National Initiative on Climate Resilient Agriculture

Research Highlights (2010-12)

Compiled and edited by

B. Venkateswarlu, M. Maheswari, M. Srinivasa Rao, V.U.M. Rao, Ch. Srinivasa Rao, D.B.V. Ramana, C.A. Rama Rao, S. Dixit and A.K. Singh

Central Research Institute for Dryland Agriculture

Santoshnagar, Saidabad, Hyderabad – 500 059.

Participating Institutes

Strategic Research

1. Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad including AICRPAM and AICRPDA
2. Indian Agricultural Research Institute (IARI), New Delhi
3. Indian Institute of Horticultural Research (IIHR), Bangalore
4. National Dairy Research Institute (NDRI), Karnal
5. Central Marine Fisheries Research Institute (CMFRI), Kochi
6. Central Institute of Agricultural Engineering (CIAE), Bhopal
7. ICAR Research Complex for NEH Region (ICAR-NEH), Umiam
8. National Research Centre on Plant Biotechnology (NRCPB), New Delhi
9. Central Rice Research Institute (CRRI), Cuttack
10. Directorate of Rice Research (DRR), Hyderabad
11. Indian Institute of Pulses Research (IIPR), Kanpur
12. Indian Institute of Vegetable Research (IIVR), Varanasi
13. ICAR Research Complex for Eastern Region (ICAR-RCER), Ranchi Centre
14. National Centre for Integrated Pest Management (NCIPM), New Delhi
15. Directorate of Water Management (DWM), Bhubaneshwar
16. National Research Centre for Agro-Forestry (NRCAF), Jhansi
17. Project Directorate for Farming System Research (PDFSR), Meerut
18. Indian Veterinary Research Institute (IVRI), Izatnagar
19. Central Inland Fisheries Research Institute (CIFRI), Barrackpore
20. Central Institute for Brackish Water Aquaculture (CIBA), Chennai
21. National Institute for Abiotic Stress Management (NIASM), Baramati

Sponsored Research Component

1. National Bureau of Plant Genetic Resources (NBPGR), New Delhi.
2. Indian Institute of Horticultural Research (IIHR), Bangalore.
3. Guru Gobind Singh Indraprastha University (GGS IPU), New Delhi
4. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru
5. West Bengal University of Animal & Fishery Sciences (WBUAS&F), Kolkata
6. University of Agricultural Sciences (UAS), Bangalore
7. Central Arid Zone Research Institute (CAZRI), Jodhpur
8. Central Sheep & Wool Research Institute (CSWRI), Avikanagar along with Central Institute for Research on Goats (CIRG), Mathura
9. University of Kalyani, Nadia
10. MIT College of Engineering, Pune
11. Indian Institute of Natural Resins and Gums (IINRG), Ranchi

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National Initiative on Climate Resilient Agriculture (NICRA)

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CONTENTS

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Dr. S. AYYAPPAN
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FOREWORD

Climate change is one of the major challenges before Indian agriculture. The Indian Council of Agricultural Research has responded to this challenge by launching a major national scheme, National Initiative on Climate Resilient Agriculture (NICRA) during XI Plan with an outlay of Rs.350 crores. The major focus of the program is on infrastructure development for strategic research, demonstration of best practices on farmers' fields to cope with climate variability, sponsored and competitive grants and capacity building.

The unique feature of this project is the multi-disciplinary approach covering all commodities like crops, horticulture, livestock, fisheries besides natural resources management and socio-economic issues. About 21 major institutes of the ICAR are partners in the strategic research. Since abiotic stresses are the key manifestations of climate variability and climate change, the major focus is on development of heat and drought tolerant crop varieties and management practices for adaptation to such abiotic stresses. Another important feature of the project is the simultaneous initiation of the technology demonstration component. While the outputs of strategic research will be available in medium to long term, to help farmers to cope with current climate variability, the technology demonstration component aims at on-farm participatory demonstration of available climate coping technologies as an integrated package in 100 most vulnerable districts. The program has been launched in all the districts with good stakeholder participation and the response from the farmers has been quite encouraging. Particularly women farmers have been willingly participating in adoption of climate resilient agricultural practices. The Village Climate Risk Management Committee is another innovation in this project who prioritize the interventions, resource allocation and running of village level institutions like custom hiring centers and seed banks. Few critical researchable issues like impact on pollinators, small ruminants and vulnerability of hill ecosystems are being addressed through competitive grants scheme.

The project has made significant progress in a short span of one year. State of the art infrastructure is coming up and excellent beginning has been made in strategic research, technology dissemination and capacity building. I compliment Dr.A.K.Singh, DDG (NRM) and Dr. B.Venkateswarlu, Director, CRIDA for successfully leading this project. The scientists from the lead center have brought out the salient finding of the first year outputs as Research Highlights to be released on the occasion of the first annual workshop. I am sure this will mark the beginning of a long and sustained effort towards climate resilient agriculture in India.

(S. Ayyappan)

Dated the 5th June, 2012
New Delhi

ACKNOWLEDGEMENTS

The formulation and launch of NICRA was made possible due to the help and guidance of large number of senior officers of the Council. Dr.S.Ayyappan, Secretary (DARE) and Director General, ICAR and Shri Rajiv Mehrishi, Secretary (ICAR) and Special Secretary (DARE) have played significant role in getting this major scheme approved by the Planning Commission and the Union Cabinet. Dr.A.K.Singh, Deputy Director General (NRM) was the main source of inspiration in successful implementation of this large project involving several Institutions and Agricultural Universities. All the DDGs of ICAR and ADGs of the concerned SMDs provided guidance through different stages of the project development and the final technical programme. We also place on record the guidance provided by the Expert Technical Committee lead by Dr.Y.P.Abrol in screening and approval process of sponsored and competitive grant projects. The guidance and cooperation provided by Dr. K. D. Kokate, Deputy Director General (Extn.) in development of action plans and implementation of technology demonstration component across 100 KVKs is gratefully acknowledged. The senior officers of the NRM Division Dr.J.C.Dagar, Assistant Director General (Agronomy), Dr. A. Arunachalam, Principal Scientist (Forestry) and other office staff have been extending their full cooperation in implementation of this project and also organizing several review meetings of high level committees in New Delhi. The Directors of all the participating Institutes have extended their full cooperation in the project implementation. We also acknowledge large number of farmers, State Department officers, public representatives who helped us in launching this participatory programme across the country in a big way. A multi-disciplinary team of scientists led by Dr M. Maheswari from CRIDA have put in their best efforts in overall coordination and implementation of the project and so also large number of scientists from all participating institutes.

B. Venkateswarlu

(B.VENKATESWARLU)
Director, CRIDA

National Initiative on Climate Resilient Agriculture (NICRA)

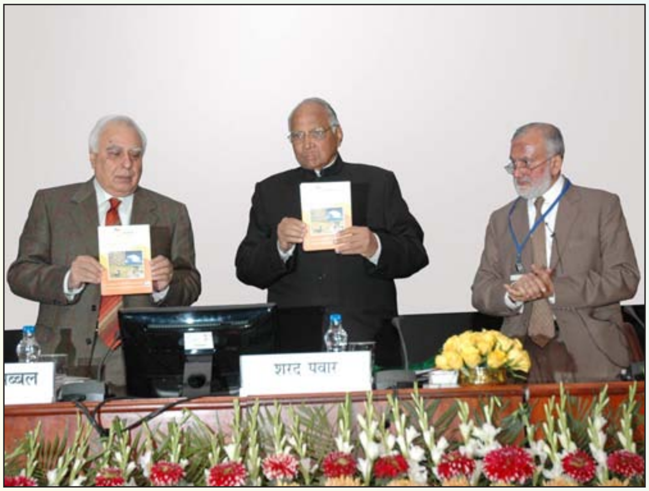
1. Background

Climate change has become an important area of concern for India to ensure food and nutritional security for growing population. The impacts of climate change are global, but countries like India are more vulnerable in view of the high population depending on agriculture. In India, significant negative impacts have been implied with medium-term (2010-2039) climate change, predicted to reduce yields by 4.5 to 9 percent, depending on the magnitude and distribution of warming. Since agriculture makes up roughly 16 percent of India's GDP, a 4.5 to 9% negative impact on production implies a cost of climate change to be roughly up to 1.5 percent of GDP per year. The Government of India has accorded high priority on research and development to cope with climate change in agriculture sector. The Prime Minister's National Action Plan on climate change has identified Agriculture as one of the eight national missions.

2. Objectives

With this background, the ICAR has launched a major Project entitled, **National Initiative on Climate Resilient Agriculture (NICRA)** during 2010-11 with an outlay of Rs.350 crores for the XI Plan with the following objectives.

- To enhance the resilience of Indian agriculture covering crops, livestock and fisheries to climatic variability and climate change through development and application of improved production and risk management technologies
- To demonstrate site specific technology packages on farmers' fields for adapting to current climate risks
- To enhance the capacity building of scientists and other stakeholders in climate resilient agricultural research and its application.



Hon'ble Minister for Agriculture and Food Processing Industries Shri Sharad Pawar launched NICRA on 2nd February, 2011

3. Project Components

Both short term and long terms outputs are expected from the project in terms of new and improved varieties of crops, livestock breeds, management practices that help in adaptation and mitigation and inputs for policy making to mainstream climate resilient agriculture in the developmental planning. The overall expected outcome is enhanced resilience of agricultural production to climate variability in vulnerable regions. The project is comprised of four components.

1. Strategic research on adaptation and mitigation
2. Technology demonstration on farmers' fields to cope with current climate variability
3. Sponsored and competitive research grants to fill critical research gaps
4. Capacity building of different stake holders

3.1 Strategic Research

The strategic research has been planned at leading research institutes of ICAR in a network mode covering crops, horticulture, livestock, natural resource management and fisheries sectors. To begin with, the project is focusing on crops like wheat, rice, maize, pigeonpea, groundnut, tomato, mango and banana; cattle, buffalo and small ruminants among livestock and both marine and freshwater fish species of economic importance. The major research themes are:

- Vulnerability assessment of major production zones
- Linking weather based agro-advisories to contingency planning
- Assessing the impacts and developing genotypes/varieties tolerant to key climatic stresses (drought, heat, frost, flooding, etc.) in major food and horticulture crops
- Continuous monitoring of greenhouse gases in open field conditions in major production systems
- Evolving adaptation and mitigation strategies through enhancing water and nutrient use efficiency and conservation agriculture
- Studying changes in pest dynamics, pest/pathogen-crop relationships and emergence of new pests and pathogens under changing climate
- Adaptation strategies in livestock through nutritional and environmental manipulations
- Harnessing the beneficial effects of temperature in inland and marine fisheries through better understanding of the spawning behaviour.

The list of participating institutes in the strategic, sponsored and competetive research componenets of NICRA is given saperately.

The research was initiated during 2011-12 in all the above themes. The major emphasis during the year was on building state of art research infrastructure like high throughput phenotyping platforms, free air temperature elevation systems in open fields, network of 100 automatic weather stations, environmental growth chambers with CO_2 and temperature controls and special calorimetric system to study livestock response to heat stress. These are some of the unique facilities being set up for the first time in Asia. In all the target crops like rice, wheat, maize, pigeonpea, tomato and mango, core sets of genetic resources were assembled and field phenotyped at different institutions with a view to identify sources of tolerance to climatic stresses and related genes and traits. For the first time, all the germplasm of wheat with NBPGR has been multiplied for field phenotyping and currently under evaluation. Country wide studies have been initiated to understand the impact of temperature on flowering behavior in mango. A nation wide pest surveillance and monitoring system has been put in place for all the target crops for major pests and diseases wherein real time incidence is being monitored along with weather parameters to build pest warning models. Methods for measurement of green house gas emissions in the marine ecosystem have been standardized. Carbon sequestration potential through agroforestry systems across the country is being quantified. Monitoring of experiments on conservation agriculture in different production systems is initiated to assess the adaptation and mitigation potential of CA practices. The vulnerability of all the rural districts in the country (about 540) is being quantified in terms of exposure, sensitivity and adaptive capacity in order to prepare a vulnerability atlas.

3.2 Sponsored and Competitive Grants

Under this component, critical researchable issues like germplasm collection from climate hot spots, impact on plant pollinators, fisheries in esturian habitats, hail storm management, hill and mountain eco-system, small ruminants and socio economic aspects of climate change etc. are provided.

4. Research Highlights

4.1 Vulnerability Assessment

Assessment of district-level vulnerability to climate change (CRIDA)

Assessing vulnerability to climate change and variability is an important first step in evolving appropriate adaptation strategies to changing climate. Such an analysis also helps in targeting adaptation investments to regions or entities that are more vulnerable.

Vulnerability in the climate change context is generally related to the residual impact of climate change after accounting for the adaptation. According to IPCC, vulnerability is "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity". This definition is adopted for this study. Vulnerability is assessed by using the indicator method.

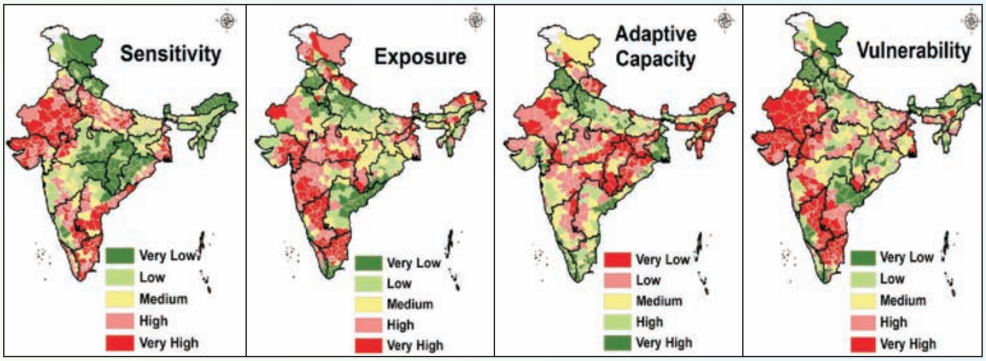
Relevant indicator variables were chosen based on review of literature and causal relationship with the three components of vulnerability and a database for 572 districts in India was developed. All the districts as appearing in the 2001 census excluding the urban districts (Delhi, Kolkata, Chennai, Mumbai etc) and the Union Territory of Lakshwadweep and Minicoy were included in the study. Three indices for sensitivity, exposure and adaptive capacity were computed and finally a vulnerability index was computed for all the 572 districts. The variables included to represent sensitivity are net sown area, length of coast line, drought intensity, flood proneness, ground water exploitation, population density etc. which determines the level of sensitivity of the district to changing climate. In order to capture the degree of change in climate in terms of change in drought occurrence, incidence of dry spells, change in annual rainfall, heat wave, cold wave, etc. the district is exposed to and climate projections of the PRECIS model for A1B scenario for the period 2021-2050 were considered. The changes in different climatic parameters were computed relative to the baseline 1961-90 of the same model. Variables considered to represent adaptive capacity include rural poverty, literacy, work force engaged in agriculture, consumption of fertilizer nutrients, net irrigated area, ground water availability, etc. which determine the adaptation behaviour of the districts with respect to climate change. Districts with higher adaptive capacity are assumed to adapt better to changing climate.

The data on these indicators were normalized based on the nature of relationship. They were then averaged with equal weights to get an index of the relevant component of vulnerability. Individual maps were produced for each indicator. Finally, the vulnerability index (VI) was computed as

VI = Sensitivity + Exposure – Adaptive Capacity.

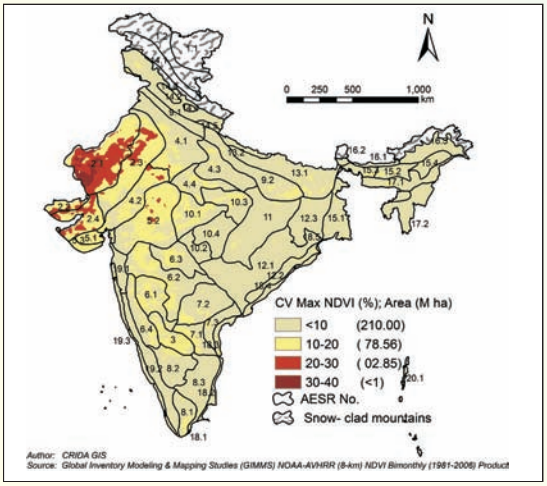
Based on the index, all the districts were divided into five categories with equal number of districts (One more district was added to each of the two lower categories).

It can be observed that districts with higher levels of vulnerability are located in the western and peninsular India. It is also observed that the highly fertile indo-gangetic plains are relatively more sensitive, but less vulnerable because of higher adaptive capacity and lower exposure. The vulnerability index map is an interim output and final outputs with refinements will be brought out as Vulnerability Atlas of India for Agriculture.

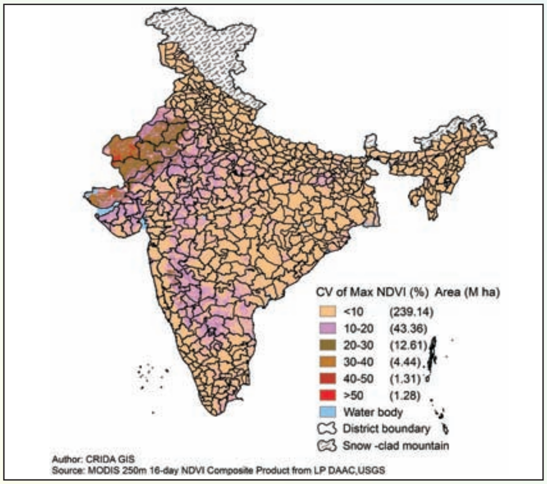


Districts mapped based on the components of vulnerability to climate change

Another exercise was carried out by CRIDA to prepare agroecological zone wise and district level vulnerability maps using NDVI. This does not capture adaptation capacity and also future exposure. The maps are generated based on CV percentage of maximum NDVI which indicates the vulnerability of region to the environmental stresses. These maps showed broad agreement with the vulnerability index map generated by the indicator method.



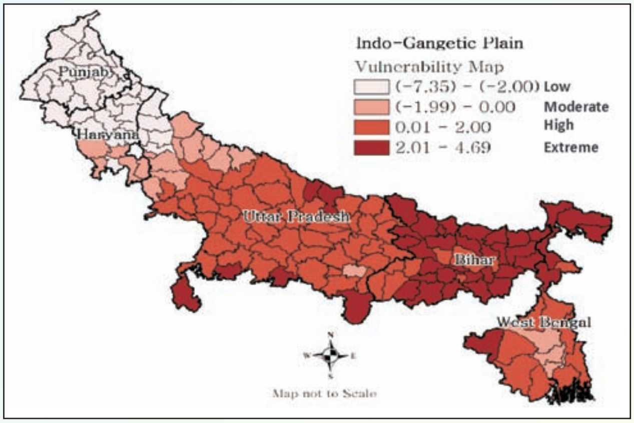
Vulnerability Agro-ecological Sub region of India based on AVHRR (8km) NDVI data (1982-2006)



India-District level Vulnerability based on MODIS-NDVI (2001-2011)

Mapping regional vulnerability (IARI)

The vulnerability of Indo-Gangetic Plains (IGP) was mapped under a separate exercise using exposure, sensitivity, adaptive capacity. In this case, 8 indicators were computed using meteorological data of 1951-2009 for exposure. Sensitivity was computed from 6 indicators based on crop and soil characteristics and adaptive capacity was based on another 7 indicators of agricultural technology, infrastructure and human development. The indicators were ranked and their weights were computed using multi-criteria decision making techniques in GIS like Analytic Hierarchal Process.



Vulnerability of different districts of the Indo-Gangetic Plain to climate change.

The eastern and southern parts of UP and Bihar districts were found most vulnerable regions in Indo-Gangetic plains Districts in north western Bihar (Sheohar, Sitamarhi, Madhubani, Purba Champaran, Darbhanga) were highly vulnerable due to high exposure to hazard and high sensitivity of agriculture. Districts in southern Bihar (Nawada, Banka, Lakhisarai, Jehanabad, Jamui) were highly vulnerable due to low adaptive capacity to recover. Sheohar, Sitamarhi, Madhubani, Purba Champaran in Bihar and Shrawasti in UP were ranked as highly vulnerable districts in overall assessment. Districts in central UP and West Bengal were high to moderately vulnerable. On contrary, state of Punjab and the northern parts of Haryana had low vulnerability.

Vulnerability of coastal region in Karnataka due to salt water intrusion (TERI)

A study carried out by TERI evaluated the extent of salt water intrusion in the coastal region of Karnataka and create village level baseline data for various environmental and socio-conomic indicators. Based on secondary data obtained from relevant government departments, eight talukas of the three coastal districts of Karnataka viz. Uttara Kannada, Udupi and Dakshina Kannada have been chosen to carry out the study. Soil and water samples were collected from the study area in the month of January 2012 from 24 locations at every 10 km interval in the 320 km stretch of the coast. At every sampling location, five samples representing approximately 0.0, 0.5 km, 1 km, 3 km and 5 km were collected from shore towards inland. Further, to study the depth to which salt water has leached into the soil, samples at varying depths (10, 50 and 100 cm) were collected. A total of 120 water samples and 360 soil samples were collected which are under analysis.

