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Breeding Climate Smart Sugarcane Varieties for Diversified Uses

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Sugarcane is a tropical crop grown in over 100 countries, with Brazil, India, China and Thailand being the major producers. Sugarcane in India dates back to pre-vedic period (2000BC) and the country is also one of the principal centers of origin of the *Saccharum* complex (*Saccharum, Erianthus, Sclerostachya, Narenga, Miscanthus*). Presently, this crop is the prime source of raw material for all major sweeteners produced in the country, while the crop is also emerging as a crop of diversified products. Sugarcane's attention is all the more relevant now when India in its mission for energy security, has achieved a 10% blending of bioethanol with petrol during 2022, while aiming to achieve 20% blending with petrol in 2025. The export of sugar has reached an all-time high of 10.8 MT during 2022, and sugar emerged as the single largest export commodity from the agricultural sector.

Though inter-specific hybridization is the mantra of sugarcane improvement, deleterious effects of climate, human activities and growing importance of the crop for the production of sugar, ethanol, energy, several non-food products, value-added products, fertilizers, other bio-fuels, chemicals and products with high nutritive, industrial and pharmaceutical value necessitates development of climate smart sugarcane varieties and varieties for special needs suitable for specific regions. This adds to the importance of research attention to preserve, characterize and utilize accessions of the Saccharum complex in a systematic way. The wealth of germplasm with potential sources to every stress or combinations of stresses is the strength that sustained sugarcane over a century and for future needs. Like every country engaged in sugarcane improvement retaining a collection of sugarcane clones, which evolves over time with new additions, Indian collection grew over years and now ICAR Sugarcane Breeding Institute houses the largest germplasm collection in the world. In several countries, some early generation progeny derived from *S. spontaneum* have provided good biomass yields, particularly in ratoon crops.

With plateauing of yield experienced during 1970s after a remarkable achievement which heralded a sugar revolution since 1918 in India and also in Indonesia through successful inter-specific hybrids between *Saccharum officinarum* and *S. spontaneum*, which formed the founding clones for variety development worldwide, genetic improvement became a professionally directed and scientific endeavor since 1980. Enhancement of sugarcane germplasm through pre-breeding is a long term research activity, involving collection of new germplasm accessions from natural stress affected regions, maintenance of new and available genetic resources, characterization for different stresses and varied uses based on agronomic, cytological, molecular, anatomical and morphological parameters and utilization. Genetic diversity present in the sugarcane germplasm, among different Saccharum species and related taxa, represents a large reservoir of genes to develop new varieties and hybrids for any character or ecosystem. In India, this is addressed through a national active germplasm assembled at ICAR Sugarcane Breeding Institute at its research centre at Agali near Coimbatore to facilitate wide hybridization under national sugarcane research system to supply fluff of wide crosses to 24 research stations spread across the length and breadth of the country. This initiative unlocks the genetic potential through making available the best parents characterised as donors of the different stresses as outcome of several years of focused research on trait specific germplasm.

A recent assessment of success through harnessing wild resources of leading countrie,s the Indian success has been creditable. While many countries experimented with a large number of germplasm accessions, success in terms of released varieties has been limited to a handful of ancestor clones from *S. officinarum, S. spontaneum and S. barberi* . The reasons for low success rate in comparison with large efforts of over 30 years in Australia were listed by Roach (1984, 1989). Inferior traits in the wild donor clones, difficulties in selecting and combining the appropriate desirable portions of both the wild type and the recurrent parents during subsequent selection cycles have been the major bottlenecks. The Indian experience showed that totally 91 different sources were successfully incorporated into the commercial pool (Hemaprabha *et al.,* 2021). However, reports of many novel creations have been developed from Saccharum complex including Sorghum, bamboo and maize have been encouraging through bridge crosses and other innovative approaches.

Cytoplasm of wild species is another source of novel genes, and different cytotypes of S. spontaneum also could be successfully incorporated to commercial level through repeated backcrossing. Cytoplasm of *Erianthus* was incorporated utilising *S. spontaneum* as a bridge species to create novel cytoplasmic lines in addition to *S. spontaneum*. Premachandran *et al.,* (2012) reported successful development of new cytoplasm substitution lines in sugarcane with the cytoplasm from *S. spontaneum* and *E. arundinaceus*. The F_1 hybrids involving intergeneric hybrids of *S. spontaneum x E. arundinaceus* and *S. spontaneum x E. bengalensis* were backcrossed up to BC_5 stage to get novel hybrids of commercial status. Chromosome contribution from *Erianthus* was confirmed through Genomic In Situ Hybridization (GISH). Two Co canes thus developed are Co 15015 with *E. arundinaceus* cytoplasm and Co 16018 with *S. spontaneum* cytoplasm and are under AICRP testing. Further evaluation of hybrids under CYM series could identify hybrids with high drought tolerance potential (Mohanraj *et al.,* 2018). Intergeneric hybridization at ICAR-SBI has come of age with the release of three varieties from intergeneric hybrids as immediate parents viz. Co 06022, Co 06027 and Co 06030, and quite many hybrid derivatives in advance stages of evaluation.

Several significant findings on trait enhancement using *S. spontaneum* are as providing good sources of resistance to diseases such as sugarcane mosaic, red rot, sugarcane yellow leaf virus, pests and multipests, environmental stress such as cold tolerance, waterlogging tolerance, high temperature, salinity, alkalinity and drought. Linkage drag has been a bottleneck to hastening noblilization process, though some alleles with more favourable effects than in existing commercial materials may exist in *S. spontaneum*. Hence, breeders identify favourable alleles in advanced backcross populations as well as in the donor germplasm with the aid of DNA markers or molecular cytological tools.

In addition to using sugarcane juice for varied uses, wild members of Saccharum complex which have high fibre and low sucrose content are desirable in breeding programs for increasing biomass production, ratoonability, better adaptability to varied climatic conditions, which would further enhance bioenergy production systems. Energy canes with harvestable biomass as high as 279.01 t/ha/year (SBIEC11001) and cane fibre as high as 31.86% (SBIEC 13001) have been developed. Recently an energy cane SBIEC14006 has been commercialized. Since the energycanes are capable of growing in the marginal land with low rainfall, salinity, alkalinity, water logging or hilly slopes, barren lands available around the mill can be profitably utilized. Establishment of energy plantations in a corporate or community mode by bringing groups of farmers will ensure the uninterrupted supply of quality and economically feasible raw materials throughout the year (Govindaraj, 2021).

Second generation ethanol from Lignocellulosic biomass of sugarcane is one of the preferred feedstocks for biofuel production to compensate for the future fossil fuel demand. With a high level of adaptability to biotic and abiotic stress and a lignin content of about 23%, Erianthus species is considered as an exemplary bioenergy crop. Lignolytic enzymes such as lignin peroxidase, laccase, dye-decolorizing peroxidase, ascorbate oxidase, ferroxidase, nitrite reductase and ferroxidase enzymes are considered for developing enzymatic pretreatment options. Kasinathan and aruchamy (2016) described the laccase extracted from Haloferax volcanii strains for treatment of Erianthus biomass to determine lignin breakdown and lignin modified wild clone will be ready in the near future .

Thus sugarcane crop and wild relatives and derived hybrids suited to diverse ecological and environmental situations and being able converters of solar energy provide a varied range of applications for the future requirement and situations. Concerted efforts of multispecialty experts from research and industry with the farmer's / enterpreneur's participation are needed to harness the best out of this wonder tropical plant.

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