VARIETY DEVELOPMENT PROCEDURE IN SUGARCANE

Muhammad Ehsan khan* and Waqas Raza Arshad*
*Sugarcane Research and Development Board, Punjab, AARI, Faisalabad.
Corresponding Autor: ehsansrdb@gmail.com

ABSTRACT

Sugarcane (*Saccharum officinarum* L.) is an imperative cash as well as industrial crop of different agriculturally based countries including Brazil, India, China, Pakistan and USA. A versatile crop with rich sources of food, fiber, fuel chemicals and fertilizers. Preliminary sugarcane production in Pakistan trusted on imported germplasm (True seed clones). The popular and highly successful varieties including SPF-234, HSF-240, CP 77-400, CP 43-33, CP 72-2086, SPF-213, SPF-245, CPF-237, CPF-246, CPF-248, CPF-249, NGS-599, CPF-250, CPF-251, CPF-252 and CPF-253 were selected from crosses imported from Agriculture Research Service, USDA, Canal point, USA, Sao Paul, Brazil and SRI, Sri-Lanka. HSF-240 and SPF-234 were grown successfully in several districts of Punjab where they produced high yield and ratooning ability. In Pakistan there is a lack of breeding program due to un-favorable humidity (80 to 85%), temperature (20 to 26 ° C), dark night (11:30 hr), lack of viable seed setting and lack of proper glasshouse (controlled conditions) facility at research stations. Naturally, flowering was done at Sugarcane Breeding Sub-Station, Murree, Thatta (Sajawal), Sindh and Mardan, Khyber Pakhtunkhwa. Nine-stage breeding program is currently being executed in the variety development process. More than twenty-three varieties have been approved from commercial cultivation. These clones/varieties were imported different countries and after being selected/evaluated from different varietal tests/stages got approved from commercial cultivation. There is a dire need to enhance sugarcane germplasm so that it is being used for sugarcane variety development in Pakistan. Currently, high realized selection gains are evident in most of advanced selection populations. Efforts to enhance breeding program include introgression, family evaluation, selection models and use of molecular markers.

Keywords: Sugarcane breeding, conventional, progress future prospects

INTRODUCTION

Sugarcane is one of the major cash crops of Pakistan after cotton and ranked 4th largest in terms of area among 13 crops being cultivated in Pakistan (Qureshi, 2004). Pakistan ranks at the fifth position in production of sugarcane with 7.31 m t after Brazil (51.4 m t), India (35.5 m t), China (10.63 m t) and Thailand (11.43 m t) (FAO, 2016).

Pakistan was dependent on regular imports of new varieties and over time these varieties became susceptible to local diseases such as red rot, whip smut, rust, mosaic and other diseases (Shafi, 1994). In Pakistan import of the variety SPF-234 (*S. sinensis*) in the 2002 gave growers a respite, because it was resistant to ret rot. It also ratooned better than previous varieties, and each stool produced many stalks. Although SPF-234 was pleasing to the growers, the millers did not like it because it was high in fiber and low in sucrose content leading to poor sugar recovering at processing. The majority of imported varieties were not adapted to local conditions and often succumbed to pests and diseases (Shafi, 1994). The failure of the majority of imported varieties led to the initiation of the SRI breeding programs. Despite that the area, production and yield of sugarcane increased continuously since 1947 to 2020 (Annual report of PSMA, 2020). The data shown in table-1, indicated that during 2019-20, sugarcane production decreased by 0.4 percent to 66.8 million tonnes as compared to 67.1 million

tonnes of last year (Economic Survey of Pakistan, 2019-20).

Graphical Representation of Area, Production and Yield of Sugarcane from 1974 to 2020

Source: Pakistan Bureau of Statistics, 2020. Area and Production of Important Crops.
(Economic Survey of Pakistan, 2019-20).

In Pakistan, Sugarcane Breeding Sub-Station (SBSS), Murree was established in early 1950s with prime objective of variety development. It is situated in northern mountainous region (Murree, Punjab) of Pakistan at latitude of 33.8° North and altitude of 400m. Most of the genotypes flowers abundantly which reveals the value of the experimental location. Sugarcane flower emergence in Pakistan occurs in winter when temperatures often drop below 20˚C thereby causing pollen sterility. Pollen infertility was overcome by keeping sugarcane flowers under temperatures above 20˚C in heated glasshouses (Malik, 2020). The issue of reduced fuzz viability is related to a single environmental factor i.e. low night temperature that kills the pollen and ultimately adversely effects fertility. Merely, by controlling the night temperature, viability can be improved to a greater extent. Flowering is seasonal; floral initials and few inflorescences in couple of breeding lines can be observed in November-January with peak of flowering in April-May. The germplasm comprises more than 170 genotypes including land races, introductions, approved varieties and imported breeding material from different countries. Further experiments developed procedures for inducing flowering by exposing the sugarcane plants to the day-lengths that occur in tropical countries where flowering is profuse (Malik, 2020).