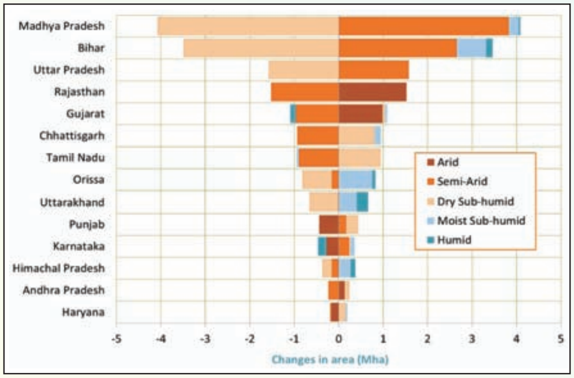
Regional impacts of climate change on rice (IARI)

Regional impact of climate change on yields of irrigated and rainfed rice were assessed using the InfoCrop-Rice model. On an aggregated scale, irrigated rice yields are projected to reduce by ~4% in 2020, 7% in 2050 and by ~10% in 2080 scenarios. On the other hand, rainfed rice yields in India are likely to be reduced by ~6% in 2020 scenario, but in 2050 and 2080 scenarios they are projected to decrease only marginally (<2.5%). Irrigated rice in north-west India is projected to decrease more (6-8%) than in other parts of the country (<5%) in 2020 scenario. Adopting improved varieties with efficient input use and providing 25% of additional nitrogen can offset the adverse impacts and improve the production by 6-17% in irrigated and 20-35% in rainfed conditions in future climate scenarios.

Revisiting the climatic classification of India

The traditional climatic classification of India based on Thornthwaite has been followed for several years for research and developmental planning. The major classes include, arid, semi arid, dry sub humid, moist sub humid, humid and per humid. However, there is a need to relook at the areas falling under these zones in view of the changing rainfall and temperature patterns over the last few decades. Accordingly, a study was carried out by **ICRISAT** under NICRA to revisit the areas falling in major climatic zones and find out whether there is any increase or decrease in area under a particular climate type in major states. Rainfall, maximum and minimum temperature (one degree resolution data) from IMD was interpolated by the inverse distance weighed technique and the water balance for entire country was worked out and the areas falling under different climatic zones were delineated.

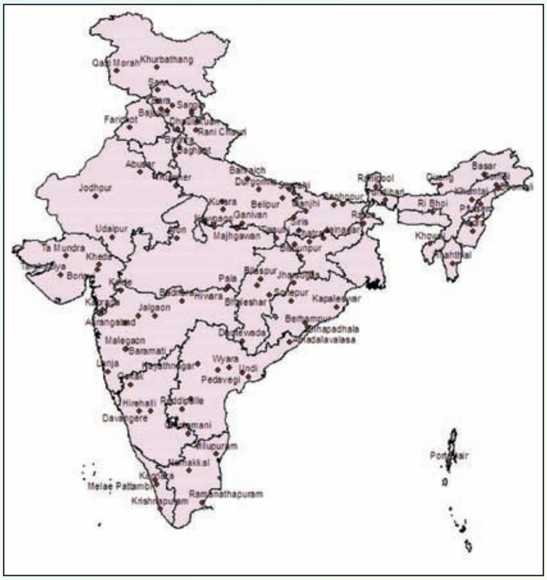
Overall, there has been a significant decrease in the dry sub humid area (13.2 m ha) in the country. However, a marginal area of 2.5 m ha has become wetter (moist sub humid, humid). Compared to past, there has been a significant increase in semi arid area in Madhya Pradesh (3.82 m ha) followed by Bihar (2.65 m ha). In Rajasthan and Gujarat also the arid area has increased and the semi arid area has decreased in equal proportion. These changes are due to increased dryness in these four states. Some regions are becoming drier while others becoming wetter, but overall, the dryness is increasing in the country. However, these results are based on one degree resolution data of IMD which need to be further confirmed with other interpolation techniques.



Changes in area under different climate types during (1971-1990) to 1991-2004

4.2 Weather-based Agro-Advisories and Development of Weather Indices

Dissemination of timely agro-advisories based on weather forecast is key to achieving climate resilient agriculture at farm level. Access to accurate weather data is critical to formulate and disseminate agro-advisories a the micro level (district, block, village, etc.) To strengthen this component, 100 KVKs were selected across the country according to climatic vulnerability for the installation of Automatic Weather Stations (AWS). As on 13th March 2012, the installation of all the AWS was completed at 100 locations. The AWS are measuring meteorological parameters, like Maximum & Minimum Temperature, Relative Humidity, Wind speed & direction, Rainfall, Solar Radiation and Potential evapotranspiration at 30 minute interval. The AWS uses GSM-GPRS/SMS Communication system for wireless Data Transfer.



Location map of 100 Automatic Weather Stations installed

The data from the AWS flows to the Central Server established at Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad and is available on line. A web site is designed and developed to retrieve the data from all the 100 AWS and after the quality check it is made accessible to all KVKs through NICRA AWS website http://www.aicrpam-nicra-aws.in.

NICRA-AWS Website

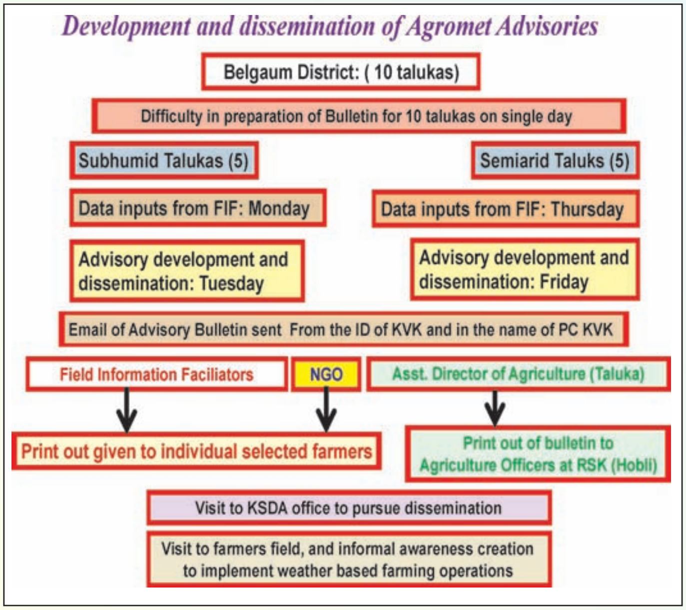
The main purpose of installing 100 AWS is to generate crop yield and climate data from KVK experimental farms on long term basis. Also by accessing current weather data, the program coordinators of KVKs can refine the agro-advisories given by the concerned state agricultural universities based on district/block level forecast issued by IMD.

Block level advisory service - A pre-pilot in Belgaum District

Timely and accurate weather forecast can reduce losses in farm produce due to aberrant weather conditions. At present, IMD is issuing forecast at district level. under NICRA project, the district level weather forecast is being used along with current crop and weather condition for preparation of block level advisories by respective KVK. A pilot methodology for preparing and issuing agromet advisories at block level has been tested at KVK, Belgaum. The main innovation in this project is to set up an architecture involving KVKs, state line departments and field information facilitation for collection of real time crop data formulation of an appropriate advisory and its dissemination. Field Information Facilitators (FIF) have been appointed in 10 Talukas of the district to collect information on weather, crops, disease and pest incidence.

The FIFs also collect qualitative information on soil moisture stress and animal husbandry. They supply information by phone or by e-mail to contact staff at KVK who in turn develops a qualitative Agromet Advisory specific to the village/farmers, in consultation with Agrometeorologist of SAU and Scientists of KVK. This helps in further value addition in terms of management options.

Each FIF is covering 200 farmers in each Taluka and FIFs then disseminate the advisory through distribution of handouts individually to selected farmers and by visiting farmers fields and holding informal awareness programs. This facilitates the farmer to utilize the forecast with maximum lead time. So far this pre-pilot worked successfully, but upscaling issues need to be addressed.



Methodology for dissemination of AAS

Development of weather indices

In a related activity, a detailed analysis of impact of maximum and minimum temperatures on growth and yields of wheat was undertaken at 4 locations (Kanpur, Faizabad, Anand and Raipur) to identify the most critical phenological phase and the quantum of yield loss as a result of unit increase or decrease in temperature. These data are being generated for a variety of crops grown for different agro climatic zones which are critical for formulating a science based weather insurance product.

TOPS to monitor real time weather (NIRUTHI)

In a related weather monitoring study by using satellite data, a new technique of Terrestial Observation and Prediction System (TOPS) was applied to monitor rainfall, vegetation and temperature over large areas and relate with the crop growth and yields at ground level. This pilot was taken up for East Godavari and Prakasam districts of Andhra Pradesh during 2011-12. This project is implemented by NIRUTHI Climatic Services, Hyderabad.

4.3 Resilience through Improvement and Adaptation of Major Food and Horticulture Crops

Improvement and adaptation of major food and horticultural crops

Development of crops and varieties adapted to climatic stresses is an important activity under NICRA. To address this objective, major food and horticultural crops are being evaluated for tolerance to abiotic stresses (drought, heat, flooding, salinity) and work on genetic enhancement was initiated in a multi-institutional and multi-disciplinary network mode. Crops like wheat, rice, maize, pigeonpea, mango and tomato are being focussed initially by premier institutes of ICAR and SAUS.

Phenotyping for drought and heat stress adaptive traits in wheat (IARI)

At **IARI,** a core set of 300 genetic resources including drought-adapted cultivars, advanced lines, elite land races, products of inter-specific hybridization were assembled and phenotyped for drought and heat stress adaptive morphological and physiological traits under rainfed situation in open field conditions during the rabi 2010-11 season. The inter-relationship between physiological traits with grain yield was worked out in the stress environment (heat and drought). Based on the morpho-physiological trait phenotyping, parental combinations which were estimated as informative and productive were identified and seven crosses were attempted involving resistant donor and well adapted agronomic base lines which were otherwise lacking in stress tolerance. F_1s from twenty three such crosses were advanced in the off-season nursery at Lahaul-Spiti. F_1s were backcrossed with the high yielding recurrent parent to generate BC_1F_1populations. These Bc_1F_1s are advanced in the current crop- season to generate BC_2F_1populations.

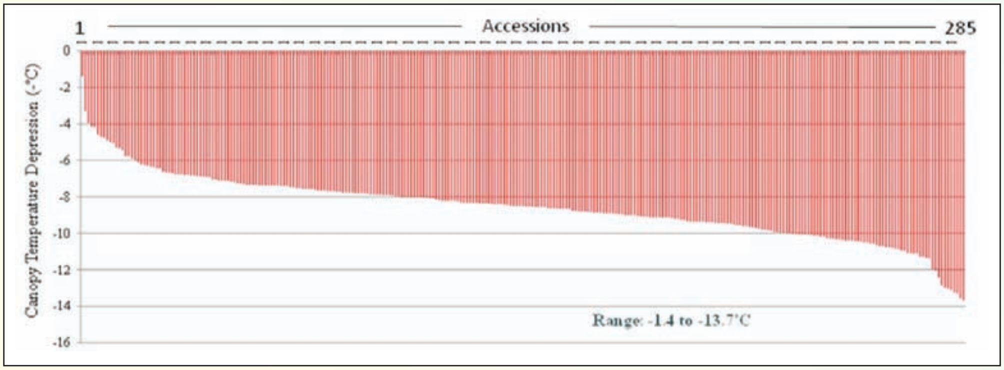
The information on available QTLs was validated considering more than 95 QTLs distributed across the wheat genome, of which 43 were found validated on the parental lines covering 17 chromosomes. In addition, the background parental genotyping for polymorphism was carried out adopting 800 microsatellite (SSR) markers. 23 new crosses using QTL validated donors for drought tolerance and 4 crosses for heat tolerance were generated with a view to introgressing the QTLs into established varieties like HD 2733, GW 322, GW 366, PBW 550. The traits phenotyped were early vigour, ground cover (NDVI), days to flag leaf emergence, days to panicle emergence, days to flowering, chlorophyll content, canopy temperature and days to maturity.

Phenotyping of wheat lines for drought and heat stress tolerance

Screening of gene bank material of wheat for terminal heat stresses (NBPGR)

NBPGR, for the first time screened the entire germplasm of wheat (~22000 accessions) conserved in the National Gene Bank, against abiotic stresses. During Kharif 2011, about 16,000 accessions of wheat germplasm were multiplied in the offseason at IARI Regional Station, Wellington.

At **CCS HAU**, Hisar, 21,822 accessions comprising *T. aestivum, T. durum* and *T. dicoccum,* were sown (during Nov 7-12, 2011 and Dec 1-3, 2011) under optimum conditions in three rows plots in Augmented Block Design with 8 national checks (Kharchia-65, Raj-3765, DBW-17, C-306, DDK1025, DDK1029, UAS-415, DWR 1006) for the respective species. A total of 36 agromorphological characters are recorded for development of a core-set to utilize in wheat breeding programmes.



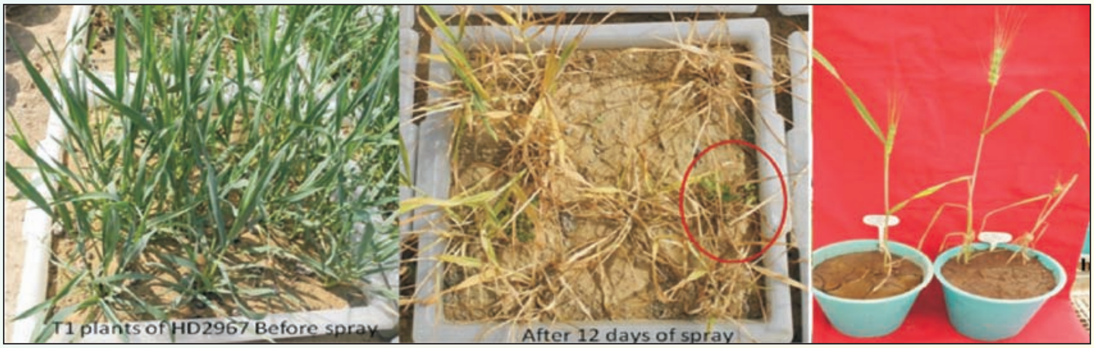
Variation in Canopy Temperature Depression in wheat germplasm

At **NBPGR**, Issapur Farm, two sets of wheat germplasm, first set of 21,445 accessions under normal sowing (during Dec 1-5, 2011) and a second set of 21,258 under late sowing were planted in single row plots in Augmented Block Design with 8 national checks for the respective species. A total of 17 agro-morphological characters are recorded to screen against terminal heat tolerance.

Characterization of 22,000 accessions of wheat at CCS HAU, Hissar, Haryana

Development of thermo tolerant transgenic wheat (NRCPB)

For developing transgenic wheat with enhanced heat tolerance, **NRCPB,** New Delhi standardized protocols for *in vitro* callus transformation in HD2967 and *in planta* transformation in HD2894. The transformation protocol is agrobacterium-mediated using *A. tumefaciens* strain EHA105 harboring binary plasmid pGreen0229 containing genes *csp*B (cold shock protein B) and EPSPS (5-enolpyruvyl shikimate 3-phosphate synthase) under the control of ubiquitin and 35S CaMV promoter, respectively. The transformants were confirmed by PCR analysis and 8 T_0 plants are currently at grain filling stage in phytotron. Two T_1 plants transformed through *in planta* method have survived after 1% glyphosate spray and are at grain filling stage.



T_1 generation of HD2894. A : one month old seedlings before spraying 1% glyphosate; B: Plants survived after glyphosate spray; C: Plants survived after glyphosate spray at grain filling stage

Proteome analysis in wheat under elevated CO_2 (Jamia Hamdard University)

Proteome analysis of nitrogen efficient (*cv* UP-2382) and nitrogen inefficient (*cv* VL-616) wheat varieties at elevated CO_2 (ambient, 500 and 600 ppm) conditions and two nitrogen levels (10 & 4 mM N) was carried out at **Jamia Hamdard University,** New

Delhi. Differential expression pattern of proteins in the leaves of two genotypes was analyzed using 2D gel electrophoresis. Quantitative image analysis of the differentially expressed proteins was done by using the PD Quest ImageMaster software. The intensity of the indicated spots were quantified, normalized and relatively expressed as arbitrary volume. The relative expression in terms of number of protein spots was better in N efficient cultivar under ambient and elevated CO_2 levels as well as lower and higher N concentrations as compared to the N inefficient cultivar.

Phenotyping for high temperature tolerance in rice (IARI)

At **IARI**, A field experiment was conducted for phenotyping high temperature tolerance in 71 rice lines (including N22 as a check) obtained from IARI and IRRI, Philippines. All the lines were sown during the month of March and transplanted in early April to expose them to high temperature stress during vegetative as well as flowering stages. All the thirty three lines showed large diversity in their flowering duration starting from mid June to early August. Maximum day temperature during flowering ranged from 32 to 44°C, which was 10°C higher than the optimum temperature for anthesis. Some of the NERICA lines exhibited spikelet fertility higher than that of the check (N 22). NERICA L-44 was identified as the most heat tolerant genotype based on survival percentage, spikelet fertility (85%), grain yield and 1000 grain weight. Other rice lines like Nerica-7, Nerica L-23, 29, IR 78937-B-20-B-B-1, IRGC- 46459 also showed high spikelet fertility under high temperature but their grain yields were lower than that of check and L44.

Evaluation of key rice germplasm for tolerance to submergence, drought and salinity (CRRI)

At **CRRI,** Cuttack field phenotyping of rice germplasm was carried out for assessing tolerance to submergence, drought and salinity and tolerant cultivars were identified as follows.

Anaerobic germination	AC34245, AC34280, AC40331-A, AC40346, AC41622-A, AC41647, AC41644-A, AC41644-B, AC39397, AC39418, AC39416-A
Water logging:	AC1125-A, AC1781, AC1996, AC813, AC85, AC39416A
Complete submergence for 20 days better than Swarna-Sub1:	AC38575, AC37887, IC258990, IC258830, AC42087, and AC20431-B
Vegetative stage drought:	IC568024, IC568009, IC568114, IC568060, IC568016, IC568030, IC568083, IC568112 and IC568065

Reproductive stage drought:	CR 143-2-2, IR 55419-04, Mahulata, IR77298-14-1-2-10, IR83614-1001-B-B, CT9993-5-10-1-M, IR72667-16-1-B-B-3, and IR 80461-B-7-1
Seedling stage salinity:	FL478, Korgut, Chettivirippu (AC39389), Chettivirippu (AC39394
Reproductive stage salinity:	Pokkali (AC41485), Chettivirippu (AC39389) and Chettivirippu (AC39394)
Tolerant to both anaerobic germination and salinity:	AC39416(A), Kamini, Ravana, Talmugra, Langalmutha, Paloi, Murisal and Rashpanjor
Tolerant to anaerobic germination, salinity and water logging:	AC39416(A)

The genotypes with greater tolerance compared to the SUB1 possessing cultivars e.g. Swarna-Sub1, IR64-Sub1, SambaMahsuri-Sub1also had SUB1 locus. The genotypes (e.g. AC38575, AC37887, IC258990, IC258830, AC42087, and AC20431(B), which showed more than 80 % survival after 20 days of submergence possessed almost double the quantities of non-structural carbohydrate before submergence compared to SUB1 introgression lines. Survival percentage after 20 days of complete submergence was 12, 30 and 14 % in Swarna-Sub1, IR64-Sub1, SambaMahsuri-Sub1, respectively.

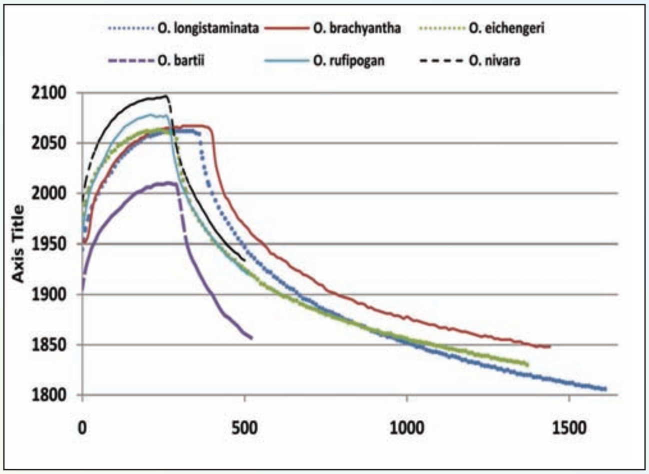
Genetic diversity of germplasm in *saltol* region was done by Principal Component Analysis, which suggested that Chettivirippu (AC39389) and Pokkali (AC41585) were distantly located in respect of other genotypes including FL478. Like UPGMA dendrogram, FL478 was also found closer with Pokkali (AC39416) in 2D plot. Their locational proximity could be explained by the possession of similar introgressed fragment, responsible for salt tolerance. PCA depicted that highly salt tolerant accessions such as Pokkali (AC41585) and Chettivirippu (AC39389) were distantly located in 2D plot in respect of another highly tolerant group comprising FL478 and Pokkali (AC39416). Moderately tolerant lines such as Kamini, Talmugur and Hasawi were found in three distant locations in 2D plot. Kamini and Talmugur were also found distant from this group. This allelic diversity in *saltol* locus in respect of FL478 or Pokkali could be utilized by introducing those identified salt tolerant lines in breeding for developing salt tolerant lines.

