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Accelerated Breeding Approaches for Minor Crops

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These minor or orphan or potential or the Underutilized plants, in general, constitute those plant species that occur as life support species in extreme environmental situations and threatened habitats, having genetic tolerance to survive under difficult conditions and possess qualities of nutritional importance for a variety of purposes for the present as well as future needs of mankind. Their cultivation is restricted to remote areas in different agro-ecological regions, mainly by the poor farming communities who have limited access to modern agro-inputs and well organized marketing structure. Plant breeders must confess all issues to make food production sustainable in the climate change scenario. Crop improvement procedures have been constantly evolving to meet the increasing food demand. In conventional crop improvement, development of a cultivar may take around 10-12 years and may even exceed this period based on the plant habit, reproductive cycle and complexity of traits involved. The rapid climate change necessitates the development of varieties in a shorter span to cope with the unpredictable weather parameters. In order to achieve self-sufficiency in food production, there should be a transition in breeding work to develop crop varieties that can give sustainable yields under rapid climate change.

Role of Minor or Underutilized Crops

- Orphan crops or minor particularly the grain legumes and pseudo cereals be given due attention in terms of their adoption, varietal development, value addition and marketing so that these crops can be profitably grown by the farmers on their marginal lands.
- On account of low water requirement in raising amaranth, the area under this crop in Banaskantha district of Gujarat has been increasing over that of potato and wheat during the lean years.
- About 65000 to 1,00,000 q of grain amaranth from an area of about 4000 ha is being produced and marketed every year in Banaskantha District only.
- Buckwheat which contains Rutin, is also important pseudo cereal in higher hills regions. It is considered to be a very important agent for strengthening blood vessels.
- Among legumes, rice bean is an important pulse crop of high hills as it is immune to yellow mosaic virus which is quite serious in green gram and black gram.
- Apart from the food crops medicinal value and source of bio-fuels.

Accelerated Breeding Approaches

- Genetic improvement of crop plants is traditionally a slow process and it takes at least 12-14 years for release of new varieties.
- Recent developments in crop breeding methodology have resulted in persistent increase in crop performance, but the major constraint is generation time of plants which is biologically fixed.

- Hence, the major challenge for current breeding is to speed up the generation time of breeding cycle in order to accelerate the genetic gain in any breeding program.

1. **Shuttle Breeding**

- The concept of this method was devised by the Noble Laureate Dr. Norman E. Borlaug at International Wheat and Maize Improvement Centre (CIMMYT), Mexico.
- Shuttle breeding will allow an additional generation per year by raising the crop at a different location. Wheat breeding programme in Mexico utilized two different locations, which allowed use of the off season for breeding activities.
- The merits of this approach are development of varieties or breeding lines adopted across large geographical and agro-ecological areas.

2. Rapid Generation Advance (RGA)

- This is the most successful breeding technique in rice and in this method, extensive single plant selections are made and screening for desired characters is done in segregating generations and finally yield testing of identified homozygous lines in target environment.
- RGA breeding method is used to develop homozygous lines.
- RGA facilitates the development of true breeding lines to be achieved rapidly by controlling plant growth conditions there by enforcing early dehiscence and rapid seed set than under normal growing conditions.
- In this method, plants are grown in a controlled condition from F_2 to F_6 generations within a shorter time period than under routine growing conditions.

3. Doubled Haploids (DH)

- DH systems were used to hasten the breeding cycle in many of crops.
- DH production includes both *in vivo* (pseudogamy, parthenogenesis) or *in vitro* (androgenesis and gynogenesis) methods. Androgenesis is widely used among all the methods.
- Double haploid production at large scale depends on the embryogenesis rate and regeneration of plants, the amount of obtaining albinism among regenerates and the frequency of chromosome doubling required to obtain fertile DH plants.
- Colchicine is commonly used as chromosome doubling agent and may also affect the androgenetic process.
- It has the potential to reduce the generation time of line development leading to production of complete homozygous plants.
- DH technique is best suited for variety development, fixation of heterosis, back cross breeding, mapping, gene identification, discovery of gene and genetically modified plant development.

4. Genomic Selection (GS)

- GS is a specialized method of MAS in which genotype data on marker alleles covering the entire genome constitutes the basis of selection.
- For training population firstly, genotyping and phenotyping is done for the targeted trait.
- The breeding population without phenotyping is evaluated for the same set of markers on which basis, model parameters were estimated in the training population.
- The marker genotype data and associated effects calculated from the training population are used for estimating the GEBVs of the breeding population's individuals / lines.

5. Speed Breeding

- Speed breeding is the technique which uses supplemental lighting in enclosed and controlled-environment growth chambers that shortens generation time and speeds up the breeding and research programmes.
- By using light-emitting diode (LED) and harvesting immature seeds, six generations per year can be obtained in crops like spring wheat, durum wheat, barley, chickpea and pea, and four generations for canola, instead of 2–3 under normal glass house conditions.

- With the help of speed breeding, climate resilient varieties can be developed in a short period of time.

6. Genome Editing

- There are two categories of genome editing first one is Oligonucleotide Directed Mutagenesis (ODM) in which chemically synthesized 20-100 nucleotides are delivered into plant cells where they induce mutations in the target site.
- Site-directed nucleases (SDNs) are enzymes that can bind specifically to targeted short DNA sequences that range from 9 to 40 nucleotides and leads to introduction of Double-Strand Breaks (DSBs), acetylation, methylation, demethylation, and deamination to alter a biological activity (e.g., base editing, gene silencing, gene expression, etc.).
- For repairing of DSB, homologous recombination and non-homologous end joining are the two mechanisms in living cells. SDNs includes Zinc Finger Nucleases (ZFNs), mega nucleases, Transcription Activator-Like Effector Nucleases (TALENs), and clustered regularly interspaced short palindromic repeats (CRISPR)-associated protein (CRISPR/Cas).
- Genome editing has been used recently in soybean for incorporating salt and drought tolerance by disrupting the *DREB2b* and *DREB2a* genes.

Conclusion

Developing multiple stress tolerant crops to combat yield losses in climate change scenario. Speed breeding protocol must be developed and optimized for all crops to accelerate or increasing the plant breeding programs. Genomic prediction tools must be utilized for effective and enhanced crop breeding program to cope with climate change. Genetic engineering and gene editing tools like CRISPR/Cas should be utilized to precisely induce gene mutations in key genes that have role in climate change adaptation, to improve their functionality. Crop simulation genetic modelling can assist in prediction and selection of best breeding methodology based on gene frequency, breeding value and genotype environment interaction under different climatic conditions in order to develop climate resilient cultivar like potential crop or genotype.