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# NIASM-Plant Phenomics

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भाकृअनुप-राष्ट्रीय अजैविक स्ट्रैस प्रबंधन संस्थान

ICAR-National Institute of Abiotic Stress Management

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# NIASM-Plant Phenomics at a glance

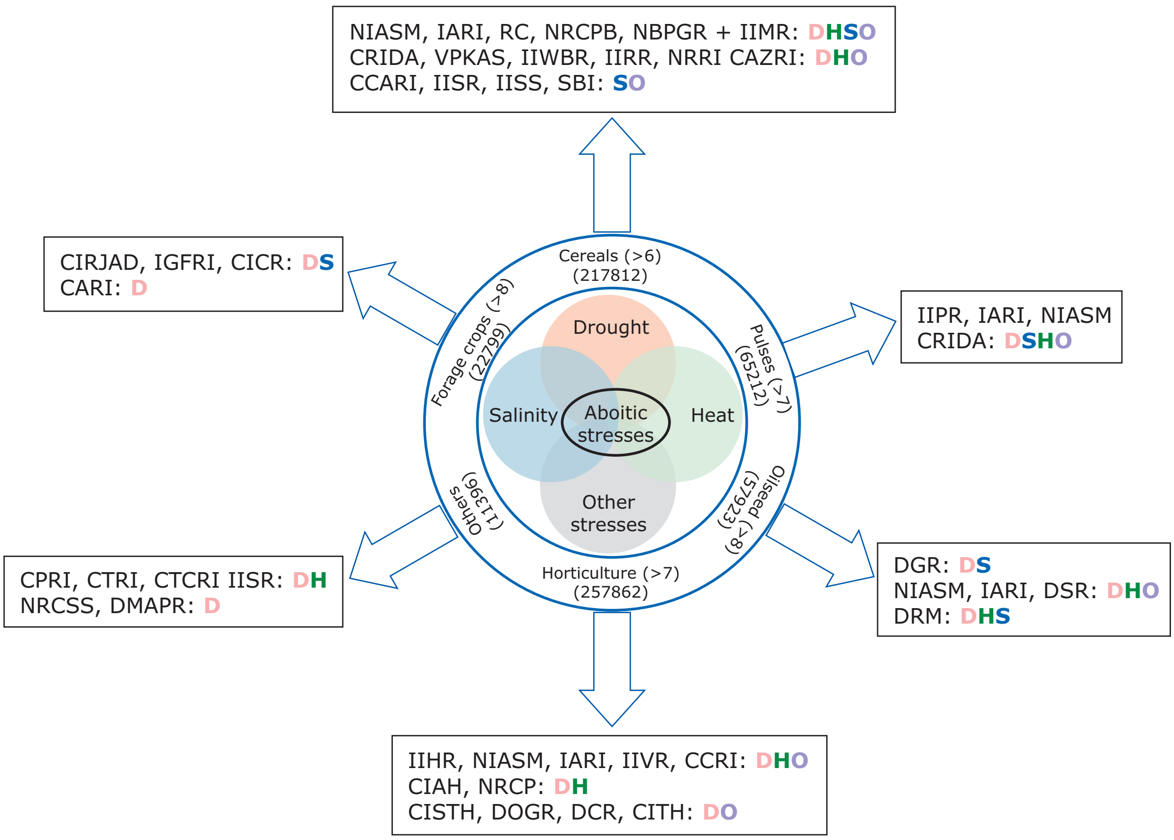
Plant responds to various environmental growth stimuli by adjusting its morphology, anatomy, phenology and cellular metabolism. As a consequence growth, development and productivity of crop increase or decrease in favorable and unfavorable environments respectively. Much of the achievements so far in improving the productivity of crops is attributed to empirical selection for yield and yield components. This was more apparent in favorable growth environment than in those affected by drought, high temperature, salinity etc. Hence, there is an increasing focus on traits associated with tolerance to these abiotic stresses. Further genes associated with such traits are the keys for further improvement as plant responses to stresses are manifestation of gene action in cellular and molecular mechanisms. To establish the association between genes and traits it is essential to understand both these components while the power of prediction of association is largely governed by number of genotypes characterized. There is a significant progress in genomics, the science of understanding structure and function of genes, but lack of matching advances in understanding the trait and characterizing plant responses in large scale is the major bottleneck. Hence, Plant Phenomics is emerging as a science that aims at characterization of plant responses to environmental factors precisely and rapidly through non-destructive methods that allow screening of genotypes in a large scale.