Field screening of rice germplasm for heat tolerance and nitrogen use efficiency (DRR)

At **DRR,** Hyderabad more than 800 lines of rice germplasm were grown at two different planting dates (varying by 15 days) in rabi 2011 and kharif 2012 so that the reproductive stage coincides with high temperatures (2-5 ^{0}C). Sensitive lines such as CPAU 30 (IR88633:12-126-B-1) IRHTN 131 (IR 59418-7B-9-2-26), IRHTN 142 (IR 6), IRHTN 137(DOMSOFID), IRHTN 132 (ARC 15210) were identified. Further, 437 single plants selections were made from the above eight hundred genotypes for phenotyping studies.

Based on physiological and morphological traits, IET 20924 fitted well into the critical levels of photo-nyctoperiods for improved grain yields in medium duration group. It was identified and recommended for use as pre-breeding material.

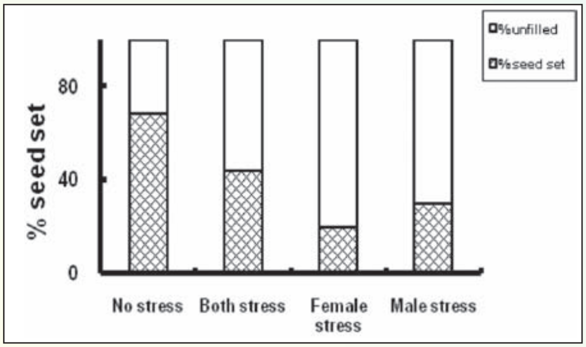
Studies for identifying sources of heat tolerance indicated that some of the wild species *O.nivara*, *O.barthii* and *O.rufipogon* had lower oxygen consumption rates as well as lower stomatal frequency which are useful tolerance related traits. Seven introgressed lines (IL) of KMR3 – *O.rufipogon*, and 4 ILs of Swarna - *O. nivara* withstood germination and growth at seedling stage at high temperature.



Oxygen evolution and consumption curves of wild rice germplasm

Investigations on relative contribution of microgametogenesis (pollen fertility, germination etc.,) and megagametogenesis (stigma receptivity and seed set) for reduction in grain yield revealed that :

- Three to seven °C increase in temperature results in 24% of loss in grain yield.
- Factors related to microgametogensisis contributed to 8% while approximately 16% yield reduction was contributed by megagametogenesis.



Influence of high temperature on % seed set

In view of the above, selections are needed during megagametogenesis for developing climate resilient genotypes with heat tolerance. As an adaptation strategy for heat tolerance, foliar spray of boron @ 0.4 ppm at the anthesis stage could alleviate grain yield losses to an extent of 1.0-9.6% in rice genotypes.

Developing nitrogen use efficient rice genotypes

DRR has conducted field studies on NUE during rabi 2011 and kharif 2012 with 15 genotypes in previously developed low (N0) and high (N100) plots. Agronomic, physiological, internal and N recovery efficiencies, partial factor productivity (PFP) nitrogen harvest index (NHI) were computed for ranking the genotypes.

Ranking of genotypes duration wise based on NUE indices

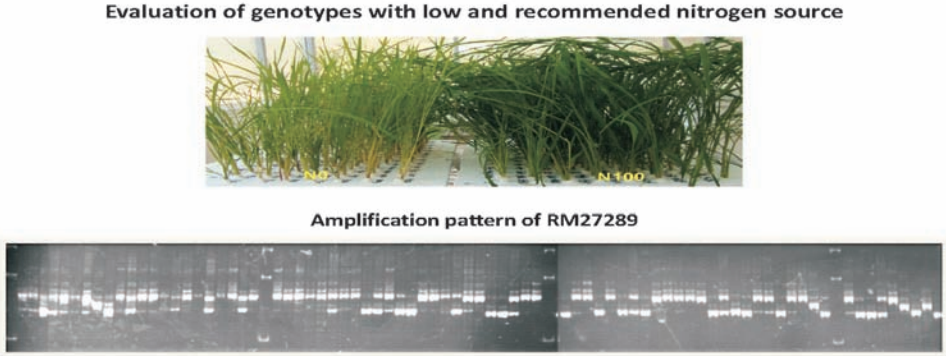
***Kharif* - 2010 & Rabi 2011**		
Early duration	***Medium duration***	**Late duration**
Rasi, MTU 1010 Sampada, DRRH2	**Varadhan**, PA6444, Jaya, Swarna	**BPT 5204,** Mahsuri,

Association mapping for nitrogen use efficiency (NUE)

Out of 800 genotypes screened at seedling stage under low (0 applied N) and recommended (100kg applied N) in hydroponics, a set of 100 genotypes were subjected to association mapping with 50 SSR markers. Four markers found to be associated with seven parameters involved in nitrogen metabolism. Two of the loci (RM28157 and RM206) found to be associated with chlorophyll content (0 applied N) and root weight (100kg applied N). Two loci (RM27289 and RM1375) were associated with fresh and dry root weight in both low and recommended N. Differential expression of

Association mapping for identification of genomic regions associated with NUE

Evaluation of genotypes with low and recommended nitrogen source



Two of the loci (RM28157 and RM206) found to be associated with low N chlorophyll content and recommended N fresh root weight. Two loci (RM27289 and RM1375) were associated with fresh and dry root weight in both low and recommended N.

Phenylalanine Ammonia Lyase through real time quantitative PCR studies in 15 genotypes with differential response to low and recommended N indicated polymorphism for this gene.

Identification of temperature and submergence tolerant rice genotypes for NEH ecosystem (ICAR-NEH)

At **ICAR-NEH,** Umiam, screening rice genotypes for submergence tolerance revealed that among the hill rice genotypes, RCM-9 possess medium degree of tolerance (up to 10 days of full submergence). A total of 600 genotypes were screened at early vegetative stage in Meghalaya under three temperature conditions (40^0C, 45^0C and 50^0C). Seventy eight (78) genotypes recorded 80% germination at 40^0C, and 27 genotypes at 45^0C. After heat treatment of those 27 genotypes at 40^0C and 45^0C, 18 genotypes successfully recovered at 40^0C and 9 at 45^0C. The nine genotypes which recovered are: RCPL 1-136, RCM17, RCPL 1-74, RCPL 1-188, RCPL 1-185, RCPL 1-132, RCPL 1-460, RCPL 1-409 and RCPL 1-186.

Submergence tolerance in five popular rice cultivars viz., RC Maniphou-6 (RCM-5), RC Maniphou-7 (RCM-9), RCM Maniphou-4 (RCM-7), Akutphou and Taothabi of Manipur was analyzed. Full submergence for 15 days resulted in maximum spikelet sterility. Ear bearing tillers emerged under fully submerged condition in RCM-9 only and it was at par with Taothabi. On the whole, RCM-9 possessed better submergence tolerance among the tested lines.

Augmentation and conservation of germplasm from exotic sources, and targeted ecological habitats (NBPGR)

NBPGR, New Delhi undertook four explorations for collection of trait specific germplasm of rice in collaboration with CRRI, DRR and TNAU. This resulted into collection of a total of 205 accessions comprising of 63 accessions of salinity tolerant germplasm from parts of Sunderbans areas in West Bengal, 56 accessions of cold tolerant germplasm from Western Ghats of Kerala and Tamil Nadu, 17 accessions of wild species of rice (*O. rufipogon* and *O. nivara*) from parts of Chhattisgarh and Uttar Pradesh and 59 accessions of drought tolerant germplasm from parts of Odisha.

Developing pyramid genotypes for drought traits, blast and bacterial leaf blight (BLB) resistance in rice (UAS, Bangalore)

At **UAS,** Bangalore combined genomic regions containing segments of chromosomes 1, 2, 7 and 9 for root traits and grain yield under stress and three combined genes for blast and blight were analyzed with linked SSR markers. Trait specific markers, RM 144/ RG 64 linked to *Pi*- 1 resistance gene revealed the presence of 200 bp PCR fragment in the donor and segregating progenies confirming the resistant gene in the pyramid containing the root characters. Different combinations of 300 pyramids with 7 genes for root QTLs and blast and BLB were evaluated in field for stress and in hotspots for disease. SSR markers linked to the traits confirmed the presence of the genes and QTLs. About 40 genotypes were found resistant.

Advanced drought tolerant aerobic rice cultivars were evaluated for different stages of moisture stress with interval of 15-45 days. MAS 868 with 130 days duration was observed to be most water use efficient under stress at tillering stage (15-45 DAS @ 0.6 IW/CPE ratios) and at maximum vegetative stage with an average 80 q/ha. Increased grain yield, straw yield, harvest index and chlorophyll content were recorded for this variety under different duration of stress periods.

Field evaluation of elite aerobic lines, MAS 26 and MAS 868 at tillering stage

Microarray identification of N responsive genes in rice (GGS IPU)

At **GGS IPU,** New Delhi microarray identification of over two thousand genome-wide N-responsive genes was accomplished for the first time in an indica variety of rice, Panvel 1. Over a thousand genes were differentially regulated by nitrate in etiolated leaves and another thousand in green leaves, indicating that there are major differences in nitrate response in etiolated and green plants. Segregating the nitrate responsive genes into light-dependent, etiolation- dependent categories has revealed 222 light-independent nitrate responsive, or presumably “true” nitrate responsive genes. The functional classification of these genes shows that they are involved in key metabolic, binding and cellular processes. Further analysis of these results with the latest tools is under way.

Evaluation of maize genotypes for drought and heat tolerance (CRIDA)

At **CRIDA,** Hyderabad a set of 94 genotypes of maize received from NBPGR, DMR and CYMMIT was assembled and used for multiplication and field phenotyping for drought tolerance during kharif 2011-12. Among these, 50 high yielding genotypes were subsequently evaluated in Rabi 2011 and rabi-summer 2012 as well. Genotypes were screened based on 32 morpho-physiological traits and the inter-relationship between the physiological traits with grain yield has been worked out in the drought stress environment. Seven genotypes (NSJ-176, RJR-068, RJR-049, SNJ-2011-26, RJR-132, Z32-12, NSJ-189) had high yield and low Drought susceptibility index (DSI) and 5 genotypes (NSJ-221, PSRJ-13086, PSRJ-13099, RJR-037, NSJ-155) had high yield and high DSI during kharif 2011.

An analysis of interrelationships among 24 genotypes for 13 traits revealed a significant positive correlation between anthesis silking interval (ASI) and early ground cover, transpiration and relative water content while it was negatively correlated with leaf temperature.

Field phenotyping of maize genotypes for drought tolerance

A technique was standardized for accurate non destructive phenotyping of early ground cover in maize genotypes using digital image analysis.

Early ground coverage in Z40-183
Kharif-2011

Further, 50 yield contributing trait related SSR markers (from *bnlg, umc, phi, nc, dup* groups) chosen to provide uniform maize genome coverage were used for analyzing marker trait relationships among maize genotypes grown in 2 seasons under well watered and water stressed conditions. Regression of genotypic data on phenotypic data identified 10 markers commonly associated for seven traits *viz*., yield, ASI, RWC, leaf temperature, transpiration, canopy temperature and SPAD chlorophyll content. Markers such as bnlg1297 and umc1133 which showed association with more than one parameters seem to be especially effective in further screening for drought tolerance.

Assessment of genetic diversity among 91 maize genotypes using phenotypic and molecular markers indicated that 5 genotypes RJR-247, RJR-159, NSJ-179, RJR-55 and Z101-15 were most diverse suggesting their potential importance in QTL mapping and crop improvement programmes.

To field phenotype maize lines for heat tolerance, staggered sowing of 32 genotypes was undertaken in field at 2 different dates with one month interval during rabi-summer season so as to coincide high temperatures with pollination and grain filling stages. High temperature stress at reproductive stage resulted in even complete drying of tassel without pollen dehiscence, and reduced seed set in some of the genotypes.

Kernel set in maize genotypes under high temperature

Genotypes, HKI-325-17AN; RJR-068; NSJ-285; NSJ221; PSRJ-13086 and PSRJ-13038 had low ASI values while HKI-3-4-8-6ER, Z93-194, Z-40-183; Z59-11; NSJ-189; RJR-163; PSRJ-13099 and PSRJ- 13247 had higher ASI values. The genotypes with high ASI possessed lower activities of the anti-oxidative enzymes, superoxide dismutase, peroxidase and catalase while activity of sucrose synthase, an important sucrose metabolizing enzyme, was observed to be higher.

Identification of drought and high temperature tolerant maize genotypes for NEH ecosystem

At **ICAR-NEH**, 134 Maize genotypes were screened for high temperature tolerance during germination stage in Meghalaya. 5 genotypes exhibited tolerance to high temperature (50^0C). For identifying genotypes tolerant to multiple abiotic stresses, drought screening of the maize genotypes tolerant to high temperature was also undertaken. RCPL 1-132 showed highest relative water content (60.0%) after 27 days of withdrawal of watering. Other two drought tolerant genotypes were RCPL 1-136 (RWC 48.6%) and Deku (RWC 45.1%).

For assessing tolerance of maize to low temperatures in North-Eastern hill region, a total of eleven local cultivars were collected from different hill districts of Manipur, where the minimum temperature ranges between 2.1 to 9.8^0C and maximum temperature between 22.9 to 25.5^0C. Germination percentage was maximum in Chechata (93%) followed by Pusa composite-3 (89%) under field conditions.

Field evaluation of pigeonpea, blackgram and greengram for tolerance to temperature and drought stresses (IIPR)

IIPR, Kanpur conducted field evaluation of pigeonpea, blackgram and greengram for tolerance to high temperature and drought at different locations, Kanpur, Ludhiana, Durgapura, Gulbarga, Khargaone, Badnapur and Vamban. The following promising genotypes were identified.

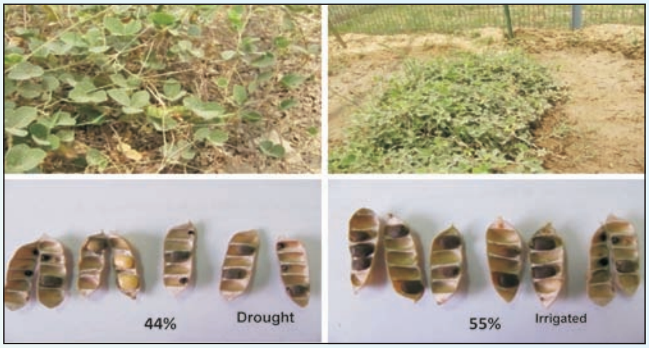
Heat tolerance

Urdbean (blackgram) :	PDU-3, IPU 94-1, IC 106088, STY- 2868, IPU 99-18, IPU 99-16, IPU 90-32, UH 99-144, UH 32-3 and PLU 557
Mungbean (greengram) :	IPM 02-16, IPM 9901-10, IPM 409-4, IPM 02-3, PDM 139, IPM 02-1, IPM 2-14, IPM 9-43-K, PDM 288, IPM 5-3-21, ML 1257, IPM 205-7, Sona Yellow, IPM 302-2

Drought tolerance

Pigeonpea :	AL1794, AL1817, AL1855 and AL1794, BSMR736, BPG51-2, Gulyal Local, WRP-1, JKM-7, JKM-189, PT221, TTB7 and ICP13673.

Field phenotyping of pigeonpea



Pod set in Cajanus scarabaeoides wild accession ICP 15671 at 40^{0}C

A mini core set of pigeonpea comprising 150 germplasm from ICRISAT were evaluated in a multi-locational network mode. The experiment enabled to identify two drought tolerant lines ICP7076 and ICP11230 which showed less than 10% yield reduction. Also, a promising pigeonpea wild accession *Cajanus scarabaeoides* ICP 15761 has been identified with tolerance to both drought and heat which is being utilized as a donor in crossing programme. This line could set pods at 40^{0}C even under low soil moisture condition. The pod set at 40^{o}C was 44% in ICP 15671 under water deficit conditions whereas it had a pod set of 55% at the same temperature but when grown under irrigated conditions.

In efforts on phenotyping pigeonpea based on osmotic adjustment (1.0-1.6 MPa), membrane stability & chlorophyll flurescence imaging, genotypes identified to be drought tolerant are: RVK-284, GRG 2009-3, ICP 13673, Pusa 2001VKS11/24-1, VKS11/24-2, Bahar, MAL-13, TTB-7, JKM-7.

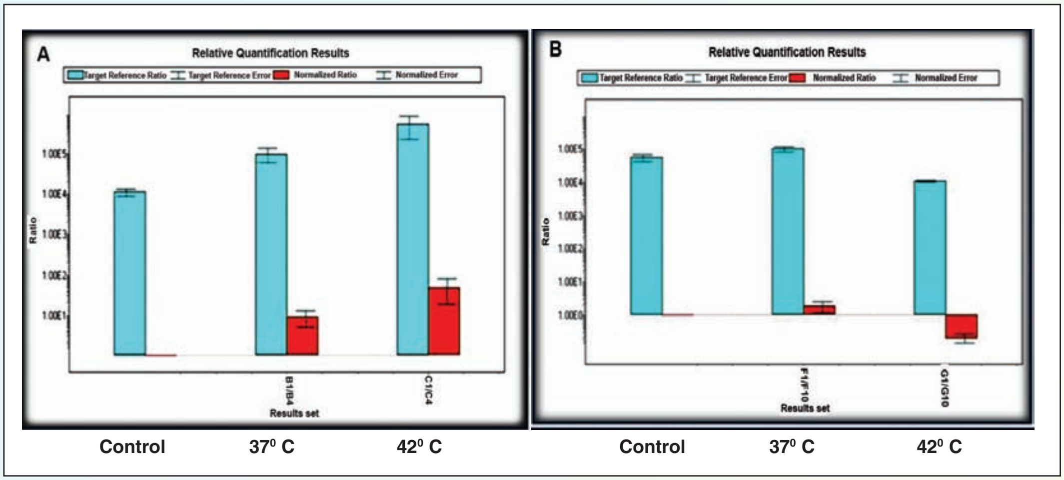
Effect of low temperature on pigeonpea apical tips

Pigeonpea is also highly sensitive to low temperature < 5^{o}C which affects adversely the apical meristem, pollen germination, and anthesis and pod formation. Forced drying and necrosis of apical meristem, rolling of apical tender leaves are the characteristics symptoms identified on the basis the cold tolerant and sensitive lines being screened.

Prospecting genes for tolerance to climatic stresses from tolerant plant and microbial resources

Subtractive cDNA library from wheat for thermo tolerant genes (NRCPB)

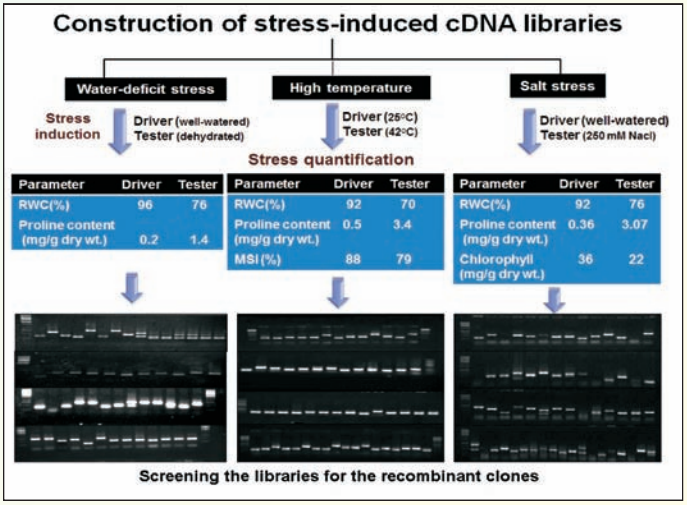
At **NRCPB**, efforts to identify thermo-tolerant genes in wheat were focussed on Raj3765, a tolerant and HD2967, a susceptible variety. Heat Stress of 37°C and 42°C was imposed at different developmental stages (seedling, tillering, stem elongation, anthesis and grain filling) for time period of 0.5, 2, 4, 6 h. Total number of 4 SSH libraries were generated and cloned using pGEMT Easy vector. About 5011 positive clones obtained were confirmed by colony PCR. Annotation of the sequencing data revealed presence of 943 good quality ESTs of which 117 were contigs and 474 were singlets. On an average 12.96% genes were associated with stress in all the four stages of wheat targetted. Heat responsive SSH library constructed in wheat cultivar Raj 3765 showed differential expression of heat stress related genes (hsp20, DnaJ, GPX) which was confirmed by qRT PCR analysis.



Real Time PCR analysis of the unknown contig in tolerant variety Raj3765 (A) and in susceptible variety HD2967 (B)

Construction of subtractive cDNA libraries from pearl millet for water deficit, high temperature and salinity tolerant genes (CRIDA)

Construction of water-deficit, high temperature and salt stress-induced cDNA libraries was attempted at **CRIDA** from pearl millet, a stress tolerant crop with a view to analyse the expression of key stress responsive transcriptomes. Three high quality subtractive cDNA libraries with mild stress intensity viz water-deficit (?RWC 20%), high temperature (42°C), and salt stress-induced (250mM NaCl)



Construction of stress induced cDNA libraries in pearl millet genotype ICMR 356 have been constructed using Suppression Subtractive Hybridization in the genotype, ICMR 356.

