (>21.4 °C) during grain development stage ultimately increase grain yield of sorghum. Sorghum crop damaged severely by fall army incidence when RH-I exceeded 95% during vegetative stage, which affect the yield of sorghum. Effect of growing environments and genotypes on plant height, maximum LAI, yield and yield attributes is presented in Table 4.22.

**Table 4.22: Effect of growing environments on plant height, yield parameters and yield of sorghum genotypes under rainfed condition during *rabi* 2021-2022 at Kovilpatti**

| Treatments                  | Plant height (cm) | LAI  | DMP (kg ha <sup>-1</sup> ) | No. of seeds panicle <sup>-1</sup> | 1000 seed weight (g) | Grain yield (kg ha <sup>-1</sup> ) | Straw yield (kg ha <sup>-1</sup> ) |
|-----------------------------|-------------------|------|----------------------------|------------------------------------|----------------------|------------------------------------|------------------------------------|
| <b>Growing environments</b> |                   |      |                            |                                    |                      |                                    |                                    |
| D <sub>1</sub> : 39 SMW     | 240.2             | 6.25 | 10420                      | 840                                | 19.3                 | 1832                               | 8588                               |
| D <sub>2</sub> : 41 SMW     | 232.8             | 6.28 | 8399                       | 436                                | 15.2                 | 324                                | 8075                               |
| D <sub>3</sub> : 43 SMW     | 218.9             | 5.24 | 7070                       | 402                                | 14.5                 | 276                                | 6760                               |
| SEd                         | 18.5              | 0.28 | 474                        | 34                                 | 1.3                  | 81                                 | 421                                |
| CD (5 %)                    | NS                | 0.79 | 1315                       | 95                                 | 3.6                  | 225                                | 1170                               |
| <b>Varieties</b>            |                   |      |                            |                                    |                      |                                    |                                    |
| V <sub>1</sub> : K 12       | 243.5             | 6.16 | 8344                       | 484                                | 15.3                 | 541                                | 7803                               |
| V <sub>2</sub> : K 8        | 174.4             | 5.66 | 5548                       | 555                                | 16.2                 | 772                                | 4777                               |
| V <sub>3</sub> : CSV 20     | 261.6             | 5.80 | 10533                      | 624                                | 17.2                 | 1041                               | 9446                               |
| V <sub>4</sub> : CO 30      | 243.0             | 6.07 | 10094                      | 575                                | 16.7                 | 891                                | 9203                               |
| SEd                         | 18.5              | 0.22 | 401                        | 36                                 | 0.8                  | 73                                 | 354                                |
| CD (5%)                     | 38.8              | NS   | 842                        | 76                                 | NS                   | 153                                | 744                                |

Higher plant height (240.2 cm), leaf area index (6.27) and dry matter production (10420 kg ha<sup>-1</sup>) was recorded by 39 standard week sown crop (D<sub>1</sub>). The increased growth attributes under D<sub>1</sub> was due to the favorable weather elements like maximum and minimum temperature, sunshine hours with higher growing degree day and evenly distributed rainfall throughout the growing season compared to monsoon (D<sub>2</sub>) and post monsoon sown crop (D<sub>3</sub>). Among the varieties, CSV 20 recorded significantly higher plant height (261.6 cm) and dry matter production (10533 kg ha<sup>-1</sup>).

## Solapur

A field experiment with four growing environments (36, 38, 40 and 42 SMWs) and three varieties (M-35-1, Mauli and Yashoda) was taken up during *rabi* 2021-22. The pooled data of 2016-17 to 2021-22 was used to estimate the Consumptive Use of Moisture (CUM) and Moisture Use Efficiency (MUE) in *rabi* sorghum and the result is presented in Table 4.23.

**Table 4.23: Consumptive Use of Moisture (CUM) and moisture use efficiency (MUE) as influenced by growing environments in *rabi* sorghum (2016-17 to 2021-22)**

| Sowing Time    | CUM (mm) |       |         |      | MUE (kg ha <sup>-1</sup> mm <sup>-1</sup> ) |       |         |      |
|----------------|----------|-------|---------|------|---------------------------------------------|-------|---------|------|
|                | M-35-1   | Mauli | Yashoda | Mean | M-35-1                                      | Mauli | Yashoda | Mean |
| S <sub>1</sub> | 290      | 270   | 267     | 276  | 2.7                                         | 2.5   | 2.3     | 2.5  |
| S <sub>2</sub> | 283      | 270   | 268     | 274  | 3.0                                         | 2.8   | 2.6     | 2.8  |
| S <sub>3</sub> | 268      | 300   | 295     | 288  | 3.0                                         | 2.8   | 2.7     | 2.8  |
| S <sub>4</sub> | 193      | 180   | 175     | 183  | 2.5                                         | 2.3   | 2.3     | 2.4  |
| Mean           | 258      | 255   | 251     | 255  | 2.8                                         | 2.6   | 2.4     | 2.6  |

S<sub>1</sub>: 26 SMW, S<sub>2</sub>: 38 SMW, S<sub>3</sub>: 40 SMW and S<sub>4</sub>: 42 SMW

Among the varieties, highest mean CUM was recorded for M-35-1 (258 mm) and the lowest was for Yashoda (251 mm). Among different growing environments, crop sown on 40 SMW recorded the highest CUM and that of 42 SMW recorded the lowest.

## Barley

### Hisar

Crop weather relationship studies in Barley was taken up during *rabi* 2021-22 with four crop growing environments (sown on 17 Nov, 30 Nov, 15 Dec and 30 Dec) and four varieties (BH 393, BH 902, BH 946 and BH 885). Effect of crop growing environments on barley varieties during *rabi* 2021-22 was studied and results are presented in Table 4.24. Leaf area of barley crop increased with advancement of crop growth and development, and reached at

peak at booting stage and decreased there after (Table 4.24). This may be due to diversion of assimilates to reproductive part and no addition of new leaf after flag leaf stage. As the sowing of barley delayed, the LAI also decreased gradually. The effect of crop growing environments and varieties on yield and yield attributes of barley is presented in Table 4.25.

Significantly higher LAI was recorded in D<sub>1</sub> as compared to other sowing environments at each phenophase of barley. Maximum LAI at booting stage was attained by barley crop sown on D<sub>1</sub> (6.42), followed by subsequent sowing environments viz. D<sub>2</sub> (5.95), D<sub>3</sub> (5.43) and D<sub>4</sub> (5.19). Among the varieties, BH 902 recorded highest LAI (6.53) followed by BH946 (5.99), BH 393 (5.58) and BH 885 (4.89). Significantly higher number of effective tillers (963 per square meter) were recorded in D<sub>1</sub> as compared to subsequent sowing environments. Among varieties, BH 902 recorded significantly more effective tillers per unit area (857 per square meter) than BH 946 (788 per square meter) and BH 885 (770 per square meter).

**Table 4.24: Effect of crop growing environments on Leaf Area Index (LAI) of barley varieties during *rabi* 2021-22 at Hisar**

| Treatment                                                                                                            | Leaf Area Index |       |       |       |       |       |       |
|----------------------------------------------------------------------------------------------------------------------|-----------------|-------|-------|-------|-------|-------|-------|
|                                                                                                                      | CRI             | T     | J     | B     | A     | M     | D     |
| <b>Planting dates</b>                                                                                                |                 |       |       |       |       |       |       |
| D <sub>1</sub> (17 Nov 21)                                                                                           | 0.83            | 3.39  | 4.96  | 6.42  | 5.46  | 3.80  | 3.11  |
| D <sub>2</sub> (30 Nov 21)                                                                                           | 0.82            | 3.02  | 4.76  | 5.95  | 4.57  | 3.29  | 2.49  |
| D <sub>3</sub> (15 Dec 21)                                                                                           | 0.73            | 2.74  | 4.17  | 5.43  | 4.01  | 3.27  | 2.32  |
| D <sub>4</sub> (30 Dec 21)                                                                                           | 0.64            | 2.53  | 3.79  | 5.19  | 3.89  | 3.18  | 2.14  |
| SE(m)                                                                                                                | 0.026           | 0.059 | 0.056 | 0.071 | 0.063 | 0.009 | 0.076 |
| CD (A) at 5%                                                                                                         | 0.091           | 0.208 | 0.198 | 0.252 | 0.221 | 0.032 | 0.269 |
| <b>Varieties</b>                                                                                                     |                 |       |       |       |       |       |       |
| V <sub>1</sub> (BH 393)                                                                                              | 0.76            | 2.91  | 4.23  | 5.58  | 4.39  | 3.38  | 2.48  |
| V <sub>2</sub> (BH 902)                                                                                              | 0.78            | 3.39  | 5.40  | 6.53  | 5.06  | 3.69  | 2.68  |
| V <sub>3</sub> (BH 946)                                                                                              | 0.76            | 2.91  | 4.50  | 5.99  | 4.69  | 3.62  | 2.53  |
| V <sub>4</sub> (BH 885)                                                                                              | 0.71            | 2.47  | 3.56  | 4.89  | 3.79  | 2.84  | 2.37  |
| SE(m)                                                                                                                | 0.012           | 0.054 | 0.068 | 0.103 | 0.078 | 0.200 | 0.056 |
| CD (B) at 5%                                                                                                         | 0.036           | 0.159 | 0.199 | 0.304 | 0.228 | 0.588 | 0.165 |
| <i>CRI- crown root initiation, T- tillering, J- jointing, B- booting, A- anthesis, M- milking and D- dough stage</i> |                 |       |       |       |       |       |       |

**Table 4.25: Effect of crop growing environments and varieties on yield attributes and yield of barley at Hisar during *rabi* 2021-22**

| Treatment                  | ET   | GS   | SL   | TW   | GY   | SY   | HI    |
|----------------------------|------|------|------|------|------|------|-------|
| <b>Planting dates</b>      |      |      |      |      |      |      |       |
| D <sub>1</sub> (17 Nov 21) | 963  | 45.7 | 8.78 | 43.6 | 4790 | 6840 | 0.42  |
| D <sub>2</sub> (30 Nov 21) | 860  | 49.9 | 8.81 | 44.7 | 4400 | 7030 | 0.39  |
| D <sub>3</sub> (15 Dec 21) | 738  | 49.8 | 9.35 | 39.1 | 4300 | 7580 | 0.37  |
| D <sub>4</sub> (30 Dec 21) | 593  | 47.0 | 9.04 | 37.8 | 3780 | 7980 | 0.33  |
| SE(m)                      | 25.8 | 1.46 | 0.18 | 1.51 | 110  | 370  | 0.019 |
| CD (A) at 5%               | 90.9 | NS   | NS   | 5.32 | 389  | NS   | NS    |
| <b>Varieties</b>           |      |      |      |      |      |      |       |
| V <sub>1</sub> (BH 393)    | 740  | 55.5 | 9.20 | 37.7 | 4480 | 6920 | 0.37  |
| V <sub>2</sub> (BH 902)    | 857  | 55.7 | 9.18 | 44.0 | 4410 | 8730 | 0.35  |
| V <sub>3</sub> (BH 946)    | 788  | 55.9 | 8.90 | 40.3 | 4250 | 6450 | 0.43  |
| V <sub>4</sub> (BH 885)    | 770  | 25.2 | 8.71 | 43.2 | 4140 | 7330 | 0.36  |
| SE(m)                      | 22.6 | 1.42 | 0.25 | 1.11 | 126  | 176  | 0.011 |
| CD (B) at 5%               | 66.5 | 4.17 | NS   | 3.25 | 369  | 517  | 0.034 |

ET- Effective Tillers per square meter, GS- Grains per spike (number), SL- spike length (cm), TW- test weight (g), GY- grain yield (kg ha<sup>-1</sup>), SY- straw yield (kg ha<sup>-1</sup>), HI- harvest index

The variety BH 393 recorded significantly lesser effective tillers (740 per square meter). Highest grains per spike were found in D<sub>2</sub> (49.9). Among the varieties, maximum grains per spike were observed in BH946 (55.9) followed by BH902 (56) and BH393 (55). BH 885 recorded minimum grains per spike *i.e.* 25, as this is 2-row variety. The spike length was more under D<sub>3</sub> sowing and BH 393 variety but the difference was non-significant.

## Chickpea

### Akola

A field experiment with three crop growing environments (44, 45 and 46 SMWs) and three varieties (JAKI-1298, Akash and Vijay) was taken up during *rabi* 2021-22. Effect of growing environments on Heat use efficiency (HUE) of chickpea varieties is presented in Table 4.26.

**Table 4.26: Heat use efficiency of chickpea varieties in terms of seed and biomass production ( $\text{kg ha}^{-1} \text{ }^{\circ}\text{C day}^{-1}$ ) under different dates of sowing**

| Varieties      | Sowing date |             |             |             |
|----------------|-------------|-------------|-------------|-------------|
|                | D1          | D2          | D3          | Mean        |
| V1 - JAKI-9218 | 0.98        | 0.99        | 1.02        | 1.00        |
|                | <b>2.30</b> | <b>2.36</b> | <b>2.37</b> | <b>2.34</b> |
| V2 - Akash     | 1.00        | 0.90        | 0.91        | 0.94        |
|                | <b>2.33</b> | <b>2.12</b> | <b>2.04</b> | <b>2.17</b> |
| V3 - Vijay     | 0.98        | 0.88        | 0.90        | 0.92        |
|                | <b>2.30</b> | <b>2.06</b> | <b>2.00</b> | <b>2.12</b> |
| Mean           | 0.99        | 0.92        | 0.94        |             |
|                | <b>2.31</b> | <b>2.18</b> | <b>2.14</b> |             |

$D_1$ : 44 SMW (02 Nov),  $D_2$ : 45 SMW (09 Nov) and  $D_3$ : 46 SMW (15 Nov)

Bold figures indicate heat use efficiency in terms of biomass

Crop sown on 02 November ( $D_1$ ) recorded higher heat use efficiency with respect to both seed and biomass production. Amongst the varieties, heat use efficiency with respect to grain yield and biomass production was higher in the variety JAKI-9218. Whereas, variety Vijay ( $V_3$ ) recorded the minimum heat use efficiency. Seed and biomass yield as influenced by the treatments is presented in Table 4.27.

**Table 4.27: Seed and biomass yield ( $\text{kg ha}^{-1}$ ) as influenced by growing environments and varieties in chickpea at Akola**

| Treatment              | Seed yield ( $\text{kg ha}^{-1}$ ) | Biomass yield ( $\text{kg ha}^{-1}$ ) |
|------------------------|------------------------------------|---------------------------------------|
| <b>Dates of sowing</b> |                                    |                                       |
| $D_1$ 44 SMW (02 Nov.) | 1495                               | 3500                                  |
| $D_2$ 45 SMW (09 Nov.) | 1415                               | 3344                                  |
| $D_3$ 46 SMW (15 Nov.) | 1380                               | 3127                                  |
| SEm $\pm$              | 62.6                               | 138.7                                 |
| CD (P=0.05)            | 187.7                              | 416.2                                 |
| <b>Varieties</b>       |                                    |                                       |
| $V_1$ JAKI-9218        | 1521                               | 3568                                  |
| $V_2$ Akash-797        | 1402                               | 3241                                  |
| $V_3$ Vijay            | 1366                               | 3162                                  |
| SEm $\pm$              | 62.6                               | 138.7                                 |
| CD (P=0.05)            | 187.7                              | 416.0                                 |
| <b>Interaction</b>     |                                    |                                       |
| SEm $\pm$              | 108.4                              | 240.3                                 |
| CD (P=0.05)            | NS                                 | NS                                    |
| CV (%)                 | 13.1                               | 12.5                                  |

Significantly higher seed ( $1495 \text{ kg ha}^{-1}$ ) and biomass ( $3500 \text{ kg ha}^{-1}$ ) yields were obtained when crop was sown on November 02 (44 SMW). However, it was at par with November 09 (45 SMW) sowing as regards both seed and biomass yields. Crop sown on November 15 (46 SMW) yielded the lowest seed ( $1380 \text{ kg ha}^{-1}$ ) and biomass ( $3127 \text{ kg ha}^{-1}$ ). Among the varieties, JAKI-9218 recorded significantly higher seed over Vijay, however it was at par with Akash-797. Biomass yield was found non-significant. Interaction effect of date of sowing and varieties in respect seed yield was also found to be non-significant.

## Raipur

The chickpea crop field experiment consisted of three growing environments ( $D_1$  - 10 Nov,  $D_2$  - 25 Nov,  $D_3$  - 10 Dec) and three cultivars ( $V_1$  - Vaibhav,  $V_2$  - JG 14,  $V_3$  - JG16) during *rabi* 2021-22 was taken up. Effect of treatments on Radiation Use Efficiency (RUE) of chickpea is presented in Table 4.28.

**Table 4.28: Effect of different crop growing environment on Radiation Use Efficiency ( $\text{g MJ}^{-1}$ ) of different chickpea varieties during *rabi* 2021-22**

| RUE ( $\text{g MJ}^{-1}$ ) of chickpea genotypes |                   |      |      |      |      |          |
|--------------------------------------------------|-------------------|------|------|------|------|----------|
| Treatments                                       | Days after sowing |      |      |      |      |          |
|                                                  | 20                | 40   | 60   | 80   | 100  | Maturity |
| $D_1 V_1$                                        | 0.26              | 0.16 | 0.22 | 0.27 | 0.46 | 0.46     |
| $D_1 V_2$                                        | 0.13              | 0.13 | 0.13 | 0.20 | 0.34 | 0.34     |
| $D_1 V_3$                                        | 0.15              | 0.12 | 0.35 | 0.33 | 0.55 | 0.55     |
| $D_2 V_1$                                        | 0.16              | 0.14 | 0.34 | 0.37 | 0.67 | 0.67     |
| $D_2 V_2$                                        | 0.14              | 0.12 | 0.27 | 0.27 | 0.48 | 0.48     |
| $D_2 V_3$                                        | 0.16              | 0.14 | 0.24 | 0.45 | 0.67 | 0.67     |
| $D_3 V_1$                                        | 0.17              | 0.15 | 0.28 | 0.56 | 0.63 | 0.63     |
| $D_3 V_2$                                        | 0.12              | 0.12 | 0.18 | 0.38 | 0.67 | 0.67     |
| $D_3 V_3$                                        | 0.06              | 0.08 | 0.18 | 0.20 | 0.23 | 0.21     |

The highest RUE was recorded at maturity stage. Among the treatments, the highest RUE was recorded by three treatments ( $0.67 \text{ g MJ}^{-1}$ ) viz., Vaibhav sown on 10 Nov, JG-16 sown on 25 Nov and JG-14 (ZC) sown on 10 Dec. JG-16 sown on 10 Dec recorded the lowest RUE of  $0.21 \text{ g MJ}^{-1}$  across the treatments. Effect of treatments on yield and yield attributes of chickpea is presented in Table 4.29.

**Table 4.29: Yield and yield attributes of chickpea varieties as influenced by different growing environments (*rabi* 2021-22)**

| Treatments             | Plant height at maturity (cm) | Dry matter production at maturity (g) | Test weight (g) | Stover yield (kg ha <sup>-1</sup> ) | Grain yield (kg ha <sup>-1</sup> ) | Total number of seed per plant | Harvest index (%) |
|------------------------|-------------------------------|---------------------------------------|-----------------|-------------------------------------|------------------------------------|--------------------------------|-------------------|
| <b>Dates of sowing</b> |                               |                                       |                 |                                     |                                    |                                |                   |
| D <sub>1</sub>         | 39.8                          | 35.6                                  | 23.7            | 1551.2                              | 1423.8                             | 29                             | 47.3              |
| D <sub>2</sub>         | 40.4                          | 51.2                                  | 22.5            | 1165.5                              | 1152.9                             | 31                             | 49.8              |
| D <sub>3</sub>         | 41.8                          | 58.2                                  | 22.1            | 2111.1                              | 1501.2                             | 33                             | 41.3              |
| SEm ±                  | 1.1                           | 2.6                                   | 0.3             | 95.1                                | 111.9                              | 3.9                            | 1.6               |
| CD (p=0.05)            | NS                            | S                                     | S               | S                                   | S                                  | NS                             | S                 |
| <b>Varieties</b>       |                               |                                       |                 |                                     |                                    |                                |                   |
| V <sub>1</sub>         | 42.2                          | 49.2                                  | 25.1            | 1760.9                              | 1495.4                             | 27                             | 46.6              |
| V <sub>2</sub>         | 43.0                          | 51.9                                  | 25.9            | 1417.0                              | 1214.0                             | 29                             | 46.1              |
| V <sub>3</sub>         | 37.0                          | 43.8                                  | 17.4            | 1649.9                              | 1368.4                             | 36                             | 45.6              |
| SEm ±                  | 1.1                           | 2.6                                   | 0.3             | 95.1                                | 111.9                              | 3.9                            | 1.6               |
| CD (p=0.05)            | 3.4                           | 7.8                                   | 0.8             | 285.0                               | NS                                 | NS                             | 4.8               |
| SEm ± (DxV)            | 2.0                           | 4.5                                   | 0.5             | 164.7                               | 193.8                              | 6.7                            | 2.8               |
| CD (p=0.05)            | NS                            | NS                                    | NS              | NS                                  | NS                                 | NS                             | NS                |

Varieties: V<sub>1</sub>: Vaibhav V<sub>2</sub>: JG-14 (ZC) V<sub>3</sub>: JG-16

Growing Environments: D<sub>1</sub>-10/11/2021, D<sub>2</sub>-25/11/2021, D<sub>3</sub> 10/12/2021

Significantly higher grain yield was recorded in the crop sown on D<sub>3</sub> (1501 kg ha<sup>-1</sup>) while lowest grain yield was produced under normal sowing (D<sub>2</sub>). The highest grain yield was recorded by Vaibhav (1495 kg ha<sup>-1</sup>) followed by JG-16 variety (1368 kg ha<sup>-1</sup>) and JG-14 (1214 kg ha<sup>-1</sup>). There was no statistical difference among the varieties in terms of grain yield. Highest harvest index observed under D<sub>2</sub> (49.8%) followed by D<sub>1</sub> (47.3%). Treatments of growing environments significantly different to each other and lowest harvest index was recorded under D<sub>3</sub> (41.3%). Among different varieties, data recorded pertaining to harvest index were not significantly different to each other, however among growing environments HI attribute differed significantly. Lowest HI was observed in D<sub>3</sub> due to thermal stress.

## Ranchi

Crop weather relationship studies in chickpea was undertaken in factorial RBD with three growing environments [ $D_1$ : 10 Nov (Early),  $D_2$ : 25 Nov (Normal),  $D_3$ : 10 Dec (Late)] and three varieties [ $V_1$ : JG 14,  $V_2$ : GNG 1581 and  $V_3$ : Birsa Chana 3]. Effect of treatments on HUE and RUE of chickpea was studied and the result is presented in Table 4.30.

