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Climate-Ready Genebanks for Climate-Smart Agriculture

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Climate-smart agriculture demands development of new crop varieties involving the use of a wider range of intra-specific diversity so as to increase adaptability and resilience, and improve ecosystem services. Indian agriculture is well served by availability of disease-resistant or heat/drought tolerant. However, varietal development programmes, need to be constantly fed by genotypes with excellent adaptation potential. The best way to identify germplasm suitable for abiotic stress tolerance is to evaluate them based on specific traits. The challenge is to prepare the genebanks to be climate-ready in terms of availability of resilient germplasm accessions and planning and executing collection and conservation activities. Genebank housed at ICAR-NBPGR, needs to consider working on systematic identification of germplasm accessions that are multiple-stress tolerant using all possible methodologies including climate-analogue studies and field/lab evaluation.

Introduction

Climate has been the most important determinant of agricultural operations and yields in India. Indian farming, with more than 50% area being rainfed, is exposed to severe and multiple biotic and abiotic stresses making it vulnerable to fluctuating climate. Climate change makes Indian agriculture riskier and unsustainable (Pathak, 2022). India is considered to be one of the most vulnerable regions to witness climatic changes at a large scale. The unseasonal rain, drought and flood are rising while the duration of rainfall is reducing (IPCC, 2019). It is well known that, if climate goes wrong, Indian agriculture and consequently Indian economy stare down the barrel. Reports show that the changing climate can have multiple negative effects (individually or in combination) including (i) decline in yields of major crops by 3-18% (Naresh Kumar *et al.*, 2020); decline in cultivable area (e.g. rainfed rice area to decline by 15- 40%); (iii) significant change in areas of cultivation (e.g. coconut plantations to gain in west-coast but lose in the east-coast); (iv) Significant change in orchard altitude (e.g. apple belt shifts from 1250 msl to 2500 msl); (v) loss of economic product (e.g. lower output in Assam tea and Arabica coffee); (vi) reduction in quality of output (e.g. protein content in wheat to decrease by 1%; Zn/Fe to lower in many food grains) (Pathak, 2022). It is also possible to have some positive impacts of climate change viz. expected yield gain due to elevated CO_2 level or increased arable areas due either to water availability in hot dry areas or to increased temperature in cold dry areas (Pathak, 2022).

Climate change exacerbates biotic stress faced by Indian agriculture in terms of pest/pathogen load, emergence of new strains and races, diminished scope for change in sowing time, choice of varieties, change in cropping systems and land use, etc. (Naresh Kumar *et al.*, 2020). Changing temperature regimes are expected influence the interactions among plants-pests-natural predators leading to excessive feeding on foliage, additional generations and increased pest load on crops, emergence of new invasive species (e.g., Asian fruit fly, blackfly, American tomato moth, fall armyworm and mango fruit borer) and intensified desert locust attack on crops. India can face a silent attack on nutritional status of low-income households because increased pests and diseases on home gardens, which provide substantial supplementary nutrition to rural families.

Indian Agriculture Needs to be Climate-smart

To address the emerging challenges and harness a few benefits of climate change, Indian agriculture needs to be climate-smart, which is defined as "an

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integrated approach for developing technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change" (FAO, 2013). Technologies and policy options for climate smart agriculture include weather (forecasting, agro-advisory, geo-ICT delivery, eco-regional crop planning), crop, water (increased efficiency in micro-irrigation, rainwater harvesting, drainage and approaches like direct-seeded rice), nutrient management, (site-specific Integrated nutrient management, neem-coated urea and bio-fertilizer), livestock (stress tolerant breeds, reviving small ruminants, managing feed, shelter and health), fisheries (composite/cage/wastewater culture and diversification), energy (conservation agriculture/ protected cultivation, energy plantation), policy (contingency plan, insurance, credit, incentivization, seed bank) (Fig. 1, top frame) (Pathak, 2021). Among these options, working with the "crops" option requires access to plant genetic resources (PGR) in all their forms (multi-stress tolerant and input-efficient varieties, diversification, cultivation of new crops) (Fig. 1, middle frame). Many other researchers have also identified genetic solution to develop varieties that are inherently robust and resilient.