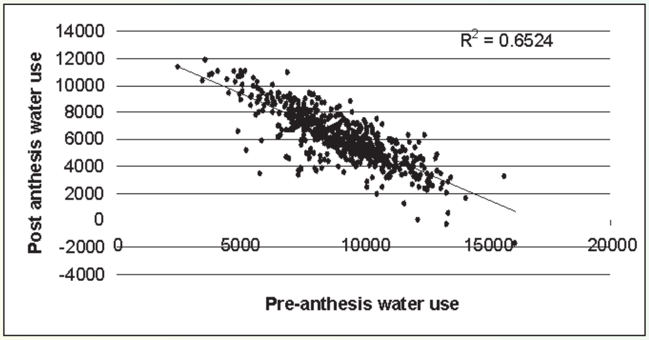
Of the 202 and 158 ESTs analyzed from water-deficit and high temperature stressed libraries, respectively, 77 and 83% were identified to be stress responsive. Uncharacterized genes contributed to 13-15% of the transcriptomes. Among the sequences analysed, 104 and 102 uniESTs were specifically induced in water-deficit and high temperature stresses respectively while 6 genes viz, zinc finger CCCH domain-containing protein 20, Calcium-dependent protein kinase-related kinase, phospholipase D delta, aquaporin PIP1 (PIP1), ADP/ATP carrier and high affinity inorganic phosphate transporter were commonly expressed in both the stresses. Annotation of salt stress induced library clones is underway.

Screening of pearl millet and clusterbean for high temperature and drought tolerance (CAZRI)

At **CAZRI**, Jodhpur pearl millet and clusterbean varieties were evaluated at two different sowing dates with one month interval in kharif 2011. Mean minimum and maximum temperature during the crop season varied from 32.9 to 37.1^{0}C and 20.3 to 27.6^{0}C. Total rainfall received during the crop season was 304.6 & 212.3 mm in 28 and 18 rainy days in case of July and August sown crops, respectively. Pearl millet genotype CZP 2K-9 recorded maximum grain and dry fodder yield and water use efficiency in both the dates of sowing. In clusterbean genotype RGC 1031 and 1066 chlorophyll content and photosynthetic efficiency were higher indicating their tolerance to abiotic stresses.

Screening of promising sorghum genotypes for tolerance to post-flowering drought stress (DSR)

At **DSR,** Hyderabad, genetic variability has been identified among a fairly large set of sorghum genotypes evaluated under multi-locational trials. Genotypes have been grouped into tolerant and susceptible sets, which will be used under lysimeter and root chamber experiments during next season onward. Preliminary studies conducted using lysimeter facility indicated that water extraction in pre-anthesis period is negatively correlated to the water extracted in the post anthesis period.



Relationship between pre and post-anthesis water use in 50 genotypes of sorghum

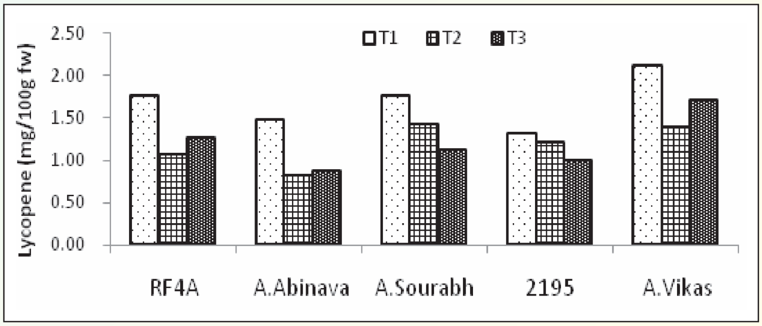
Phenotyping and incorporation of tolerance traits in tomato and banana - high temperature tolerance in tomato

At **IIHR,** a set of 55 genotypes of tomato have been assembled comprising of two varieties (Vybhav and Nandi), seven commercial F_1 hybrids and forty three advanced breeding lines and three accessions of wild species *viz. Solanum peruvianum* (IIHR-1940 and IIHR-1970) and *Solanum habrochaites* LA-1777 (IIHR-2101) and are being grown during summer 2012 to screen for high temperature tolerance under field conditions. Field phenotyping is in progress.

Evaluation of two tomato germplasm lines, RF4A and 2195 and three commercial cultivars, Arka Abhinav, Arka Sourabh and Arka Vikas under elevated temperature was taken up in temperature gradient chamber (TGC) with three temperatures viz. 29.7°C, 30.6°C and 31.2°C during November 2011 to March 2012.

Analysis of growth and development, physiological and biochemical parameters indicated that flowering was hastened by two days at a mean temperature of 31.2°C as compared to 29.7°C. Number of trusses, total flowers, flower drop percentage as well as overall fruit set percentage was found to be more at 31.2°C. Cultivar Arka Vikas had maximum number of trusses and flowers as well as flower drop percertage whereas overall fruit set percentage was found to be more in cv Abhinav at 31.2°C. Genotype 2195, due to its smaller fruit size, had higher number of fruits per tree.

The photosynthesis rate recorded at fruiting stage decreased as the temperature increased from 29.2°C to 31.2°C. Among the genotypes RF4A and Abhinav showed higher photosynthesis rates even at 31.2°C. The decrease in maximal photochemical efficiency of PSII (Fv/Fm) in all genotypes was observed with increase in temperature. The soluble sugar concentration increased in all the genotypes with increase in temperature from 29.7 to 31.2°C. A decrease in total carotenoids and lycopene was observed with increase in temperature.



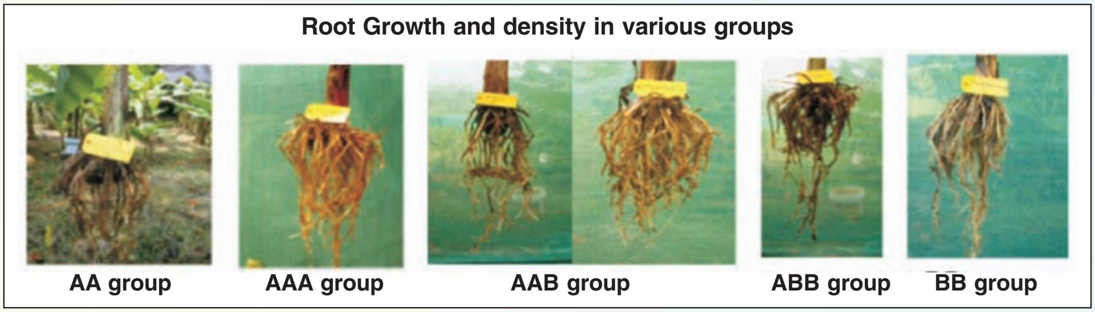
Lycopene content in 6 tomato genotypes grown under different temperatures.
T1 (29.7°C), T2 (30.6°C) and T3 (31.2°C)

Phenotyping of germplasm lines for drought tolerance in tomato

A total of 43 genotypes were evaluated for drought tolerance under field conditions during rabi-2011 at vegetative and flowering stages at **IIHR**. Based on morpho-physiological assessment, genotypes/lines IIHR 2338, IIHR 2274, IIHR 2201, IIHR 2777, IIHR 2336, IIHR 2327,IIHR 2195, Arka Vikas, Arka Ashish, 15 SB, W-1, W-2 were tolerant while the lines IIHR 2626, IIHR 1614, IIHR 2337, IIHR 2335, Arka Ananya, Arka Alok were found to be moderately tolerant. On the other hand IIHR 2265, IIHR 2621, IIHR 2617, IIHR 2615, IIHR 2294, IIHR 2331, Arka Vybhav, Arka Rakshak were susceptible.

Evaluation of banana genotypes for drought and heat tolerance

Thirty six container grown banana accessions including wild types (AA=11, AAA=4, AB=2, AAB=7, ABB=4, BB=8), were screened for tolerance to limited water conditions. Significant variability existed for traits like shoot length, stem girth, shoot weight, number of roots, root girth and number of stomata.



Root growth and density in banana genotypes

Banana *cv* Grand Naine plantlets with 3-4 leaves were subjected to different temperatures and durations such as 40°, 45° and 50°C for 2, 4, 6 and 8 hours along with an ambient control. The plantlets showed maximum survival of 90-100 percent at 40° and 45°C whereas the plantlets exposed to 50°C for 8 hours showed complete mortality. However when the plantlets were exposed to induction temperature from 30°C to 50°C where temperature was gradually raised by 5°C after every 30 minutes up to 50°C and kept for 6 hours at 50°C showed less wilting and 85% recovery.

Studies on mango phenology

IIHR initiated a study to record the phenology of mango in five cultivars, two regular bearing (Totapuri and Banganpalli) and three irregular bearing (Alphonso, Dashehari and Langra). Vegetative growth of the shoots was maximum in cv. Totapuri (66%) followed by cv. Banganpalli (52%). Lowest vegetative shoots were recorded in cvs.

Alphonso and Langra. Since the minimum temperature below 15°C were available by 47th SMW flowering was observed during last week of January and highest number of flowered shoots (84%) was recorded in Dashehari followed by Banganpalli (83%). The regular bearing cultivars Totapuri and Banganpalli showed earliness in flowering. The minimum temperature increased above 15°C during 1st and 2nd week of January and subsequently the temperature was below 15°C up to March second week. In cultivars Alphonso, Dashehari and Langra flowering was delayed by 3-4 weeks and it was observed up to 14th of March. Though fruit set ranged from 8.26 to 16.78% initially among the cultivars, later at 45 days it ranged from 0.15 to 1.55%. Least fruit retention was observed in Alphonso followed by Banganpalli. Maximum retention was observed in Dashehari and was on par with Langra and Totapuri. From the study it was observed that vegetative extension of mature shoots was less in irregular bearers compared to regular bearers. Among the cultivars, Dashehari showed maximum flowered shoots with maximum number of fruits, fruit set and retention.

Vegetative growth, flowering and fruit set of mango cultivars

Cultivar	Vegetative shoots (%)	Flowered shoots (%)	Date of flowering		Duration of flowering (Days)	Panicle length (cm)	Fruit set (%) at 15 days	Fruit retention (%) at 45 days
			Starting	Ending				
Totapuri	66	56	30/12/11	13/2/12	45	11.78	9.32	1.10
Banganapalli	52	83	30/12/11	28/2/12	60	13.56	11.87	0.66
Alphonso	10	27	28/1/12	14/3/12	45	8.53	8.26	0.15
Dashehari	24	84	28/1/12	14/3/12	45	7.80	16.78	1.55
Langra	10	50	28/1/12	14/3/12	45	10.58	12.19	1.06
F-Test	*	**	-	-	-	*	**	**
S.Em±	13.81	7.52	-	-	-	1.15	1.47	0.20
C.D. @ 5%	41.45	22.58	-	-	-	3.46	4.41	0.62

***Significant @ 5%   **Significant @ 1%**

Evaluation of ber in arid regions (CAZRI)

At **CAZRI**, out of 13 varieties of ber (*Zyzyphus*) tested, **CAZRI** Gola, Gola and Tikadi were the most adapted. In Gola variety, pruning after second week of June resulted in significant increase in fruit set and decreased fruit drop which ultimately resulted in higher fruit yield.

Flowering, fruit set and fruit retention of Nagpur mandarin orchards in response to water deficit stress (NRCC)

NRCC, Nagpur conducted experiments on the effect of temperature RH and water deficit on mandarin crop at crucial reproductive stage in five different mandarin orchards selected in Nagpur and Kalmeshwar tehsils. The intensity of flowering differed significantly among the orchards and the maximum number of flowers per meter shoot length was observed in the orchard which received maximum stress of 38 days followed by the orchard which received 37 days of stress. Fruit set ranged between 27.83-37.89% which was recorded in February when the maximum temperature averaged 31.22 with a relative humidity of 74.15%. Fruit set was the maximum in orchards which received irrigation in the first week of January as compared to those which received irrigation in third and fourth weeks of January. Final fruit retention was significantly higher in orchards which received early January irrigation.

Final fruit retention also was reflected in terms of number of fruits/tree. The yields in orchards where stress was alleviated by the end of January were higher than the others indicating that it is important to alleviate the water deficit stress earlier in the month of January in central India. Further, the time of alleviating water stress is more crucial than the duration of water deficit.

Flowering, fruit set, fruit retention and fruit yield of Nagpur mandarin orchards in relation to duration of water deficit stress and date of resumption of watering

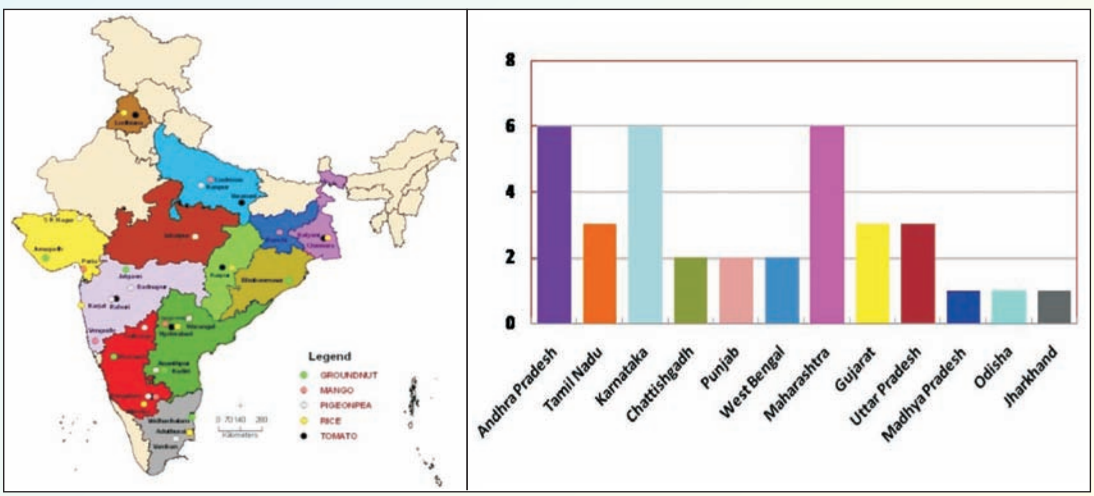
Orchard no.	Stress (Days)	Date of recovery	Flowering intensity (m^{-1} shoot length)	Maximum temperature (T) (^0C) and RH (%), and RH (%), fruit set and fruit retention (FR) (%)								Fruit yield	
				Feb.		Mar.		April		May		No. of fruits/	t/ha
				T/RH	Fruit set	T/RH	FR	T/RH	FR	T/RH	FR tree		
1	37	14 Jan.	140.37	31.22/ 74.15	27.83	39.24/ **59.73**	21.49	38.77/ 53.17	15.77	44.28/ **36.48**	11.14	705	22.65
2	34	3 Jan.	118.27		35.39		22.42		16.34		12.64	843	27.55
3	38	24 Jan.	147.33		30.73		16.27		13.22		8.62	461	16.01
4	28	29 Jan.	107.12		34.78		15.41		12.22		9.77	537	18.03
5	27	5 Jan.	114.29		37.89		20.58		14.22		13.28	864	27.88
CD (P=0.05)			17.37		2.87		2.48		1.85		3.52	243	7.34

4.4 Pest and Disease Dynamics, Pollinators and Emergence of new Pests/ Diseases in Crops

Real time pest surveillance in relation to weather

Since climate change can significantly impact the dynamics and incidence of pests and diseases, a detailed study on changes in crop – insect pest/pathogen/beneficial interactions under changing climate scenarios was initiated in a network mode. Thirty six AICRP centers across 12 States representing 11 agro climatic zones (3 -13) and 14 agro ecological regions (R2-12 & R15, 18 &19) were covered for pest surveillance for five target crops *viz.,* rice (7), pigeonpea (10), groundnut (6), tomato (7) and mango (6). Development and implementation of surveillance protocols by evolving standard data formats, guidelines and crop wise manuals for surveillance were prepared and the real time pest surveillance (RTPS) was implemented during 2011-12 across 36 centers by CRIDA, NCIPM, DRR, IIHR and ICAR-RCER.

A web based system consisting of centralized database, offline client data capture, admin panel, and data reporting and analysis was designed and made functional through NCIPM NICRA website http://www.ncipm.org.in/nicra/.



Real Time Pest Surveillance Centres of NICRA

Current season surveillance outputs

Pest scenario of 2011-12 through RTPS brought out severe gall midge damage on late plantings attributable to high rainfall at Nalgonda (AP), reducing gall midge and increasing cut worms and rat menace due to reduced and erratic rainfall at Raipur (CH) and epidemic occurrence of brown plant hopper at Karjat (MH) with increasing temperature and rainfall on ***rice.***

Low rainfall, less rainy days, and prolonged dry spells with low humidity and moisture conditions were responsible for less pest incidence at Badnapur (Maharashtra). Higher severity of green leaf hoppers and pod bugs due to long dry spells *vis a vis* early cessation of monsoon at Gulbarga (KA), rise in pod fly damage due to rainfall during flowering inducing second flush at Warangal (AP) and hither to non-occurring of sterility mosaic disease at Kanpur (UP) and phyllody on rabi crop at Ananthpur (AP) were the key findings in ***pigeonpea***.

In ***groundnut***, locations hit by Thane cyclonic storm completely devoid of biostages of *S. litura* and *A. modicella* (TN), low rainfall with more and long dry spells in September (Sep 3rd – 13th; 22st-31st), October (13th -23rd) and November (5th - 25th)resulting in outbreak of leaf miner at Kadiri (AP), absence of rains leading to non-emergence of *Helicoverpa* and semilooper at Jalgaon (MP), leaf spot and rust diseases favoured by heavy rainfall (963 mm in 45 days during the entire crop period) and high humidity (76% in morning and 43% in evening) at Junagadh (Gujarat) and high temperature and humidity conditions increasing collar rot at Bhubaneshwar (Odhisa) were key observations.

Higher temperature *vis a vis* most severe late blight > early blight >*Septoria* leaf spot with no wilt at Bengaluru (KA), emerging status of bacterial spot, leaf curl, mosaic and spotted wilt among diseases and mealybugs and thrips among insects at Varanasi (UP), delayed transplanting, survival of leaf miner during frosty winter and delayed winter resulting early termination of Kharif crop by a month at Ludhiana (PB), occurrence of *Spiroplasma* and increasing viral diseases at Hyderabad (AP), higher viral and leaf miner incidence at Raipur (CH) and higher August rainfall delaying transplanting with *Spodoptera litura* and *Liriomyza trifolii* assuming pest status at Kalyani (WB) were the pest status on ***tomato***.

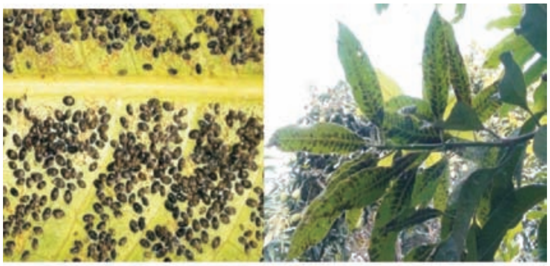
In a detailed survey coordinated by **ICAR RCER, Ranchi** across all AICRP centers of Mango, the driving weather factors for incidence of major pests and diseases were documented.

In Konkan region, occurrence of mango hopper, *Idioscopus neveosparsus* was extended till March. Incidence of inflorescence midge, *Eriosomia indica* was found severe from October to December. The incidence of stem borer, *Batocera rufomaculata* was observed increasing in Vengurle Taluka of Sindhudurg District. A new disease called branch dyeing was found increasing in entire Konkan region during monsoon and post monsoon period. In 13 th agro-climatic zone of Western Gujarat, besides the major pests like hopper, thrips, fruit fly, shoot borer, powdery mildew and anthracnose, emergence of new pests like snails, bacterial fruit rot of mango have been recorded during the year.

In 5th agro-climatic zone, infestation of mango mealy bug (*D. mangiferae*) commenced when temperature under canopy was recorded 16.7°C and relative humidity was 69.9 %. First emergence of mango hopper *(I. clypealis)* started when temperature under canopy was 25.8°C and relative humidity by 46.0 %. The first appearance of powdery mildew was observed on 03.02.2012 on mango panicles *cv.* Dashehari with 23.8°C temperature and 37.8 % relative humidity. In South Karantaka, due to unusual cold temperature (minimum), the occurrence of *I. nagpurensis* was more compared to *I. nitidulus*. The increased infestation of leaf miner and leaf weevil was mainly due to increased minimum temperature. In northern Telangana region of Andhra Pradesh, mango leaf hopper, leaf webber, thrips, scales and leaf minors were recorded as major pests and powdery mildew, sooty mould, anthracnose, bacterial leaf blight, malformation were recorded as minor pests. In Jharkhand, incidence of mango hopper and powdery mildew was found to be severe during the year 2011-12 which may be attributed to early increase in temperature in January.