**Table 4.30: Heat and radiation Use Efficiency of chickpea cultivars under different growing environments at Ranchi during *rabi* 2021-22**

| Sowing date     | Variety       | HUE (kg ha <sup>-1</sup> °C days <sup>-1</sup> ) | RUE (kg ha <sup>-1</sup> MJ <sup>-1</sup> ) | Yield (kg ha <sup>-1</sup> ) |
|-----------------|---------------|--------------------------------------------------|---------------------------------------------|------------------------------|
| Early (10 Nov)  | IG -14        | 0.9                                              | 0.8                                         | 1533                         |
|                 | GNG -1581     | 1.0                                              | 0.8                                         | 1722                         |
|                 | Birsa chana 3 | 1.0                                              | 0.9                                         | 1871                         |
| Normal (25 Nov) | IG -14        | 1.1                                              | 0.9                                         | 1735                         |
|                 | GNG -1581     | 1.6                                              | 1.3                                         | 2601                         |
|                 | Birsa chana 3 | 1.4                                              | 1.1                                         | 2279                         |
| Late (10 Dec)   | IG -14        | 0.9                                              | 0.7                                         | 1312                         |
|                 | GNG -1581     | 1.5                                              | 1.2                                         | 2252                         |
|                 | Birsa chana 3 | 1.4                                              | 1.1                                         | 2195                         |

Normal sown crop recorded higher HUE and RUE compared to late sown crop. Among the varieties, GNG -1581 achieved highest heat use efficiency (1.6 kg ha<sup>-1</sup> °C days<sup>-1</sup>) as well as highest radiation (1.3 kg ha<sup>-1</sup> MJ<sup>-1</sup>) use efficiencies in normal sown condition. The higher heat and radiation use efficiencies in case of normal sowing and GNG -1581 were also reflected in their highest yields as presented in Table 4.31.

Performance of chickpea sown by 25 November (Early) was significantly higher (2205 kg ha<sup>-1</sup>) than crop sown on 10 November (1709 kg ha<sup>-1</sup>) and 10 December (1946 kg ha<sup>-1</sup>) during 2021-22. Among the varieties, significantly higher yield was recorded by GNG 1581 (2192 kg ha<sup>-1</sup>) with 53% harvest index followed by Birsa Chana3 (2115 kg ha<sup>-1</sup>) and JG 14 (1527 kg ha<sup>-1</sup>).

**Table 4.31: Yield and yield attributes of chickpea under different growing environments at Ranchi during *rabi* 2021-22**

| Treatments             | No. of filled pod per plant | No. of seed per pod | 100 seed weight (g) | TDM (kg ha <sup>-1</sup> ) | Yield (kg ha <sup>-1</sup> ) | HI (%) |
|------------------------|-----------------------------|---------------------|---------------------|----------------------------|------------------------------|--------|
| <b>Dates of sowing</b> |                             |                     |                     |                            |                              |        |
| Early                  | 41                          | 1.6                 | 18.6                | 3626                       | 1709                         | 47     |
| Normal                 | 37                          | 1.7                 | 18                  | 4257                       | 2205                         | 51     |
| Late                   | 34                          | 1.7                 | 17.8                | 3419                       | 1919                         | 57     |
| SEm                    | 2.5                         | 0.06                | 0.2                 | 200                        | 100                          | 2      |
| CD at 5%               | NS                          | NS                  | NS                  | 610                        | 320                          | 4.8    |
| <b>Varieties</b>       |                             |                     |                     |                            |                              |        |
| JG 14                  | 34                          | 1.2                 | 25.5                | 3299                       | 1527                         | 48     |
| GNG 1581               | 37                          | 2.1                 | 14.6                | 4122                       | 2192                         | 53     |
| Birsa Chana3           | 42                          | 1.6                 | 14.4                | 3882                       | 2115                         | 54     |
| SEm                    | 2.5                         | 0.06                | 0.2                 | 200                        | 109                          | 1.6    |
| CD at 5%               | NS                          | 0.19                | 0.6                 | 610                        | 320                          | 4.8    |
| <b>Interaction</b>     |                             |                     |                     |                            |                              |        |
| SEm                    | 4                           | 0.11                | 0.3                 | 3.5                        | 1.9                          | 2.7    |
| CD at 5%               | NS                          | NS                  | NS                  | 10                         | NS                           | 8.3    |

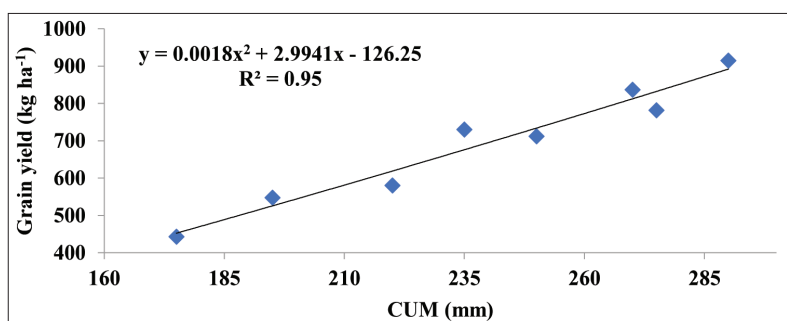
## Solapur

The treatments consisted of four growing environments ( $S_1$ : SMW 38,  $S_2$ : SMW 40,  $S_3$ : SMW 42 and  $S_4$ : SMW 44) and two varieties ( $V_1$ : Vijay and  $V_2$ : Dig Vijay). Effect of treatments on periodic Radiation Use Efficiency (RUE) in chickpea is presented in Table 4.32, which is the pooled data of the experiments conducted during 2016-17 to 2021-22.

**Table 4.32: Periodical Radiation Use Efficiency (g MJ<sup>-1</sup>) in chickpea (2016-17 to 2021-22)**

| SMW | DAS | $S_1$ |          | $S_2$ |          | $S_3$ |          | $S_4$ |          |
|-----|-----|-------|----------|-------|----------|-------|----------|-------|----------|
|     |     | Vijay | Digvijay | Vijay | Digvijay | Vijay | Digvijay | Vijay | Digvijay |
| 38  |     |       |          | -     | -        | -     | -        | -     | -        |
| 40  | 14  | 0.31  | 0.35     |       |          | -     | -        | -     | -        |
| 42  | 28  | 1.27  | 1.27     | 0.25  | 0.26     |       |          |       |          |
| 44  | 42  | 2.21  | 2.36     | 1.19  | 1.19     | 0.25  | 0.26     | 0.18  | 0.19     |
| 46  | 56  | 2.15  | 2.22     | 2.09  | 2.14     | 1.13  | 1.19     | 1.05  | 1.06     |
| 48  | 70  | 1.96  | 2.01     | 1.99  | 2.02     | 2.09  | 2.12     | 1.89  | 1.98     |
| 50  | 84  | 1.68  | 1.75     | 1.73  | 1.75     | 1.99  | 2.03     | 1.77  | 1.79     |
| 52  | 98  | -     | 1.55     | 1.51  | 1.48     | 1.69  | 1.73     | 1.57  | 1.65     |
| 2   | 112 | -     | -        | 1.25  | 1.29     | 1.39  | 1.48     | 1.24  | 1.42     |
| 3   | 119 | -     | -        | -     | -        | -     | 1.29     | -     | 1.09     |

Highest RUE was recorded around 42 days after sowing. Among different growing environments, crop sown 38 SMW and 44 SMW recorded highest and lowest RUE, respectively. Among the varieties, Digvijay recorded higher RUE than Vijay across all the growing environments. The relationship of seed yield with Consumptive Use of Moisture (CUM) is presented in Fig. 4.13. Seed yield showed a linear relationship with CUM with an  $R^2$  value of 0.95.



**Fig. 4.13: Relationship between consumptive use of moisture (CUM) and seed yield of chickpea at Solapur**

## Green gram

### Jorhat

Crop weather relationship studies in green gram was undertaken with three varieties (SGC-16, SGC-20 and IPBM-02-3) and three Micro-climatic Regimes [sown on 20 Sept. (MR-I), 25 Sept. (MR-II) and 30 Sept. (MR-III) 2021]. Effect of treatments on crop phenology was quantified and presented in Table 4.33.

**Table 4.33: Effect of crop growing environments on occurrence of different phenological events in three green gram cultivars sown during *kharif* 2021**

| Phenological stages | MR-I                    | MR-II                   | MR-III                  |
|---------------------|-------------------------|-------------------------|-------------------------|
|                     | For all three cultivars | For all three cultivars | For all three cultivars |
| Germination         | 5                       | 5                       | 5                       |
| Bud stage           | 36 (31)                 | 34(29)                  | 36(31)                  |
| Flowering           | 40(9)                   | 39(5)                   | 42(6)                   |
| Pod initiation      | 47(7)                   | 46(7)                   | 49(7)                   |
| Phy. maturity       | 63(16)                  | 66(20)                  | 64(15)                  |
| Vegetative          | 36                      | 34                      | 36                      |
| Reproductive        | 16                      | 12                      | 13                      |
| Maturity            | 16                      | 20                      | 15                      |

(Data within the parenthesis represents the number of days required in between occurrence of two successive phenophases)

The crop sown under three different crop growing environments require 34 to 36 number of days to complete the vegetative stage. Irrespective of the varieties and different dates of sowing, the crop requires same number of days to complete different phenological stages. The number of days required to attain physiological maturity from sowing was recorded almost same in all three cultivars *i.e.* 63 to 66 days with maximum days in MR-II followed by MR-III and minimum in MR-I. Less variation in number of days required for attaining different crop growth stages and to complete crop life cycle was observed among the three cultivars and three crop growing environments which might be attributed to shorter gap between three dates of sowings. Effect of growing environments on yield and yield attributes of green gram is presented in Table 4.34.

**Table 4.34: Effect of crop growing environments on yield and yield attributing characteristics of *kharif* green gram during 2021 at Jorhat**

| Treatment                        | Plant height (cm) | No of pods plant <sup>-1</sup> | Pod length (cm) | No of seeds per pod | Test weight (g) | Yield (kg ha <sup>-1</sup> ) |
|----------------------------------|-------------------|--------------------------------|-----------------|---------------------|-----------------|------------------------------|
| <b>Varieties</b>                 |                   |                                |                 |                     |                 |                              |
| SGC- 16                          | 32.67             | 19.02                          | 5.90            | 12.4                | 37.19           | 865.2                        |
| SGC- 20                          | 32.94             | 16.28                          | 6.03            | 11.1                | 34.11           | 805.7                        |
| IPBM-02-3                        | 31.36             | 18.00                          | 5.83            | 11.7                | 37.11           | 821.3                        |
| Mean                             | 32.32             | 17.76                          | 5.92            | 11.7                | 36.13           | 830.7                        |
| CD at 5%                         | NS                | NS                             | NS              | NS                  | 0.02            | 13.1                         |
| <b>Crop growing environments</b> |                   |                                |                 |                     |                 |                              |
| MR-I                             | 33.28             | 18.8                           | 6.02            | 12.8                | 36.25           | 889.7                        |
| MR-II                            | 31.44             | 17.4                           | 5.73            | 11.8                | 36.17           | 811.3                        |
| MR-III                           | 32.25             | 17.1                           | 6.01            | 10.6                | 35.99           | 791.1                        |
| Mean                             | 32.32             | 17.76                          | 5.92            | 11.7                | 36.13           | 830.7                        |
| CD at 5%                         | NS                | NS                             | 0.56            | NS                  | 0.06            | 24.5                         |
| <b>Interaction (V×MR)</b>        |                   |                                |                 |                     |                 |                              |
| CD at 5% (V×MR)                  | NS                | NS                             | NS              | NS                  | 0.03            | 32.18                        |

The mean plant height at harvest was found maximum in SGC-20 (32.94 cm) followed by SGC-16 (32.67 cm) and least in IPBM-02-3 (31.36 cm). The vegetative growth of the crop was found relatively higher in crop grown under MR-I followed by MR-II and least in MR-III. No statistically significant variation in mean plant height was observed among three cultivars. Similarly, irrespective of the varieties mean maximum value of plant height was recorded in MR-I (33.28 cm) followed by MR-III (32.25 cm) and least in MR-II (31.44 cm). The mean number of pods per plant at harvest was 17.76. Among the three varieties SGC-16 recorded maximum number of pods per plant (19.02) followed by in

IPBM-02-3 (18.00) and lowest in SGC-20 (16.28). This has indicated that, the significant variations among the three cultivars are more or less due to genetic makeup of cultivar. All the yield attributing characteristics *i.e.* number of pods per plant, number of seeds per pod, 1000 seeds weight etc. were found to be higher in SGC-16 and IPBM-02-3 whereas lowest in SGC-20 which ultimately defined the yield as of 865.2 kg ha<sup>-1</sup>, 821.3 kg ha<sup>-1</sup> and 805.7 kg ha<sup>-1</sup>, respectively. Statistically significant variation in seed yield exists among the three cultivars with CD value 13.1 kg ha<sup>-1</sup>. Similarly, among the three microclimatic regimes, highest yield was recorded under MR-I (889.7 kg ha<sup>-1</sup>) followed by MR-II (811.3 kg ha<sup>-1</sup>) and least in MR-III (791.1 kg ha<sup>-1</sup>). Decrease in seed yield was observed when sowing was done during the last week of September month. Thus, prevailing weather parameters corresponding to the crop sown under the MR-I and MR-II (20 August and 25 August) was found to be moderately suitable.

## Mohanpur

A field experiment was taken up with three growing environments (D<sub>1</sub>- 25 Sept., D<sub>2</sub>- 07 Oct. and D<sub>3</sub>- 22 Oct. 2021) and three varieties (V<sub>1</sub>- Samrat, V<sub>2</sub>- PM 05 and V<sub>3</sub>- Meha). Effect of treatments on Seasonal Evapotranspiration (SET) and Water Use Efficiency (WUE) is presented in Table 4.35.

**Table 4.35: Effect of growing environments and cultivars on seasonal evapotranspiration, yield and water use efficiency in green gram at Mohanpur**

| Growing environment | Variety | Rainfall (mm) | SWS (mm) | SET (mm) | Yield (kg ha <sup>-1</sup> ) | WUE (kg m <sup>-3</sup> ) |
|---------------------|---------|---------------|----------|----------|------------------------------|---------------------------|
| D <sub>1</sub>      | Samrat  | 216           | 74       | 289      | 956                          | 0.33                      |
|                     | PM-05   | 216           | 100      | 316      | 1075                         | 0.34                      |
|                     | Meha    | 216           | 104      | 319      | 1265                         | 0.4                       |
| D <sub>2</sub>      | Samrat  | 264           | 80       | 344      | 990                          | 0.29                      |
|                     | PM-05   | 264           | 71       | 335      | 769                          | 0.23                      |
|                     | Meha    | 264           | 78       | 341      | 897                          | 0.26                      |
| D <sub>3</sub>      | Samrat  | 176           | 112      | 288      | 227                          | 0.08                      |
|                     | PM-05   | 176           | 99       | 275      | 361                          | 0.13                      |
|                     | Meha    | 176           | 113      | 289      | 682                          | 0.24                      |

Though crop sown on 07 October received higher seasonal rainfall, highest yield was recorded by Meha sown on 25 September (1265 kg ha<sup>-1</sup>), followed by PM-05 (1075 kg ha<sup>-1</sup>). Highest seasonal evapotranspiration was recorded for crop sown on 07 October which might have reduced the water use efficiency of the varieties. The highest water use

efficiency was recorded by cv. Meha sown on 25 September, followed by PM-05 sown on 25 September. The effect of growing environments and cultivars on absorbed PAR and RUE was also studied and the result is presented in Table 4.36.

**Table 4.36: Variation of total Absorbed PAR and Radiation Use Efficiency as affected by growing environments and cultivars in green gram at Mohanpur**

| DOS × VAR                     | APAR (MJ) | RUE (g MJ <sup>-1</sup> ) | Yield (kg ha <sup>-1</sup> ) |
|-------------------------------|-----------|---------------------------|------------------------------|
| D <sub>1</sub> V <sub>1</sub> | 259.2     | 0.37                      | 956.0                        |
| D <sub>1</sub> V <sub>2</sub> | 267.6     | 0.40                      | 1074.8                       |
| D <sub>1</sub> V <sub>3</sub> | 252.2     | 0.50                      | 1265.0                       |
| D <sub>2</sub> V <sub>1</sub> | 303.8     | 0.33                      | 990.8                        |
| D <sub>2</sub> V <sub>2</sub> | 312.7     | 0.25                      | 769.4                        |
| D <sub>2</sub> V <sub>3</sub> | 295.2     | 0.30                      | 897.3                        |
| D <sub>3</sub> V <sub>1</sub> | 303.8     | 0.07                      | 227.4                        |
| D <sub>3</sub> V <sub>2</sub> | 312.3     | 0.12                      | 360.6                        |
| D <sub>3</sub> V <sub>3</sub> | 280.9     | 0.24                      | 682.2                        |

Among the treatments, variety PM-05 sown on 07 October recorded highest APAR, followed by PM-05 sown on 22 October Meha sown on 25 September recorded the lowest APAR among the treatments. In the case of RUE, Meha sown on 25 September recorded highest value of 0.50 g MJ<sup>-1</sup>, followed by PM-05 sown on the same date (0.40 g MJ<sup>-1</sup>).

## Potato

### Hisar

The field experiment consisting four growing environments (D<sub>1</sub>: 16 Nov., D<sub>2</sub>: 22 Nov., D<sub>3</sub>: 30 Nov. and D<sub>4</sub>: 7 Dec. 2021) and three varieties (V<sub>1</sub>: Kufri Bahar, V<sub>2</sub>: Kufri Pushkar and V<sub>3</sub>: Kufri Lima) was taken up. Effect of growing environments on chlorophyll content index (CCI) of potato varieties is presented in Table 4.37. Chlorophyll content was measured with Chlorophyll meter (CCM-200; Opti-Sciences Inc., Hudson, NH, USA) which gives CCI relative indicator of chlorophyll content of leaf. The dates of sowing and varieties didn't influence significantly the leaf CCI. The highest CCI values were coincide with the highest LAI *i.e.* at tuber bulking stage. Among the different growing environments, the highest CCI was recorded by early planted crop *i.e.* D<sub>1</sub> (96.9) and lower by subsequent plantings. Among the varieties Kufri Pushkar recoded highest CCI value (92.3) followed by Kufri Lime (91.3) and lowest by Kufri Bahar (86.1).

**Table 4.37: Effect of different growing environments on Chlorophyll Content Index (CCI) of potato varieties during 2021-22**

| Treatment                      | Chlorophyll Content Index of potato |               |                  |               |                        |
|--------------------------------|-------------------------------------|---------------|------------------|---------------|------------------------|
|                                | Emergence                           | Stolonization | Tuber initiation | Tuber bulking | Physiological maturity |
| <b>Growing environments</b>    |                                     |               |                  |               |                        |
| D <sub>1</sub> (16 Nov 21)     | 66.4                                | 73.3          | 82.6             | 96.9          | 76.6                   |
| D <sub>2</sub> (22 Nov 21)     | 60.2                                | 62.3          | 74.3             | 92.5          | 75.8                   |
| D <sub>3</sub> (30 Nov 21)     | 57.1                                | 63.1          | 70.9             | 86.2          | 75.2                   |
| D <sub>4</sub> (7 Dec 21)      | 44.4                                | 59.0          | 65.7             | 84.1          | 72.5                   |
| SEm±                           | 5.49                                | 3.46          | 2.98             | 5.48          | 3.46                   |
| CD (A) at 5%                   | NS                                  | 10.01         | 8.62             | NS            | NS                     |
| <b>Varieties</b>               |                                     |               |                  |               |                        |
| V <sub>1</sub> (Kufri Bahar)   | 49.1                                | 61.5          | 70.9             | 86.1          | 72.1                   |
| V <sub>2</sub> (Kufri Pushkar) | 66.6                                | 70.6          | 75.3             | 92.3          | 81.2                   |
| V <sub>3</sub> (Kufri Lima)    | 55.3                                | 61.1          | 73.9             | 91.3          | 71.7                   |
| SEm±                           | 4.75                                | 3.00          | 2.58             | 4.74          | 3.00                   |
| CD (B) at 5%                   | 13.73                               | NS            | NS               | NS            | NS                     |

Effect of different growing environments on yield attributes and yield of potato varieties during 2021-22 at Hisar is presented in Table 4.38.

**Table 4.38: Effect of different growing environments on yield attributes and yield of potato varieties during 2021-22**

| Treatment                      | No. of tubers per plant | Tuber weight (gram per tuber) | Tuber yield per plant (g) | Tuber yield (kg ha <sup>-1</sup> ) |
|--------------------------------|-------------------------|-------------------------------|---------------------------|------------------------------------|
| <b>Growing environments</b>    |                         |                               |                           |                                    |
| D <sub>1</sub> (16 Nov 21)     | 6.1                     | 64.5                          | 364.3                     | 32470                              |
| D <sub>2</sub> (22 Nov 21)     | 7.4                     | 51.8                          | 360.4                     | 36000                              |
| D <sub>3</sub> (30 Nov 21)     | 10.4                    | 35.3                          | 345.0                     | 31720                              |
| D <sub>4</sub> (7 Dec 21)      | 9.6                     | 33.6                          | 277.6                     | 24330                              |
| SEm±                           | 0.7                     | 3.5                           | 19.1                      | 9166                               |
| CD at 5%                       | 2.1                     | 10.3                          | 55.2                      | 2649                               |
| <b>Varieties</b>               |                         |                               |                           |                                    |
| V <sub>1</sub> (Kufri Bahar)   | 8.0                     | 40.3                          | 283.0                     | 29940                              |
| V <sub>2</sub> (Kufri Pushkar) | 10.0                    | 39.1                          | 363.5                     | 31980                              |
| V <sub>3</sub> (Kufri Lima)    | 7.0                     | 59.5                          | 364.0                     | 31470                              |
| SEm±                           | 0.6                     | 3.1                           | 16.5                      | 7938                               |
| CD at 5%                       | 1.8                     | 8.9                           | 47.8                      | NS                                 |

Different sowing environments had significant influence on number of tubers per plant in potato crop. Maximum number of tubers per plant were observed in  $D_3$  (10.4 tubers per plant) followed by  $D_4$  (9.6 tubers per plant),  $D_2$  (7.4 tubers per plant) and  $D_1$  (6.1 tubers per plant). Among the varieties, significantly higher numbers of tubers per plant were recorded in Kufri Pushkar (10) than Kufri Bahar (8) and Kufri Lima (7) at physiological maturity. Planting dates had significant influence on potato tuber weight (g per tuber). Maximum tuber weight *i.e.* 64.5 g per tuber was recorded in  $D_1$  treatment followed by  $D_2$  (51.8 g per tuber). Tuber yield per plant (g per plant) also followed the similar trend.

Significantly higher tuber yield *i.e.* 36000 kg ha<sup>-1</sup> was recorded under  $D_2$  treatment due to favourable weather conditions as compared to other plantings. The  $D_1$  planting recorded lower yields (non-significant) as compared to the  $D_2$  due to the frost events occurred during 19-21 December 2021. The varieties didn't differ significantly in tuber yield and the highest yield was recorded by K. Pushkar (31980 kg ha<sup>-1</sup>) followed by K. Lima (31470 kg ha<sup>-1</sup>) and K. Bahar (29940 kg ha<sup>-1</sup>).

## Mustard

### Anand

A field experiment was undertaken with four growing environments ( $D_1$ - 10 Oct.,  $D_2$ - 20 Oct.,  $D_3$ - 30 Oct. and  $D_4$ - 10 Nov.) and three varieties ( $V_1$ : Bio-902,  $V_2$ : GM-3 and  $V_3$ : GDM 4). Effect of treatments on periodic Leaf Area Index (LAI) is presented in Fig. 4.14.

