History and Current Status of Sugarcane Breeding in Egypt

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Abstract Sugarcane has been cultivated in Egypt since 641 AD and is a source of raw material to various agro-based industries. The development of new varieties of sugarcane from controlled crosses in Egypt has developed greatly during recent decades with the majority of the present commercial varieties originating from the local breeding program. Egyptian sugarcane breeding program objectives are high cane and sugar yield, early maturing, good ratooning ability, resistance and tolerance to pests as well as diseases. This program depends on artificial flowering at Giza Research Station (latitude of 30.01° N and longitude of 31.20° E) and natural flowering at Sabahia Research Station, Alexandria (latitude of 31° 12' N and longitude of 29.57° E). There are four stations for selection trials, extending from middle to southern Egypt, namely Mallawi (Minia governorate), Shandaweel (Sohag governorate), Mattana Station (Luxor governorate), and Kom Ombo (Aswan governorate), respectively. Current sugar production in Egypt is about 2.458 million tons with 62.2% from sugar beet and 37.8% from sugarcane.

Keywords Sugarcane · Breeding · Natural · Flowering and selection

Introduction

Sugarcane (*Saccharum spp.* hybrids) is a major cash and industrial crop in Egypt. It has been cultivated since 641 AD, following the introduction of the crop by the Arabs. Sugarcane is currently grown along the Nile River, from Minia governorate, Middle Egypt (latitude of 27.73° N and longitude of 30.84° E) and, south to Aswan governorate in Egypt (24.46° N and longitude of 32.93° E). Sugarcane was the only raw material used for sugar production in Egypt until 1982, when sugar beet was first grown on a small scale. However, by 2012, sugar beet production had increased and produced 50.1% of the total sugar yield (2.004 million tons). In 2019, 62.2% and 37.8% of 2.458 million tons of sugar were extracted from sugar beet and sugarcane, respectively (Table 1). Egypt suffers from the scarcity of water resources, which makes it difficult to expand the area planted under sugarcane (almost fixed at 135,000 ha) due to its high water requirement in Egyptian condition, while sugar beet, as a winter crop, can be grown in the newly reclaimed soils under modern surface irrigation systems (Anonymous 2019). In Egypt, sugarcane crop is fully irrigated using water mainly from the Nile river.

The economic income in south Egypt, is greatly dependent on sugarcane production. Any disturbances to the sugarcane zone would directly impact the livelihoods of the estimated 200,000 families that plant sugarcane. Given an average family size of 5.3 persons, just above a million persons are directly dependent on sugarcane production. Additional 300,000 families that depend on the supplementary businesses around sugar production would also be indirectly affected by a downturn in the industry (USDA GAIN Report 2019). There are three organizations responsible for sugarcane

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Table 1 Basic statistics and information of current sugarcane industry in Egypt

Current total area growing sugarcane	104.2 thousand ha
Average yield in past five years (t/ha)	91.7 t/ha
Average commercial cane sugar content (%)	10.5–11.0%
Average number of ratoon crops	5 ratoons
Total sugar production	0.930 MT
% of area mechanically harvested	–
Number of sugar mills	Eight
Major diseases and pests	Borers, soft scale insects and smut
Major abiotic stresses	–
% of area irrigated and rainfed	100% irrigated

breeding and production in Egypt, and they are presented in Table 2.

History of Sugarcane Improvement in Egypt

Sugarcane varieties are considered the corner stone in cane sugar production. At the beginning in 1868, the massive government-supported sugar industry in Egypt relied for a long time on importing commercial cane varieties from other countries for cultivation (Table 3). In 1913, when a Sugarcane Research Section was established within the Department of Agriculture, sugarcane seeds were obtained from sugarcane experimental stations in Hawaii, Mauritius, Puerto Rico and Queensland in Australia for germination

