Recent Achievements of Egyptian Sugarcane Breeding Program

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Abstract

Egyptian sugarcane breeding program depends upon natural flowering and artificial flowering. Natural flowering at El-Sabahia Agriculture Research Station (31.2^{O} N latitude), Alexandria, Egypt is used to evaluate number of sugarcane germplasm for natural flowering ability and determine their flowering dates. The natural flowering season extendes from November, 1st to the end of June.

Artificial flowering conducts at Giza Agriculture Research Station (30.01^{O} N latitude), Giza, Egypt and used to estimate the number of inductive cycles for inducing the desirable parents from the available germplasms in the program to flower and synchronize their flowering dates to make planed crosses. Fuzz produced from planed crosses is used to establish the seedling stage, which follow by other selection stages to develop improving sugarcane variety.

Increasing the size of the germplasm collection, promising clones at all selection stages and registration of Giza.3 and Giza.4 verities were the recent achievements of the breeding program. In addition to, resistant to smut disease Giza.3 and Giza.4 varieties have high cane and sugar yields. Besides, Giza.3 is an early mature variety and Giza.4 is a moderate mature variety.

Keywords: Sugarcane, Breeding program, Crossing, Selection and flower photoperiod .

Introduction

Successful sugarcane breeding program requires sufficient germplasm collection with flowering ability and desired traits to achieve the program objectives. In addition to effective crossing and selection program to develop improved varieties and maintain sustainable sugar industry throughout supplying the sugarcane growers with the superior varieties. Photoperiod

chambers which have facilities providing suitable artificial condition for flowering induction, flowering synchronization, pollen viability and allowing a better planning of desired crosses are also required. Furthermore, controlled crosses house providing the optimum conditions for hybridization is essential ***(Coleman 1968)***.

Sugarcane improvement programs worldwide are closely linked with the exploration, collection and utilization of sugar cane genetic resources. Interspecific hybridization involving cultivated and wild species of Saccharum has formed the basis of varietal improvement programs. With the introduction of improved varieties, sugarcane yield and sugar production have increased considerably worldwide and cane sugar constitutes about 60% of the total sugar produced in the world ***(Amalrai and Balasundaram 2016)***. Effective use and conservation of large germplasm collection could be greatly facility by identification of a small, and well-characterized collection known as "coreset'' which represents most of genetic diversity ***(Balakrishnan et al. 2000)***.

Sugarcane flowering is essential and fundamental stage in any breeding program. There are many factors affecting sugarcane flowering. These factors are sugarcane genotypes, photoperiod, air temperature and soil moisture ***(Moore and Nuss 1987)***.

A day length of 12,30 h is commonly cited as the inductive day length for sugarcane. Individual clones responded to varying day length between 12 and 13,30 h. Ten inductive cycles are considered necessary for inflorescence initiation. Fifteen inductive days needed to achieve a high percentage of induction in most commercial clones ***(Martin 1993)***. The minimum temperature rarely falls below 18^{o}C and the maximum never exceed 32^{o}C in area with abundant flowering ***(Berding 1995)*** and ***(Berding et al. 2007).*** However, temperature below 21^{o}C delay growth and panicels emergence

(Clement and Awada 1967). Pollen grain is affected by cold temperature, resulting in pollen grains that are unviable at night temperature below 15^{o}C before or during flowering may cause anther abortion and male sterility ***(Berding 1981)***. Besides water deficit during the inductive period delay flowering because of a lack of water inhibits the translocation of photo-assimilates to the apex and elongation of the inflorescence peduncles and anthers exposure ***(Moore and Nuss 1987)***.

Flowering is induced by imposing differential photoperiod treatments prearranged to synchronize the flowering of all sugarcane clones intended for use as parents in the breeding campaign when parents have full emergence tassels, they are used for crossing in the crossing house. Crossing decisions are based on expected progeny performance using an additive genetic (mid parent) model. Cross performance based on non additive genetic variation is accounted for by information derived from the cross appraisal test and percent of clones advancing through the different stages of the breeding program ***(Berg et al. (1986)*** and ***(Gravois et al. 1991)***.