When various strategies and technologies advocated by experts were compared for their potential benefits to achieve climate smart agriculture in India, the genetic resources-based technology —revolving around adoption of new crops/development of stress tolerant varieties/ diversification —performed the best. Novel genetic resources would infuse excellent adaption benefit, productivity gain, income gain along with ease of implementation and suitability to small farmers (Agrawal *et al*., 2021).

PGR for the Rescue

On one hand, climate change may render cultivated crop varieties and perennial trees inadequate to survive or to be economically viable underscoring the importance of access to PGR sources from different regions and countries. For instance, after centuries of breeding, wheat has a narrow genetic base making it difficult to breed new varieties with increased yields tolerance to biotic and abiotic stresses that are anticipated with climate change. Genebank accessions and crop wild relatives are potential sources of new genetic diversity (Kumar *et al*., 2016). A systematic approach (including pre-breeding) is required to identify suitable accessions. On the other, climate change has brought the wild, neglected and underutilized species into focus. Neglected and underused crops are domesticated plant species that have been traditionally used for centuries in India for

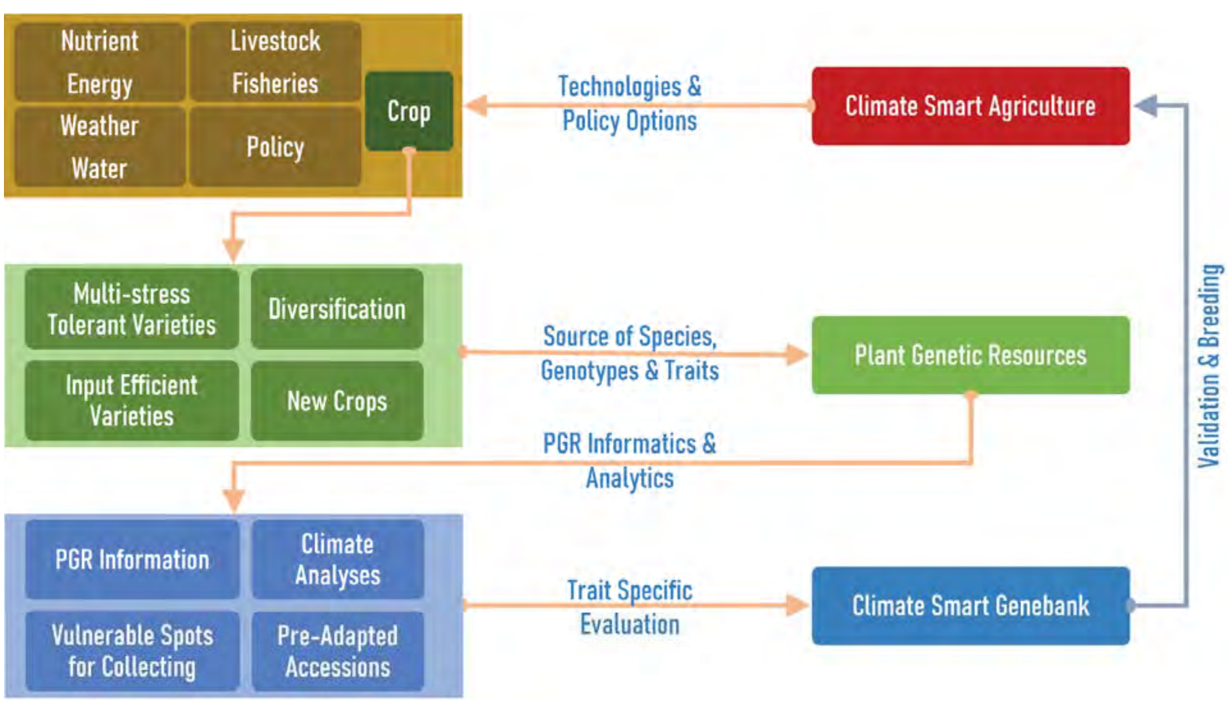

Fig. 1. Climate smart genebank an important prerequisite for achieving climate smart agriculture in India

their food, fibre, fodder or medicinal properties, but have been reduced in importance over time because of preponderance of "green revolution" crops. Fortunately, India has a number of such species distributed across different agroecologies and habitats.