Table 2 Organisations involved in sugarcane improvement in Egypt

Organisation	Funding source	Notes, key activities	Website/ email address
Sugar Crops Research Institute (SCRI)	Government	The only government agency. Responsible for breeding, producing and improving new varieties of sugarcane	http://www.arc.sci.eg
Egyptian Sugar and Integrated Industries Company (ESIIC)	Government	Responsible for sugar manufacture	https://www.siicegypt.com
Sugar Crops Council	Private-Governmental supervisory body	Responsible for industry communication, introduction of farm services for sugarcane growers in cooperation with SCRI and ESIIC	https://gb.kompass.com/c/sugar-crops-council/eg032352/

Table 3 History of sugarcane varieties in Egypt

Cane variety	Date/duration	Country Source	Advantage	Reason for decline
1. Jamaica varieties (red, red-stripped and white)	1892–1902	Jamaica	Early maturity	Diseases
2. M. 1030	1909	Mauritius	Moderate length and ratoon	Streak and borers
3. POJ. 105	1905–1940	Indonesia	Moderate diameter, high length, good ratooning	Low sugar yield, low purity
4. POJ. 2878	1937–1967	Indonesia	High cane yield, strong growth	Streak, borers, smut, poor ratooning ability
5. Co. 281	1940–1943	India	Strong growth, good ratooning	Late maturity, smut
6. Co. 413	1947–1960	India	High cane yield, good sugar content, good ratooning	Pith, borers, Smut, late maturity
7- NCo310	1960–1980	South Africa	High sugar content, high cane yield, early maturity	Smut, mosaic, poor ratooning
9. G.T. 54–9	1983–Now	Egypt	High sugar yield, high cane yield, stable in ratoon, moderate to late maturity	–
10. G. 74-96	1990	Egypt	Resistance for smut, borers, mosaic	Poor ratooning
11. G. 35-37	1990	Egypt	Early maturity, resistance diseases	Poor ratooning
12. Ph. 8013	1998–2004	Philippines	Higher cane and sugar yield than G.T. 54-9	Poor ratooning
13. G. 84-47	2009	Egypt	High cane and sugar yield, good ratooning, thin diameter	Low sugar yield
14. G. 2003-47	2016–Now	Egypt	High sugar content than G.T. 54-9, high cane yield, good ratooning	–

Table 4 Day length in Alexandria (mean of 5 years, 2013–2017)

Date	Day length	Date	Day length	Date	Day length
01-Sep	12:47	11-Sep	12:28	21-Sep	12:10
02-Sep	12:45	12-Sep	12:27	22-Sep	12:08
03-Sep	12:44	13-Sep	12:25	23-Sep	12:06
04-Sep	12:41	14-Sep	12:23	24-Sep	12:05
05-Sep	12:40	15-Sep	12:21	25-Sep	12:03
06-Sep	12:38	16-Sep	12:19	26-Sep	12:01
07-Sep	12:36	17-Sep	12:17	27-Sep	11:59
08-Sep	12:34	18-Sep	12:16	28-Sep	11:57
09-Sep	12:32	19-Sep	12:14	29-Sep	11:55
10-Sep	12:31	20-Sep	12:12	30-Sep	11:53

Fig. 1 Average monthly Air temperature in Alexandria (mean of 5 years, 2013–2017) **Fig. 2** Average monthly relative humidity % in Alexandria (mean of 5 years, 2013–2017)

and selection under the Egyptian conditions. Importing of new commercial varieties and their evaluation were also continued.

In 1970, a Sugarcane Experimental Station was established in the Sabahia area of Alexandria (latitude of 31° 12' N and longitude of 29° 57' E), with the assistance of Dr. J. T. Rao (India). At this station, sugarcane was grown for natural open pollination, and seeds from cross-pollination were used for selection and release of several varieties since then.

Overview of Current Sugarcane Breeding Program in Egypt

The Egyptian Sugarcane Variety Development Program is accomplished through the genetic material available from the sugarcane germplasm collection in Egypt that flower locally for cross-hybridization and selection of desirable new sugarcane clones. Egyptian sugarcane breeding program is mainly focusing on enhancing sucrose percentage,

ratooning ability, high cane yield, and disease and insect resistance.