Efficient selection program is a great challenge in sugarcane breeding programs. Selection in original seedlings is the least effective of all stages of selection because broad sense heritability are low for most characters and it is too time-consuming, in addition to expensive to assess many thousands of clones for many important characters ***(Skinner, 1982)***. However, it is a vital stage of selection which provides the base population for the remaining and more effective stages of selection. The selected clones pass through several stages of selection, its number being reduced at each stage and tested in larger plots in which its performance can be evaluated more reliably. Family selection followed by individual clone selection was more effective than either family or individual selection alone ***(Skinner et al. 1982***; ***Cox*** *and* ***Hogarth 1993***;

Kimbeing *and* ***Cox 2003****;* ***Shanthi et al. 2008****;* ***Stringer et al. 2010*** *and* ***Mahmoud et al. 2012)****.*

The objective of this paper was to describe the Egyptian sugarcane breeding program and its recent achievements.

Breeding program facilities

There are six Research Station belong to the breeding program, i.e.,

1- El-Sabahia Research Station (31.2^{O} N latitude), Alexandria Governorate in which flowering ability of germplasm collection is evaluated under its natural environment conditions.

2- Giza Research Station (30.01^{O} N latitude), Giza Governorate in which the facilities for inducing flowering, synchronizing flowering, applying crossing and sowing the fuzz were established in 2002, in addition to field of germplasm collection and seedling stage of clones. The breeding facilities includes:

A- Four photoperiod chambers which used to provide the potted canes with scheduled photo-inductive-cycles and optimum conditions for flowering. Each pot holed four sugarcane stalks. The size of each chambers 8.1 x 3.35 x 6.5 m and the chambers temperature controlled by air conditioners (hot/cold) to keep the chamber temperature at 24^{o}C at night. A supplementary artificial light is obtained by installing twelve incandescent lamps of 250 watts for the controlling the photoperiod treatments.

B- Misting system that is an outdoor misting system consists of nozzles delivering tap water in the form of a fine mist spray. The canes in pots an each carts when pushed outside the photoperiod chambers were positioned directly under water sprays fixed at a hight of 5m

above the ground levels. Water sprays operated daily from 10 am to 5 pm to control the temperature below 32°C during the day.

C- Two crossing house each divided into 20 isolated cubic. A single cross in each cubic is conducted and they have systems to kept the temperature above 21°C and humidity above 75%.

D- Planting fuzz house has heating and irrigation systems provid optimum condition for fuzz germination and seedling growth.

3- Malway Research Station (27.73^{O} N latitude), El-Menia Governorate in which the advanced replicated trials of selection stages of clones are conducted.

4- Shandweel Research Station (26.33^{O} N latitude), Sohag Governorate in which advanced replicated trials of selection stages clones are conducted.

5- El-Matanaa Research Station (25.41^{O} N latitude), Luxor Governorate in at which the first and second line clones trials, in addition to advanced replicated trials of selection stages are conducted.

6- Kom-Ombo Research Station (24.05^{O} N latitude), Aswan Governorate at which all advanced replicated trails of selection stage are conducted. Seed multiplication of promising clones are conducted in Malway, Shandweel, El-Matana and Kom-Ombo Research Stations locate in sugarcane production Governorates.

Breeding process:

1- Parent selection:

Parents selection is the first step in the breeding Program Parents are selected based on high cane yield, high sucrose content, high sugar yield, good ratooning ability and proven crosses method. The current parents

collection includes 224 parents (Tables 1, 2 and 3). Four single-eye cuttings from each parent are planted in 40 liter plastic pot in September annually. All pots are filled with a mixture of clay and sand at a ratio of 3:1 as recommended by ***Viveros*** and ***Cassalett (1990)***. During growing season, the potted plants received the recommended agricultural practices, fertilizer and irrigation to maintain full active growth. The potted plants are their transferred to a greenhouse by the winter month start to maintain normal growth required to pass the juvenile phase, where sugarcane plants required a certain state of maturity or ripeness before the growing point responds to flowering stimulus ***(Coleman, 1968*** *and* ***Evans, 1969)***