ICAR-NBPGR houses one of the top three genebanks in the world. Many programmes on evaluating germplasm to identify accessions tolerant to biotic stresses or suitable for abiotic stress conditions. For instance, multi-location evaluation of wheat germplasm conserved in the Indian National Genebank to identify sources of resistance to powdery mildew and resistance to rust and spot blotch diseases (Kumar *et al*., 2016; Vikas *et al.*, 2020) was successfully carried out with funding from NICRA funding of ICAR. However, such trait specific evaluation studies are challenging because of large number of accessions. Alternative approaches, including genomics or climate analysis, to choose a small sample for detailed studies need to be explored.

Climate Analysis of PGR

It is possible to link specific geographic origins of germplasm accessions with current and future climatic data. By effectively accessing and interpreting such information, one could shortlist prospective germplasm accessions that are pre-adapted (value addition to genebank collections) to predicted changes in climate. This approach could improve the resilience and capacity of agricultural systems to adapt to environmental changes in India. It also meant that germplasm collection activities could be planned based on climate analysis and identification of sites immediately vulnerable to climatic changes (Fig. 1, bottom frame).

A pilot study carried out by NBPGR researchers has presented realistic possibilities of the approach (NBPGR 2015). Passport information on 64,467 accessions belonging to two each of cereals (rice and wheat), millets (sorghum and pearl millet), pulses (pigeon pea and chickpea), oilseeds (brassica and sesame) and vegetables (capsicum and brinjal) were georeferenced based on their collection sites and the locations were mapped. Using climatic data from the Worldclim database for current climate (1950-2000) and from UKMO HADCM3 Climate Model for near future (2010-2039), analyses for the changes in the mean maximum temperatures during the cropping season for each of the ten crop species were carried out. Climate maps, depicting the possible locations of germplasm occurrence on current and future temperature maps, could be generated for all the ten crops. Based on locations (source and test sites), climate matching, available agronomic performance data and seed availability in the genebank, 12 wheat accessions, 875 rice accessions, 150 sorghum accessions, 822 pearl millet accessions, 82 chickpea accessions, 43 pigeon pea accessions, 99 accessions of sesame wild relatives,198 chilli-pepper accessions and 12 accessions of brinjal wild relatives could be designated as pre-adapted. As many as 2039 Taluks for wheat, 912 for rice, 593 for pearl millet, 541 for sorghum (*kharif*), 1174 for sorghum (*rabi*), 1445 for chickpea, 728 for pigeon pea 178 for oil seed brassica, 912 for sesame CWR 616 for chilli-pepper and 563 for brinjal CWR were predicted as vulnerable and to draw immediate attention to conduct collection missions.

Conclusion and Action Points

Genebanks need to leverage all the available tools and technologies ranging from genomics to hyperspectral analyses to maximize the identification of trait specific germplasm for their immediate use. Climate-smart practices will be well served with a bouquet of options in terms of choice of germplasm and trait combinations. Authors recommend the following actions in this regard:

1. Establish robust PGR databases and build PGR analytics tools to link habitat data, climate data and trait data.
2. Exploit the power of GIS to link multiple sets of information.
3. Explore the power and potential of climate analog tools for value addition to the conserved germplasm as well as for the identification of vulnerable sites.
4. Coordinate with breeders and domain experts to plan and implement experiments aimed at trait specific evaluation for biotic stresses.
5. Establish standard procedures and infrastructure for screening germplasm against abiotic stress factors.

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