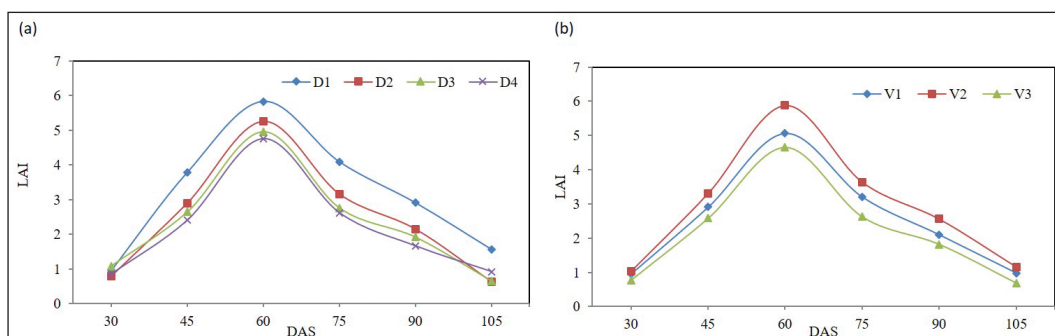
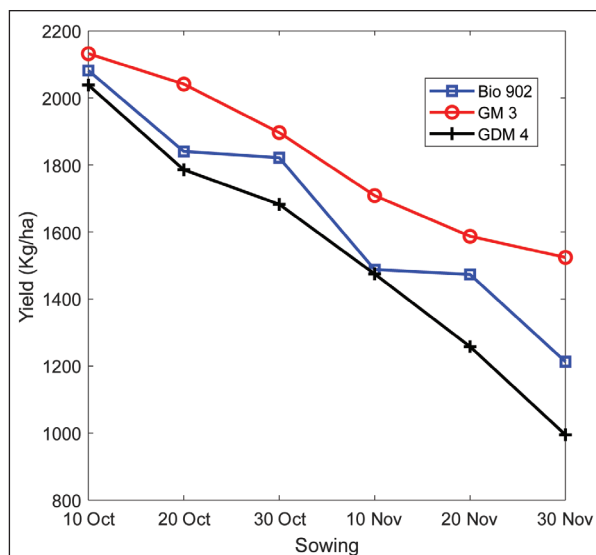


Fig. 4.14: Effect of (a) growing environments and (b) varieties on periodic LAI of mustard at Anand

Peak LAI was recorded at 60 DAS under all sowings. LAI under  $D_1$  sowing was the high as compared to rest of the sowings. Late sowing ( $D_4$ ) had the lowest LAI. In cultivars, peak LAI was recorded in cultivar  $V_1$ , while lowest LAI was in cultivar  $V_3$ . A pooled analysis of field experiments undertaken during *rabi* 2017-18 to 2021-22 was undertaken the mean productivity of mustard varieties under various growing environments is presented in Fig. 4.15.



**Fig. 4.15: Productivity of mustard cultivars during different growing environments (rabi 2017-18 to 2021-22) at Anand**

Sowing on 10 October provided favourable growing environment to all the three cultivars and they produced higher yield, which declined almost linearly with delayed sowing. Cultivar GM 3 has distinctly higher productivity under all the growing environments. Yield of Bio 902 was relatively higher than GDM 4. Under very late sowing (on 10 November), productivity of GDM 4 was comparable with that of Bio 902. Considering production performance of the cultivars under different growing environments, optimal range for weather variables during different growth stages of the crop were determined and given in Table 4.39.

**Table 4.39: Optimum weather conditions for different phenophases of mustard for high productivity (rabi 2017-18 to 2021-22)**

| Phenophases                               | BSS (hrs) | Tmin (°C) | Tmax (°C) | RH-I (%) | RH-II (%) |
|-------------------------------------------|-----------|-----------|-----------|----------|-----------|
| Emergence - Early vegetative              | 8.7-10.1  | 33.0-38.5 | 12.5-22.0 | 73-97    | 26-57     |
| Early vegetative -Flowering initiation    | 1.3-10.0  | 29.0-37.0 | 11.5-19.0 | 73-96    | 18-51     |
| Flowering initiation - Pod initiation     | 6.3-9.8   | 25.8-33.0 | 9.0-17.5  | 64-98    | 27-56     |
| Pod initiation - Seed development         | 0-9.8     | 18.2-33.0 | 6.0-17.5  | 69-100   | 20-98     |
| Seed development - Physiological Maturity | 0-10.2    | 18.2-32.5 | 5.5-17.2  | 53-96    | 16-82     |

Further, correlation analysis between mustard yield and phase wise weather parameters during 2017-18 to 2020-21 was also undertaken and the result is presented in Table 4.40.

**Table 4.40: Phase-wise correlation coefficient between weather parameters and mustard pod yield (2018-2022) at Anand ( $n=60$ )**

| Phenophases                               | BSS (hrs) | Max.T (°C) | Min.T (°C) | RHm (%) | RHe (%) |
|-------------------------------------------|-----------|------------|------------|---------|---------|
| Emergence - Early vegetative              | 0.16      | 0.72**     | 0.34**     | 0.55**  | 0.11    |
| Early vegetative -Flowering initiation    | 0.13      | 0.67**     | 0.30*      | 0.43**  | -0.10   |
| Flowering initiation - Pod initiation     | 0.18      | 0.33**     | 0.07       | 0.03    | -0.12   |
| Pod initiation - Seed development         | -0.04     | 0.28*      | 0.09       | -0.02   | -0.01   |
| Seed development - Physiological Maturity | -0.32*    | -0.42**    | -0.31*     | 0.04    | 0.35**  |

Maximum temperature, minimum temperature and morning relative humidity prevailed during early growth stages (up to flowering initiation) of mustard had strong positive association with seed yield. Sunshine hours and afternoon relative humidity of initial growth phases were not associated to crop yield. BSS and temperatures during pod initiation to maturity had negative association to yield which agrees with the almost linear drop in crop yield with delay in sowing. Afternoon relative humidity of this phase was positively associated with crop yield.

### Faizabad

A field experiment was taken up with three growing environments (25 Oct., 04 Nov. and 14 Nov. 2021) and three varieties (NDR-8501, Bio-902 and Varuna). The yield attributes and yield of mustard as affected by growing environments and mustard varieties is presented in Table 4.41.

**Table 4.41: Yields attributes of mustard as affected by growing environment and varieties**

| Treatments                       | No. of Siliquae per plant | Length of siliqua (cm) | No. of seeds per siliqua | Test weight (g) | Seed yield (kg ha <sup>-1</sup> ) |
|----------------------------------|---------------------------|------------------------|--------------------------|-----------------|-----------------------------------|
| <b>Crop growing environments</b> |                           |                        |                          |                 |                                   |
| 25 Oct.                          | 282.2                     | 7.2                    | 14.5                     | 4.3             | 1900                              |
| 04 Nov.                          | 271.2                     | 7.3                    | 12.4                     | 4.0             | 1810                              |
| 14 Nov.                          | 243.2                     | 6.2                    | 11.5                     | 4.3             | 1540                              |
| SEm±                             | 4.14                      | 0.15                   | 0.23                     | 0.03            | 333                               |
| CD at 5%                         | 12.13                     | 0.32                   | 0.74                     | NS              | 985                               |
| <b>Varieties</b>                 |                           |                        |                          |                 |                                   |
| NDR-8501                         | 295.5                     | 7.4                    | 14.2                     | 4.4             | 1850                              |
| Bio-902                          | 270.4                     | 6.1                    | 13.5                     | 4.2             | 1620                              |
| Varuna                           | 242.1                     | 6.4                    | 11.4                     | 4.5             | 1720                              |
| SEm±                             | 4.14                      | 0.13                   | 0.23                     | 0.04            | 331                               |
| CD at 5%                         | 12.16                     | 0.32                   | 0.74                     | NS              | 985                               |

The Thermal Use Efficiency (TUE) of mustard as affected by growing environments and varieties is presented in Table 4.42.

**Table 4.42: Thermal Use Efficiency ( $\text{g m}^{-2} \text{ }^{\circ}\text{C days}^{-1}$ ) of mustard as affected by growing environment and varieties**

| Treatments                  | Thermal use efficiency ( $\text{g m}^{-2} \text{ }^{\circ}\text{C days}^{-1}$ ) |        |        |        |        |         |            |
|-----------------------------|---------------------------------------------------------------------------------|--------|--------|--------|--------|---------|------------|
|                             | 30 DAS                                                                          | 45 DAS | 60 DAS | 75 DAS | 90 DAS | 105 DAS | At harvest |
| <b>Growing environments</b> |                                                                                 |        |        |        |        |         |            |
| 25 Oct.                     | 0.11                                                                            | 0.13   | 0.23   | 0.40   | 0.52   | 0.64    | 0.64       |
| 04 Nov.                     | 0.13                                                                            | 0.15   | 0.26   | 0.32   | 0.50   | 0.53    | 0.60       |
| 14 Nov.                     | 0.14                                                                            | 0.13   | 0.22   | 0.34   | 0.45   | 0.52    | 0.54       |
| <b>Varieties</b>            |                                                                                 |        |        |        |        |         |            |
| NDR-8501                    | 0.12                                                                            | 0.12   | 0.20   | 0.43   | 0.53   | 0.52    | 0.62       |
| Bio-902                     | 0.15                                                                            | 0.15   | 0.15   | 0.42   | 0.51   | 0.53    | 0.60       |
| Varuna                      | 0.12                                                                            | 0.13   | 0.12   | 0.32   | 0.43   | 0.44    | 0.42       |

The maximum TUE from sowing to maturity recorded was  $0.62 \text{ g m}^{-2} \text{ }^{\circ}\text{C days}^{-1}$  for crop sown on 25 October while minimum TUE recorded was  $0.52 \text{ g m}^{-2} \text{ }^{\circ}\text{C days}^{-1}$  by crop sown on 14 November. Different varieties had marked influence on TUE of mustard during all the phenophases. TUE ranged from 0.43 to 0.63, irrespective of varieties. Maximum TUE (0.63) from sowing to maturity was recorded by NDR-8501 variety, while minimum was recorded by Varuna (0.43).

## Mango

### Dapoli

Impact of weather parameters on yield of alphonso mango at different locations of Maharashtra was undertaken. Data was collected on 25 years old trees (10 plant) at weekly interval on 20 shoot per tree (5 shoot tagged in each direction). Correlation between mean weather parameters during different phenological stages and yield of alphonso mango was studied and the significant results are presented in Table 4.43.

**Table 4.43: Weather parameter at different phenological stages correlated at 1 and 5 per cent level of significance of mango cv. Alphonso of Konkan region (June 2020 - May 2021)**

| Stage              | * @ 5% Level of significance |                  | ** @ 1% Level of significance                                               |                                                                                      |
|--------------------|------------------------------|------------------|-----------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
|                    | Positive                     | Negative         | Positive                                                                    | Negative                                                                             |
| Dormant bud        | RH-II (46.5-91.8)            | -                | RH-I (76.95-94.9)                                                           | Epan (1.3-5.37)                                                                      |
| Vegetative stage   | RH-II (46.5-95.8)            | -                | Rainfall (0-448.4)                                                          | -                                                                                    |
| Flower bud opening | RH-I (76.0-94.3)             | Tmax (29.9-36.4) | Tmin (15.9-24.3)                                                            | Wind speed (0.5-0.7)<br>Rainfall (0-5.1)<br>Epan (1.6-5.4)                           |
| Flowering          | -                            | RH-I (76.0-95.7) | BSS (1.55-5.6)                                                              | Tmin (15.9-24.7)<br>RH-II (46.5-5.8)<br>Wind speed (1.0-5.7)<br>Rainfall (0.0-223.0) |
| Flower drop        | Tmin (15.9-24.6)             | -                | Tmax (30.4-36.4)<br>Wind speed (1.6-5.7)<br>BSS (1.9-5.5)<br>Epan (2.2-5.4) | RH-I (61.0-94.6)                                                                     |
| Fruiting           | -                            | -                | Tmax (31.3-36.4)<br>BSS (1.9-5.5)<br>Epan (2.3-5.4)                         | RH-I (76.0-89.7)<br>RH-II (46.5-77.9)                                                |
| Fruit drop         | Tmax (31.4-36.4)             | RH-I (76.0-89.7) | Wind speed (1.6-5.7)<br>Epan (2.3-5.4)                                      | -                                                                                    |

In general, during vegetative stages, evening relative humidity showed significant positive relation with fruit yield. During flower bud opening, while Tmin showed positive relationship, Tmax, evaporation, rainfall and windspeed showed negative relationship with yield. During flowering also, wind speed, rainfall, Tmin and evening relative humidity showed significant negative relationship. During fruiting, Tmax, BSS and pan evaporation showed significant positive correlation and both morning and evening relative humidity showed negative relation.

## Cashew

### Dapoli

Phenological observations of cashew was collected 15-25 years old trees (10 plant) at weekly interval on 20 shoots per tree (5 shoot tagged in each direction). Out of this, five plants of variety Vengurla-4 and five local plants was selected for experiment. Correlation between phenophases-wise mean weather parameters and cashew nut yield

was undertaken and the result is presented in Table 4.44. At vegetative and bud opening stages (101-109) weather parameters Tmin (66%), RH-I (66%), RH-II (84%) and RF (78%) showed significant positive correlation at 1 per cent significance level whereas Tmax (68%), BSS (79%) and Epan (70%) exhibit negative correlation at 1 per cent significance level. Weather parameter Tmax (55%) and BSS (50%) showed positive correlation with flowering (200-206), at 1 per cent significance level. Weather parameters Tmin (68%), RH-II (34%), WS (68%) and RF (42%) showed significant negative correlation at 1 per cent significance level. This indicates that the decrease in minimum temperature, evening relative humidity, rainfall, WS along with increase maximum temperature and bright sunshine hours may be responsible weather parameters for flowering in Cashew cv. Vengurla-4. Tmin (53%), RH-II (38%) and WS (54%) showed significant positive correlation with flower drop (207) at 1 per cent of significance level. While weather parameters Tmax and RH-I exhibited negative correlation with flower drop. Weather parameters Tmax (70%), BSS (55%) and Epan (79%) showed significant positive correlation at 1 per cent significance level at fruiting stage (300-307) whereas weather parameters RH-I (68%), RH-II (58%) and RF (40%) showed negative correlation at 1 per cent significance level.

**Table 4.44: Weather parameter at different phenological stages and correlation between weather parameter and different phenological stages of Cashew nut cv. Ven-4 at Dapoli Centre (Pooled)**

| Stage                                      | Year    | Period           | Tmax<br>(°C)           | Tmin<br>(°C)            | RH-I<br>(%)             | RH-II<br>(%)            | WS<br>(kmph)          | Rainfall<br>(mm)        | BSS<br>(hrs)          | Epan<br>(mm)          |
|--------------------------------------------|---------|------------------|------------------------|-------------------------|-------------------------|-------------------------|-----------------------|-------------------------|-----------------------|-----------------------|
| Vegetative and bud opening stage (101-109) | 2019-22 | SMW 23 to SMW 47 | -0.675**<br>(28-33.3)  | 0.662**<br>(18.3-23.9)  | 0.606**<br>(88.4-97.3)  | 0.840**<br>(55.6-94.0)  | 0.257<br>(23.-9.3)    | 0.786**<br>(0.9-506.7)  | -0.794**<br>(1.0-8.6) | -0.709**<br>(1.0-3.8) |
| Flowering (200-206)                        | 2019-22 | SMW 40 to SMW 11 | 0.547**<br>(30.3-35)   | -0.675**<br>(12.1-22.6) | 0.227<br>(86.0-94.4)    | -0.385**<br>(45.3-77.2) | -0.677**<br>(2.1-3.9) | -0.415**<br>(0.0-56.8)  | 0.495**<br>(5.2-9.6)  | -0.248<br>(2.8-5.3)   |
| Flower drop (207)                          | 2019-22 | SMW 02 to SMW 22 | -0.177<br>(30.3-35.0)  | 0.527**<br>(12.1-22.6)  | -0.021<br>(86.0-94.4)   | 0.381**<br>(45.3-77.2)  | 0.539**<br>(2.1-3.9)  | 0.203<br>(0.0-56.8)     | 0.296<br>(5.2-9.6)    | 0.104<br>(2.8-5.3)    |
| Fruiting (300-307)                         | 2019-22 | SMW 05 to SMW 22 | 0.700**<br>(29.6-35.0) | -0.200<br>(12.1-23.8)   | -0.679**<br>(84.5-94.9) | -0.578**<br>(45.3-86.7) | -0.003<br>(3.1-7.3)   | -0.398**<br>(0.0-284.9) | 0.548**<br>(3.0-9.7)  | 0.787**<br>(2.3-5.7)  |

(Value in the parenthesis indicates range of weather parameter)

**Tmax:** Maximum Temperature; **Tmin:** Minimum Temperature; **RH-I:** Morning Relative humidity; **RH-II:** Evening Relative humidity;

**WS:** Wind Speed; **BSS:** Bright sun shine; **Epan:** Evaporation

## Guava

### Hisar

Crop weather relationship studied in guava was started at Hisar during 2013-14. Hisar-Safeda, the popular existing guava variety in university orchard was studied in relation to prevalent weather parameters using appropriate correlation techniques. The plant age was 12 years and the planting density was 275 plants ha<sup>-1</sup>. Correlation of fruit yield and quality parameters with mean seasonal weather parameters is presented in Table 4.45.

**Table 4.45: Correlation of fruit yield and quality parameters of guava variety Hisar-Safeda with weather parameter under Hisar condition (pooled data analysis, 2013-14 to 2021-22)**

| Weather parameters                           | Yield and quality parameters       |                                   |                                 |            |                |
|----------------------------------------------|------------------------------------|-----------------------------------|---------------------------------|------------|----------------|
|                                              | Avg. fruit weight<br>(g per fruit) | Yield per plant<br>(kg per plant) | Yield<br>(kg ha <sup>-1</sup> ) | TSS<br>(%) | Acidity<br>(%) |
| T <sub>max</sub> (°C)                        | -0.65*                             | 0.25                              | 0.25                            | -0.13      | 0.31           |
| T <sub>min</sub> (°C)                        | -0.48*                             | 0.37                              | 0.37                            | 0.06       | 0.117          |
| SVPm (mm of Hg)                              | -0.39*                             | 0.44*                             | 0.44*                           | 0.11       | 0.13           |
| SVPe (mm of Hg)                              | -0.36                              | 0.43*                             | 0.43*                           | 0.12       | 0.08           |
| RH <sub>m</sub> (%)                          | 0.79*                              | 0.06                              | 0.06                            | 0.52*      | -0.43*         |
| RH <sub>e</sub> (%)                          | 0.44*                              | 0.37                              | 0.37                            | 0.46*      | -0.47*         |
| WS (km per hour)                             | -0.62*                             | 0.19                              | 0.19                            | -0.23      | 0.33           |
| BSS (hrs)                                    | -0.57*                             | 0.05                              | 0.05                            | -0.19      | 0.41*          |
| Ep (mm per day)                              | -0.63*                             | 0.26                              | 0.26                            | -0.15      | 0.40*          |
| Rf (mm per day)                              | -0.19                              | 0.23                              | 0.23                            | 0.09       | -0.04          |
| RD (day)                                     | -0.26                              | 0.34                              | 0.39*                           | 0.14       | 0.09           |
| RF (mm per season)                           | 0.05                               | -0.46*                            | -0.46*                          | -0.23      | -0.44*         |
| PAR (MJ m <sup>-2</sup> day <sup>-1</sup> )  | -0.04                              | 0.01                              | 0.08                            | 0.09       | 0.41*          |
| Rnet (MJ m <sup>-2</sup> day <sup>-1</sup> ) | -0.08                              | 0.25                              | 0.25                            | 0.08       | 0.47*          |
| Max. possible sunshine hours (hrs)           | -0.77*                             | 0.14                              | 0.14                            | -0.29      | 0.44*          |
| Et (mm)                                      | -0.08                              | 0.13                              | 0.13                            | 0.04       | 0.39*          |
| WUE (kg ha <sup>-1</sup> mm <sup>-1</sup> )  | 0.68*                              | 0.22                              | 0.22                            | 0.49*      | -0.17          |

\*Significant at 0.05 probability level, n=27

The results indicated that average fruit yield per plant showed significant positive correlation with saturation vapor pressure (both morning and evening) and negative correlation with seasonal rainfall. The average fruit weight showed significant negative correlation with Tmax, Tmin, morning saturation vapor pressure, wind speed and sunshine hours.

Total soluble solids (TSS) showed significant positive correlation with relative humidity (morning and evening) and water use efficiency. Acidity content of the fruit showed significant negative correlation with morning and evening relative humidity and seasonal rainfall. It showed significant positive correlation with bright sunshine hours, evaporation, PAR and net radiation.

## Black pepper

### Thrissur

Crop weather relationship studied in black pepper was started at Thrissur during 2018 in two popular varieties viz., Panniyur-I and II. Correlation of phenophases-wise mean weather parameters with pepper yield of Panniyur-I during 2018-2021 was studied and the result is presented in Table 4.46.

**Table 4.46: Correlation between yield of pepper variety Panniyur-I and weather variables during the year 2018 to 2021 at Thrissur**

| Growth stages      | Tmax<br>(° C) | Tmin<br>(° C) | RH I<br>(%) | RH II<br>(%) | WS<br>(kmph) | BSS<br>(hrs) | Evp<br>(mm) |
|--------------------|---------------|---------------|-------------|--------------|--------------|--------------|-------------|
| Spike Initiation   | 0.65          | -0.67         | -0.65       | -0.60        | 0.55         | 0.81         | 0.70        |
| Spike Emergence    | 0.64          | 0.16          | -0.67       | -0.68        | 0.95         | 0.55         | 0.64        |
| Spike Enlargement  | -0.72         | -0.39         | 0.38        | 0.95*        | -0.17        | -0.95        | 0.06        |
| Berry Development  | -0.54         | -0.26         | 0.28        | 0.70         | -0.29        | 0.21         | -0.09       |
| Maturity & Harvest | 0.17          | 0.24          | 0.02        | -0.28        | -0.54        | 0.21         | -0.16       |

The result indicated that the only significant correlation observed was between evening relative humidity during spike enlargement with pepper yield. Tmax during spike enlargement, Tmin during spike initiation, morning relative humidity during spike initiation and spike emergence showed negative correlation. Correlation of phenophases-wise mean weather parameters with pepper yield of Panniyur-II during 2018 to 2021 was studied and the result is presented in Table 4.47.

**Table 4.47: Correlation between yield of pepper variety Panniyur-II and weather variables during 2018-2021 at Thrissur**

| Growth stages      | Tmax<br>(° C) | Tmin<br>(°C) | RH I<br>(%) | RH II<br>(%) | WS<br>(kmph) | BSS<br>(hrs) | Evp<br>(mm) |
|--------------------|---------------|--------------|-------------|--------------|--------------|--------------|-------------|
| Spike Initiation   | 0.62          | 0.14         | -0.59       | -0.47        | 0.48         | 0.79         | 0.64        |
| Spike Emergence    | 0.53          | 0.67         | -0.57       | -0.59        | 0.85         | 0.37         | 0.54        |
| Spike Enlargement  | -0.59         | -0.58        | 0.17        | 0.93         | -0.34        | -0.85        | -0.34       |
| Berry Development  | 0.17          | -0.47        | 0.06        | -0.15        | -0.71        | 0.42         | 0.14        |
| Maturity & Harvest | 0.29          | 0.14         | -0.19       | -0.46        | -0.43        | 0.24         | -0.01       |

The results were almost similar compared to Panniyur-1. Evening relative humidity during spike enlargement showed high positive correlation with pepper yield. Tmax, Tmin and BSS during spike enlargement showed negative correlation.