2- Flower induction and crossing:

There are three flowering photo-inductive cycles treatments are used i.e 21, 30 and 60 days of 12.30 hours day length followed by decreasing rate 0.5 or 1.0 minute/day. The start date during June or July and decreasing rate of the photo period depend on the flowering date of planed crossing parents. The tassel emerge after 85 to 115 days of photo-period treatments. A parent is used as male or female based on the amount of viable pollen produced When the first florets is opened, anthers are collected and the amount and viability of pollen is determined to classify the parent as a male or female. During crossing, the minimum temperature is kept above 21^{o}C and humidity levels are maintained above 75% to insure good pollen viability, pollen survival and seed set. After two weeks of crossing, when shedding of pollen ceases, the males are discard and female flower is ripen. The matured flowers are harvested and dried. The fuzz obtained are dried for 24 hours at 30^{o}C. A sample of seed is taken for a germination test and the remaining seeds from each cross is placed in a plastic sachet and sealed and stored at -20^{o}C until planting.

3- The selection program:

The ultimate objective of the program is to develop improved varieties suited to agro-climatic sugarcane production region. The main selection criteria are sugar and cane yield, ratooning ability and resistance to pests, disease and adverse condition in production area. Selection program consists of three main stages, i.e., 1) seedlings stage which established at Giza Research Station. 2) line stage which established at El-Matanaa Research Station, Luxor governorate, and 3) advanced variety trials which established at Malway Research Station, El-Menia governorate, Shandweel Research Station, Sohag governorate, El-Matana Research Station, Luxor governorate and Kom-Ombo Research Station, Aswan governorate (***Mehareb et al. 2015***).

I. Seedling stage:

Each cross is sown in separate box by spereading fuzz evenly oven the surface of a mixture of peatmoss and sand. The fuzz is lightly covered with peatmoss, watered and placed in heated germination house at 30^{o}C. Germination occurs within three days. One week after sowing the seedlings are counted and transplanted to small pots when they are 3-5 cm in height. The seedlings remain in the green house until April 1st when they are transplanted to the field.

The seedlings are left to grow for twelve months. The selection rate in this stage is 30-35% and the selection criteria are stalk height, stalk diameter, number of millable cane per stool and Brix.

II. Line stages:

A- First line stage:

The seed set of selected clones in seedling stage are planted individual row in a 7m long with a 1m distant. Every ten the row is planted with GT.54-9 variety as control.

B- Second line stage:

The seed set of selected clones in first line stage are planted in two row, 7m long and one m apart. As in first line stage, every ten the row is planted with GT.54-9 variety as control.

The selection criteria in first and second lines stages are stalk height, stalk diameter, number of millable cane per stool and Brix.

III. Advanced variety trails:

Advanced variety trials provide the final evaluation before a genotype is recommended for commercial planting and they include primary advanced variety trial, secondary advanced variety trial and final advanced variety trial, All the advanced variety trials are planted in randomized complete block design with four replications. The data for stalk height, stalk diameter, millable cane number, Brix, sucrose%, purity%, recovery sugar% and cane and sugar yields is estimated as selection criteria in this stage. The trials are conducted at Kom-Ombo, El-Matanaa, Shandweel and Malway Research Stations to evaluate genotype environment interaction and harvested in the plant, where first, second, third and fourth ratoon crops to evaluate ratooning ability. Disease and pests screening trial are established at this stage to determine resistance for smut, mosaic, streak and borer. Combined data analysis is used to recommend varieties for release by determining the area of adaptability and ratooning ability. Genotype recommended for release are expected to produce

equal or higher cane and sugar yields than that of control and possess higher levels of resistance to diseases and pests prevalent in the agro-ecological production area. Seed multiplication is conducted during the final advanced variety trials in the same stations.

Achievements

I) Germplasm collection and the number of phot-inductive-cycles determination.