Record of a new pest on mango

Survey during May 2011 led to the recoridng of hither to unreported blackfly *Aleurocanthus terminaliae* Dubey & Sundararaj (Aleyrodidae: Hemiptera) in the mango orchards of Etah and J.P. Nagar districts of Uttar Pradesh (registration no. 951-960/11) and in Delhi on mango in large numbers. The weather pattern of these locations are being anlayzed.



Colonies of *A. terminaliae* Infestation on branches

Meta analysis of impact of elevated CO_2 on insect pests

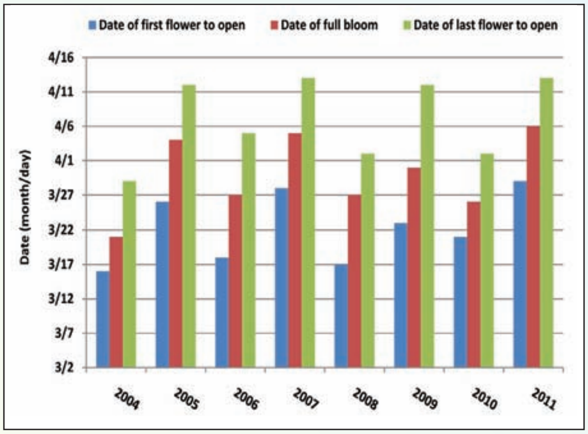
At **CRIDA** attempts were made to quantify the impact of elevated carbon dioxide (eCO_2) on incidence of insect pests through statistical synthesis of published results using 'meta analysis'. Integration of findings of independent studies by calculating the magnitude of treatment effects i.e., "effect size" is the primary step of meta-analysis. Data for the meta analysis were gathered from 88 published articles in selected journals (28) for comparing the growth and development of insect herbivores under eCO_2 conditions and compared with ambient CO_2 condition. The mean effect sizes for various insect parameters varied significantly. Among the insect primary parameters consumption (2.94) and duration of insect species (0.751) were found to be significantly positive under eCO_2 and other parameters like weight (-0.46) and population abundance (-0.05) of species were negative. Meta analysis of biochemical constituents of host plants indicated that the effect sizes were found to be negative (Nitrogen) and positive (Carbon and C: N ratio) indicating a significant variation of constituents under eCO_2 condition than ambient CO_2.

At **CRIDA,** studies were conducted to quantify the effect of rainfall events of 40 mm or more on *Spodoptera litura* moth emergence. Rainfall plays an important role in annual and seasonal population fluctuations of the polyphagous pest, *S. litura.* Rainfall events of 40 mm or more coinciding with 2 days prior to moth emergence was tested against the polyphagous insect pest, *S. litura* (Fabricius) using rainfall simulator. Moth emergence was highest (87%) in the absence of rainfall events while it gradually decreased to 63.4, 57.2 and 45.3% with rainfall events of 40, 60 and 80 mm, respectively, indicating the adverse role of high intensity rainfall events on moth emergence and subsequent population build-up which explains why mean populations of *Spodoptera* fluctuate from season to season experiencing variability in rainfall amount and distribution.

At **DRR,** Brown Plant Hopper (BPH) was collected across India and the populations are now in 6th to 14th generation. Preliminary studies on biology of BPH under different stress situations like crowding resulted in higher proportion of adults developing larger wings (macropterous), especially in west Godavari populations as compared to DRR greenhouse population. BPH populations also differed in their virulence levels against resistant varieties like MTU1010, IR64 and Ptb33 in honeydew and nymphal survival tests. Existence of wide genetic base of the collected BPH populations was confirmed.

Impact on pollinators (UAS, IIHR)

Climate change has a significant impact on pollinators particularly in fruit and vegetable crops. A detailed study was taken up covering apple, mango, water melon, mustard and coffee at different locations across the country by **UAS, TNAU, YSPUH&F** and **GBPUA&T**. The salient findings are given here under :



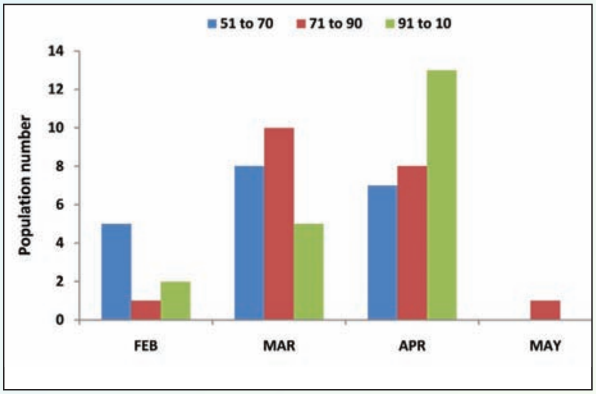
Delayed onset of flowering in apple (var.Vance Delicious) in Kullu, HP

(i) Due to increase in temperature in apple growing regions of Himachal Pradesh there was shift towards flower opening by about 10 days. Its impact on pollinator populations and pollination success are under study;

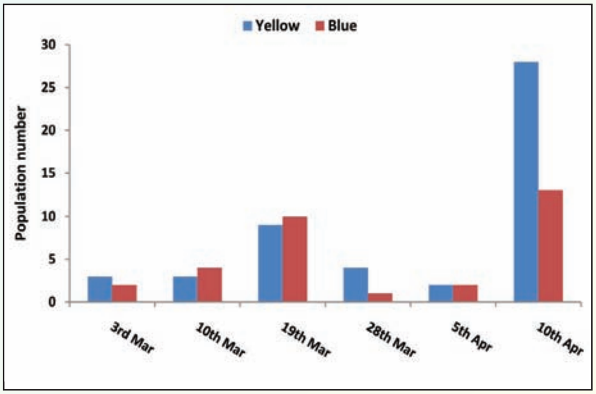
(ii) Surveys were conducted in mango orchards in the Konkan region of Maharashtra, Chittoor district of Andhra Pradesh and Lucknow (UP) for documenting pollinator density and diversity. In the Konkan region, *Trigona iridipennis* was the most dominant forager (2-4/ 10 panicle) followed by *Apis florea* (0.5-1.0). In Chittoor

District, *Apis florea* and *A. cerana* followed by *Trigona* and calliphorid, *Chrysomya megacephala* were major species found foraging on mango. However the density was very low (<0.25/10 panicle) compared to standard undisturbed orchard at IIHR. In Lucknow, *Apis dorsata* was found to actively forage on mango. Dipteran diversity was also high (1.6/10 panicles) in the region,

(iii) Population dynamics of *A. florea* and three dipterans *viz., Eristalinus arvorum* (Family: Syrphidae), *Chrysomya megacephala* and *Stomorhina discolour* (Family: Caliphoridae) was studied in relation to climatic factors during mango blossom period from November to March. Pollinator density was positively influenced by the flowering. The population of *A. florea*, was in positive correlation with maximum temperature up to 28^0C but declined with further increase in temperature. However dipteran pollinators were not significantly affected by increase in temperature beyond 28^0C. It shows that they are more adaptable to elevated temperatures compared to *Apis* spp.



Delayed blossom showers for coffee



Monitoring bees in coffee & cardamom

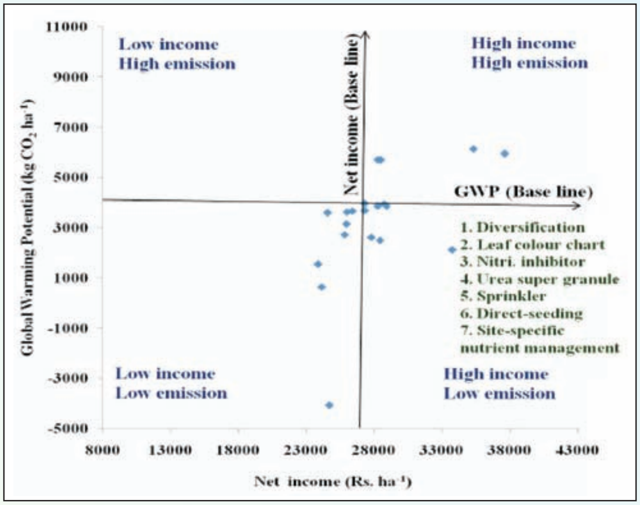
(iv) Attempts were made to collect historical information about blossom showers and flowering in coffee for the last 60 years. A preliminary analysis has shown that in the last two decades there has been a significant delay in blossom showers with high frequency of showers (65%) being received in the month of April.

During the current year (2011-12) also there has been a delay in blossom showers and coffee flowered only on the 10^{th} of April. However, several farmers resort to irrigating their farms using sprinklers, which make Robusta coffee to flower earlier. The blossom showers over the past 60 years have shifted by almost a month in coffee. Historical meteorological data, more particularly on minimum and maximum temperatures and rainfall have been collected from all the centres.

4.5 Adaptation and Mitigation through Soil, Water, Nutrient and Energy use Efficiency

Efficient management of natural resources such as soil, water, nutrient etc are key to climate change adaptation. Several institutes of ICAR, SAUs, IIT, ICRISAT participated in this multi disciplinary research on adaptation and mitigation through efficient soil, water, nutrient and energy management.

Assessing low carbon technologies for IGP



Potential and cost for various mitigation technologies in rice in the upper Indo-Gangetic Plains.

At IARI, New Delhi, twenty technologies were analyzed for their potential to mitigate GHGs emission in rice in the upper and lower Indo-Gangetic Plains (IGP). In the upper-IGP, seven technologies, viz. sprinkler irrigation, direct seeded rice, use of nitrification inhibitor, use of urea super granules, leaf colour chart, site-specific nutrient management (SSNM) and crop diversification have showed potential to reduce Global Warming Potential (GWP) without any additional cost. In the lower-IGP, use of nitrification inhibitor, use of leaf colour chart, SSNM and crop diversification showed reduction in GWP with no additional cost. Among the ten technologies assessed in wheat, zero tillage, INM, use of nitrification inhibitor and SSNM proved to be effective in terms of GWP reduction and profit enhancement in the upper-IGP. In the lower-IGP, zero tillage, INM, nitrification inhibitor and SSNM technologies were GHG-friendly and economically feasible. The study showed that there is a potential to promote low carbon technologies in agriculture, but appropriate policy incentives need to be built to encourage farmers to adopt such technologies.

GHG emissions in rice-wheat system

At IARI, field studies indicated that direct seeded rice (DSR) reduced methane emission compared to transplanted rice. Nitrous oxide emission increased marginally under DSR. Zero-till wheat reduced emission of CO_2 but increased emission of nitrous oxide. The global warming potential (GWP) significantly reduced due to adoption of DSR + ZTW in comparison to conventionally tilled wheat. Cumulative GWP in the rice–wheat system (from crop) ranged from 1141 to 1935 kg CO_2 eq. ha^{-1} in different treatments. Direct-seeded rice followed by zero-till wheat reduced GWP by 41% as compared to conventional transplanted rice followed by tilled wheat.

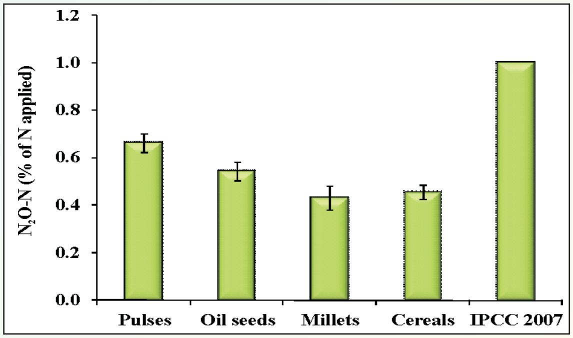
Effect of tillage on global warming potential (GWP) of soil in rice-wheat system at IARI.

Treatments in rice-wheat	GWP (kg CO_2 eq. ha^{-1})
TPR- CTW	1935a
TPR - ZTW	1799b
DSR - ZTW	1141d
DSR- ZTW+ RR	1167d
DSR + GM - ZTW	1295c
DSR +GM – ZTW+RR	1304c

TPR- Transplanted puddle rice, DSR – direct seeded rice, CTW- conventionally tilled wheat, ZTW- Zero tilled wheat, RR- rice residue, GM – green manure

Emission coefficients for other crops

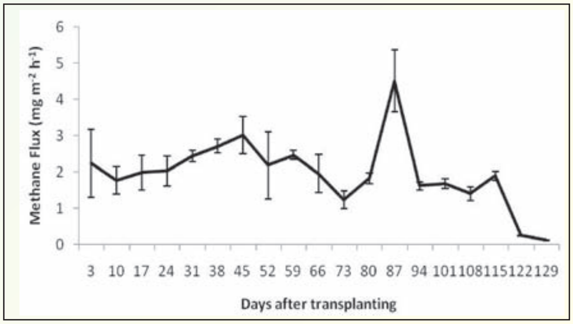
Different crops were evaluated for nitrous oxide emissions (N_2O). Pulse crops (green gram, pigeon pea, chickpea) emitted more N_2O followed by oilseeds (soybean, mustard, groundnut), millets (sorghum, pearl millet), and cereals (rice, wheat, maize). These data are useful to develop emission coefficients.



Nitrous oxide emissions from soil under irrigated crops of IGP

CH_4 emissions from flooded rice system

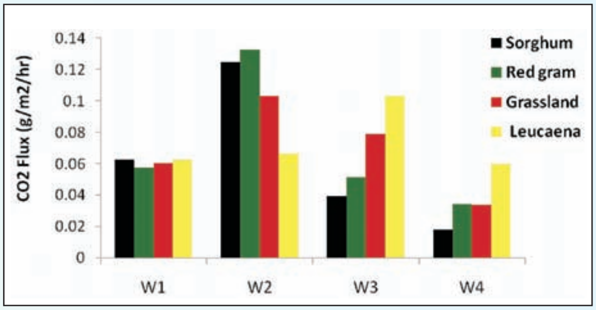
At **CRRI,** methane (CH_4) emission from flooded rice field (cv.Gayatri) were studied for 129 days of cropping season by closed chamber method. The fluxes of methane under submerged condition (*cv. Gayatri*) varied between 0.41-4.51 mg m^{-2} h^{-1} during the period. Initially (at 10, 20 DAT) the fluxes were low in all the treatments but increased significantly with the successive growth of the crop. The highest fluxes were observed at 87 DAT at 4.51 mg m^{-2} h^{-1}. The impact of organic carbon input and methonogenic microbes is being investigated on the methane flux over the season.



Methane emission in transplanted rice during the crop growing season at Cuttack

GHG emissions from rainfed systems

At **CRIDA**, GHG emissions were quantified in rainfed production systems (sorghum, redgram, Cenchrus based grassland, *leuceana* based agroforestry) during the off season from the month of March 2012 onwards at weekly intervals. Among the four systems studied, the CO_2 emissions ranged from 0.06 to 0.12 $g/m^2/hr$. Relatively higher emissions were recorded in redgram, grassland and *leucaena* based systems compared to sorghum. A rainy event increased CO_2 emissions in all these systems (W2). Methane emissions from these systems ranged from 0.02 to 0.1 mg/m^2 /hr, where as the N_2O emissions recorded were up to 8 micro grams/ m^2/hr. This was a preliminary study and year long observations will be made during 2012.



CO_2 Emissions at weekly intervals during March-April 2012 in various rainfed production systems at Hyderabad

N-Use Efficiency and N_2O emissions

At **CRRI,** field experiments were conducted during kharif 2011 on the impact of nutrient management practices in paddy on GHG emissions. Peak N_2O emissions were observed 2-3 days after fertilizer application. Highest emissions (213 $\mu g\ m^{-2}\ hr^{-1}$) were recorded with Swarna sub-1 variety and 120 kg N/ha fertilizer dose at 67 days after transplanting. Depending upon N treatment and variety, total seasonal emissions ranged from 0.78 kg ha^{-1} to 2.5 kg ha^{-1}. Highest yield (averaged varieties) was observed under T_2 followed by T_3 and T_1. Global warming potential (GWP) per unit yield under T_3 was lower than the T_2 in both the varieties.

Yield and Global warming potential per unit yield under different N application regimes

Treatment	Yield (t ha^{-1})			GWP per unit yield	
	Ranjit	Swarna-Sub1	Mean	Ranjit	Swarna-Sub1
T_1	3.3	3.6	3.4	0.082	0.067
T_2	4.9	4.6	4.8	0.137	0.162
T_3	4.0	4.4	4.2	0.123	0.123
Mean	**4.1**	**4.2**	**—-**	**0.114**	**0.117**

T_1 = no nitrogen; T_2 = 120 kg N/ha (60 kg basal, 30 kg at Maximum Tillering, 30 kg at Panicle Initiation; T_3 = LCC based N application schedule (30 kg at 14 DAT, 30 kg at 47 DAT, 30 kg at 67 DAT when LCC reading <4.0)

Seasonal NEE from rice ecosystem

At **CRRI,** the CO_2 concentration in the atmosphere was measured with Eddy covariance towers. The CO_2 concentration over the crop canopy varied from 360 to 385 ìmol mol^{-1} during the season. Maximum CO_2 assimilation or uptake by rice crop was found at 13.30 hrs during the whole cropping season and maximum emission was observed at 4.00 hrs. The season-long integrated NEE value was -414 g C m^{-2}. The amplitude of the daily variation in NEE increased and reached its peak around anthesis and / or heading to flowering stage and, then on, decreased gradually till maturity. Almost over the entire season rice crop behaved as net CO_2 sink except few days during the maturity period. With regard to N_2O-N emissions, the GWP per unit yield (8-18%) was less in LCC based N application as compared to recommended dose of N-application. LCC based N-management greatly helped in saving the amount of N without reduction in yields in variety Swarna-Sub1.

Adaptation and mitigation through CA practices

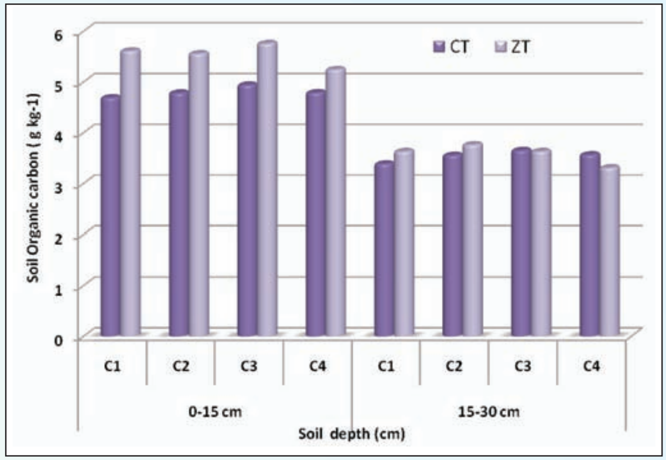
Conservation agricultural (CA) practices have potential to reduce GHG emissions and improve the efficiency of nutrient water and energy and thus contribute to climate change adaptation and mitigation. A number of CA experiments under different production systems have been evaluated for their adaptation and mitigation potential.

At **IARI,** direct-seeded rice combined with *Sesbania* brown manuring or *in situ* mungbean residue incorporation and rice residues resulted in higher water productivity and had lower global warming potential. In wheat, double zero-till *(kharif+rabi)* plots resulted in reduction in weed population compared to double conventional-till *(kharif+rabi)* plots.

At **CRIDA**, CA experiments in maize and pigeonpea based systems were initiated. Horsegram as a cover crop was established successfully following maize during kharif and it was possible to maintain upto 15-20% surface cover by May with the cover cropping**.** In another experiment at Hayatnagar Research Farm, the positive impacts of CA practices in a sorghum based cropping system were studied and it was found that for significant positive impacts on the soil to be measured, it requires 10-12 years of CA adoption.

Maize residue left over in CA system (left) and residue cover measurements in succeeding horse gram crop in rainfed conditions

At **ICAR-Research Complex** for North East Hill Regions, Meghalaya, the effect of tillage and residue management on rice productivity and C-sequestration was studied in a long term experiment initiated in 2006. Among the three tillage (conventional, CT, minimum, MT and zero, ZT) and 6 residue management practices (50% NPK, 100 % NPK (80:60:40 kg/ha), 50% NPK + weed biomass, 50% NPK+ green manure, 50% NPK + rice straw and FYM + weed biomass+ Rock Phosphate), **t**he SOC was maximum under ZT followed by MT at 0-15 cm and 15-30 cm soil depth. The SOC values in FYM + weed biomass+ rock phosphate treatment was higher in 0-15 cm and 15-30 cm. Application of crop/weed biomass along with 50% resulted in substantial improvement of organic carbon in the soil.



Effect of tillage and cropping systems on soil organic carbon (SOC) at different depths

At **IISS,** a field experiment was established on soybean-chickpea-wheat system to monitor the impact of CA practices on yield and soil properties on a long term basis representing Vertisols of central India.

Under arid zone conditions at Jodhpur, clusterbean crop performed better followed by greengram and pearlmillet with zero till in a tillage experiment conducted by **CAZRI**. Among rabi crops, mustard performed better followed by chickpea and wheat.

At **PDFSR,** SOC values were monitored in a field experiment related to tillage (conventional tillage and no tillage) and cropping system (rice-wheat, rice-winter maize, rice-barley, rice-mustard) along with different residue and nutrient management practices to assess the soil carbon sequestration potential. The SOC was significantly higher in ZT (5.55 gkg^{-1}) than CT (4.80 g kg^{-1}) at 0-15 cm. The SOC was not significantly affected by cropping systems.