1978s to Mid-2019s

The structure of the breeding programs remained largely unchanged from the early 1978s until the mid-2019 (Tiawari, *et al.,* 2009).

Table–2 The list of varieties being cultivated from 1978 to 2019 are below

Varieties	Year of release	Av. Yield (t/ha)	Sugar recovery (%)	Remarks
1978-2021 (42 years)				
Triton	**1983**	**84**	**10.10**	Medium Recovery, Severe Lodging
BF-162	**1990**	89	**10.35**	Red Rot & Rust Susceptible. Erect growing
CP43-33	**1996**	**80**	**11.69**	Thin cane, High Fiber, Low-extraction. Stress Tolerant
CP72-2086	**1996**	**85**	**12.35**	High Sugar, Soft cane
CP77-400	**1996**	89	**11.90**	Disease Resistant, Good ratooner
CoJ-84	**2000**	**90**	**9.80**	Red Rot Susceptible, Good Ratooner
SPF-213	**2000**	**90**	**10.50**	Late Maturing, Sever Lodging
CPF-237	**2000**	**94**	**12.50**	Disease Resistant, Poor Ratooner
HSF-240	**2002**	**95**	**11.70**	Whip Smut Susceptible. Non-Lodging
SPF-234	**2002**	**101**	**11.60**	Red Rot, Rust S. Good Ratooner.
SPF-245	**2004**	**101**	**11.00**	Late Maturing, Disease Resistant
HSF-242	**2006**	**102**	**12.50**	High Sugar, stress S. & Pithy
CPF-243	**2006**	**102**	**12.55**	High Sugar & Severe Lodging
CPF-246	**2011**	**104**	**12.15**	Red Rot & Stem borer Susceptible
CPF-247	**2011**	**104**	**12.25**	Red Rot S., Sunburn, Non-lodging
CPF-248	**2013**	**119**	**12.45**	Red Rot S., Good Ratooner
CPF-249	**2016**	**115**	**12.46**	Red Rot S., Poor Ratooner
CPF-250	**2019**	**104**	**12.56**	Red Rot, Good Ratooner, Non-lodging
CPF-251	**2019**	**105**	**12.79**	High Sugar, Poor Ratooner
CPF-252	**2019**	**118**	**12.80**	High Sugar, High Yield,
CPF-253	**2019**	**110**	**12.20**	Red rot, High Yield

Annul Program of Research Work, 2019-20, Sugarcane Research Institute, Faisalabad.

The different locations were established to develop varieties adapted to the different growing conditions that prevailed in the agro-ecological regions where sugarcane is grown in Pakistan. In Pakistan, differences in agro-climatic zones results in 3 main zones, *viz*. Irrigated, coastal and high altitude (Midlands), and two harvest cycles, *viz*. 12 months and 16 - 18 respectively. Genotype by environment interaction for optimum harvest age is large and determines the structure of the breeding programs (Junejo *et al.,* 2010). In addition, pest and disease risk differs across the industry zones. For example, smut is prevalent in the coastal and irrigated regions, borers are an endemic in irrigated areas while mosaic and brown rust dominate the Midlands region.

DISCUSSION

1. Sugarcane Breeding

The main purpose of sugarcane breeding is to develop varieties having high per hectare production of sugar. In few countries, there is an increase of 25 to 50% in sugar production. Actually, the importance of varieties was due to its high sugar recovery percentage from industry side and per hectare yield from farmers side (Natrajin, 2005). Climate change, soil condition, use of machinery to increase yield, new bio-types of insect, pest and diseases mechanized sowing and harvesting are the factors which effect the production of new varieties. These new varieties have better sugar recovery, milling, processing and clarification process for industry point of view (Junejo *et al.,* 2010).