## Features of Plant Phenomics in controlled environment

- Automated control of growth environment including soil moisture
- Desired level of water stress is maintained and monitored with greater precision
- Controlled environment allows screening for high temperatures and other abiotic stresses
- Acquisition, processing and analysis of images invloved in assessing plant response
- Automation minimizes labour requirement for repeated characterization of huge set of germplasm
- Non-destructive as plant responses are captured in images obtained from different electromagnetic radiation
- Images from visible range reveals changes in morphology and developmental stages
- Images from infra-red range reveals variation in plant temperature
- Images from near infrared range reveals plant water status

## Why we need phenomics platform?

- The traditional approach with emphasis only on yield components for improvement of crop productivity is not as efficient as it was at the beginning of green revolution.
- Trait based selection is essential for each of the diverse agro-ecosystems vulnerable to climate change
- It is necessary to phenotype plant population that have been generated for genetic dissection of plant responses to stresses
- Large collection of germplasm of different crops needs to be phenotyped for identifying promising source of stress tolerance




More than 40 institutes, more than 60 SAUs and private organisations are investigating abiotic stress tolerance in more than 56 crops and a total of 4.3 lakh accessions are in germplasm bank needs phenotyping services. In addition, with emphasis on common protocol for phenotyping in the context of global demand for phenotype database of different crops, high throughput and image based screening protocols are gaining immense importance.