Great attention was given to the collection, conservation and utilization of germplasm. Four hundred genotypes were collected and characterized including natives and introducing promising clones and commercial varieties which represent wild variability in geographical origin and individual characters. The development of the germplasm collection being used to enhance the breeding program.

Out of 284 genotypes evaluated for natural flowering ability under El-Sabahia Research Station an where the inductive days (day length and temperature) prevailing from September 26th to October 14$^{th.}$. One-hundred and forty six genotypes (Table 1) induced to flower and successfully used in the artificial flowering program at Giza Research Station by applying the same number of inductive days prevailing naturally at El-Sabahia Research Station.

Furthermore, the inductive cycles were determined for 88 genotypes under artificial photoperiod treatments at Giza Research Station. Thirty eight genotypes were induced to flower under 30 inductive cycles while the remaining 50 genotypes were induced to flower under 60 inductive cycles (Tables 2 & 3).

Table .1 Genotypes induced to flower under natural conditions at El-Sabahia Research Station

No.	Genotype	No.	Genotype	No.	Genotype	No.	Genotype	No.	Genotype
1	62D.509	29	Bo.19	56	EI.8-129	83	G.2009-21	110	G.2009-98
2	77/31-56	30	Bo.3	57	EL.18-1	84	G.2009-22	111	G.68-421
3	82/14-1	31	BO.41-227	58	EN.3-3	85	G.2009-27	112	G.69-55
4	82/4-21	32	Bo.41-24	59	EN.8-4	86	G.2009-31	113	G.70-112
5	82/4-26	33	CoK.30	60	G.2004-27	87	G.2009-37	114	G.73-185
6	83C.37	34	EH.128-2	61	G.2007-111	88	G.2009-40	115	G.73-189
7	84 E.1	35	EH.1-5	62	G.2007-13	89	G.2009-42	116	G.73-211
8	EI.85/14-1	36	EH.16-1	63	G.2007-133	90	G.2009-44	117	G.74-99
9	EI.85/14-4	37	EH.26-2	64	G.2008-20	91	G.2009-45	118	G.84-68
10	86 E.409	38	EH.5-1	65	G.2008-44	92	G.2009-49	119	G.99-160
11	EI.87/27-2	39	EH.67-11	66	G.2008-59	93	G.2009-5	120	GH.128
12	EI.87/28-4	40	EI.13-6	67	G.2008-64	94	G.2009-56	121	GT.54-9
13	EI.87/40-17	41	EI.24-2	68	G.2009-100	95	G.2009-67	122	IN.84-003
14	EI.88/7-25	42	EI.258-3	69	G.2009-11	96	G.2009-73	123	M.253-48
15	EI.89/101-5	43	EI.262-2	70	G.2009-12	97	G.2009-84	124	M.55-157
16	EI.89/8-27	44	EI.32-70	71	G.2009-13	98	G.2009-85	125	Mex.58-1866
17	AN.56-79	45	EI.36-80	72	G.2009-15	99	G.2009-86	126	Ps.80-1424
18	B.37-61	46	EI.4-40	73	G.2009-18	100	G.2009-86	127	PS.80-1429
19	B.63-21	47	EI.67-11	74	G.2009-2	101	G.2009-91	128	SP.79-2233
20	EI.88/27-1	48	Bo.18	75	EH.73-11	102	EI.18-1	129	EI.18-10
21	EN.3-4	49	G.2007-56	76	G.2009-10	103	G.2009-38	130	G.2009-41
22	G.84-47	50	83 D.49	77	AN.3-4	104	B.34-104	131	EH.16-9
23	EI.264-2	51	EI.60-42	78	EI.62-15	105	G.2005-44	132	G.2005-64
24	G.2007-28	52	G.2007-61	79	G.2008-14	106	G.2009-99	133	G.75-313
25	H.86-371	53	IR.16-5	80	K.8-1113	107	N.11	134	Ps.87-22951
26	EI.88/101-5	54	EI.88/5-7	81	EH.26-3	108	EI.264-2	135	EI.37-10
27	EN.4-2	55	G.2009-71	82	G.73-36	109	G.74-96	136	IK.76-79
28	L.61-49								