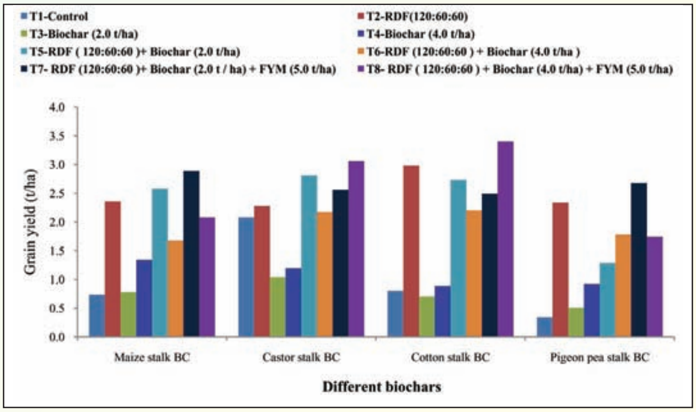
Biochar for adaptation and mitigation

In view of the potential of biochar to sequester carbon and help in adaptation of rainfed crops to drought conditions, laboratory and field experiments were conducted at different institutions on scientific understanding of the properties of biochar produced from Indian crops and its impact on field crops.

At **IARI,** physical and chemical characters of biochar prepared from various crop residues at 400^{o}C were studied. The char prepared from rice residues showed highest CEC and that from pearl millet showed the lowest. The pH of maize (10.7) and pearl millet (10.6) biochar was higher than that in wheat (8.8) and rice (8.6) biochar. The bulk density of rice and wheat biochar was comparatively lower than maize and pearl millet biochar. The water holding capacity of wheat biochar was highest (561%) followed by maize biochar (456%).Total carbon contents was highest in pearl millet biochar (61%) followed by wheat biochar (52%), rice biochar (49%) while maize biochar had lowest carbon content (37%). However, maize biochar was richer in major (N, P, K), secondary (Ca, Mg) and micronutrient (Fe, Mn, Zn and Cu) contents.

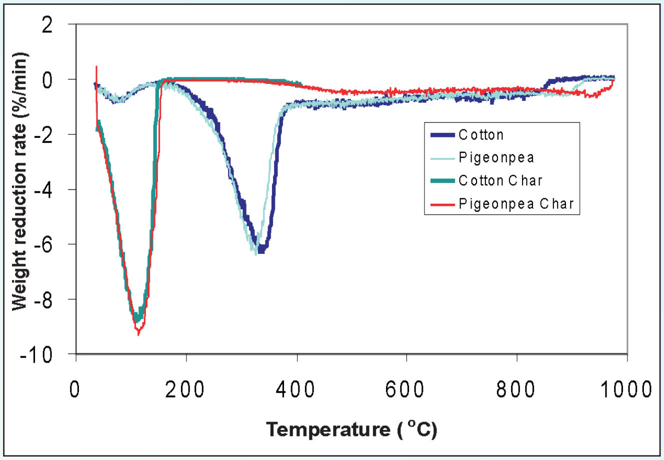
At **ICAR Research Complex** for North East Hill Regions, Umiam, Meghalaya, studies on production and characterization of biochar and its effect on soil properties were carried out. Pine needles, maize stalk, and five weed biomasses were processed for making biochar. Biochar recovery was more in pine needles (47.72%) and less in setaria (23.23%). Through a pot culture experiment, the performance of biochar at different levels on maize crop and soil physical properties is under investigation. A 500 kg per hour industrial biochar kiln procured for mass production of char from extensive biomass is available in north east.

At **CRIDA,** experiments were initiated with four sources of biochar (BC) to study the effect of single application of BC @ 2 and 4 t/ha in combination with inorganic and organics nutrients applied regularly. Biochar produced from maize, castor, cotton and pigeon pea stalks are applied separately one time for whole study period. Maize (DHM 117) was the test crop during the year 2011. During the first year, the crop performed better with application of castor stalk BC at 4 t/ha in combination with RDF (120:60:60) + FYM (5 t/ha) and recorded maximum grain yield increase of 34% over RDF (T_2) followed by 23 % yield increase to application of maize stalk BC at 2 t / ha + RDF (120:60:60) + FYM (5 t/ha) whereas 14 % increase was observed for pigeon pea and cotton stalk BC at T_7 and T_8 level of application compared to RDF (T_2), respectively. In the first year of the study, combination of biochar with inorganic and organic amendments enhanced the crop performance.



Maize (DHM 117) grain yield as influenced by different biochars

At **CIAE,** production of bio-char was done using CIAE charring kiln. Among biochars made, soybean char had the highest total carbon of 94.22% and subsequently highest potential for CO_2 sequestration. Therefore, it was suggested to use this kiln for the purpose of getting maximum carbon in bio-char at farm level. Temperature profile of charring kiln was monitored and maximum temperature reached was upto 380 °C. Thermo gravimetric analysis of raw material and char was performed for pigeon pea and cotton stalks. Agro residues were pyrolysed in an electrically heated vertical cylinder bio-char reactor at different pyrolysis temperatures and the bio-char products obtained were characterized. The crop residues were charred in the reactor at different constant temperatures ranging from 250 to 450 °C at an interval of 50 °C. It took 45 min to reach the temperature of 300 °C and about 52 min to reach 400° C.



Differential thermo gram of raw and char materials.

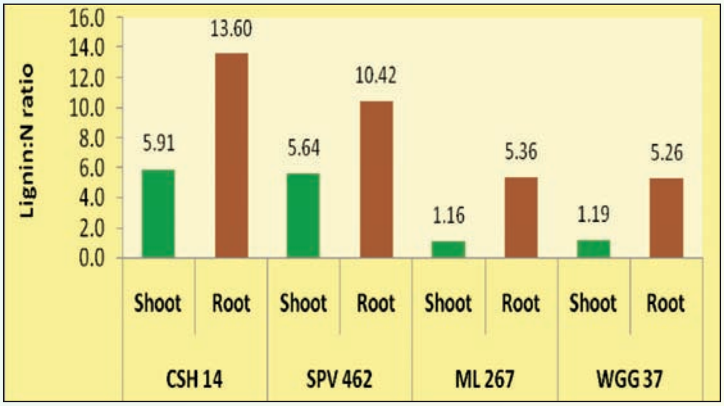
At **TNAU,** Coimbatore, biochar produced from prosopis had alkaline pH (9.5) and depressed the yield of crops. Among various chars, biochar produced from maize straw was superior in enhancing the yields of maize crops.

Carbon Sequestration through Agroforestry (AF)

Trees outside forest sequester significant quantity of carbon which helps in GHG mitigation. To generate national data base on carbon sequestration through AF, **NRCAF,** Jhansi standardized methodology for estimation of area under AF based on remote sensing and GIS. The average C- sequestration potential of agroforestry in four selected districts (Ludhiana, Sultanpur, Vaishali and North Dhinajpur) of Indo-Gangetic plains was estimated at about 18.10 tC ha^{-1}. Based on the agroforestry area in these districts, the average C-sequestration potential in the four districts was estimated at 0.44 m tC. Based on projections, this potential will be 0.89 m tC 25 years from now. Biofuel crops like jatropha and pongamia are being promoted in the country. At **CRIDA,** the above and below ground biomass of *jatropha curcus* was quantified by destructive sampling. The contribution of different components is being worked out to come out with a biomass coefficient.

Agroforestry systems in IGP with carbon sequestration potential

Trials are in progress at **RVSKVV,** Gwalior for identification of best land management and biomass plantation options to stabilize ravines and enhance carbon sequestration in this fragile ecosystem.



Lignin:N ratios of plant parts of sorghum and green gram varieties

At CRIDA, role of roots in soil carbon sequestration was studied in terms of root:shoot ratio and biochemical analysis of different roots. Lignin/N ratio, the best predictor of decomposition rate, was considerably lower for roots, indicating that roots may decompose much more slowly compared to aboveground residues and could play significant role in carbon sequestration.

Nutrient management through foliar spray for drought mitigation

At **CRIDA,** foliar spray of a combination of macro, micro and beneficial elements was tried to mitigate mid season drought impacts on maize crop in red soil. Application of RDF followed by foliar spray of potassium (1.5%), zinc sulphate (0.25%) and selenium (20 g/ha of sodium selenate) at 25 days as a preventive measure was found to be the best treatment to protect the maize crop to withstand late season drought common in Peninsular India.

Adaptation and mitigation through water management

Management of water resources is key for successful adaptation to climate change. Programmes have been developed on harvesting surface water in deficit areas, removal of excess water in flood prone regions and ground water recharge in hard rock areas. The idea is to quantify the potential of these technologies in adaptation of the local cropping systems during droughts and floods.

At **CRIDA,** a number of surface water harvesting models were created at the Gunegal Research Farm during 2011. The runoff harvest was quantified, supplemental irrigation was given to maize, cotton and vegetables during the dry spell in September 2011, the agronomic yield advantage and water productivity were worked out. Methodology is now being developed to quantify the climate resilience potential of surface water harvesting and supplemental irrigation during dry spells.

Water harvesting ponds (3 ha catchment-left) and 4 ha catchment (right) at CRIDA farm helped in life saving irrigation of crop in deficit rainfall year (2011)

At **ICAR-Research Complex for North East Hill Regions, Meghalaya**, crop residue management as a low cost means of in situ moisture conservation has been tried in different cropping systems. Although hill regions recieve high rainfall, the crops experience intermittent moisture stress due to low water holding capacity of the soils and high runoff. Hence, residue retention is a low cost adaptation strategy to the hill farmers.

Toria under zero tillage and *in-situ* maize stock mulching

Frenchbean under zero tillage and *in-situ* maize stock mulching

At **TNAU,** different land levelling and residue application methods have been tried for moisture conservation and crop yield. Across several locations in Tamil Nadu, a comprehensive combination of in situ and ex situ water harvesting systems are being tried to drought proof field crops like cotton and maize in the low rainfall regions.

At **DWM,** Bhubaneshwar the major focus was on innovative means of recharging ground water and judicious integration of surface water to meet the crop requirement during the increasing frequency of dry spells as a result of climate variability. Development of suitable ground water recharge structures and standardization of methodology of multiple uses for enhancing water productivity through IWRM was attempted during the year. Different types of recharge structures were tried in Udaipur district of Rajasthan and Coimbatore in Tamilnadu. Dry stone masonry pond as ground water recharge structure was found to be affective for hard rock areas of Rajasthan. Different types of community based ground water recharge structures are designed which will be tested in Rajasthan. In case of Odisha which receives relatively high rainfall, several villages and farmers have been identified for creating water harvesting ponds and dug wells in order to provide supplemental irrigation to *rabi* crops. At **IIT,** Kharagpur development of a field water balance tool is under progress to determine the precise water harvesting potential of individual fields in relation to the rainfall received. A generalized field water balance model based on volume balance approach for different rainfed agro-ecological zones of Eastern India is being attempted which will be validated through field experiments.

Effect of Dry Stone Masonry Pond on Groundwater Recharging of Open Well

A study carried out by **ICRISAT** at Gulberga in Karnataka, showed that all the components of water balance were reduced with increased temperature because of shortened crop growing period in pigeonpea and higher usage of water per day by the crop. The study further showed that the negative impacts of temperature can not be neutralized by higher rainfall as the predicted high rainfall in this region under climate change scenario might occur mainly due to increased intensity but not more number of rainy days.

Energy use efficiency and mitigation

At **CIAE,** Bhopal, research was initiated on improving the efficiency of farm machinery in order to reduce fuel consumption and direct CO_2 emissions. An extensive pilot survey of 207 farmers was conducted in IGP covering the states of Punjab, Haryana, Uttar Pradesh and Madhya Pradesh on the adoption of conservation agricultural practices by farmers and the energy saving. Wide variation in fuel consumption was found among the CA machinery like zero till drill, turbo happy seeder, direct rice seeder, raised bed planter and roto till drill. There is a need to rationalize the use of these machines in the context of GHG mitigation. An image processing software was successfully used on experimental basis to assess the burning of crop residues in Sehore and Raisen districts of Madhya Pradesh. This is being further validated to be used as a tool to quantify the percentage crop residues burnt in any given district every year so that the efforts to conserve and use the crop residues can be promoted in such areas.

4.6 Impact and Adaptation Strategies in Livestock and Poultry

Many premier research institutes and universities have participated in climate change research on livestock covering cattle, buffalo, sheep, goat, pig and poultry production systems. The major focus was on understanding the impact of climatic factors on production and reproduction behaviour and to identify adaptation strategies. The salient findings are summarized below:

Large ruminants (NDRI)

Physical, biochemical and hormonal profile of different breeds viz., Gir (Navsari), Tharparkar (Chandan), Rathi (Bikaner), Kankrej (Bhuj and Palanpur), Murrah (Hissar), Nili Ravi (Nabha) and Surti (Navsari) were determined with the help of different co-operating centres to identify unique climate resilient traits in different breeds.

Identification and regulation of genes involved in adaptation

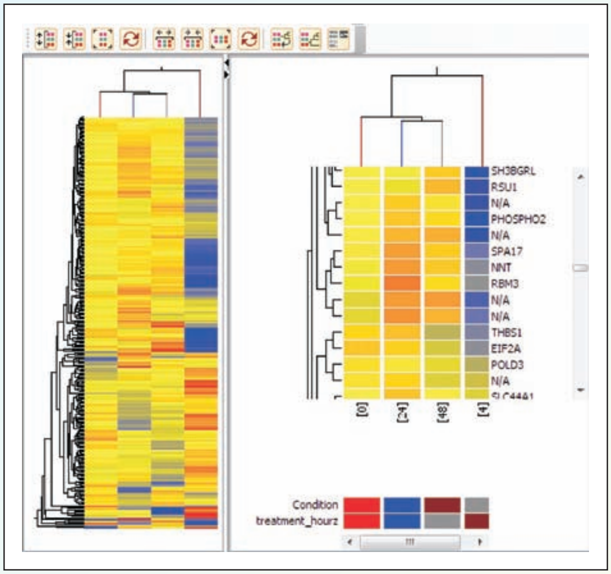
Transcriptome and proteome analysis in relation to heat stress was carried at NDRI, Karnal. Genes encoding proteins spanning a wide range of functions (e.g., protein folding/chaperoning, protein synthesis, metabolism, oxidative phosphorylation, protein transport, signal transduction, transcription regulation) were changed following heat stress.

Observed expression pattern across various time points

Expression pattern	Increase-Increase	Decrease-Decrease	Increase-Decrease	Decrease-Increase
#Upregulated_genes	11	40	37	52
#Downregulated_genes	17	13	19	27

Heat stress and adaptation genes

In Sahiwal cattle, genes for protein synthesis, ribosomal protein S7 (RPS7), was briefly up regulated (up to 3-fold) and induced during recovery from heat stress. Genes for Ubiquitin, UBA6, a protein used as a tag for protein degradation, was induced following heat stress as early as 24 hr after heat treatment and remained up regulated as late as 48 hr into recovery.



Hierarchical cluster analysis of the differentially expressed mRNAs. *Red bars* represent high expression levels, *blue bars* represent low expression levels, and *black bars* indicate normalized median gene expression levels.

Genes for protein transport, SEC61A2 and RAB25, were induced as early as 4 hr after heat stress and remained elevated as late as 48 hr into recovery. Genes for carbohydrate metabolism, PKM2, was induced as early as 4 hr after heat stress and remained elevated as late as 48 hr into recovery. Genes related to lipid metabolism like FAR1, AGPS, HMGCS1 were down regulated in heat stress in comparison to control groups. SC4MOL involved in cholesterol biosynthesis was down regulated following heat stress.

Nutritional Manipulation for Methane reduction : Feeding cotton seed cake and mustard cake based concentrate mixtures significantly reduced methane production in buffaloes. Supplementation of Na_2SO_4 @ 1.0 and 2.0g/kg ration resulted in improved digestibility of most of the nutrients, reduction in methane production and reductive acetogenesis in buffaloes. Fumarate supplementation @2% of dietary DM has also reduced methane production ($P<0.01$).

Water footprints (WPF) for milk production : In Karnal district of Haryana, data on direct and indirect water consumption by bovines, crops grown, feed and fodder consumption and milk yield has been collected from 150 respondents. Data for blue WPF and green WPF were collected and tabulated.

Vulnerability Mapping at District Level : Indicators used for mapping at district level were Adaptive Capacity (Wealth and Income, Technology, Inputs and Infrastructure, Socio Economics), Sensitivity (Soil quality, Groundwater availability, THI Load, No. of years in past 10 years the average rainfall was below normal) and

Exposure (Change in Temperature/Humidity/Rainfall/THI in 2030 or 2050 from base year). All India district level data of 600 districts for each of the vulnerability component has been downloaded, tabulated and checked. Also the generation of maps of individual indicators of the adaptive capacity components was completed.

Assessment of the interrelationship between climate & disease occurrence in livestock and developing database (IVRI)

For collecting disease and climate data, 147 districts covering all 15 agro-climatic zones, 28 states, 7 union territories were shortlisted by stratified random sampling. A questionnaire was developed to collect the disease information from selected district. The proforma include information on climatic zones, district, location, year, month, name of species, breed, number of outbreaks, attach, number of death, vaccination status, etc.

A database application had been created in VS2010 using C# and SQL server 2008 for storing diseases and climate data. In the database, seven data tables were used which included diseases and climate data. The database provided flexibility to the user to get information on climate and disease-zone wise, state-wise, district-wise, disease-wise and species-wise.

Heat stress and adaptability of sheep (CSWRI and CIRG)

At **Central Sheep and Wool Research Institute, Avikanagar**, a study was conducted during peak summer session (May-June) on Malpura ewes to understand the impact of heat stress on growth, water requirement, physiological adaptability and blood biochemical parameters. The results indicate that Malpura ewes adapt to summer season by altering their feeding behavior and physiological responses. This is reflected on the low feed intake, high water intake and significant differences in the physiological responses in heat stressed ewes. Further, the study proved that heat stress during summer season is detrimental to reproductive performance which is evident from the significant ($P < 0.05$) changes in the reproductive hormone levels in these ewes.

Ameliorative measures to combat environmental stress

The ameliorative affect of specific mineral supplementation against negative effects of heat stress and changes in physiological adaptability in Malpura ewes exposed to heat stress has been studied. Supplementation of mineral mixture (Zinc sulphate 164.0 mg, Colbalt sulphate 0.95 mg, Chromium acetate 1.2g, Selenium chloride 0.1mg, and Vitamin E 40.0 mg per kg feed) @ 20gm/Kg body weight has significantly increased productive and reproductive efficiency in Malpura ewes and reduced impact of heat stress.

A study was conducted to assess the effectiveness of indigenously devised bamboodome structure as cold protection device and to observe its effects on adaptive capability of one month old Malpura lambs during winter season. The structure was able to protect the lambs from cold stress which was evident from the significant reduction in level of stress hormone cortisol and significant lowering of metabolic hormones as compared to cold stress exposed lambs.

Ameliorative effect of concentrate mixture supplementation in sheep exposed to different kinds of stress (water, grazing resources and heat) has been studied at CRIDA, Hyderabad. Supplementation improved ($P<0.01$) body weight gain and ADG in grazing sheep under stress.

Heat stress and rumen microbes

Impact of different levels of heat stress on microbiota in rumen fluid was assessed in Nellore and Deccani rams at CRIDA, Hyderabad. Rumen microbiota counts progressively reduced ($P<0.05$) as the exposure to heat stress increases from 0 to 8 hrs. This reveals the importance of proper shade during hot summer by maintaining optimum ruminal microbiota, thereby helping in proper digestion of coarse feed material.

Heat stress and adaptability of goat and biomarkers

At **Central Institute for Research on Goats, Makhdoom, Mathura,** the physiological responses of goats during different seasons as a stress indicator revealed that hot humid season is more stressful to goats than cold dry season under semi intensive system of management. It was also observed that respiration rate and heart rate can be used as stress indicator for identifying contrasting genotypes i.e low stress susceptible genotype, high stress susceptible genotype and intermediate type also.

Growth hormone, T_3 and T_4 levels are significantly different among heat stress tolerant and susceptible goat genotypes hence, GH, T_3 and T_4 biomarkers can be used in identification of climate resilient goat genotypes. Supplementation of plants having anti-stress activity reduced thermal stress and increased productivity in goats.

Piggery

Understanding the unique traits of indigenous pig which make them resilient to climate change has been studied at **ICAR Research Complex** for North Eastern Region, Barapani. Unique traits of disease resistance and adaptation to adverse climatic condition were identified in local pig germplasms.