The variety development program begins with the flowering and hybridization stages, which is conducted at two sites exclusively. Crosses based on natural flowering are made at Sabahia Research Station, and crosses based on artificially induced flowering are made at Giza Research Station.

Facilities of Flowering Station

Sugar Crops Research Institute at Sabahia and Giza Station have well-qualified technical staff to conduct cane breeding. The following are the sugarcane breeding activities at SCRI and its agricultural experimental stations.

Sabahia Experiment Station

Natural flowering occurs under the conditions of the Sabahia station due to favourable climatic conditions (day length, temperature, and humidity). Flower induction occurs primarily during 15 days in September, where day

Table 5 Selection stages at different stations in Egypt

Year	Stage	Experimentation/selection	Location
1	Hybridization		Giza
2	Seedling raising	About 5000 sugarcane seedlings. Selection is based on stalk diameter, brix, stalk weight and tillering. 20–30% of test clones will be selected for the next stage of evaluation	Giza
3	Clonal I	Evaluation (about 1000–1500 clones) in single rows of 3 m, along with GT 54/9 as check (local variety). Selection based on disease incidence, tillers, pith, thickness, height, brix. About 30% of test clones will be selected	Mattana (Luxor)
4	Clonal II	Trial of 300–450 clones from Clonal I stage with each clone grown in single row of 6 m. Selection based on millable canes, thickness, height, brix, sucrose % of plant crop and previous ratoon crop. About 20% of test clones will be selected	Mattana (Luxor)
5	Primary Trial	Trial of Clonal II selections with each clone grown in 6 rows of 7 m length. 3 reps, RCBD. GT54/9 Check. yield traits, plot yield, brix, sucrose %, commercial cane sugar content (CCS), reducing sugars, diseases, ratoon data of previous stage. 2 ratoons, about 90–100 clones are evaluated	Mattana (Luxor)
6	Main Experiment	Trial of Clonal II selections with each clone grown in 6 rows of 7 m length. RCBD, 4 reps. GT54/9 Check. yield traits, plot yield, brix, sucrose %, CCS, reducing sugars, diseases, ratoon data of previous expt. 2 ratoons, about 25–30 clones are evaluated	Mattana, Malawi (Minia governorate), Shandaweel (Sohag governorate), Kom Ombo (Aswan governorate)
7	Final Experiment	8–10 entries at this stage each grown in 6 rows of 7 m length. RCBD, 4 reps. GT54/9 Check. Yield traits, plot yield, brix, sucrose %, CCS, reducing sugars, diseases, ratoon data of previous expt. 2 ratoons.)	Mattana, Malawi, Shandaweel, Kom Ombo
8	Demonstration	The selections from the 4 stations are pooled and grown in 10 rows of 7 m length. About 1–2 clone will be grown at this stage	At the Stations and Sugar factories

length reaches 12:15–12:40 h, as shown in Table 4 and Figs. 1 and 2.

Giza Station

Two photoperiod rooms similar to those used in Louisiana, USA, are used to grow cane and produce flowers for crossing. Each photoperiod room can hold a total of 60 pots placed on two carts, with four stalks growing in each pot. The size of each photoperiod room is $8.1 \times 3.35 \times 6.5$ m, and the room temperature is controlled to keep the room temperature up to 24°C during the cold nights. A supplementary artificial light provided by twelve incandescent lamps of 250 watts each ensures the required photoperiodic treatments. These lamps are placed about 1.25 m above the upper stalk leaves. The out-of-door misting system consists of nozzles delivering tap water in the form of a fine mist spray, fixed about 5 m above ground level and operated daily from 10 am to 5 pm. Each crossing chamber is divided into 36 isolated crossing cubicles. Cubicle during crossing is kept at temperature at 23°C and humidity over 85%. A seed germination chamber with heating and irrigation systems provides optimum conditions for seed

germination and seedling growth. The research station annually produces 150–200 hybrids.