## Ginger

### Thrissur

A field experiment was conducted to characterize crop weather relationship in two ginger varieties, Varada (released from ICAR-IISR) and Maran (local variety) under four different dates of planting. The treatments consist of 4 planting dates planted at a spacing of 25 x 25 cm on raised beds of 3m x 1m x15 cm size at 15 days interval starting from 15 May to 1 July. Correlation between dry yield of ginger and weather variables during different phenophases was estimated and presented in Table 4.48. The results indicated that most of the weather parameters had either significant positive or negative correlation with ginger yield. Same parameter showed significant positive correlation during some phenophases and significant negative correlation during other phenophases. For example, Tmax and Tmin during planting to sprouting showed significant positive correlation. At the same time, Tmax during Active tillering to bulking and Tmin during bulking to physiological maturity showed significant negative correlation.

The Principal Component Analysis was carried out for ginger variety Maran by using the weather parameters experienced in four stages of ginger *i.e.* planting to 50% sprouting, 50% sprouting to active tillering, and active tillering to bulking and bulking to physiological maturity. Weather parameters considered include maximum temperature (Tmax), minimum temperature (Tmin), rainfall (RF), rainy days (RD), relative humidity (RH), wind speed (WS) and solar radiation (SRAD). The number of principal components were retained using scree plot methods. Two principal components at varying proportions were identified that are given in Table 4.49.

**Table 4.48: Principal components and their proportion of variance in the case of PCA conducted for weather parameters and ginger yield at Thrissur**

| Parameter              | Component 1 | Component 2 | Cumulative proportion of variances |
|------------------------|-------------|-------------|------------------------------------|
| Eigen value            | 19.75       | 5.36        | -                                  |
| Proportion of variance | 70.54       | 19.16       | 89.70                              |

**Table 4.49: Correlation between dry ginger yield and phenophases-wise mean weather variables at Thrissur**

| Dates of Planting | Var            | Tmax (°C) | Tmin (°C) | RH(%)   | WS (kmhr <sup>-1</sup> ) | RF (mm) | RD      | BSS (hrs) | SRAD (MJ) | Evp (mm) | ST I5 (°C) | stI20 (°C) | stII5 (°C) | stII20 (°C) | SM5 (%) | SM20 (%) |
|-------------------|----------------|-----------|-----------|---------|--------------------------|---------|---------|-----------|-----------|----------|------------|------------|------------|-------------|---------|----------|
| P <sub>1</sub>    | V <sub>1</sub> | 0.78**    | 0.82**    | -0.71** | 0.74**                   | 0.227   | 0.59*   | 0.73**    | 0.82**    | 0.59*    | 0.77**     | 0.83**     | 0.68**     | 0.79**      | -0.87** | -0.56*   |
|                   | V <sub>2</sub> | 0.89**    | 0.89**    | -0.92** | 0.69**                   | 0.276   | 0.71**  | 0.86**    | 0.66**    | 0.78**   | 0.92**     | 0.90**     | 0.85**     | 0.88**      | -0.81** | -0.90**  |
| P <sub>2</sub>    | V <sub>1</sub> | 0.15      | 0.74**    | 0.24    | -0.86**                  | -0.564* | -0.60*  | -0.59*    | -0.86**   | -0.81**  | 0.87**     | 0.43       | -0.73**    | 0.68**      | -0.81** | -0.83**  |
|                   | V <sub>2</sub> | -0.26     | 0.75**    | -0.24   | -0.86**                  | -0.81** | -0.75** | -0.35     | -0.38     | -0.92**  | -0.71**    | -0.06      | 0.12       | 0.57*       | -0.73** | -0.79**  |
| P <sub>3</sub>    | V <sub>1</sub> | -0.84**   | 0.82**    | 0.81**  | -0.76**                  | 0.78**  | 0.82**  | -0.79**   | -0.75**   | -0.46    | 0.85**     | -0.22      | -0.69**    | -0.26       | 0.74**  | -0.22    |
|                   | V <sub>2</sub> | -0.86**   | 0.91**    | 0.85**  | -0.749**                 | 0.81**  | 0.76**  | -0.89**   | -0.89**   | -0.83**  | 0.38       | -0.47      | -0.65**    | -0.47       | 0.37    | -0.08    |
| P <sub>4</sub>    | V <sub>1</sub> | 0.43      | -0.03     | 0.77**  | -0.859**                 | 0.51*   | 0.54*   | -0.03     | 0.83**    | -0.03    | -0.74**    | -0.48      | -0.75**    | -0.47       | 0.22    | 0.22     |
|                   | V <sub>2</sub> | 0.25      | -0.75**   | 0.84**  | -0.872**                 | 0.74**  | 0.78**  | -0.38     | 0.52*     | -0.01    | -0.42      | -0.4       | -0.67**    | -0.75**     | 0.03    | -0.34    |

\*Significant at 5% level, \*\* Significant at 1% level, P1: Planting to sprouting, P2: Sprouting to active tillering, P3: Active tillering to bulking,

P4: Bulking to physiological maturity, V1: *Maran*, V2: *Varada*

A cumulative proportion of 89.70% was obtained for first two components *i.e.*, component 1 and component 2. Component 1 contributed a variance of 70.54 per cent, with eigen value 19.75 and component 2, a variance per cent of 19.16 with 5.36 eigen value. The cumulative proportion of different weather parameters is represented in a scree plot (Fig. 4.16). So, for the yield prediction of Maran only first two components were used in fitting the regression equation. The importance of various weather parameters in forming the two components are depicted in the variables factor map obtained from PCA and are given Fig. 4.17.

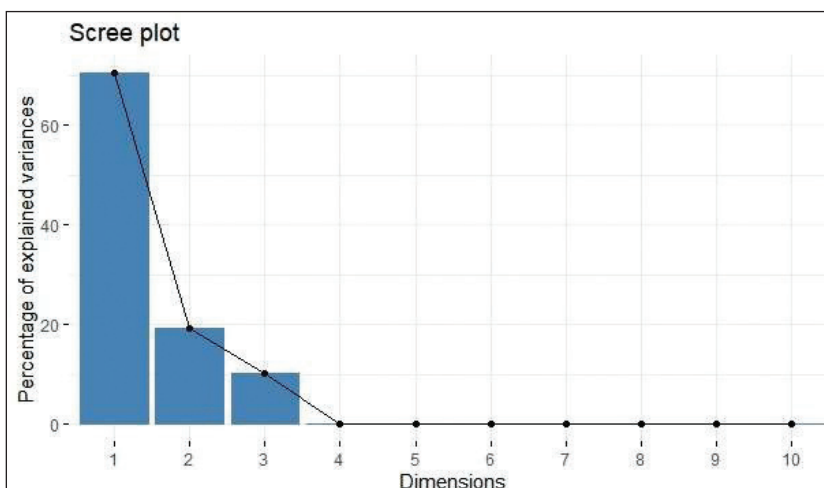


Fig. 4.16: Scree plot of variance percentage of cumulative proportion of different weather parameters of ginger variety Maran

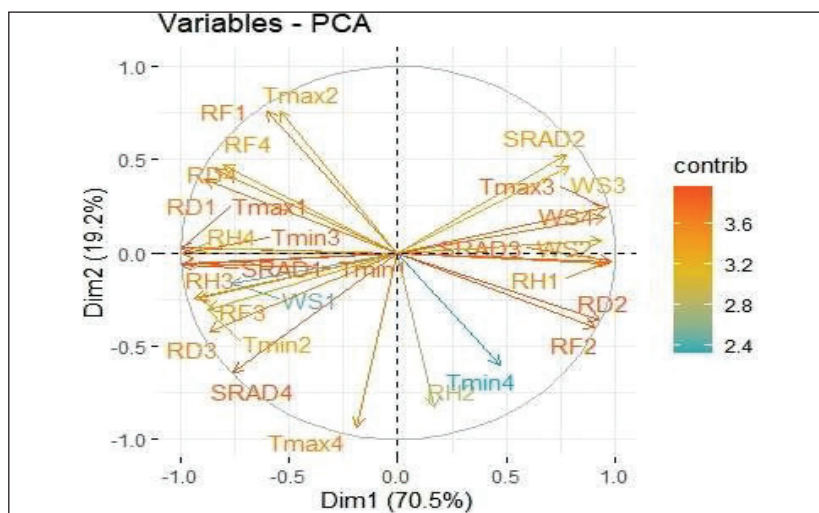


Fig. 4.17: Variables factor map obtained after PCA in ginger variety Maran

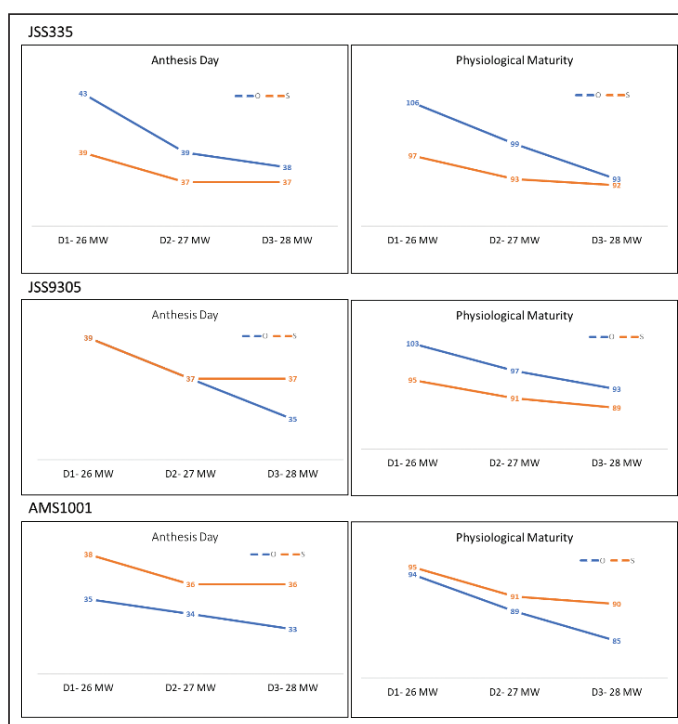
## 5. Crop Growth Modeling

### Akola

#### Soybean

Soybean model in DSSAT CSM was calibrated and validated for new soybean cultivars (JS-335, JS-9305 and AMS-1001) with the experimental field and weather data collected by Akola center. Genetic coefficients for each cultivar were determined with the GLUE coefficient estimator. Days to anthesis, first pod, first seed and physiological maturity of the three soybean varieties were simulated.

Since all the growth stages were predicted by the model with Per cent Error (PE) less than 10%, it can be concluded that phenology was well predicted by the model (Fig. 5.1).



**Fig. 5.1: Observed and simulated dates of various phenological stages in three different cultivars sown under three environments**

#### Seed yield

Relevant data on error per cent by simulated seed yield from observed is presented in Table 5.1. Observed and predicted mean seed yield across the sowing management was 1654 and

1617; 1488 and 1567; 1579 and 1615 for the varieties JS-335, JS-9305 and AMS-1001, respectively. The degree of agreement was 1.00. The PE was 3.92, 9.03 and 2.51, for JS-335, JS-9305 and AMS-1001, respectively across different sowing managements. Therefore, the prediction was well matched with observed values for all varieties particularly in AMS-1001 and JS 335 followed by JS 9305.

### Protective irrigation application using the calibrated model

The real field condition of south-west monsoon season of 2020 with timely onset followed by early mid-season dry spell in *kharif* crops with varying degree of adverse effect depending upon the sowing time and duration of crops was taken as case study. Continues rainfall received during 25 June-29 July made wet spell conditions. Mid-season dry spell during 31 MW (30 Jul-6 Aug) received only 8.7 mm rainfall (2 rainy days) coinciding with reproductive stage. Continues rainfall coincided at flowering to pod/seed development phase across different sowing times of soybean crop which might have boost the final yield performance of the crop.

Under environmental modification in DSSAT (CROPGRO Soybean), application of protective irrigation (60 mm) was added considering JS 335 cultivar and the model output showed that the light extent of yield gain with applied protective irrigation (Table 5.1). The yield gain through simulated protective irrigation was of greater magnitude in late sown soybean and more so at reproductive stage (pod formation to seed development) across all sowings.

**Table 5.1: Effect of environmental modification of added irrigation application on soybean seed yield during *kharif* 2021**

| Sowing time | Seed yield (kg ha <sup>-1</sup> ) |                                  |                                   |                         |                                   |
|-------------|-----------------------------------|----------------------------------|-----------------------------------|-------------------------|-----------------------------------|
|             | Observed<br>(normal<br>rainfed)   | Simulated<br>(normal<br>rainfed) | Simulated (protective irrigation) |                         |                                   |
|             |                                   |                                  | 1 irrigation<br>(Aug 13)          | 1 irrigation<br>(Sep 8) | 2 irrigations<br>(Aug 13 & Sep 8) |
| JS-335      |                                   |                                  |                                   |                         |                                   |
| D1 (26 MW)  | 1986                              | 2187                             | 2210 (FL-IN)                      | 2412 (PF-SF)            | 2787                              |
| D2 (27 MW)  | 1700                              | 1999                             | 2022 (MVG)                        | 2276 (PF)               | 2640                              |
| D3 (28 MW)  | 1276                              | 1819                             | 1914 (EVG)                        | 2018 (FL-PI)            | 2322                              |
| JS-9305     |                                   |                                  |                                   |                         |                                   |
| D1 (26 MW)  | 1616                              | 2102                             | 1834 (FL-IN)                      | 1887 (PF-SF)            | 1913                              |
| D2 (27 MW)  | 1590                              | 1986                             | 1598 (MVG)                        | 1658 (PF)               | 1686                              |
| D3 (28 MW)  | 1259                              | 1266                             | 1391 (EVG)                        | 1455 (FL-PI)            | 1566                              |
| AMS -1001   |                                   |                                  |                                   |                         |                                   |
| D1 (26 MW)  | 1965                              | 2040                             | 1986 (FL-IN)                      | 2056 (PF-SF)            | 2083                              |
| D2 (27 MW)  | 1513                              | 2133                             | 1783 (MVG)                        | 1823 (PF)               | 1903                              |
| D3 (28 MW)  | 1260                              | 1619                             | 1718 (EVG)                        | 1782 (FL-PI)            | 1819                              |

## Anand

### Pearl millet

Crop simulation model CERES-millet was calibrated using 2017 experimental crop and weather data at Anand. Further, the model was validated with four years field data of 2018, 2019, 2020 and 2021. The deviation of the simulation compared to observed values are depicted in Fig. 5.2. Model validation for 4 years showed that it is predicting the phenology, biomass yield and final grain yields well within the limits. The D index values for anthesis (days) 0.97, maturity (days) 0.99, LAI 0.99, grain yield ( $\text{kg ha}^{-1}$ ) 0.91 and above ground mass ( $\text{kg ha}^{-1}$ ) 0.91 were showing a good fit.

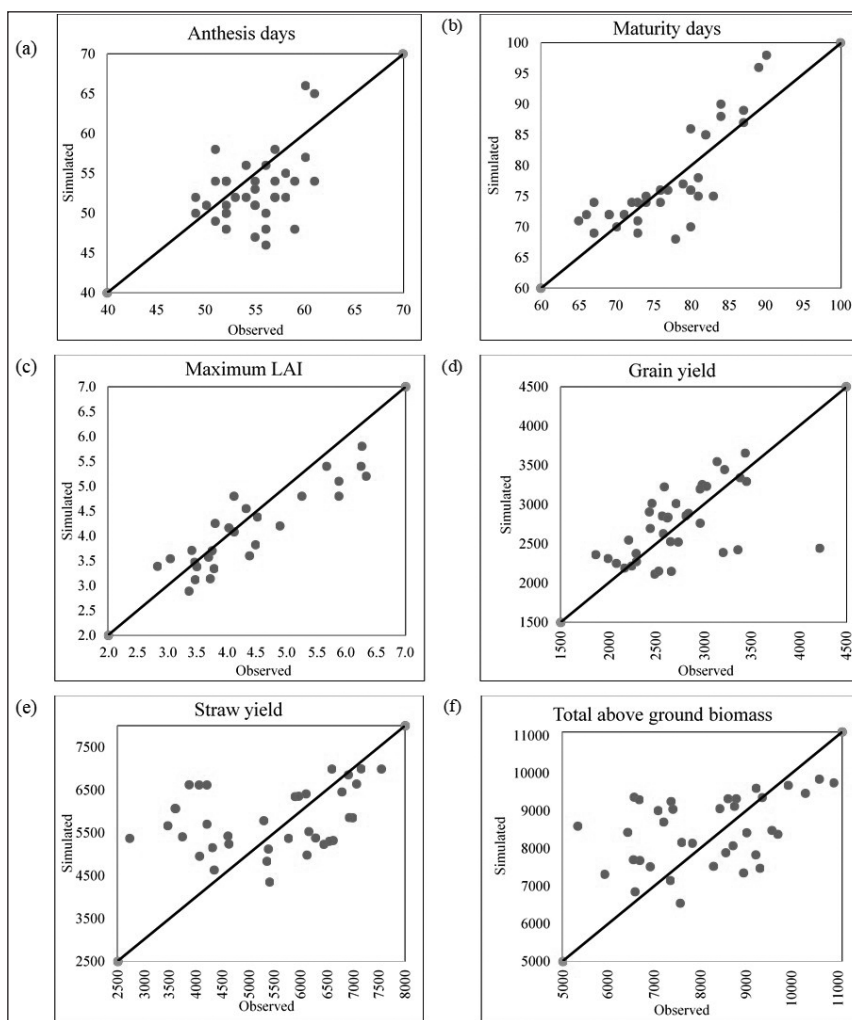


Fig. 5.2: Observed vs simulated growth and yield variables of pearl millet (2018 - 2021)

## Chatha

### Wheat yield prediction model for sub-tropical condition of Jammu

In order to develop the wheat yield prediction model, seven years weather data of different parameters and crop experimental data sets (*rabi* 2015-16 to 2021-22) were collected and analyzed at Chatha center, Jammu. Step-wise regression model was used to develop the prediction equation. It was found that, the step 3 regression model with weather parameters (Max T, Min T, RH, bright sunshine hours and evaporation) at different growth stages improved the accuracy of prediction up to 56 per cent (Table 5.2).

**Table 5.2: Step-wise regression model for wheat seed yield prediction**

|        | Regression model                                                                                                                                                                                                                                                                                                                | R <sup>2</sup> | Adj R <sup>2</sup> | SEm ± |
|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------|--------------------|-------|
| Step 1 | $Y = 21.26 + 0.12 (\text{MaxT}_3) + 0.74 (\text{MinT}_2) - 0.002 (\text{RH-II}_9) + 0.030 (\text{RF}_8) + 0.958 (\text{BSS}_3)$                                                                                                                                                                                                 | 0.35           | 0.30               | 4.66  |
| Step 2 | $Y = 36.30 - 0.001 (\text{MaxT}_2) + 0.423 (\text{MaxT}_3) - 0.139 (\text{MaxT}_4) - 0.139 (\text{MaxT}_4) - 0.251 (\text{MinT}_1) + 0.550 (\text{MinT}_2) - 0.006 (\text{MinT}_3) - 1.496 (\text{MinT}_5)$                                                                                                                     | 0.42           | 0.34               | 4.51  |
| Step 3 | $Y = 49.79 + 0.271 (\text{MaxT}_2) + 0.032 (\text{MaxT}_3) - 0.407 (\text{MaxT}_4) - 0.310 (\text{MinT}_1) + 0.332 (\text{MinT}_2) + 0.641 (\text{MinT}_3) - 0.751 (\text{MinT}_5) - 0.109 (\text{RH-II}_9) + 0.630 (\text{BSS}_3) - 0.424 (\text{BSS}_9) - 0.064 (\text{EP}_8) - 0.038 (\text{EP}_9) - 0.059 (\text{EP}_{10})$ | 0.56           | 0.44               | 4.1   |

*RH-II<sub>9</sub>* - Evening relative humidity at hard dough; *BSS<sub>3</sub>* - Bright sun shine hours at tillering stage

*BSS<sub>9</sub>* - Bright sun shine hours at hard dough stage; *EP<sub>8</sub>* - Evaporation (mm) at milking stage

*EP<sub>9</sub>* - Evaporation (mm) at hard dough stage; *EP<sub>10</sub>* - Evaporation (mm) at Physiological stage

*RF<sub>8</sub>* - Rainfall (mm) at milking stage

## 6. Weather Effects on Pest and Diseases

### *Kharif*

#### Anantapuramu

#### Spotted pod borer in red gram

Anantapuramu center studied the relationship between weather and incidence of spotted pod borer (*Maruca vitrata*) on red gram during 2019, 2020 and 2021. Data on larvae per square meter was recorded in the field experiments. It was found that, number of webs, larvae per square meter was high during the month of December 2019, attributed to low temperatures prevailing during the month. The statistical analysis showed, negative correlation between the number of webs, larvae per square meter with the temperature, SSH and positive correlation with relative humidity. Number of webs, larvae per square meter was recorded high during the months of November and December 2020 due to low temperatures. Negative correlation was noticed between the number of webs, larvae per square meter and temperature, SSH and positive correlation with relative humidity were also observed.

**Table 6.1: Number of webs and live larvae per square meter in red gram as influenced by sowing environment under rainfed conditions during 2021-22 at ARS, Rekulakunta**

| DAS            | D1- II FN of June      |                         | DAS             | D2- I FN of July       |                         | DAS             | D3- II FN of July      |                         | DAS             | D4- I FN of August     |                         |
|----------------|------------------------|-------------------------|-----------------|------------------------|-------------------------|-----------------|------------------------|-------------------------|-----------------|------------------------|-------------------------|
|                | NOW<br>m <sup>-2</sup> | NOLL<br>m <sup>-2</sup> |                 | NOW<br>m <sup>-2</sup> | NOLL<br>m <sup>-2</sup> |                 | NOW<br>m <sup>-2</sup> | NOLL<br>m <sup>-2</sup> |                 | NOW<br>m <sup>-2</sup> | NOLL<br>m <sup>-2</sup> |
| 135            | 12                     | 3                       | 138             | 4                      | 2                       | 128             | 6                      | 1                       | 104             | 5                      | 2                       |
| 142            | 18                     | 4                       | 145             | 8                      | 5                       | 135             | 6                      | 2                       | 111             | 13                     | 9                       |
| 149            | 29                     | 13                      | 152             | 19                     | 8                       | 142             | 9                      | 4                       | 118             | 18                     | 14                      |
| 156            | 24                     | 10                      | 159             | 25                     | 13                      | 149             | 15                     | 10                      | 125             | 29                     | 19                      |
| 163            | 25                     | 16                      | 166             | 25                     | 15                      | 156             | 21                     | 13                      | 132             | 19                     | 16                      |
| 170            | 20                     | 12                      | 173             | 23                     | 10                      | 163             | 18                     | 15                      | 139             | 11                     | 7                       |
| 177            | 17                     | 11                      | 180             | 18                     | 8                       | 170             | 14                     | 10                      | 146             | 4                      | 2                       |
| 184            | 15                     | 7                       | 187             | 10                     | 2                       | 177             | 9                      | 4                       | 153             | 4                      | 0                       |
| 191            | 10                     | 2                       | 194             | 4                      | 0                       | 184             | 4                      | 0                       | 160             | 1                      | 0                       |
| 198            | 2                      | 0                       | 201             | 2                      | 0                       | 191             | 2                      | 0                       | 167             | 1                      | 0                       |
| 205            | 1                      | 0                       | 208             | 1                      | 0                       |                 |                        |                         |                 |                        |                         |
| 11 Nov- 20 Jan |                        |                         | 21 Nov - 30 Jan |                        |                         | 29 Nov - 30 Jan |                        |                         | 25 Nov - 27 Jan |                        |                         |

\*NOW- No. of Webs      \*NOLL- No. of Live Larvae

During 2021-22, incidence of spotted pod borer was first observed on 11.11.2021 in II FN of June sown crop followed by the 1 July sown crop, I FN of August and II FN of July sown red gram crop. Irrespective of date of sowing, the spotted pod borer infestation in red gram crop was observed for 8 weeks. Peak incidence of pod borer was noticed between 02.12.2021 and 23.12.2021 in all dates of sowing. Higher incidence of pest (>5 webs per square meter and >3 live larvae per square meter) was observed for longer period of 7 weeks in II FN of June sown crop and maximum number of webs per square meter and live larvae per square meter was recorded at 149 DAS (Table 6.1). Yield and yield attributes of red gram as affected by spotted pod borer during *kharif* 2021 is presented in Table 6.2.