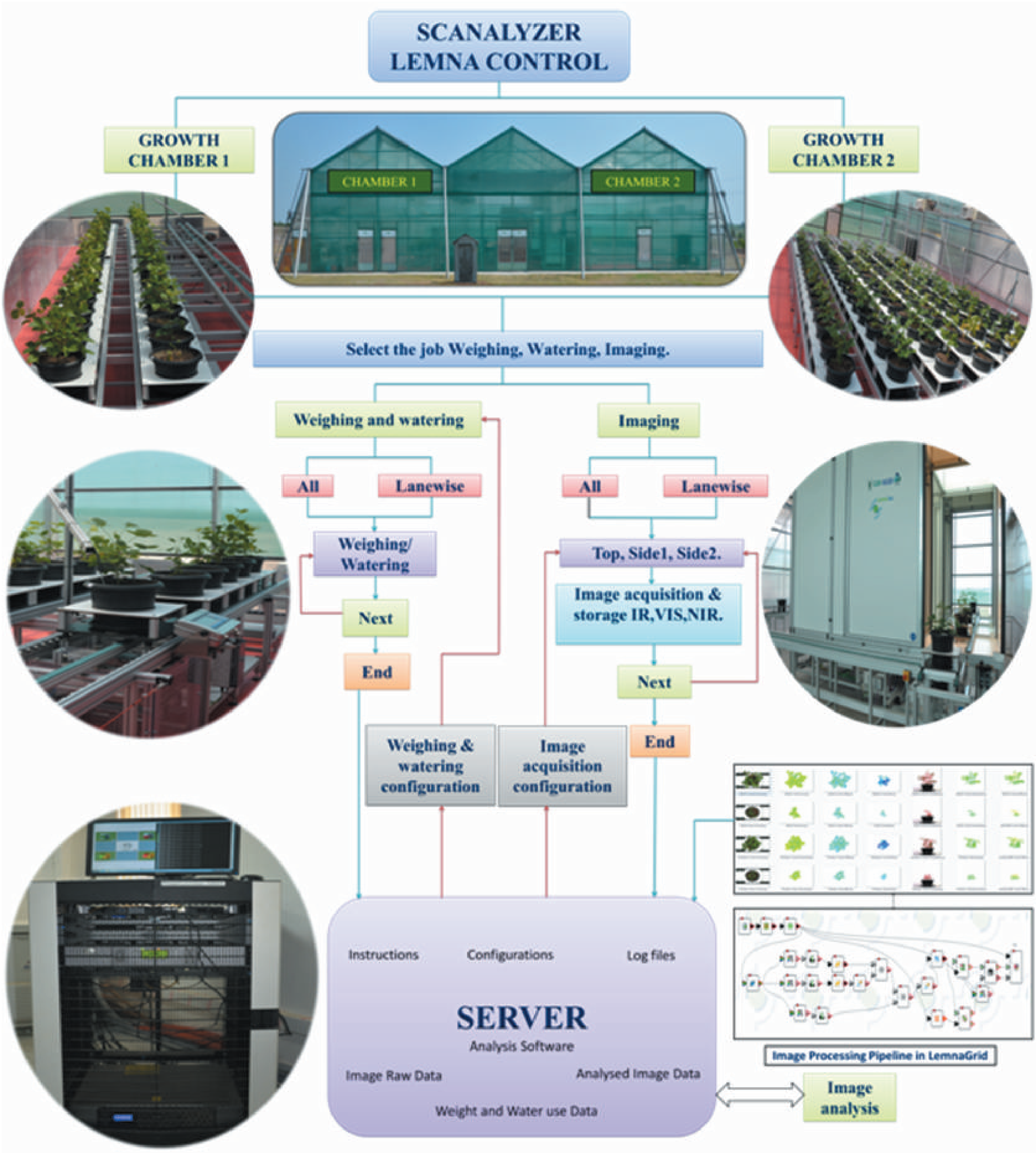
## Plant phenomics facility at NIASM

The installation of facility was completed on September 01-09-2015 by LemnaTec, GMBH, Germany under National Innovations for Climate Resilient Agriculture (NICRA). The facilities allow screening of 216 plants at a time and it is possible to screen thousands of lines for responses of plants to a particular phase of crop growth with staggered planting and growth initially under natural condition. The facility is equipped with cameras for acquiring images in visual, infrared and near infrared range for morpho-physiological traits, surface of electro mangentic spectrum temperature and plant water relations respectively. It has programmable and automated irrigation and weighing system to create and monitor soil moisture stress. Automated temperature regulation can allows screening for high temperature tolerance. Robust software and hardware allow acquisition, storage and analysis of huge set of images. Research projects facilitated by this technology vary from large scale screening of early growth and tolerance to abiotic factors like soil moisture stress, salinity and nutrient imbalance. It has diverse application ranging from phenotyping for known traits to identification of novel or surrogate traits associated with stress tolerance. The facility has been provided with dedicated power supply and also the power backup for uninterrupted functioning.

### Objectives

- To develop plant phenomics protocols for characterization of responses of crops to abiotic stresses mainly drought, high temperature and salinity
- To identify alternative traits to accelerate characterisation of plants responses to complex and difficult to measure traits associated with stress tolerance
- To identify promising genotypes that have attributes contributing to stress tolerance
- To identify traits and genes associated with tolerance to drought, high temperature and salinity
- To complement efforts of plant breeder and molecular biologists involved in investigation of genes associated with tolerance to abiotic stresses in field and horticultural crops
- To develop plant phenome database by employing common methods and comparable procedures
- To facilitate development low cost indigenous plant phenotyping tools for controlled and field experiments by validation of results in HTP phenotyping

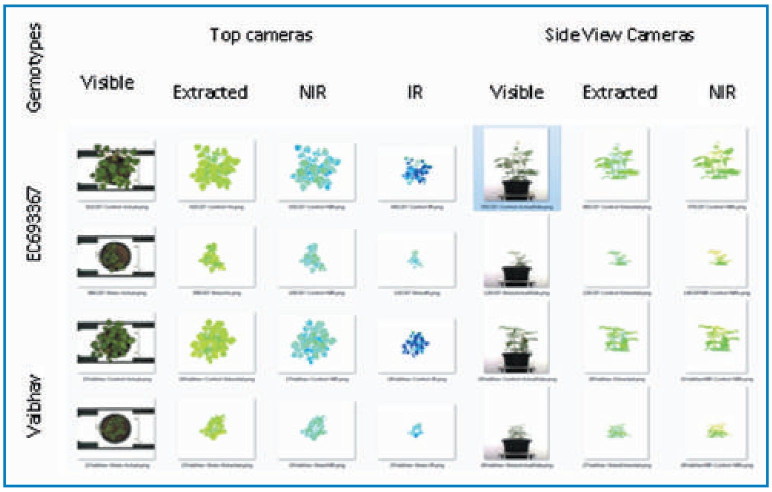
## LEMNATEC SCANALYZER-PROCESS AND FUNCTION