Following are the steps involved in sugarcane breeding programs:

1. Selection of Male and female parent
2. Capacity of flower initiation in these parents
3. Timing of flower opening and pollen fertility
4. Synchronization in flowering
5. Method of fuzz sowing and selection of seedling
6. Proper selection cycle for advance lines
7. Selection of disease resistant varieties

For farmers concern, the sugar variety must be high yielding, free from insect, pest and disease attack and capable to grow in all type of soil and water deficient. For economic concern, sugar production is more important as compared to per hectare yield. For industry concern, production is less important as compared to sugar recovery. With the increase in inflation rate it is very difficult to increase per hectare yield of sugarcane. This challenge an only be overcome by develop more sugar varieties with desired traits through conventional breeding and through modern biotechnological techniques.

2. Selection Process

2.1. Parent Selection

The size of the seedling population and the number of first clonal selection that can be handled commonly judge a selection program. Seedling selection rate varies at different stations depending on the germplasm (Afghan *et al.,* 2013). The seedling population of a parent / cross shows a large variation from plant to plant and need a critic eye and sense of judgement for selection of an elite clone. Selection of plant based on some quantitative and qualitative characters is made through phenotypic expression in a given environment (Afghan *et al.,* 2013). The growth, tillering, stooling, cane height, girth, inter-node pattern, erect-ness, toughness Vs brittleness, pithiness and diseases and pests infestation are the main characters under study. Data of required characters are recorded on grade (0-9) basis. The brix taken by hand refractometer is the main criteria of quality evaluation at this stage. In economic crop production varieties must have good ratooning potential. In most of the cane breeding stations first plant crop of field nursery is harvested without selection and clones are kept ratoon. First clonal selection is made in ratoon crop and it helps to evaluate seedling clones with additional character of ratooning. At single plant stage 10-20% of seedlings are selected by rejection of

absolutely useless material.

2.2. Selection Program

The main objective of the programs is to select varieties suited to the major agro-climatic regions of Pakistan. To achieve this objective, selection is carried out at six research stations. The first four stages of the selection program are established at the research stations. Stage 5 genotypes are planted across research stations and on-farm trials to evaluate for genotype by environment interaction. It takes between 11 (irrigated program) and 20 (Midlands) years from the seedling stage to the release of a new commercial sugar cane variety (Nuss, 2005).

2.2.1 Raising of seedling

The selection programs start with seedlings raised in the glasshouse. If the facility of glasshouse is not available than seedling must be sown on beds with 8inch height and 2feet width (Figure:1). After that the beds were cover with a layer of special media. The water was given with the help of spray pump. During this the temperature must be around about 30˚C. If weather conditions were suitable, the germination starts after 72 hours of planting seedlings. Germination occurs within three days. Five days after sowing the seedlings are counted. If temperature is below 25 °C than germination process was slow. The development of plants was very slow in first two weeks after germination. At this stage, there is a high rate of insect and disease attack so care must be given to plants. When the seedlings are 3-5 cm tall, they are transplanted to airbricks in a nursery. The seedlings in a cross are divided into three groups and each group is planted in a replication.

Fig. 1: Raising of seedlings on beds

2.2.2: Transplanting of seedlings

The method of seed transplanting is different in every sugarcane producing country. In Pakistan, after raising of seedlings from seed the plants were directly shifted into open fields. Every plant is genetically different in a population of seedling. Usually, when the plants were 60 to 70 days they were transferred from beds/trays to small earthen pots. These earthen pots made up of polyethnic bags or mud pots. The raising of seedling and transplanting and then transferred into field must be in appropriate weather and climatic conditions.

Fig. 2: Transplanting of seedling in open field conditions

2.2.3. Stage-1
Selected seedling clones are planted in single rows of 5 meters. In single line Nursery the material may be as large as 2000 or even more. For handling a large number, row length may be reduced. Efforts have to be made to provide uniformly fertile soil and equal inputs to the entire field. A standard variety is planted after 15 to 20 clones to differentiate the environmental variations in the same field. It also helps in statistical analysis of the data. Observations are recorded on phenotypic expression of visible characters of growth, stooling habit, mill-able canes, girth, erect-ness, pithiness, foliage habit, diseases and pests; characters are mainly graded. Brix reading of clones give the quality comparison with the standard variety. Screening is designed to select superior clones to improve average value of whole population and at the same time avoiding the planting of too many poor varieties in next stage. Usually 10-20% of clones are selected.

2.2.4. Stage-2:
The clones selected from stage-I, are planted in 2 rows x 5m long. This stage includes one or two standard varieties replicated at uniform internals. Observations are made on desired quantitative and qualitative characters. The weights of mill-able canes are recorded to estimate per cane weight of each clone.