Selection Stages

The breeding program includes three major stages of clonal selection (Table 5). The first stage (seedlings stage) occurs at Giza Station. The second (line stage) is conducted at El-Matana Research Station, and the third stage (advanced variety trials) is conducted at Malawi, Shandweel, El-Matana and Kom-Ombo Stations.

Goals of Sugarcane Breeding Program

High Cane and Sugar Yields

Data in Table 6 presents the description of some Egyptian sugarcane varieties. G. 98-28, G.T. 54-9, and G. 2003-47 are used in sugarcane breeding program as parents based on their high sugar content, aiming to produce progeny with higher sugar content. The variety G. 84-47, G. 98-28, and G. 2003-47 mature earlier than the other varieties.

Table 6 List of current major cultivars in Egypt

Variety	% of crop	Parents		Notes on characteristics: good and bad features
		Female	Male	
G. 84-47	> 1%	‘NCo310’	–	Semi-prolific tillering, no flowering, excellent ratooning, erect, medium fibre content, resistant to smut, borers and frost, high sugar and cane yield
G. 99-160	Promising	‘Cp.76-1306’	‘Q.76-1053’	Good tillering, no flowering, good ratooning, erect, medium fibre content, resistant to smut, borers and frost, high sugar and cane yield
G. 98-28	–	‘C34-33’	–	Good tillering, no flowering, good ratooning, nil pith, erect, medium fibre content, resistant to smut, borers and frost, high sugar and cane yield
G.T.54-9	99%	‘NCo310’	‘F. 337/925’	Good tillering, no flowering, good ratooning, nil pith, erect, medium fibre content, resistant to smut and borers, frost tolerance, mid-late maturity, high sugar and cane yield
G. 2003-47	New variety > 1%	‘CP 55-30’	‘CP 85-1697’	Good tillering, no flowering, good ratooning, nil pith, erect, medium fibre content, resistant to smut, borers, frost tolerance, early maturity, highest sugar yield
G. 2004-27	New variety > 1%	‘CP 55-30’	‘RoC 22’	Good tillering, no flowering, good ratooning, nil pith, erect, medium fibre content, resistant to smut, borers, frost tolerance, mid-maturity, high sugar and cane yield
G. 99-103	> 1%	‘US.74-3’	‘CP.76-1055’	Good tillering, no flowering, good ratooning, nil pith, erect, medium fibre content, resistant to smut, borers, frost tolerance, mid-maturity, highest cane yield

Good ratooning growth is an important attribute of sugarcane varieties, with 4–5 ratoon crops being common in commercial crops. Some growers may keep crops for more ratoons where there is good soil conditions and agricultural practices. G. 84-47, G. 2003-47 and G. 2004-27 have particularly good ratooning ability. In the sugarcane breeding program in Egypt, clones normally are evaluated through one or more ratoon crops in most stages of selection. Evaluation of ratoon crops in a multi-stage multi-location selection program significantly increases the time and resources needed for selection.

Diseases and Pests

Diseases and pests present a major challenge for the sugarcane industry in Egypt. Borers and soft scale insect are important sugarcane pests, and weeds cause large losses to cane and sugar yield. However, sugarcane smut is the most serious problem, causing losses of 20–60% in cane yield (Anonymous 2017).

Conclusion

The key objective of Egyptian Sugarcane Variety Breeding Program is to develop new genetically improved cultivars of sugarcane for an economically viable and environmentally sustainable Egyptian sugar industry. The success of sugarcane breeding program depends essentially on the selection of parents and identification of desirable clones for crop production. Increasingly, the breeder must focus on environmental conditions that affect production, such as biotic and abiotic stresses, in a country like Egypt. Water shortage is a

major challenge facing Egyptian agriculture, especially after building the Renaissance Dam. Thus, it is inevitable that breeding programs must put more efforts for development of water use efficient and drought tolerant new varieties.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s12355-021-01010-5>.

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