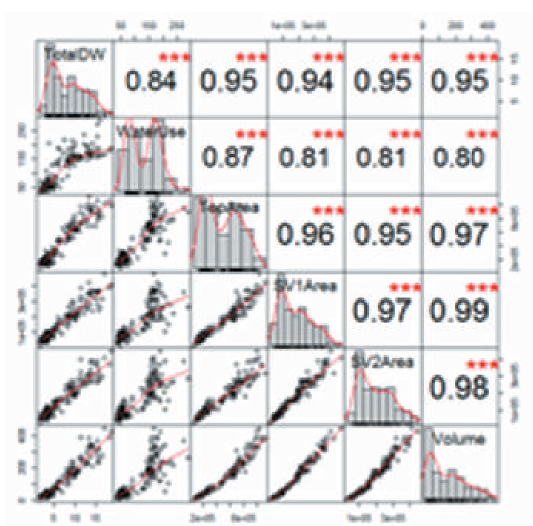
## Optimisation of phenomics protocol

For efficient phenotyping image based protocols needs to be optimised for each crop. Hence several experiments were carried out with different crops such as mungbean, chickpea, soybean, maize and wheat. Methods have been standardized to predict biomass of mungbean based on area sensed by visible camera as derived from specifically designed image analysis configuration. Methods are being optimised for other crops.

## Extraction of images from original images




## Visible area as surrogate parameter




Visible area derived from 24 Genotypes grown with or without water stress in three replications (144 pots). Area and volume derived from images could explain the variation in water use and biomass (Total DW) in mungbean. This optimised method can now be used to assess mungbean genotypes for their capacity to utilise soil moisture effectively during the growth period.

# Field Phenomics initiatives

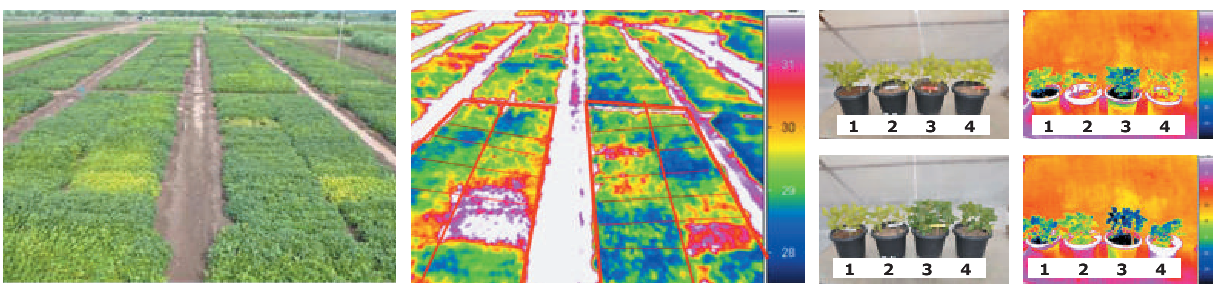
## Prototype of tools for image based phenotyping

Taking into consideration the need to accelerate phenotyping in field, efforts have been made to develop phenotyping tools. A hand operated track mounted trolley was designed for imaging purpose which hosts a camera and a Lap Top PC. The system acquires images of each plot in the experimental field after recognising the barcode. Images are stored with plot name. Tools have also been developed to rapidly analyse these images. Promising results have been obtained with image acquisition and analysis tool. This field based, semi- automated platforms potentially allow high-throughput phenotyping at a low cost.