Table .2 Genotypes flowered genotypes under 30 inductive cycles

No.	Genotype	No.	Genotype	No.	Genotype	No.	Genotype
1	56/31-77	11	Co.1157	21	EH.67-11	31	G.73-211
2	85/14-1	12	Co.617	22	EI.2006-2	32	IK.76-99
3	87/15-1	13	Co.744	23	EI.36-80	33	L.62-96
4	BO.18	14	CP.43-44	24	G.2003-47	34	Mex.2001-80
5	BO.19	15	CP.46-115	25	G.2006-3	35	Mex.2001-86
6	BO.22	16	CP.57-614	26	G.2006-41	36	NCo.339
7	BO.3	17	CP.63-35	27	G.2008-47	37	PS.80-1424
8	BO.41-24	18	CP.67-412	28	G.2008-64	38	SP.81-1763
9	BoT.49	19	EH.1-5	29	G.2009-99		
10	Co.1129	20	EH.26-8	30	G.68-421		

Table. 3 Genotypes flowered genotypes under 60 inductive cycles

No.	Genotype	No.	Genotype	No.	Genotype	No.	Genotype
1	56/31-77	14	Co.798	27	EI.36-80	40	IR.23-2
2	83C.37	15	CP.43-44	28	F.146	41	L.62-96
3	85/14-1	16	CP.44-101	29	F.161	42	M.55-157
4	87/15-1	17	CP.46-115	30	G.2003-49	43	Mex 2001-80
5	BO.18	18	CP.57-614	31	G.2006-3	44	Mex 2001-86
6	BO.19	19	CP.63-35	32	G.2008-20	45	Mex.58-1866
7	BO.3	20	CP.67-412	33	G.2008-64	46	NCo.339
8	BO.41-24	21	CP.70-1143	34	G.2009-99	47	Phil.8013
9	Co. 617	22	CP.82-1597	35	G.68-421	48	SP.72-5181
10	Co.1129	23	EH.1-5	36	G.73-211	49	SP.80-1424
11	Co.1157	24	EH.26-8	37	G.74-96	50	SP.81-1763
12	Co.284	25	EH.67-11	38	G2006-41		
13	Co.744	26	EI.2006-2	39	H.86-37		

II) Promising genotypes.

Four promising genotypes were identified at the final advanced variety trial (Table 4). The combined analysis of data collected from the advanced trials for number of millable cane, stalk diameter, stalk height, Brix, sucrose%, recovery sugar% and cane and sugar yields were performed according to ***Snedcore and Cochran (1967)*** and means were compared using LSD at 5% of probability according to ***Waller and Duncan (1969)***. The results indicated that number of millable cane, sugar recovery and sugar yield of promising genotypes were statistically similar to the commercial variety GT.54-9. Promising genotype G.99-103 recorded the highest value of cane yield, stalk diameter and stalk height and the lowest value of Brix, sucrose% and recovery sugar%. However, G.2003-44 genotype recorded the highest recovery sugar% and the lowest cane yield.

Table . 4 Characters mean of promising genotypes compared to GT.54-9 commercial variety in plant cane and rations crops (2012-2017)

	Stalks number /fed.	Stalk diametercm	Stalk height cm	Brix	Sucrose%	Sugar recovery%	Caneyield ton/fed.	Sugar yield ton/fed.
G.2007-61	49333	2.57	300.0	21.60	18.57	12.08	46.83	5.67
G.2003-44	44000	2.53	301.3	21.73	18.85	12.92	46.00	5.92
G.99-103	42666	2.90	320.0	20.80	17.58	11.40	58.73	6.67
G.2003-49	41333	2.63	319.3	21.83	19.51	12.13	53.57	6.26
GT.54-9	49373	2.57	305.3	22.10	19.32	12.15	54.73	6.26
LSD 5%	n.s	0.18	14.1	0.81	1.27	n.s	7.21	n.s

II) Registration of G.3 and G.4 verities:

G.3 and G.4 varieties is registered in 2017 and the number of registration was 1301. The combined analysis of data collected from the advanced trials for number of millable cane, stalk diameter, stalk height, Brix, sucrose%, recovery sugar% and cane and sugar yields of G.3 and G.4

varieties were performed according to ***Snedcore*** and ***Cochran (1967)*** and means were compared using LSD at 5% of probability according to ***Waller and Duncan (1969)***.