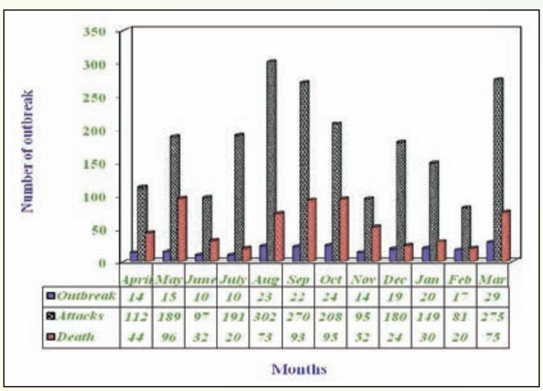

Local Pig of Meghalaya


Local Pig of Sikkim

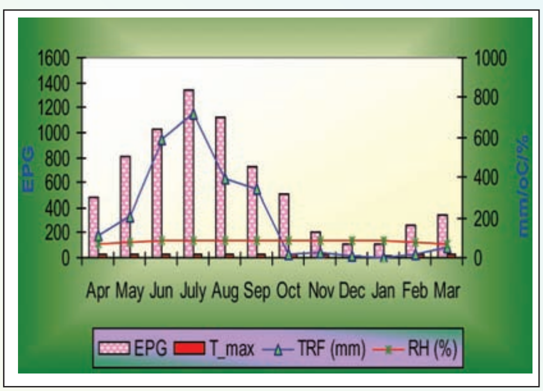

Local Pig of Manipur

Climate change and disease vulnerability

Epidemiological studies on bacterial and viral diseases of poultry were investigated by passive surveillance at **ICAR RC** for NEHR, Barapani. Correlation of diseases incidence with meteorological data revealed that disease incidences were very high during summer and rainy season. Similarly, positive correlation between parasitic disease incidence and high rainfall was found, while the incidence of Ranikhet disease was found higher during post-rainy season.



Month wise incidence of swine fever in Meghalaya during 2006-11



Correlation of meteorological data with intensity of G.I. parasitic infection

Poultry (VCRI and PDP)

Development of climate resilient practices through nutritional, genetic and physiological strategies to enhance tolerance to heat stress in commercial and backyard poultry has been initiated at **Project Directorate on Poultry, Hyderabad and Veterinary College and Research Institute, Namakkal.**

Identification of climatic resilient characteristics

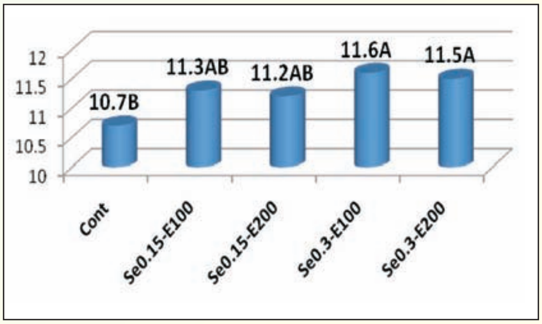
The phenotypic characterization of heat tolerant chickens (Naked neck and Dwarf) was carried out at **PDP,** Hyderabad. A total of 816 and 721 chicks of Naked neck and dwarf were produced in a pedigreed mating involving 40 sires and 160 dams, respectively to evaluate the reproductive and juvenile performance. The fertility was 80 % in Naked neck and 82.0% in dwarf chicken. The hatchability percentage on fertile (FES) and total egg set (TES) was 86.21 and 80.57 in Naked neck and 94.25 and 78.19 in Dwarf, respectively.

An epigenetic study was conducted to assess the effect of exposure to higher temperature during the embryonic stage (during 15th, 16th and 17th days of incubation for a period of 3 hours) and its post natal performance in three breeds namely, PB-2, Naked neck and Dalhem Red. The fertility and hatchability was almost similar between exposed and non exposed groups while analysis of growth upto 6 weeks of age revealed that Naked neck birds performed significantly better than the normal broiler and Dahlem Red birds. The body weight at 6 weeks of age was 1100.94, 1019.32 and 331.26 g in Naked neck, PB-2 and Dahlem red birds, respectively.

Gene expression studies were conducted on heat treated and normal birds from three breeds viz., Naked neck, PB-2 and Dalhem Red to find out the expression of hsp-70 gene in different tissues (liver, heart, spleen, bursa, thigh muscle, breast muscle and blood). The dissociation/melting curve and the amplification plot indicated a specific amplification of the Hsp70 and GAPDH gene. Hsp-70 expression was down regulated in naked neck birds in both the heat and non heat exposed birds, however, in PB-2 and Dalhem Red birds, it was up regulated.

Nutritional management of heat stress

Effect of vitamin E (100 and 200 mg/kg) and organic selenium (0.15 and 0.30 mg/kg) supplementation on performance, fertility, hatchability, immune responses and anti-oxidant responses during tropical winter and summer seasons were carried out. Supplementing combination of higher concentrations of organic Se (0.30 mg/kg) with either combination of vitamin E significantly improved antibody production to ND vaccine and anti-oxidant capacity of breeder animals. However, egg production, feed intake, feed required to produce an egg, average egg weight, hatchability was not affected by dietary supplementation of vitamin E and organic selenium in breeder diet.



Effect of supplementing Vet E and organic Se on ND Titre (Log ^{2}) in breeders

Screening of herbs / spices for anti-oxidant properties by *in-vitro* methods at **VCRI,** Namakkal revealed that *Curcuma longa* (Turmeric) and *Ocimum Sanctum* (Tulasi) are having maximum anti-oxidant activities.

Anti-oxidant activity of semi purified extracts from some herbs/spices

Herbs / spices name	Total phenolic content (GAE/g)	DPPH 50% inhibition (µg)	Total anti-oxidant activity (%)
***Curcuma longa* (in ethanol)**	610.4	16.4	**85.3**
***Ocimum Sanctum* (Tulasi)**	185.4	46.3	**21.8**
***Murraya Koenigii* (Curry leaf)**	122.0	186.9	**6.0**
***Withania Somnifera* (Ashwagandha)**	108.6	223.6	**7.7**
***Allium Sativum* (Garlic)**	**75.0**	**1610.0**	**8.4**

Assessing impact on fodder availability (NIANP)

Increased reliance on crop residues for ruminant livestock production systems is expected in future in India as the grazing lands are dwindling. Further, feed resources are the central components and drivers of production systems, whose efficient use dictates economic animal production. Modelling the impact of climate variation on feed resources availability for livestock has been initiated at **National Institute of Animal Nutrition and Physiology,** Bangalore. The data sets for feed resources and weather parameters for Karnataka state have been generated. Initial experiments revealed that seasonal rainfall has a significant effect on stover production of different crops in Karnataka state. However, the deviation of monthly mean maximum temperature and mean minimum temperature from the long period average did not have significant impact on stover production of different crops.

4.7 Impact and Adaptation Strategies in Fisheries

Many leading research institutes and Universities have participated in climate change research on fisheries covering marine, inland, estuarine and brackish water acquaculture. The major focus was on understanding the impact of climatic factors on spawning behaviour and identify adaptation strategies to higher temperatures and other climatic stresses. The salient findings are summarized below:

Marine Fisheries (CMFRI)

i) At **Central Marine Fisheries Research Institute,** Kochi, data on changes in distribution, catch and spawning behavior of ten major species of marine fish, shrimp and squid were co-related with time-series data on climatic and oceanographic parameters at different latitudinal locations, namely, Veraval, Mumbai, Mangalore Kochi, Tuticorin, Chennai, Visakhapatnam, Paradip and Digha.

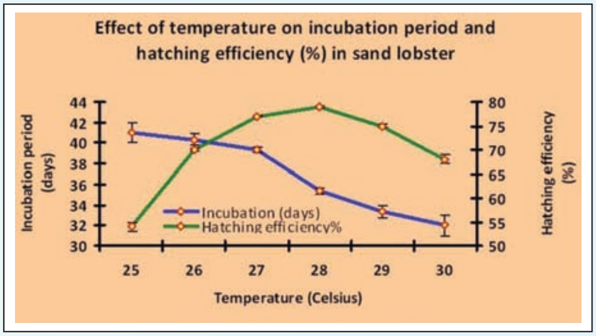
Off Veraval in Gujarat, spawning of the threadfin bream *Nemipterus japonicus* occurs when the SST is > 26°C. There are evidences of shift in spawning towards warmer months. Increase in SST during 1990-2010 has influenced the growth rate, and increased mortality rate and biomass. Off Chennai, a significant shift in spawning season of *N. japonicus* and the oil sardine *Sardinella longiceps* was noticed during 1977 – 2010. The major spawning months were January – March during 1977, which shifted to warmer months of June and July during 2007-2012. Off Visakhapatnam in Andhra Pradesh, however, (i) the peak spawning season of *N. japonicus* has shifted over the last decade from the warmer months of September-October to the relatively cooler months of November - December. (ii) The peak spawning months of Indian mackerel *Rastrelliger kanagurta* has shifted from June-August during 2001-2005 to March and April during 2006-2010. (iii) The length-at-first maturity of the mackerel reduced from 200 mm in 2003 to 185 mm in 2010, which is a significant reduction.

ii) Analysis of long-term data on climatic and oceanographic parameters indicated sea surface temperature (SST) has increased by 1.24°C along Gujarat coast in the last 110 years, by 0.5 °C along Maharashtra coast in 50 years, 0.8 °C along Karnataka coast in 105 years, 0.8 °C along Kerala coast in 100 years, 1.3 °C along Tamil Nadu coast in 110 years, 0.87 °C along Andhra Pradesh coast in 50 years, 0.78 °C along Orissa and West Bengal coasts in 50 years. There were marked spatial and seasonal differences in SST anomaly within each state. Among other parameters, seasonal wind speed has strengthened in several regions, and chlorophyll concentration has increased during southwest monsoon along Kerala coast.

iii) To find out climate resilient species for mariculture, impact of seawater temperature on egg incubation duration, hatching success, and larval survival and growth of ornamental and food fish and shellfish was studied. In general, incubation duration shortened and larval growth rate was faster at higher temperatures. However, hatching success and larval survival was low at higher temperatures.

iv) The incubation period of the sandlobster *T. unimaculatus* eggs was found to decrease from 39-41 days at 25-27°C to 32-35 days at 28-30°C. At lower seawater temperatures (25 - 26°C), hatching efficiency decreases and takes place in two spells (two days, i.e. 24 hr gap between hatching spells). At higher temperatures (29 - 30°C), hatching is faster, and in a single spell. At temperatures >30°C, hatching takes place in a single spell, but naupliosoma are disfigured with crippled legs, not in a capacity to swim, with yolk laden head region; hence settle and die.

v) The commercially important fish, cobia was bred and the hatching of eggs in different seawater temperatures was observed in hatchery. Hatching duration was lowest (9.1 hr) at 34°C, in the hatchery, but the hatching success was very low at higher temperatures. At higher temperatures (32 and 33°C), 25 to 50% of the developing larvae were deformed in the tail region. At 34°C, the eggs either did not hatch, or those hatched out, were deformed.



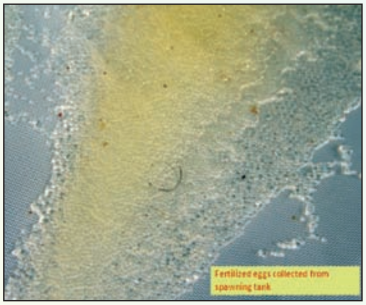
Effect of seawater temperature on incubation period and hatching efficiency (%) in the sand lobster Thenus unimaculatus

Hatching duration and success of cobia eggs

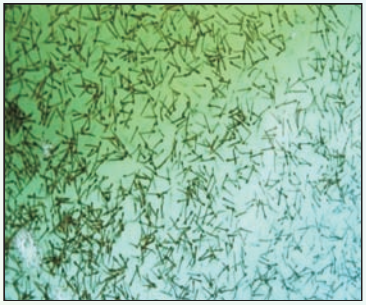
Parameters	29-30.5°C	31°C	32°C	33°C	34°C
Hatching rate (%)	89	90	84	63	13
Hatching duration (h)	11.20	10.30	9.50	9.30	9.10

Cobia breeders

Fertilized eggs



4-day old larvae



Breeders, eggs and larvae of cobia

Successful spawning of commercially important finfish, the cobia *Rachycentron canadum* was obtained at a temperature range of 27.5°C (March) to 30.6°C (July) and those of pompano *Trachinotus blochii* at a temperature range of 26.5°C (November) to 29.0°C (July) in sea cages off Mandapam.

Inland fisheries (CIFRI)

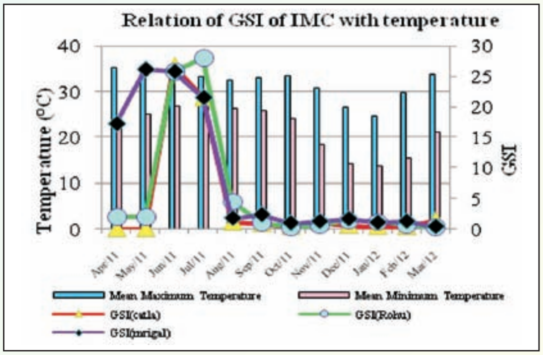
i) At **Central Inland Fisheries Research Institute,** Barrackpore, Gonadal maturity stages of Indian major carps *Labeo rohita*, *Catla catla* and *Cirrhinus mrigala* of six states viz. West Bengal, Assam, Tripura, Andhra Pradesh, Madhya Pradesh and

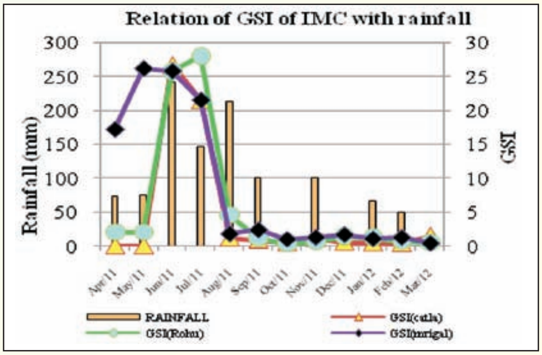
Uttar Pradesh, three coldwater fishes *Schizothorax richardsonii*, *Onchorhynchus mykiss* and *Tor putitora* in Uttarakhand and two estuarine fishes *T. ilisha* and *Liza parsia* in river Hooghly Mathla estuarine system was studied during April 2011-March 2012. Based on the occurrences of gamete (oocyte) maturity stages, GSI (Gonado Somatic Indices) and related parameters, correlation of the gonadal maturity of fish with climate data was carried out.

ii) Fish samples of Indian major carps (*Labeo rohita*, *Catla catla* and *Cirrhinus mrigala*) were collected monthly from different fish farms and carp hatcheries of selected districts of Assam, West Bengal, Odisha, Bihar, Andhra Pradesh, Madhya Pradesh and Uttar Pradesh to gather information on gonadal maturity stages, spawning behavior, gonadal recrudescence period, fecundity, etc. along with secondary information such as ambient temperature & rainfall for the last twenty five years and hatchery performance under different agro-climatic conditions. About fifty numbers of fish samples of each fish species were collected in each month and all relevant parameters recorded.

iii) **Monthly variation in the maturity stages:** Observation on the monthly variation in the maturity stages of the female gonads of the Indian major carps in West Bengal revealed maturity stages VI and VII in higher percentage in the ovaries in *Catla catla* during June-July; *Labeo rohita* during May-August and in *Cirrhinus mrigala* during April-June.

iv) **Relation of GSI with rainfall and temperature:** In *C. mrigala*, higher GSI (17.19-26.13) recorded when rainfall range is 73.0-243.0mm and the mean maximum temperature of 35.6°C in May. In *L. rohita* high GSI value was recorded in June & July when rainfall was 243 and 147mm and the mean maximum temperature range of 34.0°C & 33.4°C and in *Catla catla*, maximum GSI value was obtained in June when rainfall recorded was 243.0mm immediately followed by July when GSI value was registered as 21.5 with the corresponding rainfall as 147.0mm. and the mean maximum temperature range of 34.0°C & 33.4°C.

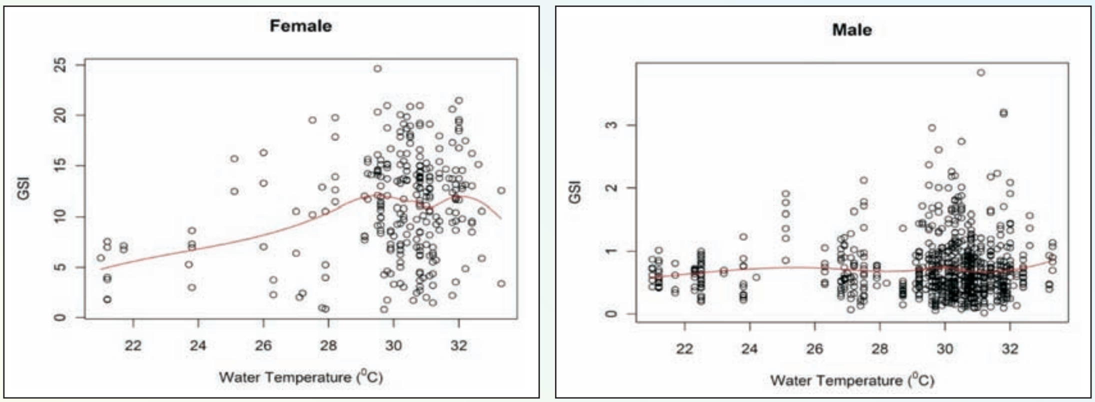




Relation of GSI whit rainfall in West Bengal

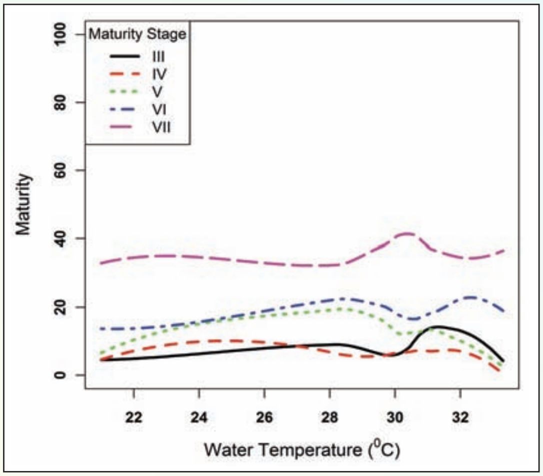
v) **Cold water fisheries :** To assess the distribution and breeding of cold water fishes in relation to climate change, extensive surveys were conducted in different parts of Uttarakhand and Himachal Pradesh to collect the brooders of Indian major carps, mahseer, snow-trout, and rainbow trout and also to assess the status of fish breeding and impacts of climate changes on different breeding aspects.

vi) **Influence of climatic factors on spawning of *T. ilisha* :** The impact of temperature on spawning behavior was investigated through regression analysis of GSI with water temperature. For this study the data for the month of April to December 2011 was used. Loess model was employed to uncover the underlying relationship between the GSI and water temperature.



Relationship between GSI and water temperature

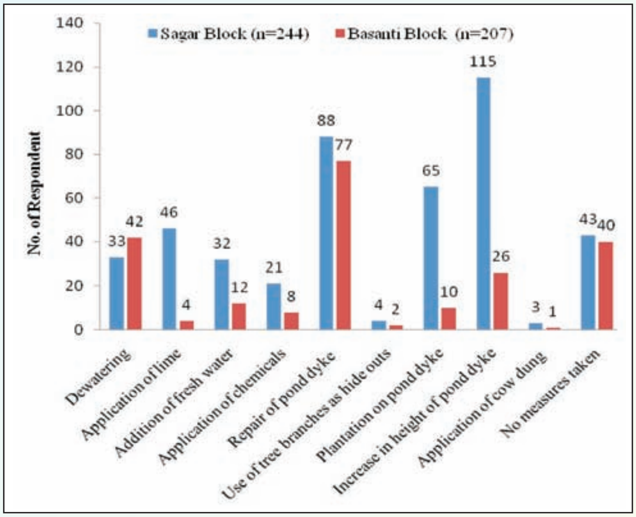
The relationship indicates that GSI attains two peaks at 29°C and 32°C respectively. The same statistical tools were employed to identify patterns of different stages of maturity in relation to water temperature. In this case also it was observed that VIIth stage of maturity attained peak in the water temperature range between 30°C and 31°C. These two findings indicated that temperature range between 29°C and 32°C could be conducive for spawning. Forecast temperature based on time series data could be plugged into a model for predicting GSI for increased or decreased temperature. For example, if the projected temperature in the region lie between 29°C and 32°C the spawning will not be disturbed. Earlier studies report optimal temperature range of 26°C to 30°C for spawning of *T.*



Relationship between maturity stages and water temperature.

ilisha. However the present study indicates favourable spawning temperature range upto 32°C.

Coping with sea water intrusion in sundarbans (WBUAFS)



Coping Measures against Saline Water Inundation

An extensive survey was conducted in Sagar and Basanti blocks of Sundarban on the recent impact of Aila : how it has damaged the fresh water ponds by inundation of saline water and the coping mechanisms followed by farmers. The fish ponds in all the low lying areas of both the islands are vulnerable to coastal flooding and sea water inundation which leads to breach of pond dyke, ingression of saline water into freshwater pond, escape of fish stock from the pond, entry of other (often unwanted) fish species, fish mortality *etc*. Risk analysis revealed that in both Sagar and Basanti blocks, farmers considered breach of pond embankment, mortality of fishes due to saline water ingression as extreme risks; escape of fish stock and diseases as high risk; entry of unwanted species, retardation of growth and deterioration of water quality as medium risks; and damage of pond environment as low risks. The coping mechanisms adopted by the farmers as revealed by the survey are increase in pond dyke height; repair and strengthening of dyke; plantation on dyke; dewatering and addition of fresh/rain water; application of chemicals/ lime/ dung; addition of tree branches in pond for hide outs *etc*.