**Table 6.2: Yield and yield attributes of red gram as affected by spotted pod borer during 2021-22 at ARS, Rekulakunta**

| Treatments      | No. of pods m <sup>-2</sup> | Filled pods m <sup>-2</sup> | Unfilled pods m <sup>-2</sup> | Pod borer damaged pods m <sup>-2</sup> | 100 seed weight (g) | Seed yield (kg ha <sup>-1</sup> ) |
|-----------------|-----------------------------|-----------------------------|-------------------------------|----------------------------------------|---------------------|-----------------------------------|
| Dates of Sowing | Rainfed                     |                             |                               |                                        |                     |                                   |
| 30 June         | 904                         | 805                         | 99                            | 377                                    | 7.1                 | 282                               |
| 07 July         | 1079                        | 954                         | 125                           | 241                                    | 7.4                 | 633                               |
| 24 July         | 1140                        | 1048                        | 92                            | 219                                    | 8.4                 | 660                               |
| 14 August       | 1026                        | 783                         | 243                           | 492                                    | 7.6                 | 221                               |

The correlation analysis for the rainfed crop indicated that there was a significant negative correlation between no. of webs per square meter and live larvae per square meter with rainfall, maximum temperature, minimum temperature, wind speed and evaporation and significant positive correlation with morning relative humidity, but not significantly correlated with afternoon relative humidity and sunshine hours (Table 6.3).

**Table 6.3: Correlation between weather parameters and webs m<sup>-2</sup> and live larvae m<sup>-2</sup> in red gram as influenced by different sowing environments under rainfed and during 2021-22 at ARS, Rekulakunta**

| Parameter                   | Rainfall (mm) | T <sub>max</sub> (°C) | T <sub>min</sub> (°C) | RH <sub>1</sub> (%) | RH <sub>2</sub> (%) | WS (kmph) | SSH (hr/day) | EVP (mm) |
|-----------------------------|---------------|-----------------------|-----------------------|---------------------|---------------------|-----------|--------------|----------|
|                             | Rainfed       |                       |                       |                     |                     |           |              |          |
| Webs m <sup>-2</sup>        | -0.058        | -0.231                | -0.348*               | 0.465**             | 0.055               | -0.161    | 0.011        | -0.336*  |
| Live larvae m <sup>-2</sup> | -0.099        | -0.220                | -0.385**              | 0.452**             | 0.001               | -0.244    | 0.062        | -0.315*  |

\* significant @5% level; \*\* significant @ 1% level

## Hisar

### Leaf curl virus disease in cotton

Weekly incidence of cotton leaf curl disease in susceptible variety HS-6 was recorded during 2005-21 under natural conditions by the cotton section, CCSHAU, Hisar. A simple weather-disease prediction model for cotton leaf curl virus disease was developed by Hisar AICRPAM center.

The per cent incidence of cotton leaf curl virus disease data (2005 to 2021) was collected and correlated with various weather parameters. The maximum temperature (-0.61), minimum temperature (-0.43), wind speed (-0.61), actual vapour pressure (AVP) at morning (-0.16) and evening (-0.11), evaporation (-0.67), and rainfall (-0.05) showed negative correlation with disease development, whereas morning relative humidity and accumulated rainfall showed a significant positive relationship (Table 6.4).

**Table 6.4: Relationship between percentage incidence of leaf curl virus in cotton and weather parameters at Hisar (pooled data 2005-2021)**

| Weather parameters    | Correlation coefficient |
|-----------------------|-------------------------|
| $T_{\max}$ (°C)       | -0.61*                  |
| $T_{\min}$ (°C)       | -0.43*                  |
| AVP <sub>m</sub> (mm) | -0.16*                  |
| AVP <sub>e</sub> (mm) | -0.11                   |
| RH <sub>m</sub> (%)   | 0.53*                   |
| RH <sub>e</sub> (%)   | 0.12*                   |
| WS (kmph)             | -0.61*                  |
| SSH (hr.)             | 0.07                    |
| E <sub>p</sub> (mm)   | -0.67*                  |
| RF (mm)               | -0.05                   |
| Accu. RF (mm)         | 0.73*                   |

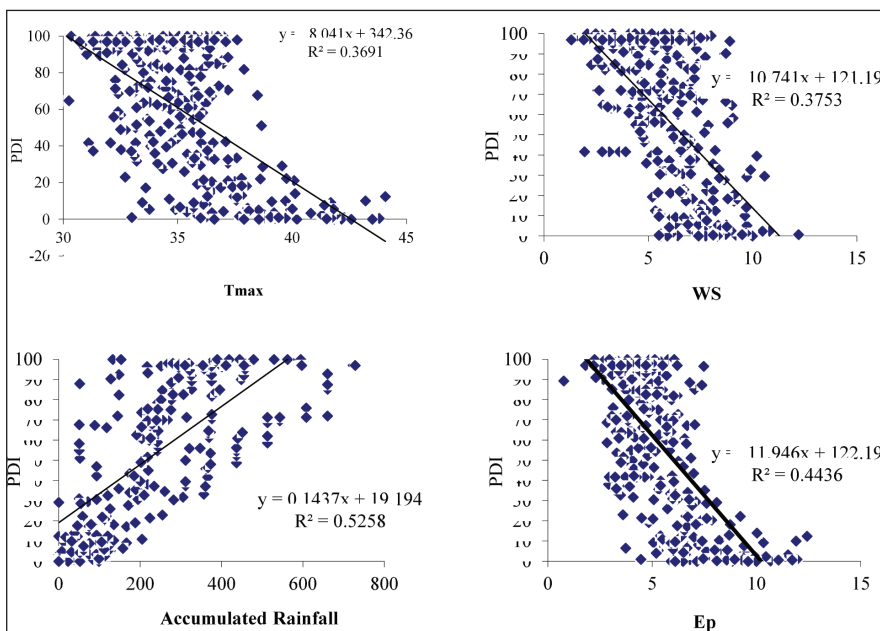
*n=304, 5% significant level\**

### Thumb rule conditions

The maximum value of percentage incidence of leaf curl virus was noticed from 22 to 45 SMWs and the optimum range of weather parameter was found to be 32.3-36.3 °C (maximum temperature), 24.5-29.6 °C (minimum temperature) and 73-87 per cent (morning relative humidity) and 7.0-9.1 hrs (bright sunshine hours).

The wind speed showed a highly significant negative correlation with disease development which may be interpreted as favorable for white fly migration. There was an exponential relationship between disease development and cumulative rainfall (sigmoid growth curve)

i.e. the rate of disease development was initially slower till the accumulation of 100 mm rainfall and thereafter increased sharply (Fig. 6.1). The sunshine hours showed a linear positive relationship with disease indicating that the clear days favored its development.



**Fig. 6.1: Scatter plot between Percentage Disease Incidence (PDI) of cotton leaf curl virus and meteorological parameters (2005-2021)**

### Prediction equations for cotton leaf curl virus disease

Using the identified weather variables, a stepwise multiple linear regression analysis was carried out to identify best suited model for predicting the cotton leaf curl virus disease (Table 6.5).

**Table 6.5: Multiple regression equation for PDI prediction (Cotton leaf curl virus disease)**

| S. No | Multiple regression models                                                                                                             | R <sup>2</sup> |
|-------|----------------------------------------------------------------------------------------------------------------------------------------|----------------|
| 1.    | $Y = 145.80 + 0.059 \cdot RH_m - 4.98 \cdot WS - 0.764 \cdot T_{min} - 7.99 \cdot Ep$                                                  | 0.51           |
| 2.    | $Y = 63.15 - 1.70 \cdot T_{max} - 0.692 \cdot AVP_m + 0.438 \cdot RH_m + 0.129 \cdot \text{Accu. RF}$                                  | 0.61           |
| 3.    | $Y = 101.63 - 1.392 \cdot T_{max} + 0.0963 \cdot \text{Accu. Rf} + 0.180 \cdot AVP_m - 3.036 \cdot WS - 1.785 \cdot Ep$                | 0.62           |
| 4.    | $Y = 168.13 - 1.61 \cdot T_{max} + 0.009 \cdot \text{Accu. Rf} - 0.644 \cdot AVP_m - 5.68 \cdot Ep + 0.233 \cdot RH_m - 4.90 \cdot WS$ | 0.52           |

Where,  $T_{max}$ : Maximum temperature (°C),  $T_{min}$ : Minimum temperature (°C),  $AVP_m$ : Actual vapor pressure morning (mm of Hg),  $WS$ : Wind speed (km/hr),  $Ep$ : Pan Evaporation (mm),  $\text{Accu. RF}$ : Accumulated rainfall (mm), The variability in occurrence of cotton leaf curl disease of Hisar zone was explained up to 61% with the

help of significant weather parameters.

### Population dynamics of mustard aphid

Mustard aphid data of 8 years (2014-2021) was collected from the department of entomology on late sown mustard crop over *Brassica* spp. i.e. *B. rapa*. Correlation studies were carried out with various weather parameters. Further correlation was performed with the pooled data from 2014 -2021 (Table 6.6).

It was found from the correlation analysis that, the significant positive correlation of aphid population with temperatures (Max., Min., and mean), sunshine hours (0.30), temperature humidity index (0.24), normal net radiation (0.36), normal photosynthetic active radiation (0.42), net radiation (0.36), growing degree days (0.23) and heliothermal units (0.30).

**Table 6.6: Correlation between mustard aphid and weather parameters/indices at Hisar (Pooled 2014-2021)**

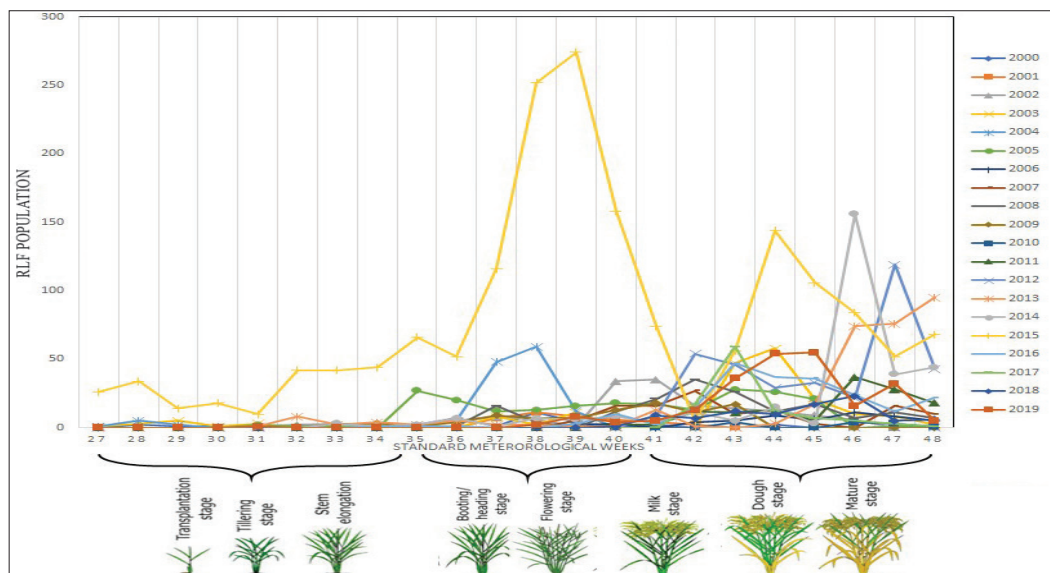
| S. No. | Weather parameters                                                             | Correlation coefficient |
|--------|--------------------------------------------------------------------------------|-------------------------|
| 1.     | Maximum Temperature (°C)                                                       | 0.29*                   |
| 2.     | Minimum Temperature (°C)                                                       | 0.28*                   |
| 3.     | Mean Temperature (°C)                                                          | 0.29*                   |
| 4.     | Relative humidity morning (%)                                                  | -0.03                   |
| 5.     | Relative humidity evening (%)                                                  | -0.27*                  |
| 6.     | Mean Relative humidity (%)                                                     | -0.21*                  |
| 7.     | Wind direction morning (degree)                                                | 0.01                    |
| 8.     | Wind direction evening (degree)                                                | -0.02                   |
| 9.     | Bright sunshine hour (hr.)                                                     | 0.30*                   |
| 10.    | Rainfall (mm)                                                                  | -0.01                   |
| 11.    | Accumulated rainfall (mm)                                                      | 0.13                    |
| 12.    | Rainy days (day)                                                               | 0.11                    |
| 13.    | Net short-wave radiation (MJ m <sup>-2</sup> day <sup>-1</sup> )               | 0.14                    |
| 14.    | Net long wave radiation (MJ m <sup>-2</sup> day <sup>-1</sup> )                | -0.12                   |
| 15.    | Net Radiation (MJ m <sup>-2</sup> day <sup>-1</sup> )                          | 0.36*                   |
| 16.    | Normal net radiation (MJ m <sup>-2</sup> day <sup>-1</sup> )                   | 0.36*                   |
| 17.    | Photosynthetic Active Radiation (MJ m <sup>-2</sup> day <sup>-1</sup> )        | 0.19                    |
| 18.    | Normal Photosynthetic Active Radiation (MJ m <sup>-2</sup> day <sup>-1</sup> ) | 0.42*                   |
| 19.    | Crop reference evapotranspiration (mm day <sup>-1</sup> )                      | 0.15                    |
| 20.    | Growing degree day (°C day)                                                    | 0.23*                   |
| 21.    | Heliothermal unit (°C day hour)                                                | 0.30*                   |
| 22.    | Photothermal unit (°C day hour)                                                | 0.23*                   |
| 23.    | Temperature Humidity Index (THI)                                               | 0.24*                   |
| 24.    | Wind Chill Index (WCI)                                                         | 0.11                    |
| 25.    | Maximum possible sunshine hours (hour)                                         | 0.25*                   |
| 26.    | Saturated vapour pressure morning (mm of Hg)                                   | 0.23*                   |
| 27.    | Saturated vapour pressure evening (mm of Hg)                                   | 0.14                    |

\*Significant at 0.05 probability level,  $n = 102$  for pooled data (2014-15 to 2021-22)

## Raipur

### Rice leaf folder

Rice crop experiment was conducted during 27 to 48 weeks from the year 2000 to 2019 at Raipur. Rice Leaf Folder (RLF) data and weather variables were collected and analyzed (Fig. 6.2).



**Fig. 6.2: Relationship between rice leaf folder and different growth stages**

The highest moth population of leaf folder was recorded during 43-45 SMW (*i.e.*, from October last week to November second week). Correlation analysis of RLF population and weather parameters over the years from 2000 to 2019 was done and presented in the Table 6.7. There is a strong negative correlation between leaf folder population and minimum temperature ( $r = -0.75^{**}$ ), rainfall ( $r = -0.87^{**}$ ) and evening relative humidity ( $r = -0.82^{**}$ ) whereas a significant positive correlation with sunshine hours ( $r = 0.9^{**}$ ) was observed. From these results, it can be concluded that warm, humid climate with 6-8 hours of sunshine hours is favourable for the moth population to develop and cause significant infestation. Temperature optimal for development of larva to adult is 31.5-32.0 °C. A

comprehensive summarization of leaf folder behavior in significant weeks with parameters and phenophases of rice crop has been shown in Table 6.7.

**Table 6.7: Correlation between RLF population and weather parameters in different weeks & phenophases based on long term data analysis over 2000-2019**

| Week No. | Phenophase       | RLF population dynamics                                                                            | Significant parameters | Correlation                   |
|----------|------------------|----------------------------------------------------------------------------------------------------|------------------------|-------------------------------|
| 34       | Stem Elongation  | Usual buildup of population initiation from this week forth                                        | Min. Temp. (°C)        | Corresponding week (positive) |
|          |                  |                                                                                                    | RH-I (%)               | Corresponding week (negative) |
| 35       | Booting/ Heading | Gradual increase in average RLF population                                                         | RH-I (%)               | 1-week lag (negative)         |
|          |                  |                                                                                                    | RH-II (%)              | 1-week lag (negative)         |
| 36       | Booting/ Heading | Average of 5 moths                                                                                 | RH-I (%)               | 2-week lag (negative)         |
| 37       | Flowering        | Average of 11 months                                                                               | Max. Temp. (°C)        | Corresponding week (positive) |
|          |                  |                                                                                                    | RH-I (%)               | 3-week lag (negative)         |
|          |                  |                                                                                                    | SSH-I (hours)          | 1-week lag (positive)         |
| 38       | Flowering        | Average of 19 moths, population started steep increase                                             | Max. Temp. (°C)        | 4-week lag (negative)         |
|          |                  |                                                                                                    | RH-I (%)               | 4-week lag (negative)         |
| 44       | Dough            | Average of 22 population, almost peak of 54 moths for the year 2019                                | Max. Temp. (°C)        | 4-week lag (negative)         |
| 45       | Maturity         | Average of 18 population, peak of 55 moths for the year 2019                                       | Max. Temp. (°C)        | 4-week lag (negative)         |
| 46       | Maturity         | Average of 24, population started declining                                                        | Min. Temp. (°C)        | 3-week lag (positive)         |
| 47       | Maturity         | Average of 21, population of 32 registered during 2019, population steeply declined from this week | Rainfall (mm)          | 2-week lag (positive)         |
|          |                  |                                                                                                    | Rainfall (mm)          | 3-week lag (positive)         |
|          |                  |                                                                                                    | RH-I (%)               | 2-week lag (positive)         |
|          |                  |                                                                                                    | RH-II (%)              | Corresponding week (positive) |
|          |                  |                                                                                                    | SSH (hours)            | 4-week lag (negative)         |

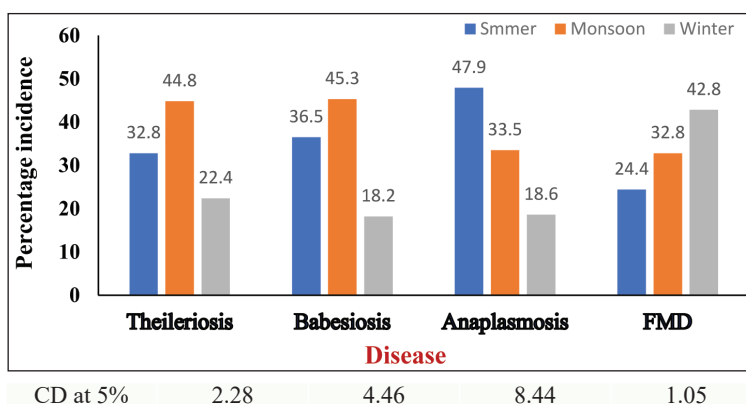
## Ranchi

### Diseases in cattle

An investigation was undertaken on the occurrence of haemo-protozoan disease especially Theileriosis, Babesiosis, Anaplasmosis and Foot and Mouth Disease (FMD) in livestock at Ranchi District by using the retrospective data from the period 2012 to 2020. Data regarding the disease attack in cattle was collected from the Institute of Animal Health and Production (IAHP) Kanke, Ranchi, Instructional Bovine Farm of RVC, Kanke. The

meteorological data regarding the temperature, humidity and rainfall of Ranchi district was collected from the Agromet observatory situated in BAU, Ranchi during 2012 to 2020. Three seasons viz. summer, monsoon and winter and seasonal average temperature, humidity and rainfall were considered for analysis. The percentage incidence of the disease in the Ranchi district were correlated with the meteorological parameters. The seasonal occurrences of diseases were recorded and their statistical analysis of variance was done.

The results revealed that (Fig. 6.3) average incidence percentage of Theileriosis and Babesiosis in cattle was significantly highest in monsoon (44.8% and 45.3%) followed by summer (32.8% and 36.5%) and lowest in winter (22.4% and 18.2%), respectively. Prevalence of Anaplasmosis was significantly highest in summer (47.9%) followed by monsoon (33.5%) and lowest in winter (18.6%). Cattle was more susceptible to FMD in winter season when the average attack percentage was 42.8% followed by monsoon (32.8%) and lowest in summer season (24.4%).



**Fig 6.3: Average percentage incidence of diseases in livestock during different seasons (2012-2020) at Ranchi**

### Weather parameters vs diseases

Data presented in Table 6.8 showed that the correlation between Theileriosis and minimum temperature ( $r = 0.88^*$ ) and rainfall ( $r = 88^*$ ) was found positively significant for cattle. Non-significant and positive correlation was observed between Theileriosis and morning and evening relative humidity. Among weather parameters, minimum temperature ( $r = 0.74$ ) and rainfall ( $r = 0.72$ ) had significant positive correlation with Babesiosis in cattle similar to Theileriosis. Minimum temperature and rainfall exhibited significant positive relationship with Babesiosis. This indicates that increase in minimum temperature and rainfall will increase the incidence of Babesiosis in cattle.

The data in Table 6.8 revealed the correlation of Anaplasmosis with weather parameters, *i.e.* maximum ( $r = 0.78^*$ ) and minimum ( $r = 0.62^{**}$ ) air temperature were highly and positively significant in cattle. Other weather parameters like morning relative humidity and rainfall had positive and evening relative humidity had negative and non-significant association with prevalence of Anaplasmosis. The results indicated that cattle were more susceptible to Anaplasmosis with increase in air temperature.

The impact of weather factors on FMD in cattle during study period (2012-2020) is presented in Table 6.8. The result revealed that there was significantly negative correlation with maximum ( $r = -0.84^*$ ) and minimum ( $r = -0.75^*$ ) temperature and non-significant negative correlation with morning relative humidity and rainfall while evening relative humidity showed a non-significant positive correlation with FMD incidence. Above results indicated that lower maximum and minimum temperature is conducive for FMD incidence in cattle and decrease in maximum temperature is most detrimental for FMD than decrease in minimum temperature.