A- G.3 variety (G.2003-47)

The parents of this variety were Cp.55-30 (the female parent) and EI.85-1697 (the male parent) G.3 variety is an early mature variety, resistant to smut disease and adapted to agro-climate prevailing in sugarcane production Governorates.

Data in Table 5 revealed that cane yield component, i.e., cane and sugar yields per feddan at 12 months old of G.3 variety were statically similar to those of the commercial variety, GT.54-9 while it was superior in Brix and sucrose. However, it produce more sugar yield than that of GT.54-9 variety at 11 month old (data not shown) and recommended to harvest at the beginning of harvest season.

B- G.4 variety (G.2004-27)

The parents of this variety were Cp.55-30 (the female parent) and ROC.22 (the male parent) G.4 variety is moderate mature variety, resistant to smut and borer and adapted to all sugarcane production areas. Data in Table 5 indicates that G.4 variety recorded cane yield components and cane and sugar yields statistically similar to GT.54-9 variety and recommended to be harvest at the second half of the harvest season.

Table . 5 Characters of G.3 and G.4 varieties compared to GT.54-9 (C.9) commercial variety at 12 months old in plant cane and rations crops (2012-2017).

	Stalks number /fed.	Stalk diameter cm	Stalk height cm	Brix	Sucrose %	Sugar recovery %	Cane yield ton/fed.	Sugar yield ton/fed
G.2003-47(G.3)	49333	2.62	300	23.4	20.29	13.91	56.7	7.9
G2004-27 (G.4)	48000	2.67	306	21.5	17.80	11.93	57.2	6.8
GT.54-9 (C.9)	50667	2.70	315	20.9	18.20	12.50	55.5	6.9
LSD 5%	n.s	n.s	n.s	2.0	1.80	1.20	n.s	n.s

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الملخص العربى

أحدث إنجـازات برنـامج التربية المصري لقصـب السـكر

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يعتمد برنامج تربية قصب السكر بجمهورية مصر العربية إما على التزهير الطبيعي في محطة بحوث الصبحية بمحافظة الإسكندرية (دائرة عرض31,2 شمالاً)، وذلك لتقييم القدرة على التزهير طبيعياً. حيث أنه يمتد موسم التزهير الطبيعي من الأول من نوفمبر حتى نهاية شهر مايو من كل عام. أو على التزهير الصناعي حيث يتم في محطة بحوث الجيزة بمحافظة الجيزة (دائرة عرض30,1 شمالاً)، الذي يستخدم لتحديد عدد دورات الدفع الزهري اللازمة لدفع الآباء المتميزة من الأصول الوراثية المستخدمة في البرنامج للتزهير مع تزامن ميعاد التزهير لهذه الآباء المزمع إستخدامها للتهجين فيما بينها. البذور الناتجة من هذه التهجينات يتم زراعتها ثم نقلها في مرحلة الجورة من ثم تتبعها في مراحل الإنتخاب الأخرى حتى الحصول على أصناف محسنة.

كانت أحدث إنجازات برنامج التربية المصري زيادة عدد مجموعة الأصول الوراثية والسلالات المتفوقة في مراحل الإنتخاب المختلفة وتسجيل صنفين من قصب السكر وهما جيزة 3 وجيزة 4.

صنفي القصب جيزة 3 وجيزة 4 يتميزان بمحصولي القصب والسكر العاليين بالإضافة إلى مقاومة مرض التفحم السوطي، ويتميز الصنف جيزة 3 بالتبكير في النضج أما الصنف جيزة 4 فإنه متوسط النضج.