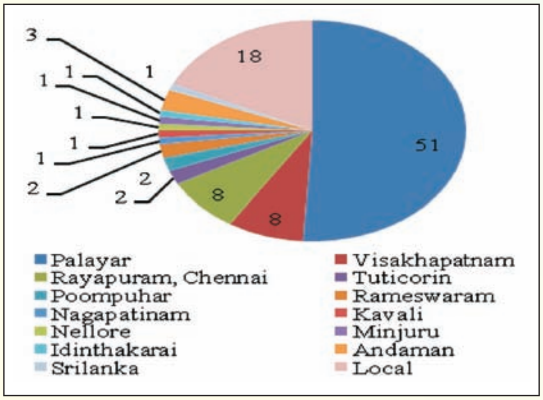
Inland aquaculture (University of Kalyani)

A mesocosm pilot study at **University of Kalyani,** within and outside the polyhouse showed about 124 % increase in chlorophyll and phytocarbon content of microalgae due to 3°C rise in water temperature (32°C; light intensity- 20400 ± 17300 lux) in tanks placed within the polyhouse compared to that of outside the polyhouse (29°C; light intensity -12300 ± 7900 lux). An interesting observation was that the fish Tilapia in closed polyhouse tanks bred and produced offspring, whereas, no such breeding activities were noticed in their counterparts held outside the polyhouse. However, fishes like rohu, bata and paku were not found suitable as their growth was reduced with rise in temperature in the closed polyhouse. As an outcome of the study, the closed polyhouse may be profitably used by the fish farmers for enhancing the hatching rate of common carp spawn in hatcheries during winter as well as for enhancing the growth of carp and other tropical fish during winter and colder region of the country in general.

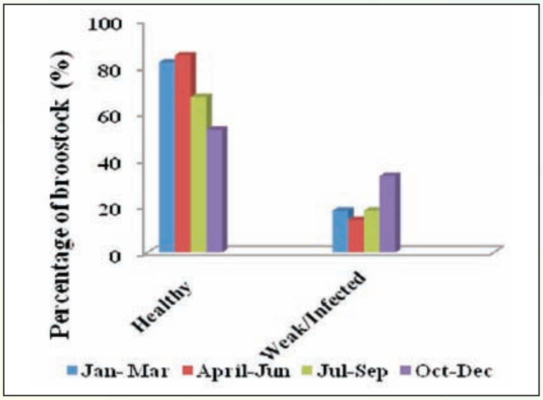
Brackishwater aquaculture (CIBA)

i) **Sea level rise and coastal aquaculture :** By using remote sensing and GIS tools, the vulnerability of coastal aquaculture to sea level rise in Nagapatnam district in Tamil Nadu was studied. One meter sea level rise will inundate 521 sq km total area and aquaculture area of 2786 ha. If the one meter sea level rise is associated with storm surges the inundated area will be 1001 sq kms. The impact on the entire coastal area of the country is under progress.

ii) **Impact on Shrimp hatcheries :** To understand the impact of climate change on shrimp hatcheries a survey of 15 hatcheries in Tamil Nadu revealed Impact of climate change on shrimp hatcheries a **s**urvey of 15 hatcheries in Tamil Nadu indicated that salinity and temperature are the most important factors affected the brood stock availability and performance and around 29-30°C the broodstock performance was maintained. The spawner availability and reproductive performance of *P. monodon* across the seasons in relation to the changing climatic variables over the past 10 years revealed that healthy broodstock with higher achievable captive maturation and effective spawning are function of season and geographic location and changing pattern was observed over the years which is greatly affecting tiger shrimp hatchery and grow-out production. The broodstock source availability for hatcheries revealed that Palayar is the best source and the shift in the geographical location was due to either insufficient quantity or more infection. Diseases such as white spot syndrome virus positive and bacterial load in the broodstock created stress to the animal causing more mortality in second half of the year.

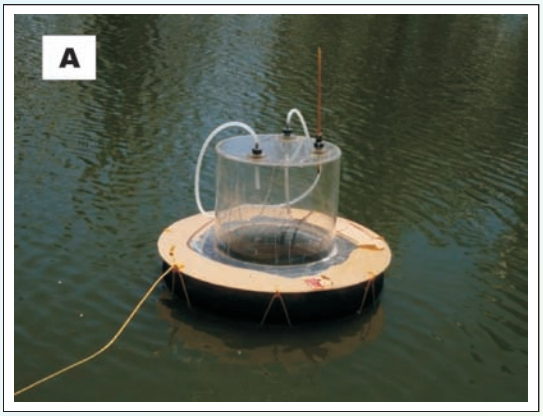


Brood stock source for shrimp hatcheries



Season wise percentage of healthy and infected broodstock

iii) **GHG measurement in aquaculture ponds :** A prototype floating chamber was fabricated to measure GHGs in aquaculture ponds. The chamber, air sampling pump and tedlar bag were connected in series by silicon tubing with a three way valve, to control the circulation of flux and further flow into the tedlar bag. The GHG fluxes (changes in concentration with time) diffusing across the water-air interface was collected at different time intervals in tedlar bags and taken to the laboratory for analysis. The simultaneous analysis and quantification of GHGs (Carbon-di-oxie, methane & nitrous oxide) from the above matrices was done with single injection using multi-valve, ìECD, methanizer - FID combination detector. Pond water and slurry were taken directly into the headspace vials and analysed with the aid of headspace auto sampler in the GHG analyser. CH_4, CO_2 and N_2O concentration in tested ponds ranged from 1.25 – 3.92 ppm, 49 – 294 ppm and 233 – 295 ppb in water and 2.06 – 6.02 ppm, 302 – 2533 ppm and 184 -1012 ppb in slurry, respectively.



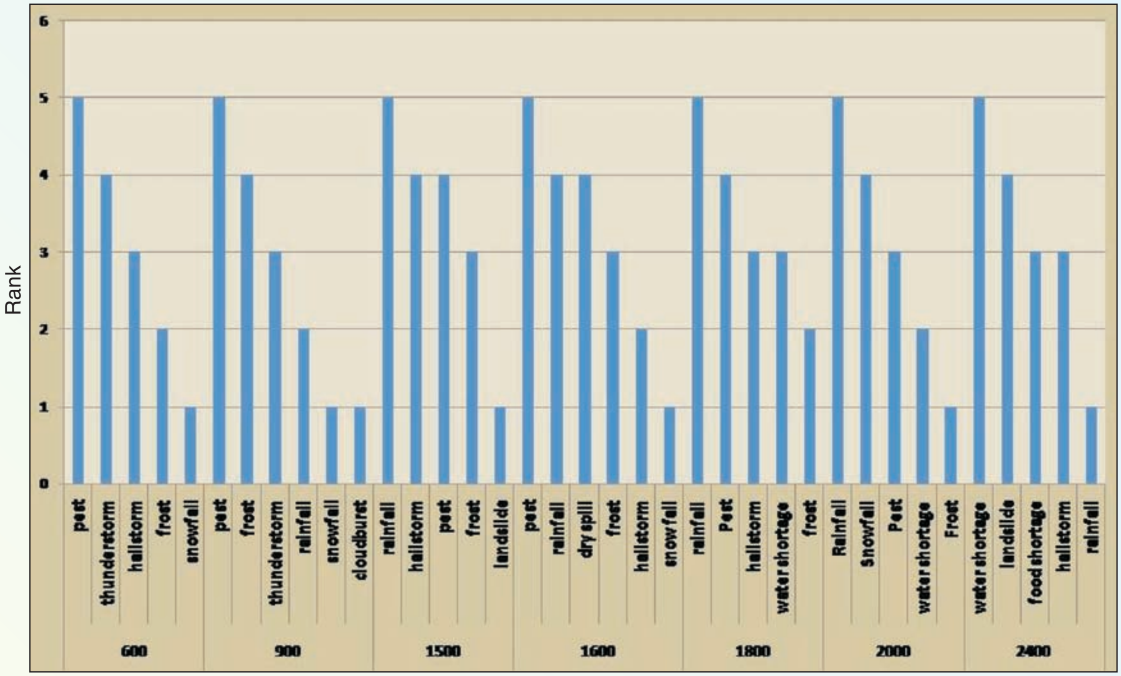
A) GHGs collection chamber for aquaculture

B) Collection of gases from shrimp culture pond

4.8 Socio Economic Impacts and Community Response

It is important to understand the impacts of climate change on the household level and the response of the community particularly in the backward regions, coastal and hill and mountain eco systems. In a study carried out by **USNPSS,** Almora, the major climatic hazards in the north-west Himalayas in Uttarakhand were analysed which indicated that horticulture based activities were more vulnerable in the hills. The farmers generally perceive that in recent years, temperature has risen significantly and rainfall has declined as well as became erratic with an increase in high intensity events. There was a significant difference in the impact and the response of the farmers based on the altitude. Interestingly, farmers perceived that altitude has an impact on the climatic hazards in the hill region.

Hazard Ranking



Altitude (m)

In another study carried out by **NEFORD,** Lucknow in eastern UP, double transplanting of rice (Sanda method) was found to be the most acceptable strategy followed by farmers to mitigate both early drought and flood. The perceptions of farmers with regard to increase in temperature and decrease in rainfall were matching with the long term data of the region.

Dr.M.S.Swaminathan Research Foundation, Chennai, has evaluated varietal choice by farmers in paddy as an adaptation strategy for drought. There was a good match between the drought tolerance characters of rice varieties released by Adudurai research station (Tamil Nadu) with the farmers field score regarding various biometric parameters. This study revealed that adaptation strategies through technology interventions have to consider the opinion of the farmers. The adaptive capacity of Indian agriculture through institutions and policies is being studied through secondary and primary data collected from 40 districts in different agro-ecological regions by a consortium of institutions like **NCAP, NAARM** and **IASRI**. The studies have been just initiated and results are awaited.

5. Technology Demonstration to Cope with Current Climate Variability

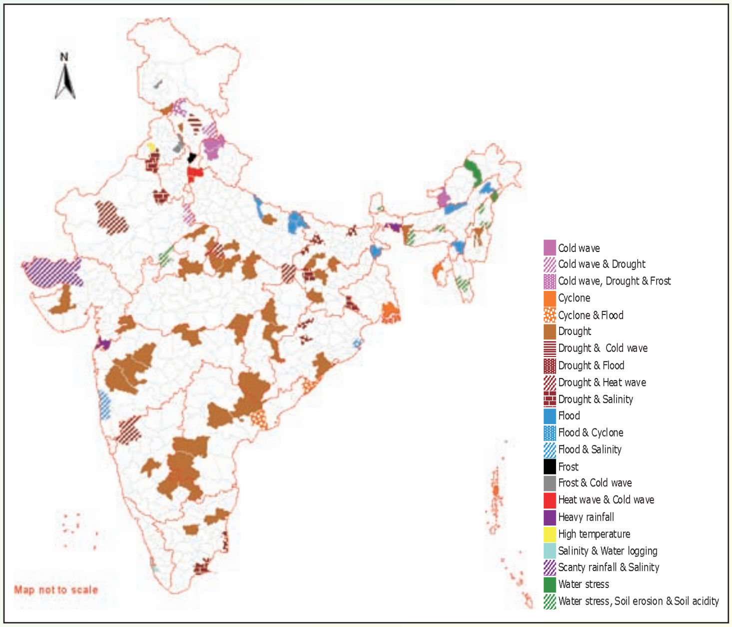
5.1 Background

The technology demonstration component of NICRA deals with demonstrating an integrated package of proven technologies for adaptation of crop and livestock production systems to climate variability. This component is implemented in selected vulnerable districts of the country through location specific interventions by Krishi Vigyan Kendras in a participatory mode. The project is implemented in 130 districts (see map) involving over one lakh farm families across the country. Following is the breakup.

1. KVKs in eight zones -100
2. Co-operating centres of AICRP on Dryland Agriculture - 23
3. Technology Transfer Divisions of Core ICAR Institutes – 7

The selection of districts for implementing Technology Demonstration Component was done by the following criteria:

- Drought proneness based on 30 years rainfall data (Source : IMD)
- Cyclone proneness based on data on frequency as recorded by IMD and in consultation with State Disaster Management Departments.
- Flood proneness based on IMD data and National Disaster Management Authority (NDMA) maps.
- Vulnerability to heat wave and cold wave based on grid data (IMD) on temperatures.
- Actual incidence of floods and droughts as recorded by AICRPAM centers



Besides, areas affected with salinity and severe groundwater crisis were identified by superimposing salinity maps developed by CSSRI with water balance maps of NBSS&LUP. The criteria mentioned above were given a weightage of 75% while the remaining 30% was given to the ability/potential of the KVK in terms of its past performance, staff strength and the rating of the ZPD. Care was taken to see that each state and important agroclimatic region is represented so that all the ZPDs and the Directors of Extension of each SAU gets first hand experience on how to deal with climate variability with the help of available technologies.

Rationale

Agriculture in India is practised for over 5000 years and during this long history, farmers have faced various climate related challenges. During the past five decades, challenges in agriculture are being dealt with application of science and technology. Over the years, a range of technologies suiting to different situations have been developed by the NARS. Though these technologies cannot be termed as climate resilient, they are applied in situations challenged by climate variability. Therefore, the TDC component aims to demonstrate these technologies with climate resilience perspective. The following points outline the rationale for the technology demonstration component under NICRA.

- Availability of improved technologies related to drought and flood tolerance with NARS
- Indigenous practices followed by farmers over time under such situations
- Need for finding immediate solutions to climate related challenges at farm level

The specific objectives of TDC are:

- To enhance the resilience of Indian agriculture (including crops, livestock and fisheries) to climatic variability and climate change through strategic research on adaptation and mitigation
- To demonstrate site specific technology packages on farmers' fields to cope with current climatic variability
- To enhance the capacity of scientists and other stakeholders in climate resilient agricultural research and awareness of impacts

5.2 The Interventions covered under the Component are Broadly Classified as Four Modules:

Module I: Natural resources

This module consists of interventions related to in-situ moisture conservation, water harvesting and recycling for supplemental irrigation, improved drainage in flood prone areas, conservation tillage where appropriate, artificial ground water recharge and water saving irrigation methods.

Module II: Crop production

This module consists of introducing drought/temperature tolerant varieties, advancement of planting dates of rabi crops in areas with terminal heat stress, water saving paddy cultivation methods (SRI, aerobic, direct seeding), frost management in horticulture through fumigation, community nurseries for delayed monsoon, custom hiring centres for timely planting, location specific intercropping systems with high sustainable yield index.

Module III: Livestock and Fisheries

Use of community lands for fodder production during droughts/floods, improved fodder/feed storage methods, preventive vaccination, improved shelters for reducing heat stress in livestock, management of fish ponds/tanks during water scarcity and excess water, etc.

Module IV: Institutional interventions

This module consist of institutional interventions either by strengthening the existing ones or initiating new ones relating to seed bank, fodder bank, commodity groups, custom hiring centre, collective marketing, introduction of weather index based insurance and climate literacy through a village level weather station.

Unique Features of the Project


Small weather station in project village to raise weather literacy

- Baseline for all the project sites established through a systematic benchmark survey
- Emphasis on natural resource management interventions to build the communities' capacity to cope with climate variability through need based investment
- Establishment of a network of automatic weather stations across 100 KVKs as well as 100 small weather stations installed in project villages as part of enhancing weather literacy.
- Establishment of custom hiring centers in each of the 100 project villages for promoting mechanization on small farms.
- Constitution of village climate risk management committees (VCRMC) in each of the 100 project villages – grassroots peoples' institutions to take need based decisions at the village level.

5.3 The Process

A multi-level **participatory approach** was followed for developing and implementing the TDC. The KVK team for each district carried out a detailed exercise on the needs of the village, the climatic vulnerability (drought/floods/heat wave/frost/cyclone) and the available technology options from the concerned Zonal Agricultural Research Stations of the SAUs. After a careful study of the gaps, specific interventions from each of the module were selected and an integrated package from all modules was formulated. Majority farmers are covered with one or more of the interventions in order to demonstrate a discernable effect. The project was launched in each village with wide publicity and by involving all the line departments under the leadership of the district administration. The launch event was used to generate wide spread awareness within the community and across line departments so as to prepare a platform for exploiting synergy through convergence of other government projects.

Project Launch at KVK, Namakkal, Tamil Nadu

5.4 Early Outcomes

The project has made some significant impact in each of the modules. Large number of farm ponds have been dug across the drought prone areas where due to shrinking of LGP the productivity of major crops was declining. This has led to increased moisture availability to cropping activity leading to higher cropping intensity.

Rainwater harvested in pond for drought resilience

VCRMC meeting in progress

Increasing the rainwater harvesting capability along with crop production supporting activities such as introduction of improved cultivars, addressing micro nutrient

deficiency through site specific nutrient management, supplemental irrigation, mulching, use of zero till drill etc. have brought in new energy into NICRA villages. For instance, Mobilizing people to build a sand bag check dam across a rivulet in Gumla, Jharkhand has improved water table in the open wells and enabled farmers to secure their rabi crop. Land shaping and harvesting rainwater has helped to reclaim the lands affected by sea water inundation due to Aila cyclone in South 24 Parganas, West Bengal. Farmers are paying user charges for hiring the equipment and many CHCs have collected sums as high as Rs.50,000/- during a single season. The custom hiring center at Namakal for instance has collected over Rs.80,000/- and has purchased an additional tractor through bank loan.

To sum-up, the following may be highlighted as the most significant outcomes from across 100 KVKs.

- Simple in-situ moisture conservation measures like broad bed and furrow method can increase rabi sorghum yield by 50% during a drought year (KVK, Baramati).
- Zero till drill machines can advance sowing date of rabi crops like wheat and chickpea by 2-3 weeks besides avoiding burning of paddy straw and saving water and energy (KVKs, Baghpat & Yamunanagar) and avoiding terminal heat stress.
- Improved housing for backyard poultry and goats drastically reduces mortality in hill regions (KVK, East Sikkim).
- Introduction of short duration varieties suitable for late sowing will help promote family food security (Improved rabi for late sown conditions-KVK, Tumkur).
- Identification of existing rainwater harvesting structures and their renovation/repair will yield quick results in terms of improved water table (KVKs, Baramati, Tumkur, Srikakulam, Gumla & Bharatpur).
- Land shaping and rainwater harvesting will help rehabilitate small holders after seawater intrusion (KVK, South 24 Parganas).
- Custom hiring services can significantly contribute to alleviating labour shortage during peak demand period (All districts).
- Coarse crop residue can be used to blend with good quality fodder through silage making thus augmenting fodder availability during dry periods.

Competitive Grants Component

1. University of Agricultural Sciences (UAS), Bangalore along with Tamil Nadu Agricultural University (TNAU), Coimbatore, Dr Yashwant Singh Parmar University of Horticulture & Forestry (YSPUH&F), Solan & Govind Ballabh Pant University of Agriculture & Technology (GBPUAT), Pantnagar
2. Anna University, Chennai along with Regional Research Station (TNAU), Paiyur
3. Rajmata Vijayaraje Scindia Krishi Vishvwa Vidhyalaya (RVSKVV), Gwalior
4. Nand Educational Foundation for Rural Development (NEFORD), Lucknow
5. Veterinary College and Research Institute (VCRI), Namakkal along with Project Directorate on Poultry (PDP), Hyderabad
6. National Centre for Agricultural Economics & Policy Research (NCAP), New Delhi along with Indian Agricultural Statistics Research Institute (IASRI), New Delhi & National Academy of Agricultural Research Management (NAARM), Hyderabad
7. Uttarakhand Seva Nidhi Paryavaran Shiksha Sansthan (USNPSS), Almora along with Doon University, Dehradun & GB Pant Institute of Himalayan Environment and Development (GBPIHED), Garhwal
8. Assam Agricultural University (AAU), Jorhat
9. Indian Institute of Soil Science (IISS), Bhopal
10. National Institute of Animal Nutrition & Physiology (NIANP), Bangalore
11. International Centre for Research in Agroforestry (ICRAF), New Delhi
12. Indian Institute of Technology (IIT), Kharagpur
13. Tamil Nadu Agricultural University (TNAU), Coimbatore
14. Jamia Hamdard University, New Delhi
15. The Energy and Resources Institute (TERI), Bangalore
16. Directorate of Sorghum Research (DSR), Hyderabad
17. Fisheries College and Research Institute (FCRI), Tuticorin
18. National Research Centre for Citrus (NRCC), Nagpur
19. MS Swaminathan Research Foundation (MSSRF), Chennai
20. Niruthi Climate & Ecosystems Private Limited, Hyderabad

Technology Demonstration Component

1 Eight Zonal Project Directorates

2. 100 Krishi Vigyan Kendras

Central Research Institute for Dryland Agriculture

Santoshnagar, Saidabad, Hyderabad – 500 059.