**Table 6.8: Correlation coefficient between weather parameters and disease attack in cattle**

| Weather Parameters              | Theileriosis | Babesiosis | Anaplasmosis | FMD    |
|---------------------------------|--------------|------------|--------------|--------|
| Maximum Temperature (°C)        | 0.49         | 0.52       | 0.78*        | -0.84* |
| Minimum Temperature (°C)        | 0.88*        | 0.74*      | 0.62**       | -0.75* |
| Relative Humidity at 7:00am (%) | 0.44         | 0.19       | 0.13         | -0.21  |
| Relative Humidity at 2:00pm (%) | 0.53         | 0.27       | -0.37        | 0.18   |
| Rainfall (mm)                   | 0.88*        | 0.72*      | 0.15         | -0.36  |

\* Significant at 0.01 level; \*\* Significant at 0.05 level

## Rabi

### Anand

#### Weather effects on aphid infestation in mustard

A study was conducted to identify the optimum weather conditions for outbreak and spread of mustard aphids. Weather-based aphid prediction models in mustard was developed by Anand center under different growing environments.

#### Aphid index under different dates of sowing

The mean aphid index (0-5 Scale) of mustard under different growing environments [ $D_1$  (10 Oct. 2021),  $D_2$  (20 Oct. 2021),  $D_3$  (30 Oct. 2021),  $D_4$  (10 Nov. 2021)] is presented in Fig. 6.4. Occurrence of aphid was noted at 50 SMW. Maximum aphid index was recorded in  $D_3$

followed by D<sub>2</sub> and D<sub>1</sub> sowing at 3 SMW. In D<sub>4</sub> sowing, highest aphid index was observed at 4 SMW.

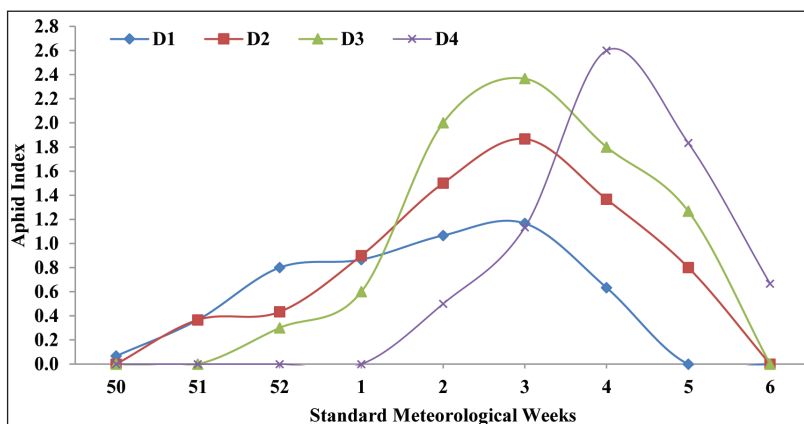


Fig. 6.4: Mean aphid index as prevailed under different growing environments

### Aphid infestation and favourable weather condition

Correlation analysis revealed that there is no statistically significant association between weather parameters prevailed during infestation and aphid population. Correlation coefficient for two days' average weather parameter of lead time and first occurrences (n=18) is given in Table 6.9. Among the weather parameters, minimum temperature shows consistent negative association with aphid index at first occurrence, though the correlation wasn't statistically significant.

**Table 6.9: Correlation between two days average weather parameter of lead time to first occurrences**

| Lead days | BSS (hours) | Tmax (°C) | Tmin (°C) | RH1 (%) | RH2 (%) |
|-----------|-------------|-----------|-----------|---------|---------|
| 1         | 0.11        | 0.18      | -0.02     | 0.02    | 0.21    |
| 2         | 0.13        | 0.12      | -0.13     | 0.29    | 0.16    |
| 3         | -0.04       | -0.02     | -0.19     | 0.37    | 0.08    |
| 4         | -0.25       | -0.23     | -0.18     | 0.31    | 0.14    |
| 5         | -0.18       | -0.19     | -0.14     | 0.30    | 0.28    |
| 6         | -0.12       | -0.12     | -0.13     | 0.08    | 0.23    |
| 7         | -0.12       | -0.05     | -0.08     | -0.01   | 0.31    |
| 8         | -0.05       | -0.05     | -0.05     | -0.15   | 0.30    |
| 9         | 0.13        | -0.19     | -0.19     | -0.25   | 0.01    |
| 10        | -0.08       | -0.24     | -0.26     | -0.22   | -0.05   |
| 11        | -0.41       | -0.21     | -0.15     | 0.01    | -0.06   |
| 12        | -0.24       | -0.20     | -0.18     | 0.29    | 0.00    |

|    |       |       |       |      |       |
|----|-------|-------|-------|------|-------|
| 13 | -0.06 | -0.14 | -0.29 | 0.39 | -0.01 |
| 14 | -0.09 | -0.10 | -0.20 | 0.30 | 0.05  |
| 15 | -0.13 | -0.11 | -0.07 | 0.00 | 0.22  |

It was observed that, low minimum temperature, more sunshine hours and high morning relative humidity prevalence for 2-5 days might be responsible for initiation of aphid infestation in mustard crop during flowering to pod initiation phase. Correlation coefficients with two days' temperature of 11-12 lead days also show that more sunshine hours and high temperature lowers aphid intensity/infestation which occurs after 12-14 days in mustard. Morning relative humidity of 12-13 days prior to first occurrence has relatively high positive association.

### Impact of aphid intensity during flowering - seed development phase on mustard seed yield

Aphid index of flowering to seed development phase and seed yield grown under four sowing environments for twenty years are depicted in Fig. 6.5. Seed yields of mustard crop were found higher ( $\geq 1500$  kg ha<sup>-1</sup>) when aphid intensities during flowering - seed development phase were lower than 1.7 and vice versa.



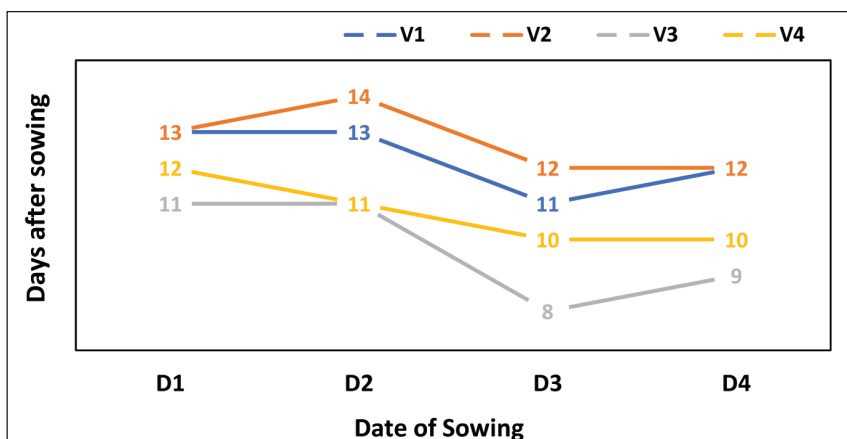
Fig. 6.5: Aphid intensity at different observations during flowering to seed development (20 years x 4 dates of sowing) at Anand

## Bhubaneswar

### Fall army worm in hybrid maize

Weather influence on Fall Army Worm (*Spodoptera frugiperda*) (FAW) in hybrid maize was exhaustively studied by Bhubaneswar center. Four hybrid maize varieties were sown in four environments during 21-31 January and 08-19 February 2021 with two hybrid DKC 9081 (V1), 900M gold (V2) maize varieties, and two sweet corn varieties Sugar 75 (V<sub>3</sub>) and NSCH130 (V4). Data on the larval population and the extent of damage (average

of four varieties under study) throughout the crop growth period under different sowing environments were collected. The date of initiation of larval infestation is plotted for four varieties (Fig. 6.6).



**Fig. 6.6: Date of initiation of larval infestation**

Maximum crop damage was observed in sweet corn varieties Sugar 75 (63%) and NSCH 130 (59%), whereas the damage of 38.5% and 36% was observed in the normal maize hybrid varieties DKC 9081 and 900 Mgold, respectively. The damage was observed during 5-7 weeks after sowing.

### **Thumb rule for the onset and spread of the FAW**

The FAW infestation was found at a maximum temperature ranging from 27.0 to 37.5 °C but peak was at a temperature between 32 and 35 °C. The infestation and larvae were found at minimum temperature at 12-23.6 °C but the peak was at temperature of 16.6-20.2 °C. The occurrence was seen from 78 to 90% RH and peak at high morning relative humidity 86-90% and evening relative humidity 35-40%.

### **Correlation between per cent damaged plants, larval intensity and weather parameters**

Correlation between percentage of damaged plant, larval intensity per plant with different weather parameters was computed. A positive significance correlation with percentage of damaged plant was observed with maximum temperature (0.54) and bright sunshine hours (0.62), while negative correlation with evening relative humidity (-0.78). whereas the Larval intensity per plant under the first sowing environment was positively correlated with maximum temperature (0.64) and bright sunshine hours (0.74) and negatively correlated with evening relative humidity (-0.77). While in the second sowing environment,

percentage of damaged plant (0.69) and Larval intensity per plant (0.60) correlated with bright sunshine hours. However, in the third and fourth sowing environments, larval intensity per plant had a significant negative correlation with maximum temperature, minimum temperature, bright sunshine hours, evening relative humidity and wind speed. The morning relative humidity (0.6) is significantly correlated with percentage of damaged plant and larval intensity per plant (0.66) in the third sowing environment.

## Faizabad

### Pod borer in chickpea

Chickpea crop was sown in November at Faizabad. Pod borer (*Helicoverpa armigera*) is an important major insect pest of chickpea grown in *rabi* season. Due to higher parasitization, its population was maintained up to ETL (more than 2 larvae per square meter or per 100 pods during reproductive stage). Weather variables *viz.* max. and minimum temperatures, relative humidity of morning and evening were recorded from the agrometeorological observatory of the university and infestation of larval population of pod borer were recorded weekly in five plants of each plots of experiment and averaged to get weekly larval population dynamics of pod borer per plant. Maximum appearance of this pod borer was noticed during reproductive phase of growth. Correlation studies have been taken up between larval population of pod borer and weather parameters in chickpea variety K-850 and presented in Table 6.10.

**Table 6.10: Pearson's correlation coefficient between chickpea pod borer (No. of larvae m<sup>-2</sup>) larval populations and weather parameters**

| Variety | Correlation coefficient |                       |                     |                     |
|---------|-------------------------|-----------------------|---------------------|---------------------|
|         | T <sub>max</sub> (°C)   | T <sub>min</sub> (°C) | RH <sub>m</sub> (%) | RH <sub>e</sub> (%) |
| K-850   | 0.728**                 | 0.632**               | -0.826**            | -0.467              |

It is evident from the result that both maximum and minimum temperature have a positive correlation with larval population. However, morning and evening RH had negative correlation with larval population. Both T<sub>max</sub> and T<sub>min</sub> had a significant positive relationship with larval population (at P=0.01 level).

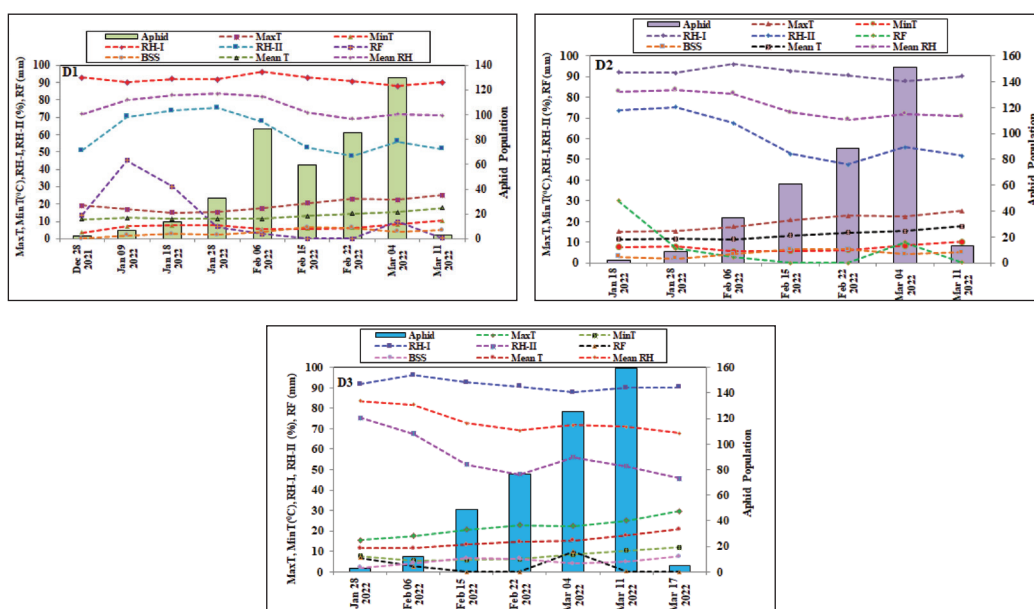
## Chatha

### Mustard aphid

Incidence and outbreak of aphids in mustard crop in conjunction with the prevailing weather parameters was studied at Chatha in the sub-tropical area of Jammu. Experiment

was conducted with three mustard varieties namely RSPR-01, RSPR-69 and RSPR-03 in three different environments 08, 18 and 28 November, 2021 following the standard package of practices. Population build-up data of aphids in mustard crop was collected.

From the correlation analysis between the aphid population and different meteorological parameters preceding ten days, reveals that the maximum temperature has a significant positive relationship with aphids. Aphids usually became visible in the 4th week of December. Thereafter, the temperature increased along with dry conditions and rendered congenial conditions for aphid multiplication and peaked with maximum temperature (18.4 to 24.6 °C), minimum temperature (5.2 to 12.4 °C), maximum relative humidity (69 to 97%) and minimum relative humidity (41 to 75%). The aphid population peak was observed in the I week (D<sub>1</sub> & D<sub>2</sub>) and II week (D<sub>3</sub>) of March when Mustard crop was at grand growth period (start of seed development) having more leaf area and hence experienced more aphid attacks (Fig. 6.7).



**Fig. 6.7: Aphid population dynamic and prevailed weather parameters at different date of sowings and varieties of mustard crop during rabi 2021-22**

## 7. Agromet Advisory Services

Farmers require timely and accurate weather forecast and advisories to plan the farm related operations/ decisions and also the remedial measures to reduce the losses in farm produce due to aberrant weather conditions. *Kharif* crop season in general is influenced by the onset of southwest monsoon rains and their distribution, which governs the entire gamut of agriculture as well as the economy of India. Extreme events such as heavy and unseasonal rainfall, flash floods, droughts, heat and cold waves, frost and hailstorms etc. are the other factors affecting the production and productivity of field and horticultural crops. Based on the improved weather forecasts and the existing crop conditions during the season, agromet advisory is prepared and issued to the farming community in time can save inputs (seeds, fertilizers, plant protection chemicals etc.) as well as the entire crop (especially at the maturity stage). This improves the crop performance and ultimately the farmers income. Agromet advisories issued through Agromet Advisory Service (AAS) is a part of Extension Agrometeorology and is defined as “Agrometeorological and agro-climatological information that can be directly applied to improve and/or protect the livelihood of farmers”.

AICRPAM with the help of its cooperating centers across the country is involved in issuing AAS bulletins twice a week, in vernacular languages. The dynamic web portal “Crop weather outlook” hosted by AICRPAM-CRIDA updates daily and weekly weather & crop information and Agromet advisories of the 25 states, where the AICRPAM centers are located in. Apart from this, the coordinating unit at CRIDA plays a major role in issuing daily sub-divisional rainfall charts, weekly Agromet advisories based on Extended Range Weather Forecasts, and monthly crop and weather bulletins for “NITI Aayog” on status of monsoon, progress in *kharif* sowing and AAS for deficit/excess rainfall areas of the country during the southwest monsoon.

All the above information uploaded dynamically on the crop weather outlook website hosted by AICRPAM from ICAR-CRIDA. The information flow on long-range weather forecasts starts from the South Asian Climate Outlook Forum (SASCOF) during April of every year on the ensuing southwest monsoon. AICRPAM by over laying the district boundary map and collects this information at district level. Further IMD also issues its first long range forecast of monsoon in the month of April. This information on district-wise and state-wise

forecast of rainfall during 2021 Southwest monsoon was shared with state government authorities during interface meetings on preparedness for monsoon 2021. AICRPAM unit, prepared the rainfall progress at the met sub-division level, based on the data of India Meteorological Department (IMD) during June 1 to September 30, 2021 on daily basis and communicated to ICAR headquarters other designated organizations. Weekly weather and crop bulletins on the status of monsoon, progress in *kharif* sowing and agromet advisories for deficit/excess rainfall areas of the country were prepared with inputs from cooperating centers of AICRPAM. Further, weekly 'National Agromet Advisory Services' (NAAS) bulletins were prepared in collaboration with IMD. This bulletin provides realized weekly weather conditions over last week and Extended Range Weather Forecast (ERFS) for the next two weeks.

The figure displays three screenshots of the AICRPAM web portals. The left screenshot shows the 'Agromet Advisories' page, which includes a map of India with color-coded regions indicating weather conditions. The middle screenshot shows the 'Crop Weather Outlook' page, which provides a 'Value Added Weather Information' section with a map of India and a table of weather data. The right screenshot shows the 'Agromet Advisories' page, which includes a table of weather data for various regions.

**Agromet Advisories**

Name of the Region : Gujarat (Gujarat)

Max Week No. : 39 Date of posting : 27-Sep-2022

Medium Range Weather forecast issued by NC/IMD for next 6 days:

| Date        | Cloud (%) | Rainfall (mm) | Wind Speed (kmph) | Wind Direction (degrees) | Temperature (°C) (Maximum/Minimum) |
|-------------|-----------|---------------|-------------------|--------------------------|------------------------------------|
| 27-Sep-2022 | 6         | 0.0           | 16                | 201                      | 31/18                              |
| 28-Sep-2022 | 7         | 0.0           | 8                 | 201                      | 31/18                              |
| 29-Sep-2022 | 7         | 0.0           | 8                 | 201                      | 31/18                              |
| 30-Sep-2022 | 7         | 0.0           | 8                 | 201                      | 31/18                              |

Weekly cumulative rainfall forecast for next week : 16.0 mm

**Crop Weather Outlook**

All India Coordinated Research Project on Agrometeorology (AICRPAM)

Value Added Weather Information

Select the AICRPAM Centre :

Select the Institute :

Data and Reports :

Weekly Report on Crop Weather Conditions

Latest Information | Submit New Report | Archive

AICRPAM provided the agromet advisories prepared for major crops for the coming week by getting the information from AICRPAM centers across the country during *kharif* season and reported to officials of ICAR, Ministry of Agriculture and Farmers Welfare and other stakeholders across the country. Apart from this, AICRPAM also provided weekly bulletins on 'Status of monsoon, *kharif* sowings progress and Agromet advisories for excess/deficit rainfall districts.

| Progress of rainfall since 01-Jun-2021 in different meteorological sub-divisions of India<br>(Departure from normal in %) |         |                        |           |           |           |           |           |           |           |           |           |           | 01-Jun-2021 to<br>30-Sep-2021<br>(mm) |        |           |        |        |
|---------------------------------------------------------------------------------------------------------------------------|---------|------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|---------------------------------------|--------|-----------|--------|--------|
| Sl No                                                                                                                     | Region  | Sub Division           | 01-Jun-21 | 01-Jul-21 | 01-Aug-21 | 01-Sep-21 | 01-Oct-21 | 01-Nov-21 | 01-Dec-21 | 01-Jan-22 | 01-Feb-22 | 01-Mar-22 | Actual                                | Normal | Dev. Surp |        |        |
| 1                                                                                                                         | North   | Andamanal Pradesh      | 4         | -23       | -23       | -31       | -36       | 36        | 36        | 36        | 36        | 36        | 1290.8                                | 1276.6 | -427.8    |        |        |
| 2                                                                                                                         |         | Assam & Meghalaya      | 6         | 19        | 9         | 15        | 21        | 25        | 23        | 19        | 16        | 13        | 20                                    | 1387.3 | 1773.7    | -386.4 |        |
| 3                                                                                                                         |         | Nag-Man-Miz-Tri        | -49       | -33       | -38       | -33       | -36       | -31       | -33       | -32       | -30       | -31       | -31                                   | 971.5  | 1426.7    | -455.2 |        |
| 4                                                                                                                         | West    | Sub Him WB & Sikkim    | 7         | 19        | 14        | 17        | 18        | 17        | 16        | 17        | 17        | 17        | 17                                    | 1794.4 | 1970.8    | -176.4 |        |
| 5                                                                                                                         |         | Gangotri West Bengal   | 21        | 23        | 24        | 27        | 33        | 30        | 24        | 16        | 10        | 21        | 36                                    | 1548.5 | 1381.5    | 367.0  |        |
| 6                                                                                                                         |         | Jharkhand              | 16        | 163       | 34        | 15        | -4        | 0         | 7         | 0         | 4         | -9        | -5                                    | 1043.4 | 1054.7    | -11.3  |        |
| 7                                                                                                                         | East    | Bihar                  | 3         | 176       | 111       | 69        | 30        | 18        | 19        | 16        | 18        | 10        | 6                                     | 1044.3 | 1017.2    | 27.1   |        |
| 8                                                                                                                         |         | East Uttar Pradesh     | 9         | 217       | 69        | 21        | 13        | 4         | 3         | 13        | 13        | 13        | 13                                    | 867.8  | 839.4     | 28.4   |        |
| 9                                                                                                                         |         | West Uttar Pradesh     | 13        | 69        | 33        | -47       | -21       | 5         | 5         | -23       | -24       | -12       | -31                                   | 572.6  | 721.3     | -148.7 |        |
| 10                                                                                                                        | Central | Uttarakhand            | -20       | 155       | 48        | 1         | 10        | 10        | 2         | -6        | -4        | -4        | -2                                    | 1152.9 | 1176.9    | -24.0  |        |
| 11                                                                                                                        |         | Haryana-Chd- Delhi     | 165       | 89        | 2         | -24       | 27        | 49        | 33        | 11        | 8         | 16        | 21                                    | 29     | 376.7     | 444.0  | -132.7 |
| 12                                                                                                                        |         | Punjab                 | 192       | 53        | 1         | -40       | 10        | 7         | -13       | -23       | -24       | -24       | -14                                   | -2     | 436.8     | 467.3  | -30.5  |
| 13                                                                                                                        | South   | Himachal Pradesh       | 23        | 41        | 105       | 31        | 7         | 11        | 152       | -20       | 0         | 10        | 14                                    | 10     | 690.1     | 763.5  | -73.4  |
| 14                                                                                                                        |         | Jammu & Kashmir        | -38       | -27       | -48       | -45       | -11       | 8         | 10        | -26       | -30       | -30       | -28                                   | -29    | 401.6     | 566.0  | -164.4 |
| 15                                                                                                                        |         | West Rajasthan         | 116       | 96        | 36        | 151       | 9         | 3         | 3         | -32       | -25       | -12       | 0                                     | 20     | 317.5     | 265.3  | 52.2   |
| 16                                                                                                                        | South   | East Rajasthan         | 39        | 15        | 115       | 44        | -39       | -21       | 25        | 28        | 27        | 1         | 1                                     | 1      | 696.7     | 602.9  | 93.8   |
| 17                                                                                                                        |         | Odisha                 | 34        | 113       | 17        | -20       | -26       | 119       | -29       | -29       | -27       | -12       | -10                                   | 1046.0 | 1155.3    | -109.3 |        |
| 18                                                                                                                        |         | West Madhya Pradesh    | 39        | 54        | 30        | 119       | -21       | 8         | 24        | 13        | 5         | 5         | 11                                    | 13     | 980.9     | 857.7  | 123.2  |
| 19                                                                                                                        | South   | East Madhya Pradesh    | 105       | 100       | 43        | 12        | -23       | 4         | 16        | 113       | -20       | -21       | 10                                    | 15     | 891.6     | 1048.4 | -156.8 |
| 20                                                                                                                        |         | Gujarat Region         | 20        | 21        | 11        | 43        | -35       | -43       | -44       | -40       | -39       | -10       | 11                                    | 13     | 788.8     | 922.9  | -134.1 |
| 21                                                                                                                        |         | Saurashtra & Kutch     | -24       | 28        | -27       | -55       | -40       | -35       | -47       | -50       | -53       | -26       | -1                                    | 13     | 626.6     | 507.2  | 119.4  |
| 22                                                                                                                        | South   | Konkan & Goa           | 66        | 107       | 41        | 16        | 45        | 38        | 32        | 16        | 11        | 17        | 20                                    | 23     | 3559.8    | 2875.3 | 684.5  |
| 23                                                                                                                        |         | Madhya Maharashtra     | 48        | 83        | 39        | 13        | 13        | 27        | 11        | 9         | 7         | 10        | 11                                    | 13     | 872.6     | 751.2  | 121.4  |
| 24                                                                                                                        |         | Maharashtra            | 107       | 85        | 31        | 20        | 40        | 36        | 11        | 12        | 11        | 36        | 37                                    | 49     | 988.5     | 668.8  | 319.7  |
| 25                                                                                                                        | South   | Vidarbha               | 72        | 71        | 19        | 2         | 12        | 4         | -12       | -9        | -15       | -8        | -3                                    | 3      | 968.9     | 943.1  | 25.8   |
| 26                                                                                                                        |         | Chhattisgarh           | 101       | 67        | 26        | 12        | -6        | 0         | -10       | -14       | -13       | -1        | -1                                    | -1     | 1107.7    | 1142.1 | -34.4  |
| 27                                                                                                                        |         | A & N Island           | 10        | -25       | -24       | -10       | 14        | 6         | 2         | 7         | 12        | 19        | 20                                    | 22     | 2025.0    | 1653.8 | 371.2  |
| 28                                                                                                                        | South   | Coastal Andhra Pradesh | 32        | -22       | -22       | -1        | 13        | 16        | 6         | 7         | 10        | 13        | 12                                    | 21     | 704.0     | 886.9  | -117.1 |
| 29                                                                                                                        |         | Telangana              | 120       | 80        | 80        | 40        | 60        | 58        | 30        | 25        | 26        | 38        | 31                                    | 40     | 1044.2    | 751.9  | 292.3  |
| 30                                                                                                                        |         | Rayalaseema            | 243       | 73        | 60        | 112       | 113       | 83        | 63        | 46        | 46        | 43        | 28                                    | 19     | 488.2     | 411.6  | 76.6   |
| 31                                                                                                                        | South   | Tamil Nadu & Puduchery | 68        | 36        | 31        | 63        | 71        | 82        | 39        | 29        | 28        | 19        | 13                                    | 12     | 593.4     | 336.1  | 57.3   |
| 32                                                                                                                        |         | Coastal Karnataka      | -29       | 29        | 21        | -24       | -29       | -29       | -14       | 13        | 13        | 12        | 11                                    | 10     | 2784.5    | 3095.1 | -310.6 |
| 33                                                                                                                        |         | Karnataka (N Interior) | 67        | 83        | 80        | 43        | 56        | 56        | 35        | 30        | 34        | 36        | 23                                    | 24     | 607.3     | 497.1  | 110.2  |
| 34                                                                                                                        | South   | Karnataka (S Interior) | 37        | 57        | 113       | 6         | 13        | 22        | 16        | 7         | 10        | 11        | 7                                     | 3      | 699.0     | 681.8  | 17.2   |
| 35                                                                                                                        |         | Kerala & Malu          | -41       | 106       | -36       | -42       | -39       | -27       | -36       | -27       | -22       | -10       | -12                                   | -13    | 1719.1    | 2049.3 | -330.2 |
| 36                                                                                                                        |         | Lakshadweep            | -26       | -48       | -52       | -49       | -54       | -49       | -39       | -36       | -25       | -26       | -28                                   | -22    | 790.9     | 1013.1 | -222.2 |