2.2.5. Stage-3: Single Lines
The clones selected from stage-II are planted in plot size of 3 rows x 8m long with two replications. Selection is made on desired characters including cane yield and laboratory analysis of cane juice for the first time.

2.2.6. Stage-4: Semi-Final Clones
At this stage the varieties have to be finally evaluated for preliminary out field tests at grower's field. The plot size is increased to 4 rows x 10 meters length. The numbers of varieties included in the trial are reduced and are planted in appropriate statistical design, simple Randomized Complete Block Design (RCBD) or Latin Square. Data on one plant and one ratoon is recorded for various quantitative and qualitative characters with detailed cane juice analysis. The varieties are also subject to replicated disease nursery for inoculated disease evaluation. Seed of promising varieties is also increased for next-year out-field zonal testing with growers.

2.2.7. Stage-5: Final Clones
The stage follows the same experimental design with testing varieties at ten to

fifteen locations in different ecological zones. Varieties selected from stage IV are planted at the research station as final variety trial and the trials repeated at grower's field as out field trials.

2.2.8. Stage-6: Promising Clones (NUVYT)

The most promising varieties confirming their adaptability with data on diseases and pests tolerance are put to national uniform variety yield trial (NUVYT). The trial includes the varieties from different research stations in the country. The same set of varieties is repeated at all the research stations with the same statistical design and lay out with uniform input conditions. As the crop matures the team of experts visits the experiments at all locations and gives remarks on the performance of the varieties in different conditions.

2.2.9. Stage-7: Commercial release of varieties

The last and final stage in a breeding program. After national uniform variety yield trials (NUVYT), an experimental sugarcane clone is eligible for release. A meeting is called for the Sugarcane Variety Evaluation Committee, which is comprised of variety development personnel from different research institutes of public and private sectors. The committee meets during the spring after the second-ratoon harvest is completed and data compiled. Data summaries are presented and discussed among the scientists. After successful approval from evaluation committee the new sugarcane variety released. If a sugarcane variety is released, a notice of release is sent out to sugarcane growers who can then order seed cane of the new variety from the secondary increase stations.

3. Progress

From the days of importing crosses from different countries up to date, significant progress has been made in the variety development programs. Associated with the elite varieties released for commercial production, a lot of progress has been made in germplasm development, parent evaluation, crossing techniques and selection procedures. The significant genetic gains among breeding populations have led to genetic gains among released genotypes.

4. Future Prospects

To enhance the opportunity of increasing genetic gains of the Sugarcane Research Institutes, breeding programs, a dedicated introgression program was established. Interest in utilization of wild germplasm resurfaced across sugar cane breeding programs worldwide when dissection of genome composition became possible using molecular marker and cytological technologies (Afghan *et al.,* 2016). The quantification of the extent of narrow genetic diversity among breeding populations has also increased the need to utilize wild germplasm using introgression. In order to save time, collaborations were sought with organizations having good collections of wild germplasm, or active introgression breeding programs. Seed of crosses with wild germ-plasm were imported from the basic breeding program at the United Stated Department of Agriculture (USDA), Houma, Louisiana. In addition, crosses with *Saccharum germplasm* were made at the CTC breeding station in Camamu, Brazil, and is being evaluated to identify genotypes to further backcross to SRI, Sri-Lanka elite germplasm (Afghan *et al.,* 2016). Efforts to generate F_1 from SRI spontaneum collection will continue to broaden genetic base as well increase biomass of the gene pool. The high biomass progenies will be evaluated for use in cogeneration as well as ethanol production from cellulose. Introgression and recurrent selection to develop elite germplasm for borers resistance continues and is expected to produce elite parents (Badaloo and Ramdoyal ,2007).

Exploration and exploitation of selection models in early (non-replicated) selection stages will enhance identification of superior genotypes. Selection models using regression analysis are used to predict the trait combinations, particularly for yield and quality that prevail in our selection populations. Yield components such as

number of stalks, stalk diameter and stalk height are used to model cane yield in these populations. This approach is expected to complement family selection in providing a mechanism to study within family population variability for yield and yield components. It is envisaged that the optimum trait combinations that impart yield advantage in different agro-climatic regions, if they exist, will be identified and could then be used as a guide during the selection process.

CONCLUSION

It was concluded from the study that more than 23 varieties were released from selection breeding efforts at Sugarcane Research Institute, Faisalabad. The future of SRI breeding programs will be enhanced by increased introgression crosses to develop new and better germplasm for use in crossing. There is dire need to develop selection models for use in optimizing selection in early stages as well as increasing the under-standing of the populations in the breeding programs.

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