Prototypes to screen genotypes in field (a) pot culture (b) tools for rapid analysis of images (c)

## Phenotyping for canopy temperature

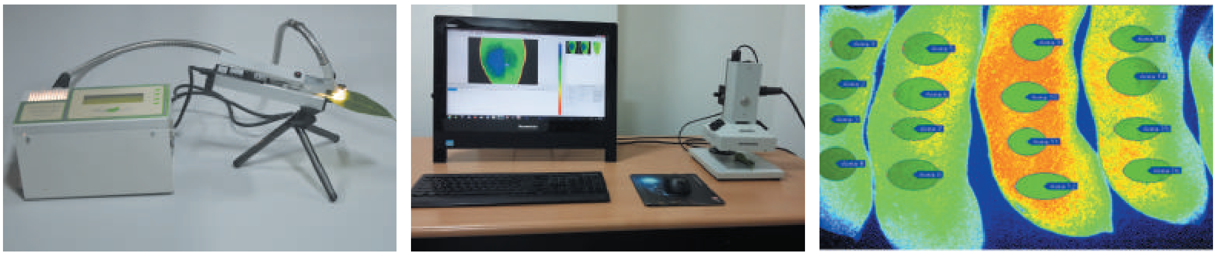
- Identification of superior and high yielding genotypes with higher canopy temperature and those with cooler canopy temperature as compared to locally adapted cultivars in wheat soybean , mungbean and chickpea.
- Higher yield in some genotypes despite its higher CT throughout its growth period as compared to other genotypes could be partially attributed to high net assimilation rate and quantum yield, as indicated by chlorophyll fluorescence parameters.
- CTD measured at the reproductive stage explained a major proportion of the variation in grain yield both under sufficient and deficit soil moisture conditions in soybean.
- Simple methods were developed to process the thermal image.




Soybean field as viewed through visible imaging (a) Infrared imaging system (b) and pot culture

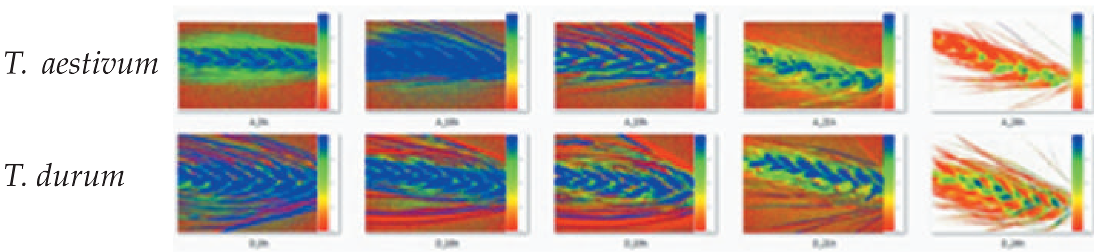
## Phenotyping for photosynthetic efficiency under stress

- Considerable genetic variability obtained in wheat, soybean and mungbean for PSII reflected by Fv/Fm.



Fluorescence monitoring system (a), fluorescence imaging system (b) and Chlorophyll fluorescence imaging of soybean pod (c)

- Chlorophyll fluorescence based imaging was effectively used to demonstrate that photosynthetic system (PSII) of spikes of *T. durum* is more tolerant than that of *T. aestivum.*




Chlorophyll fluorescence imaging to assess desiccation tolerance

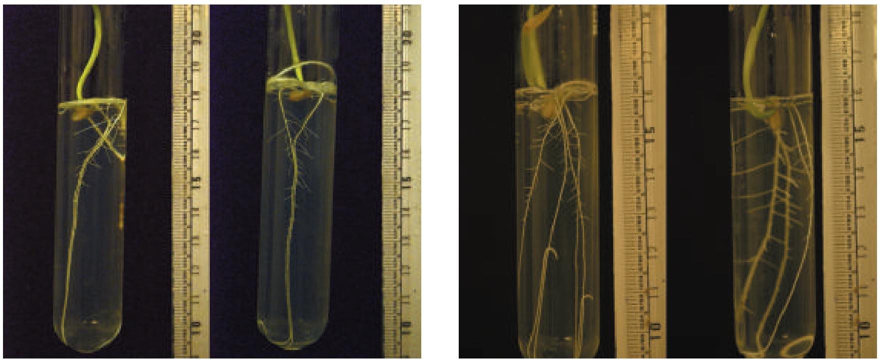
- Chlorophyll fluorescence imaging revealed that sensitivity of photosystem of dragon fruit to temperature was less than that of other fruit crops. Acid lime was more tolerant to temperature than other fruit crop.
- Photosystem of pomegranate were less sensitive while sensitivity to desiccation was conspicuous in Mango

## RGB Image based techniques

- A low-cost and non-destructive, easy to use method is being developed to evaluate the chlorophyll content of soybean using leaf image colour analysis
- Promising results have been obtained with image acquisition and analysis tool developed to assess leaf expansion rate, growth rate and leaf senescence of soybean and it can work as low cost non-destructive phenotyping tool for large scale phenotyping.