LEGEND

Large Excess [+60% above]

Excess [+20% to +50%]

Normal

Deficit [-20% to -50%]

Large Deficit [-60% to -90%]

No Rain [-100%]

• Gangotri West Bengal, Jharkhand, Konkan & Goa, Saurashtra & Kutch and Gujarat Region meteorological sub-divisions received severe rainfall > 75% of normal rainfall, while the monsoon was weak and vigorous (Rainfall < 4 times of LPA) in all the sub-divisions, except Konkan & Goa.

• The seasonal rainfall status (since 01-Jun-21) for the country as a whole remains at +1%.

Percentage departure of cumulative rainfall since 01-Jun-2021 over four homogeneous regions of the country

East and Northeast India

-12%

Central India

4%

South India

-4%

West India

11%

Country as a whole

-1%

Prepared by ACEP in Agro-meteorology (AGRO-CLIM), ICAR-CRRRI based on the data received from IMD website.

## LEGEND

Large Excess (&gt;40% above)

Excess (&gt;20% to &gt;40%)

Normal (+19% to -19%)

Deficient (-20% to -50%)

Large Deficient (&lt;-60% to &lt;-99%)

No Rain (-100%)

- Gangotri West Bengal, Jharkhand, Konkan & Goa, Saurashtra & Kutch and Gujarat Region meteorological sub-divisions received wide spread rainfall (>75% places) yesterday, wherein the monsoon activity was vigorous (Rainfall > 4 times of LPA) in all the sub-divisions, except Konkan & Goa.

- The seasonal rainfall status (since 01-Jun-21) for the country as a whole remains at -1%.

Percentage departure of cumulative rainfall since 01-June-2021 over four homogeneous regions of the country

|                          |      |                 |     |                    |     |
|--------------------------|------|-----------------|-----|--------------------|-----|
| East and Northeast India | -12% | Central India   | 4%  | Country as a whole | -1% |
| Northwest India          | -4%  | South Peninsula | 11% |                    |     |

Prepared by AICRP on Agro-meteorology (AICRPAM, ICAR-CRIDA) based on the data sourced from IMD website.




## National Agromet Advisory Service Bulletin

based on  
**Extended Range Weather Forecast (ERFS)**

Validity: 17 - 30 December 2021  
Date of issue: 17 December 2021

Issued by

AICRP on Agro-Meteorology (AICRPAM),  
Central Research Institute for Dryland Agriculture (CRIDA),  
Indian Council of Agricultural Research (ICAR)  
&  
India Meteorological Department (IMD),  
Earth System Science Organization

The Dynamic Crop Weather Calendar, a decision support system developed by AICRPAM has been validated for 75 districts in the country for major crops grown in the respective districts. Few centers have also developed Android Apps for disseminating the agromet advisories to the farmers in time. This is helping in saving the crops from damage as well as giving benefits to the farmers. Centers are also conducting climate change awareness programs and explaining to the farmers that by following agromet advisories, farmers can increase resilience towards adverse weather /climate and save their crops from the adverse condition influenced by climatic aberrations and extremes.

## 8. Summary

### Agroclimatic Characterization

- A study on vegetation responses to meteorological drought in agricultural fields at different stations of Gujarat indicated that no significant association between SPEI and NDVI at Anand was noticed, which suggests crop conditions have low dependency on monsoon wetness. However, at Bhuj, vegetation condition of crop fields found to be significantly responsive to wetness of September (SPEI1 and SPEI2) and agricultural crop conditions during *kharif* and *rabi* seasons near Bhuj are largely dependent on wetness of August and September months.
- A comprehensive drought analysis based on Standardized Precipitation Evapotranspiration Index (SPEI) was carried out to find out its spatial variability over three dry zones of south Karnataka. Results showed that, the districts like Mandya, Tumakuru, Ramanagara, Davanagere and Chitradurga, drought events with higher magnitude (SPEI 2.05, 1.65, 1.54, 1.54 and 1.18, respectively) was observed when compared to other districts.
- At Bhubaneswar, percentage probability for occurrence of meteorological drought was computed for 30 years (1991-2020) at block level for the districts of Kalahandi and Nuapada. Probability of occurrence of moderate droughts at different blocks of Kalahandi district was ranging from 7 to 27% while it was 10 to 17% in Nuapada district. In case of severe drought, the probability was only 1-3 events in 30 years period in different blocks of these two districts.
- Annual and seasonal rainfall and temperature trend over different districts of Jammu region indicated that the highest declining trend in annual rainfall was found in Samba (7.33 mm per year) followed by Batote (4.99 mm per year). The mean maximum temperatures showed significant declining trend in Rajouri, Katra and Bhaderwah while significant increase in minimum temperature were noticed in Katra and Banihal @ 0.051 and 0.022 °C per year, respectively during last 40 years.
- The variation of frost occurrence at Faizabad on monthly basis shoed that maximum number of frost days is occurring in the month January followed by February and hence frost preventing measures to be disseminated through agromet advisory services to avoid yield loss due to frost.

- At Jorhat, an analysis was carried out to assess the drought severity in 27 districts of Assam state using SPI with two-time scales (annual and southwest monsoon) for the period of 28 years (1988-2015). It is understood that extremely drought condition (SPI less than -2.0) was not witnessed in any districts of the state during the study period while extremely wet condition (SPI more than 2.0) was prevailed in three districts *viz.*, Kokrajhar, Chirang and Karimganj on both annual as well as seasonal basis.
- Changes in area under different *kharif* and *rabi* crops and climatic parameters in the Punjab state during two major time periods *viz.* green revolution period (1971-1990) and post green revolution period (1991-2018) was carried out. The study indicates no significant change in maximum temperature during pre-green revolution and post green revolution time scales. But, increase and decrease in annual, *kharif* and *rabi* season minimum temperature and rainfall was evident in the state of Punjab during post green revolution period.
- At Mohanpur centre, an attempt was made to find the accuracy and reliability of Hargreaves-Samani, Turc and Makkink PET methods against the FAO Penman-Monteith method. It is inferred that the Makkink method could efficiently estimate PET with least error and deviation when compared to other two methods.
- Occurrence of frost events at Palampur since 2008 indicates that the events were on rise during recent years and the highest number of events were observed during 2010 & 2018 (38) and 2011 (27) followed by 24 during 2005. In the case of hail, 5 to 7 events are of common occurrence in a year while Snow occurred for 2 continuous days for twice during past 15 years at and around Palampur.
- Climatic water balance was worked out for Parbhani on weekly basis and the results revealed that Moisture Availability Index began to increase from 24<sup>th</sup> SMW and declined from 42 SMW. The total length of growing period was 19 weeks *i.e.* from 24 to 42 SMW at Parbhani.
- At Samastipur, it was found that short (5-7 days) as well as long (11-15 days) dry spells during June-September months were found to increase in the recent period (1998-2018) at Pusa, Samastipur, Purnia, Bhagalpur and Patna when compared to earlier period (1979-1998).
- Significant increase in rainy days was observed in the districts like Dhule, Ahmednagar, Satara and Kolhapur districts while significant decreasing trend was noticed in Nandurbar, Pune and Solapur districts. The remaining districts did not show any significant change during the period June-September.

## **Crop Weather Relationship Studies**

### ***Kharif 2021***

#### **Rice**

- At Mohanpur, Among the growing environments, crop transplanted on 23 June recorded the highest grain yield and RUE, followed by crop transplanted on 20 July. Among the varieties, highest yield and RUE was recorded by Nayamani followed by Satabdi and Swarna.
- The highest RUE at physiological maturity was recorded for cv. Rajeshwari transplanted on 15 June, followed by MTU1010 transplanted on 01 June at Raipur.
- At Ranchi, the highest RUE was recorded by late crop sown crop ( $2.2 \text{ g MJ}^{-1}$ ) than the normal sown crop ( $2.14 \text{ g MJ}^{-1}$ ). Among the varieties, Naveen recorded highest RUE ( $2.34 \text{ g MJ}^{-1}$ ) and Sahbhagidhan recorded the lowest ( $2.07 \text{ g MJ}^{-1}$ ).

#### **Maize**

- Higher growing degree days ( $1955 \text{ }^{\circ}\text{C days}$ ) and heat use efficiency ( $10.7 \text{ g m}^{-2} \text{ }^{\circ}\text{C days}^{-1}$ ) was recorded by crop sown on 22 June when compared to 02 July ( $10.1 \text{ g m}^{-2} \text{ }^{\circ}\text{C days}^{-1}$ ) and 12 July ( $9.5 \text{ g m}^{-2} \text{ }^{\circ}\text{C days}^{-1}$ ), sowing at Kanpur.
- At Ludhiana, soil moisture content was comparatively higher for JH-19014, especially when sown on 15 June and it recorded highest yield of  $6291 \text{ kg ha}^{-1}$ .

#### **Pearl millet**

- The relationship of seasonal rainfall, available soil moisture with pear millet yield (2018-2021) at Anand indicated that seasonal rainfall about 700-800 mm and 65-70% available moisture are optimum for maximum productivity. Rainfall higher than 800 mm during the season and more than 70% mean available moisture reduced the production of pearl millet drastically.
- Study on effect of growing environments and cultivars on Leaf Area Index (LAI) at Hisar revealed that the crop attained maximum LAI at 35 DAS at flag leaf stage and decreased thereafter. The maximum LAI was recorded by crop sown on 23 July (5.68) followed by that of 15 July (5.51). Among varieties, maximum LAI was recorded by HHB-272 (5.50) followed by GHB-558 (5.38).
- At Solapur, a pooled analysis of effects of growing environments on radiation use efficiency (RUE) was studied using experimental data during 2016-2021. Among the

treatments, Dhanshakti sown during second fortnight of July recorded highest RUE at 50% flowering (2.4 g MJ<sup>-1</sup>), followed by Mahyco hybrid (2.3 g MJ<sup>-1</sup>).

### Pigeon pea

- At Anantapuramu, BRG-1 recorded significantly higher pod yield (644.8 kg ha<sup>-1</sup>) as compared to BRG-2, BRG-5 and PRG-176 (568.1, 426.5 and 398.9 kg ha<sup>-1</sup>, respectively).

### Soybean

- A similar correlation study conducted at Jabalpur indicated a negative correlation exhibited between maximum and minimum temperatures and bright sunshine hours with seed yield at vegetative stage and pod development stages.

### Groundnut

- Crop sown during first fortnight of July recorded highest HUE at Anantapur. However, HTU, AGDD and total crop duration was highest for crop sown during second fortnight of July.

### Cotton

- Bt cotton Balwan recorded significantly higher seed cotton yield (1019 kg ha<sup>-1</sup>) than hirsutum cotton AKH 081 (859.50 kg ha<sup>-1</sup>) and arboreum cotton AKA 7 (767 kg ha<sup>-1</sup>) at Akola. Thermal use efficiency was found to be higher for monsoon sown crop (28 June) with respect to both seed cotton and biomass production and it decreased in subsequent late sowing.

## Rabi 2021-22

### Wheat

- The crop sown on 06 November recorded highest RUE (1.08 g MJ<sup>-1</sup> m<sup>-2</sup>) than 22 November (0.96 g MJ<sup>-1</sup> m<sup>-2</sup>) and 06 December (0.71 g MJ<sup>-1</sup> m<sup>-2</sup>) sown crop at 120 days after sowing at Chatha. Among the varieties, RUE increased from 30 to 120 DAS and the variety HD-2967 recorded highest RUE (1.04 g MJ<sup>-1</sup> m<sup>-2</sup>) followed by RSP-561 (0.88 g MJ<sup>-1</sup> m<sup>-2</sup>) at 120 DAS.
- At Kanpur, crop sown on 30 Nov recorded highest dry matter accumulation, AGDD and HUE compared to that of crop sown on 15 Dec. Among the varieties, K-9107 recorded highest dry matter accumulation, AGDD and HUE. Wheat cv. K-307 recorded the lowest dry matter accumulation and HUE.

## Maize

- At Kovilpatti, the crop sown during 39 standard meteorological week recorded highest grain yield ( $4652 \text{ kg ha}^{-1}$ ) and stover yield ( $7916 \text{ kg ha}^{-1}$ ) than the other sowing windows. Among the genotypes, COH (M) 6 recorded the highest grain yield ( $4123 \text{ kg ha}^{-1}$ ) and stover yield ( $8354 \text{ kg ha}^{-1}$ ) than other hybrids viz., NK 6240 and S6850.
- Impact of growing environments (01 Nov, 10 Nov, 20 Nov, 30 Nov and 10 Dec) and spacing (60 x 20 cm, 75 x 20 cm and 45 x 20 cm) on absorbed PAR of *rabi* maize was studied during *rabi* 2021-22 at Samastipur. Silking stage of the crop absorbed the highest PAR ( $931.2 \mu\text{m m}^{-2} \text{ sec}^{-1}$ ), followed by tasseling stage ( $867.0 \mu\text{m m}^{-2} \text{ sec}^{-1}$ ). The highest absorption was recorded by the crop sown on 30 November and the lowest by 1 November sown crop.

## Sorghum

- Effect of minimum temperature during grain development stage and minimum temperature during vegetative stage on grain yield of *rabi* sorghum at Kovilpatti was studied. Increase in minimum temperature ( $>21.4^\circ\text{C}$ ) during grain development stage ultimately increase grain yield of sorghum.
- At Solapur, Among the varieties, highest mean consumptive use of moisture (CUM) was recorded for M-35-1 (258 mm) and the lowest was for Yashoda (251 mm). Among different growing environments, crop sown on 40 SMW recorded the highest CUM and that of 42 SMW recorded the lowest.

## Barley

- Effect of growing environments on LAI of barley varieties during *rabi* 2021-22 was studied at Hisar. Significantly higher LAI was recorded in  $D_1$  as compared to other sowing dates at each phenophase of barley. Maximum LAI at booting stage was attained by barley crop sown on 17 Nov sown crop (6.42), followed by subsequent sowing dates viz. 30 Nov (5.95), 15 Dec (5.43) and 30 Dec (5.19). Among the varieties, BH 902 recorded highest LAI (6.53) followed by BH946 (5.99), BH 393 (5.58) and BH 885 (4.89).

## Chickpea

- At Akola, crop sown on 02 November ( $D_1$ ) recorded higher heat use efficiency ( $0.99 \text{ kg ha}^{-1} ^\circ\text{C day}^{-1}$ ) with respect to both seed and biomass production. Amongst the varieties, heat use efficiency with respect to grain yield and biomass production was higher in  $V_1$  (JAKI-9218).

- At Raipur, the highest RUE was recorded by three treatments ( $0.67 \text{ g MJ}^{-1}$ ) viz., Vaibhav sown on 10 Nov, JG-16 sown on 25 Nov and JG-14 (ZC) sown on 10 Dec. JG-16 sown on 10 Dec recorded the lowest RUE of  $0.21 \text{ g MJ}^{-1}$  across the treatments.
- At Ranchi, normal sown crop (25 Nov) recorded higher HUE and RUE compared to late sown crop. Among the varieties, GNG -1581 achieved highest heat use efficiency ( $1.6 \text{ kg ha}^{-1} \text{ }^{\circ}\text{C days}^{-1}$ ) as well as highest radiation use efficiencies ( $1.3 \text{ kg ha}^{-1} \text{ MJ}^{-1}$ ) in normal sown condition.
- Among different growing environments, crop sown 38 SMW and 44 SMW recorded highest and lowest RUE, respectively, at Solapur. Among the varieties, Digvijay recorded higher RUE than Vijay across all the growing environments.

### Green gram

- Among the three microclimatic regimes studied (sown on 20 Sept., 25 Sept. and 30 Sept. 2021) at Jorhat, highest yield was recorded under MR-I ( $889.7 \text{ kg ha}^{-1}$ ) followed by MR-II ( $811.3 \text{ kg ha}^{-1}$ ) and least in MR-III ( $791.1 \text{ kg ha}^{-1}$ ). Decrease in seed yield was observed when sowing was done during the last week of September month.
- At Mohanpur, the highest seasonal evapotranspiration was recorded for crop sown on 07 October, which might have reduced the water use efficiency of the varieties. The highest water use efficiency was recorded by cv. Meha sown on 25 September, followed by PM-05 sown on 25 September.

### Mustard

- A pooled analysis of field experiments undertaken during *rabi* 2017-18 to 2021-22 at Anand indicated that sowing on 10 October provided favourable growing environment to all the three cultivars and they produced higher yield, which declined almost linearly with delayed sowing. Cultivar GM 3 has distinctly higher productivity under all the growing environments.
- At Faizabad, maximum thermal use efficiency (TUE) from sowing to maturity recorded was  $0.62 \text{ g m}^{-2} \text{ }^{\circ}\text{C days}^{-1}$  for crop sown on 25 October while minimum TUE recorded was  $0.52 \text{ g m}^{-2} \text{ }^{\circ}\text{C days}^{-1}$  by crop sown on 14 November. Maximum thermal use efficiency (0.63) from sowing to maturity was recorded by NDR-8501 variety, while minimum was recorded by Varuna (0.43).

## **Horticultural and Plantation Crops**

### **Potato**

- Effect of growing environments ( $D_1$ : 16 Nov.,  $D_2$ : 22 Nov.,  $D_3$ : 30 Nov. and  $D_4$ : 7 Dec. 2021) on chlorophyll content index (CCI) of potato varieties ( $V_1$ : Kufri Bahar,  $V_2$ : Kufri Pushkar and  $V_3$ : Kufri Lima) was studied at Hisar. Among the different growing environments, the highest CCI was recorded by early planted crop *i.e.*  $D_1$  (96.9) and lower by subsequent plantings. Among the varieties Kufri Pushkar recoded highest CCI value (92.3) followed by Kufri Lime (91.3) and lowest by Kufri Bahar (86.1).

### **Mango**

- Impact of weather parameters on yield of alphonso mango at different locations of Maharashtra was undertaken by Dapoli centre. During vegetative stages, evening relative humidity showed significant positive relation with fruit yield. During fruiting,  $T_{max}$ , BSS and pan evaporation showed significant positive correlation and both morning and evening relative humidity showed negative relation.

### **Cashew**

- Correlation study between growth-stage wise weather parameters and cashew nut yield at Dapoli indicated that at vegetative and bud opening stages,  $T_{min}$  (66%), RH-I (66%), RH-II (84%) and RF (78%) showed significant positive correlation at 1 per cent significance level.  $T_{max}$  (70%), BSS (55%) and Epan (79%) showed significant positive correlation at 1 per cent significance level at fruiting stage (300-307) whereas weather parameters RH-I (68%), RH-II (58%) and RF (40%) showed negative correlation at 1 per cent significance level.

### **Guava**

- Correlation of fruit yield and quality parameters of guava variety Hisar-Safeda with weather parameter under Hisar condition (pooled data analysis, 2013-14 to 2021-22) indicated that average fruit yield/plant showed significant positive correlation with saturation vapor pressure (both morning and evening) and negative correlation with seasonal rainfall. Total soluble solids (TSS) showed significant positive correlation with relative humidity (morning and evening) and water use efficiency. Acidity content of the fruit showed significant negative correlation with morning and evening relative humidity and seasonal rainfall.