## *In vitro* techniques for root system architecture

Techniques developed for *in vitro* root studies revealed significantly different root system architecture in terms of number of roots and length of roots in some promising wheat genotypes compared to locally adapted genotypes indicating that high biomass obtained in field was partially due to efficient root system. This technique can be scaled up as medium throughput phenotyping method for root system architecture.



*In vitro* root system of HD-2189 (a) and IC-549394 (b)

## Present collaboration

NICRA, CRIDA, Hyderabad; IIPR, Kanpur; NBPGR, New Delhi; DSR, Indore, IIWBR, Karnal

## Phenomics facilities

### India

ICAR-NIASM, Baramati
ICAR-IARI, New Delhi
ICAR-IIHR, Bangalore
ICAR-CRIDA, Hyderabad

### China

CAAS, Beijing
Harbin
Agripheno, Pudong, Shanghai

### Australia

Victoria laboratory, Horsham,
ACPGF, Adelaide

### Germany

IPK Gaterlaben
Plant Science Research Centre, Julich

### France

INRA science and impact, Dijon
INRA Montpellier

### Netherland

Keygene

### Italy

Metaponto (ITALY)

### United Kingdom

Rothamsted Research Station
Aberysstwyth University

### Canada

McGill Phenomics Platform, Canada

### USA

Donald Danfroth Plant Science Center
Arkansas State University

# Abbreviations

| | |
|---|---|
| CARI | Central Island Agricultural Research Institute , Port Blair |
| CAZRI | Central Arid Zone Research Institute, Jodhpur |
| CAZRI | Central Arid Zone Research Institute, Jodhpur |
| CCARI | Central Coastal Agricultural Research Institute, Ela, Old Goa, Goa |
| CIAH | Central Institute for Arid Horticulture, Bikaner |
| CIAH | Central Institute of Cotton Research, Nagpur |
| CICR | Central Institute of Cotton Research, Nagpur |
| CIRJAF | Central Research Institute for Jute and Allied Fibres, Barrackpore |
| CISTH | Central Institute of Sub Tropical Horticulture, Lucknow |
| CITH | Central Institute of Temperate Horticulture, Srinagar |
| CPRI | Central Potato Research Institute, Shimla |
| CRIDA | Central Research Institute of Dryland Agriculture, Hyderabad |
| CSSRI | Central Soil Salinity Research Institute, Karnal |
| CTCRI | Central Tuber Crops Research Institute, Trivandrum |
| DGR | Directorate of Groundnut Research, Junagarh |
| DMAPR | Directorate of Medicinal and Aromatic Plants Research, Anand |
| DRM | Directorate of Rapeseed & Mustard Research, Bharatpur |
| DSR | Directorate of Soybean Research, Indore |
| IARI | Indian Agricultural Research Institute, New Delhi |
| IGFRI | Indian Grassland and Fodder Research Institute, Jhansi |
| IIHR | Indian Institute of Horticultural Research, Bengaluru |
| IIMR | Indian Institute of Maize Research,New Delhi |
| IIPR | Indian Institute of Pulses Research, Kanpur |
| IIRR | Indian Institute of Rice Research, Hyderabad |
| IISR | Indian Institute of Sugarcane Research, Lucknow |
| IISS | Indian Institute of Soil Sciences, Bhopal |
| IIWBR | Indian Institute of Wheat and Barley Research, Karnal |
| NBPGR | National Bureau of Plant Genetics Resources, New Delhi |
| NIASM | National Institue of Abiotic Stress Management, Malegaon, Maharashtra |
| NRCP | National Research Centre for Pomegranate, Solapur |
| NRCPB | National Research Centre on Plant Biotechnology, New Delhi |
| NRCSS | National Research Centre on Seed Spices, Ajmer |
| NRRI | National Rice Research Institute, Cuttack |
| RC | ICAR Research Complex for Eastern Region, Patna |
| RC | ICAR Research Complex for NEH Region, Barapani |
| SBI | Sugarcane Breeding Institute, Coimbatore |
| VPKAS | Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora |

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