## Black pepper

- Correlation between yield of black pepper (variety Panniyur-I) and weather variables during the year 2018-2021 at Thrissur indicated that the only significant relationship was observed between evening relative humidity during spike enlargement with pepper yield. Tmax during spike enlargement, tmin during spike initiation, morning relative humidity during spike initiation and spike emergence showed negative correlation.

## Ginger

- The Principal Component Analysis was carried out for ginger variety Maran using the weather parameters experienced in four stages of ginger *i.e.* planting to 50% sprouting, 50% sprouting to active tillering, and active tillering to bulking and bulking to physiological maturity at Thrissur. A cumulative proportion of 89.70% was obtained for first two components *i.e.* component 1 and component 2.

## Crop Growth Modelling

- Soybean model in DSSAT CSM was calibrated and validated for new soybean cultivars (JS-335, JS-9305 and AMS-1001) by Akola centre. The impact of protective irrigation (60 cm) during long-dry spells on yield of soybean was simulated and the yield gain through simulated protective irrigation was of greater magnitude in late sown soybean and more so at reproductive development stage of pod formation to seed development across all sowings.
- Crop simulation model CERES-millet was calibrated using 2017 experimental crop and weather data at Anand and validated with four years field data of 2018, 2019, 2020 and 2021. The model is predicting the phenology, biomass yield and final grain yields well within the limits. The D-index values showed for anthesis, maturity days, LAI, grain yield and above ground biomass were 0.97, 0.99, 0.99, 0.91 and 0.91, respectively.
- Seven years weather data of different parameters and crop experimental data sets (*rabi* 2015-16 to 2021-22) were collected and analysed at Chatha center, Jammu to develop the wheat yield prediction model. Step-wise regression model indicated that, step 3 regression model with weather parameters at different growth stages (Tmax, Tmin, RH-II, sunshine hours and evaporation) improved the accuracy of prediction up to 56 per cent.

## Weather Effects on Pests and Diseases

- The relationship between weather and incidence of spotted pod borer (*Maruca vitrata*) on red gram during 2019, 2020 and 2021 was studied at Anantapuramu centre. The correlation analysis for the rainfed crop indicated that there was a significant negative correlation between no. of webs per square meter and live larvae per square meter with rainfall, maximum temperature, minimum temperature, wind speed and evaporation and significant positive correlation with morning relative humidity.
- A simple weather-based disease prediction model for cotton leaf curl virus disease was developed by Hisar center. The optimum range of weather parameter with the progression of maximum PDI value from 22 to 45 SMWs were analyzed and found to be 32.3 to 36.3°C (maximum temperature), 24.5 to 29.6 °C (minimum temperature) and 73.2 to 86.7.0 per cent (morning relative humidity) and 7.0 to 9.1 hrs (bright sunshine hours).
- The influence of weather parameters on infestation of rice leaf folder was studied by Raipur centre for the period 2000-2019. A strong negative correlation between leaf folder population and minimum temperature ( $r = -0.75^{**}$ ), rainfall ( $r = -0.87^{**}$ ) and evening relative humidity ( $r = -0.82^{**}$ ) whereas a significant positive correlation with sunshine hours ( $r = 0.9^{**}$ ) was observed.
- An investigation was undertaken on the occurrence of haemo-protozoan disease especially Theileriosis, Babesiosis, Anaplasmosis and viral disease Foot and Mouth Disease (FMD) in livestock at Ranchi district by using the retrospective data from the period 2012-2020. Average percentage disease incidence of Theileriosis and Babesiosis in cattle was significantly highest in monsoon (44.8% and 45.3%) followed by summer (32.8% and 36.5%) and lowest in winter (22.4% and 18.2%), respectively. Prevalence of Anaplasmosis was significantly highest in summer (47.9%) followed by monsoon (33.5%) and lowest in winter (18.6%). Cattle was more susceptible to FMD in winter season during which, the average percentage of disease incidence was 42.8% followed by monsoon (32.8%) and lowest in summer season (24.4%).
- A study on relationship between aphid infestation in mustard and favourable weather parameters at Anand indicated that low minimum temperature, more sunshine hours and high morning relative humidity prevalence for 2-5 days might be responsible for initiation of aphid infestation in mustard crop during flowering to pod initiation phase.

Correlation coefficients with two days' temperature of 11-12 lead days also show that more sunshine hours and high temperature lowers aphid infestation which occurs after 12-14 days in mustard.

- Weather influence on Fall Army Worm (*Spodoptera frugiperda*) in hybrid maize was studied by Bhubaneswar center. Maximum crop damage was observed in sweet corn varieties Sugar 75 (63%) and NSCH 130 (59%), whereas the damage of 38.5% and 36% was observed in the normal maize hybrid varieties DKC 9081 and 900 Mgold, respectively. The Fall Army Worm infestation was found at a maximum temperature ranging from 27.0 to 37.5 °C, but peak infestation was at a temperature of 32–35 °C. The occurrence was seen at high morning relative humidity of 86-90% and evening relative humidity of 35-40%. Sorghum crop also witnessed severe damage by fall army worm incidence when RH I exceeded 95% during vegetative stage, which affect the yield of sorghum.
- At Chatha, peak aphid infestation in mustard was observed with the following range of weather parameters: maximum temperature (18.4 to 24.6 °C), minimum temperature (5.2 to 12.4 °C), maximum relative humidity (69 to 97%) and minimum relative humidity (41 to 75%).

### Agromet Advisory Services

- AICRPAM with the help of its cooperating centers across the country is involved in issuing AAS bulletins twice a week, both in English and vernacular languages.
- The Dynamic Crop Weather Calendar (DCWC), a decision support system developed by AICRPAM has been validated for 75 districts in the country for major crops grown in the respective districts.

## 9. Research Publications 2021-22

### PC Unit, Hyderabad

#### Paper in Peer Reviewed Journals

- Bal, S.K., Sandeep, V.M., Vijaya Kumar, P., Subba Rao, A.V.M., Pramod, V.P., Manikandan, N., Srinivasa Rao., Singh, N.P. and Bhaskar, S. (2022). Assessing impact of dry spells on the principal rainfed crops in major dryland regions of India. *Agricultural and Forest Meteorology*, 313, 108768. <https://doi.org/10.1016/j.agrformet.2021.108768>
- Bal, S.K., Sarath Chandran, M.A., Sandeep, V.M., Subba Rao, A.V.M., Manikandan, N., Praveen Kumar, R., Pramod, V.P., Attri, S.D., Singh, P., Mohanty, A. and Singh, V.K. (2022). Water demand in maize is projected to decrease under changing climate in India. *Sustainability*, 14, 1419. <https://doi.org/10.3390/su14031419>
- Bal, S.K., Rao, K.V., Chandran, M.A.S., Sasmal, S. and Singh, V.K. (2021) Weather forecast, agriculture contingency plan and agromet–advisory services for climate resilient agriculture. *Indian Journal of Agronomy*, 66: S1-S14.

#### Book Chapters

- Bal, S.K. and Chandran, M.A.S. (2021). Minimizing weather-related risks in agriculture through agromet advisory services in India. In: *Climate Change and Resilient Food Systems* (Eds. Kumar, V., Mallappa, H. and Shirur, M.). Springer, Singapore. pp. 245-260.
- Banerjee, K., Bal, S.K., Chakraborty, D., Malleswari, S., Banerjee, A. and Sadhukhan, R. (2021). Crop calendars and advances in agriculture insurance products in India. In: *Agricultural Research, Technology and Policy: Innovations and Advances* (Eds. Srinivasarao *et al.*). ICAR-National Academy of Agricultural Research Management, Hyderabad, Telangana, India, pp 79-100.
- Bal, S.K. and Sarath Chandran, M.A. (2022). Insurance based climatic risk management in rainfed crops. In: *Strategies for climate risk management and resilient farming* (Eds. Nagasree, K., *et al.*). Collaborative online training programme, 20-24 September, 2021. ICAR- Central Research Institute for Dryland Agriculture, Hyderabad, India.

- Bal, S.K. and Manikandan, N. (2022). Weather-based agro - advisories for sustainable horticultural production systems. In: Natural resource management for sustainable dryland horticulture (Eds. Reddy, A.G.K., *et al.*). Collaborative online training programme, 09-11 February, 2022. ICAR- Central Research Institute for Dryland Agriculture, Hyderabad, India
- Rao, A.V.M.S., Chandran, M.A.S., Manikandan, N. and Bal, S.K. (2022). Use of agromet advisories for crop management during weather uncertainties at field level. In: Strategies for climate risk management and resilient farming (Eds. Nagasree K., Prasad J.V.N.S., Balasubramani N., Visha Kumari V., Pankaj, P.K., Rohit, J. and Ravi Shankar K.). Collaborative online training programme, 20-24 September, 2021. ICAR- Central Research Institute for Dryland Agriculture, Hyderabad, India.

## AICRPAM Centres Publications

### Anand

#### Paper in Peer Reviewed Journals

- Lunagaria, M.M. (2021). Determination of spectral and broadband albedos in visible-near infrared bands for different phenophases of wheat using hemispherical directional reflectance measurements. *International Journal of Environment and Geoinformatics*, 8(4): 460-466. DOI: 10.30897/ijgeo. 855633.
- Chauhanand, K.K. and Lunagaria M.M. (2022). Interpolation of microclimatic parameters over capsicum under open ventilated greenhouse. *International Journal of Economic Plants*, 9(1): 095-100. DOI:10.23910/2/2022.0455.

### Anantapuramu

#### Paper in Peer Reviewed Journals

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- Ashok Kumar, K., Sudheer K.V.S., Uma Devi, G.D. and Sahadeva Reddy, B. (2021). Impact of erratic rainfall on groundnut (*Arachis hypogea* L.) production in Scarce rainfall zone of Andhra Pradesh. *Annals of Agricultural Research*. 42(3):1-7
- Ashok Kumar, K., Sudheer, K.V.S., Uma Devi, G.D. and Sahadeva Reddy, B. (2021). Verification of medium range rainfall forecast in scarce rainfall zone of Andhra Pradesh. *International Journal of Agriculture Sciences*. 18(1):77-81.

## Popular Articles

- Ashok Kumar, K., Uma Devi, G.D. and Sahadeva Reddy, B. (2021). Grameena vyavasaaya vaathaavarana seva pathakam dwaara rythulaku melu chese vaathaavaranaadhaaritha salahaalu mariyu soochanalu. *Vyavasaayam*, June, 35-37
- Ashok Kumar, K., Uma Devi, G.D. and Sahadeva Reddy, B. (2021). Vaaathaavaranamlo vasthunna maarpulaku anugunangaa panta saagulo chepattavalasina melaena yaajamaanya paddathulu. *Vyavasaayam*, September, 27-28
- Ashok Kumar, K., Sudheer, K.V.S., Uma Devi, G.D. and Sahadeva Reddy, B. (2021). Rabi pyrlapai vaathaavarana prabhaavam. *Annadaatha*, 12.
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## Bengaluru

### Paper in Peer Reviewed Journals

- Sanjeevaiah, S.H., Rudrappa, K.S., Lakshminarasappa, M.T., Huggi L., Hanumanthaiah, M.M., Venkatappa, S.D., Lingegowda, N. and Sreeman, S.M. (2021). Understanding the temporal variability of rainfall for estimating agro-climatic onset of cropping season over south interior Karnataka, India. *Agronomy - Special Issue Drought and Heat Stress Regulation on Crop Development and Yield*, 11(6): 1-21 <https://doi.org/10.3390/agronomy11061135>

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- Shivaramu, H.S., Manjunatha, M.H., Lingaraj Huggi, Nagesha, L., Soumya, D.V. and Krupashree, R. (2021). Socio-economic upliftment of dry farming farmers of Eastern Dry Zone of Karnataka through Agro Met Advisories and Farmers' Awareness Programmes, in "National Conference on Managing Weather and Climate Risks in Agriculture", during 24-26 March, 2021 at SKUAST, Srinagar.
- Manjunatha, M.H., Shivaramu, H.S., Soumya, D.V., Lingaraj Huggi, Nagesha, L. and Krupashree, R. (2021). Development and validation of statistical yield forecast models for rice using agrometeorological indices for major rice growing districts

of southern Karnataka, in “National Conference on Managing Weather and Climate Risks in Agriculture”, during 24-26 March, 2021 at SKUAST, Srinagar.

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Vikas Gupta, Meenakshi Gupta, Rajeev Bharat, Mahender Singh, Sarabdeep Kour and Sharma, B.C. (2021). Effect of sowing environments and N-levels on wheat varieties under irrigated region of Jammu. *Indian Journal of Agricultural Sciences*, 91 (4): 515-520.

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Mahender Singh, Monika Banotra, Charu Sharma, Sharma, B.C. and Veena Sharma (2022). Yield forecasting of Maize (*Zea Mays*) crop in five districts of Jammu region using statistical model in Union Territory of J & K. In: Proceedings of National Conference on Managing Weather and Climate Risks in Agriculture-Adapting Crops to Climate Variability and Uncertainty during 24-26 March, 2022 at SKUAST-K, Kashmir.

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Pandey, A., Singh, A.K., Mishra, A.N. and Mishra, S.R. 2022. Study on crop weather calendar of mustard for EPZ of Uttar Pradesh. Abstract. In: Proceedings of National Conference on Managing Weather and Climate Risks in Agriculture Adapting Crops to Climate Variability and Uncertainty during 24-26 March, 2022 at SKUAST-K, Kashmir.

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Dagar, C.S., Kumar, A., Anurag, Khichar, M.L. and Singh, S. (2022). Agrometeorological variables are important for growth, development and potential yield of plants or crops: A Review. In: Research Trends in Agriculture Sciences (Volume - 31), AkiNik Publications, 123p. DOI: <https://doi.org/10.22271/ed.book.1816>

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Khande, D., Agrawal, K.K., Bhan, M. and Kumar, V. (2021). Effect of different environments and sowing methods of wheat productivity in Tawa command area of M.P. *The Pharma Innovation Journal*, 10: 949-956.

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### **Jorhat**

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## Kanpur

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### Popular articles

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## Kovilpatti

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## Ludhiana

### Paper in Peer Reviewed Journals

Prabhjyot Kaur, Sandhu, S.S., Dhillon, B.S. and Singh, H. (2021). Rice yield variability in Punjab - an overview of five decades. *Paddy and Water Environment*, 19(4):673-681.

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Prabhjyot Kaur, Sarabjot Kaur and Sukhjeet Kaur (2021). Environment – Introduction, concerns and management. Punjab Agricultural University, Ludhiana 36p.

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## Mohanpur

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Chandran, M.A.S., Banerjee, S., Mukherjee, A., Nanda, M.K. and Kumari, V.V. (2022). Evaluating the long-term impact of projected climate on rice-lentil-groundnut cropping system in Lower Gangetic Plain of India using crop simulation modelling. *International Journal of Biometeorology*, 66(1): 55- 69. DOI: 10.1007/s00484-021-02189-8.

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- Chadalavada, K., Gummadi, S., Kundeti, K.R., Kadiyala, D.M., Deevi, K.C., Dakhore, K.K., Bollipo Diana, R.K., Thirupathi, S.K. (2021). Simulating potential impacts of future climate change on post-rainy season sorghum yields in India. *Sustainability*, 14, 334.

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### Raipur

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### Ranchi

#### Technical Bulletin

Kumari Pragyan, Wadood, A., Kumar Ramesh, Chandran M.A. Sarath, Tirkey Deepak A. and Bal, S.K. (2022). Impact of El-Niño on climatic variability and crop production in Jharkhand., Department of Agrometeorology and Environmental Science, Birsa Agricultural University, Kanke, Ranchi, 28p.

### Samastipur

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## Technical Bulletin

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## Solapur

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Jadhav, J.D., Bawdekar V.R., Londhe V.M., Jadhav V.T., Pawar P.B. (2021). Scarcity places of north, central and southern Maharashtra rainfall probabilities and contingent crop planning. *Journal of Agriculture Research and Technology*, 46 (2):184-193.

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Jadhav, V.T., Londhe, V. M., Amrutsagar, V.M., Pawar, P.B., Jadhav, J.D., Birajdar, S.G., Manikandan, N. and Bal, S.K. (2021). *Agrometeorology of Chickpea*, MPKV Rahuri Research Publication. No. 2380, 40p.

## Thrissur

### Technical bulletin

Ajithkumar, K., Arjun Vysakh., Dakhore, K.K. and Aswathi, K.P. (2021). Agrometeorology of Millets. The Millet Magic, Kerala Agricultural University, Thrissur. pp: 38-48.

## Staff Position at Cooperating Centers during 2021-22

(AICRP on Agrometeorology)

| Positions Sanctioned and Filled (F) / Vacant (V) |                   |                   |                         |                 |
|--------------------------------------------------|-------------------|-------------------|-------------------------|-----------------|
| Centre                                           | Agrometeorologist | Junior Agronomist | Meteorological Observer | Field Assistant |
| Akola                                            | F                 | —                 | V                       | V               |
| Anand                                            | F                 | F                 | F                       | F               |
| Anantapuramu                                     | F                 | F                 | F                       | F               |
| Bengaluru                                        | F                 | F                 | F                       | F               |
| Bhubaneswar                                      | F                 | —                 | V                       | F               |
| Chatha                                           | F                 | —                 | F                       | F               |
| Dapoli                                           | F                 | —                 | F                       | V               |
| Faizabad                                         | V                 | F                 | F                       | F               |
| Hisar                                            | F                 | F                 | F                       | F               |
| Jabalpur                                         | F                 | F                 | V                       | F               |
| Jorhat                                           | F                 | —                 | F                       | F               |
| Kanpur                                           | F                 | —                 | F                       | F               |
| Kovilpatti                                       | F                 | F                 | F                       | F               |
| Ludhiana                                         | F                 | F                 | F                       | F               |
| Mohanpur                                         | F                 | F                 | V                       | V               |
| Palampur                                         | F                 | —                 | V                       | V               |
| Parbhani                                         | V                 | —                 | F                       | V               |
| Raipur                                           | F                 | —                 | F                       | F               |
| Ranchi                                           | V                 | F                 | V                       | F               |
| Ranichauri                                       | V                 | V                 | V                       | V               |
| Samastipur                                       | F                 | —                 | V                       | F               |
| Solapur                                          | F                 | F                 | F                       | F               |
| Thrissur                                         | F                 | —                 | F                       | F               |
| Udaipur                                          | F                 | —                 | V                       | V               |
| Vijayapura                                       | F                 | —                 | F                       | F               |
| Post Filled                                      | 21                | 11                | 16                      | 18              |
| Post Sanctioned                                  | 25                | 12                | 25                      | 25              |

## Center-wise and Head-wise RE allocation (Plan): FY 2021-22

### (AICRP on Agrometeorology)

(Amount in Rupees)

| S. No. | Centre       | RE 2021-22      |                      |                |                |          |                      |                |                |               |                 |
|--------|--------------|-----------------|----------------------|----------------|----------------|----------|----------------------|----------------|----------------|---------------|-----------------|
|        |              | Salary          | Grant-in-aid General |                |                |          | Grant-in-aid Capital |                | SC-SP          |               | Grand Total     |
|        |              |                 | TA                   | Res. Exp.      | Opr. Exp.      | HRD      | IT                   | Equipment      | General        | Capital       |                 |
| 1      | Akola        | 1525000         | 10000                | 80000          | 250000         | 0        | 3000                 | 0              | 0              | 0             | 1868000         |
| 2      | Anand        | 1950000         | 5000                 | 42500          | 187500         | 0        | 130000               | 100000         | 0              | 0             | 2415000         |
| 3      | Anantapuramu | 3273826         | 10000                | 50000          | 234000         | 0        | 3000                 | 0              | 170000         | 12500         | 3753326         |
| 4      | Bengaluru    | 4331545         | 28000                | 110000         | 320000         | 0        | 80000                | 0              | 180000         | 12500         | 5062045         |
| 5      | Bhubaneswar  | 2423000         | 15000                | 50000          | 290000         | 0        | 80000                | 0              | 0              | 0             | 2858000         |
| 6      | Chatha       | 3479853         | 15000                | 50000          | 206000         | 0        | 5000                 | 810000         | 170000         | 12000         | 4747853         |
| 7      | Dapoli       | 2079783         | 5000                 | 66500          | 180000         | 0        | 3000                 | 0              | 0              | 0             | 2334283         |
| 8      | Faizabad     | 1843000         | 14000                | 60000          | 220000         | 0        | 3000                 | 0              | 0              | 0             | 2140000         |
| 9      | Hisar        | 3400000         | 5000                 | 21000          | 256000         | 0        | 0                    | 0              | 100000         | 8500          | 3790500         |
| 10     | Jabalpur     | 2182000         | 5000                 | 70000          | 320000         | 0        | 90000                | 0              | 0              | 0             | 2667000         |
| 11     | Jorhat       | 1874000         | 5000                 | 70000          | 220000         | 0        | 3000                 | 655000         | 0              | 0             | 2827000         |
| 12     | Kanpur       | 3032869         | 18500                | 70000          | 240000         | 0        | 4000                 | 0              | 185000         | 13000         | 3563369         |
| 13     | Kovilpatti   | 4000000         | 5000                 | 80000          | 250000         | 0        | 3000                 | 0              | 185000         | 13000         | 4536000         |
| 14     | Ludhiana     | 4100000         | 10000                | 70000          | 340000         | 0        | 3000                 | 0              | 243000         | 13000         | 4779000         |
| 15     | Mohanpur     | 3492000         | 0                    | 70000          | 240000         | 0        | 0                    | 0              | 125000         | 12500         | 3939500         |
| 16     | Palampur     | 850000          | 3000                 | 35000          | 260000         | 0        | 3000                 | 0              | 120000         | 12500         | 1283500         |
| 17     | Parbhani     | 600000          | 16000                | 50000          | 260000         | 0        | 3000                 | 357000         | 0              | 0             | 1286000         |
| 18     | Raipur       | 2470000         | 21000                | 50000          | 230000         | 0        | 3000                 | 0              | 0              | 0             | 2774000         |
| 19     | Ranchi       | 760000          | 6000                 | 100000         | 100000         | 0        | 3000                 | 0              | 50000          | 0             | 1019000         |
| 20     | Ranichauri   | 0               | 14000                | 60000          | 150000         | 0        | 0                    | 0              | 0              | 0             | 224000          |
| 21     | Samastipur   | 0               | 5000                 | 50000          | 255000         | 0        | 85000                | 0              | 0              | 0             | 395000          |
| 22     | Solapur      | 3380000         | 5000                 | 42000          | 323000         | 0        | 90000                | 0              | 0              | 0             | 3840000         |
| 23     | Thrissur     | 1850000         | 28000                | 42000          | 220000         | 0        | 0                    | 340000         | 219000         | 12500         | 2711500         |
| 24     | Udaipur      | 871124          | 21000                | 50000          | 220000         | 0        | 3000                 | 0              | 0              | 0             | 1165124         |
| 25     | Vijayapura   | 3120000         | 20000                | 70000          | 230000         | 0        | 4000                 | 25000          | 0              | 0             | 3469000         |
| 26     | PC Unit      | 0               | 0                    | 0              | 850000         | 0        | 166000               | 0              | 0              | 0             | 1016000         |
|        | <b>Total</b> | <b>56888000</b> | <b>289500</b>        | <b>1509000</b> | <b>6851500</b> | <b>0</b> | <b>770000</b>        | <b>2287000</b> | <b>1747000</b> | <b>122000</b> | <b>70464000</b> |

## Field activities at AICRPAM Centres

