

RESEARCH ARTICLE

Genotypic interrelationships for flowering traits in sugarcane genotypes treated by Gibberellic acid under natural conditions

F.F.B. Abu-Ellail^{a*}, E.S.R. Salem^b and A.M. El-Sheikh^a

^a Breeding & Genetic Dept., Sugar Crops Research Institute, Agricultural Research Centre, Giza, Egypt.

^b Physiology and Chemistry Dept., Sugar Crops Research Institute, Agricultural Research Centre, Giza, Egypt.

*Corresponding author: Email: farrag_abuellaail@arc.sci.eg

Received: 04 February 2024 ; accepted: 04 April 2024

Abstract

The low flowering intensity of some sugarcane germplasm decreases seed yield. Flowering ability and intensity are desired traits for a successful sugarcane breeding program. The goal of the study was to evaluate the effects of various foliar gibberellic acid (GA₃) concentrations (0, 50, and 100 mg l⁻¹) on 20 sugarcane genotypes to improve their flowering ability and intensity under natural conditions at El-Sabahia Research Station (31° 12' 54" N and 29° 58' 23" E), Alexandria, Egypt, over the plant and ratoon cane crops grown in the 2020/2021 and 2021/2022 seasons. The results revealed that increasing GA₃ concentrations up to 100 mg/l improved the flowering percentage during the various flowering stages of the 20 sugarcane genotypes. Sugarcane genotypes, namely MEX2001-80, Co1129, and CP63-49, outperformed the others during the flowering stages. The interactions between sugarcane genotypes and GA₃ concentrations had a significant impact on flowering percentage. According to cluster analysis, the longest full emergence flowering period was 142.24 days, whereas the shortest period was 0.0 days. It was discovered that the Mex 2001–80 genotype's superiority in longevity was mostly due to its superiority in the emergence stage. The GT biplot's polygon view was used to identify the genotypes that showed good flowering responses for one or more GA₃ concentrations. According to the study, the responsive sugarcane genotypes may be treated with 100 mg/l of GA₃ to induce floral primordia, which will speed up and intensify flowering. Selection should concentrate on tip emergence stage and full emergence stage to increase flowering percentage, according to genotypic correlation. Finding the best sugarcane genotypes in natural settings is crucial, as evidenced by the necessity for additional research using higher concentrations of GA₃ to evaluate all sugarcane germplasms for flowering ability and intensity.

Keywords: Genotypic correlation; Sugarcane genotypes; Gibberellic acid; Flowering intensity.

Introduction

The flowering of sugarcane genotypes and their abundance or intensity is most important for breeders to conduct targeted crosses to produce new varieties with desirable commercial characteristics. In Egypt, the natural flowering of sugarcane is poor, i.e., having low intensity due to different factors such as suboptimal photoperiods, low humidity, and unstable temperature, in addition to the genetic variability among genotypes (Abu-Ellail and Mohamed 2020; Abu-Ellail and McCord 2019). Under natural flowering in areas located far from the Equator, breeders mostly get poor and variable flowering, poor seed setting, and little amounts of fuzz collected from the arrows

(flowers) of sugarcane after pollination (Ishaq and Olaoye 2014; Moore and Nuss 1987). The physiological process of sugarcane flowering is complex and comprises several developmental stages, each of which has its own specific physiological and environmental requirements. Therefore, the flowering processes are not constant. Fluctuations in flowering intensity in the field occur due to the deviation in minimum temperature, rainfall, light hours, and maturity of the plant in the inductive period. Moreover, for sugarcane to flower, minimum physiological maturity is required, where canes should be about 75 days old or have developed 3–4 naked internodes (Ahmed et al. 2019; Shanmugavadivu and Rao 2009).

Organic substances known as plant growth regulators (PGRs) are required in small doses to alter the processes of plant growth and development (Solaimalai et al. 2001). According to Bendigeri (1986) and Praharaj et al. (2017), these growth regulators are employed to promote sugar accumulation in cane stalks and produce elongation of upper nodes, which is required for flowering to begin. It has been proposed to use plant growth regulators in an effort to enhance sugarcane flowering. Therefore, it may be possible to improve sugarcane flowering by using plant growth regulators like gibberellic acids. According to research by Nguyen et al. 2019; El-Maghraby et al. 2008; Li and Solomon 2003 and others, gibberellins control growth and have an impact on a variety of developmental processes, such as stem elongation, flowering, leaf expansion, and tiller numbers. Spraying GA_3 on canes resulted in improved flower production and maximum plant height (Sure et al. 2012). The stalk diameter and flowering intensity of sugarcane treated with GA_3 increased significantly (Praharaj et al. 2017). Using two different sugarcane cultivars (G.T.54-9 and Co 413), El-Maghraby et al. (2008) investigated the effects of three GA_3 concentrations (0, 500, and 1000 ppm) on the ability to flower. They found that flowering percentages increased throughout the different flowering stages as GA_3 concentrations increased from zero to 1000 ppm when applied during the initiation phase.

Correlation coefficients alone may not always be a reliable breeding tool because they only offer one-dimensional information, ignoring significant and intricate relationships between plant traits (Kang 1994). Many researchers have studied genotypic correlations between different flowering traits in sugarcane. Abu-Ellail and Mohamed (2020); Abu-Ellail and MecCord (2019), and Tahir et al. (2014) studied the interrelationship between flowering

and its components in sugarcane and concluded that selection for stalk diameter, stalk length, tiller numbers, and flowering percent should be emphasized in sugarcane varietal development programs where high flowering stalks are the primary goal. The objective of the current study was to evaluate the flowering ability, intensity, and growth parameters of twenty genotypes treated with gibberellic acid under natural conditions. Also, to determine the genetic divergence among sugarcane genotypes using cluster analysis and to detect the promising flowering sugarcane genotypes using a GT biplot diagram and genotypic correlation among flowering traits.

Materials and methods

Two field experiments were carried out at El-Sabahia Research Station, Agricultural Research Center, (31° 12' 54" N and 29° 58' 23" E), Alexandria, Egypt in 2020/2021 and 2021/2022 seasons to study the effects of three concentrations of gibberellic acid (GA_3) ($C_{19}H_{22}O_6$) on flowering ability and intensity of 20 sugarcane genotypes (Table 1) under natural conditions. Gibberellic acid was dissolved in 5 ml ethanol and diluted with water to reach the studied concentrations (0, 50 and 100 $mg\ l^{-1}$) in 25 liters. Plants in each experimental pot were sprayed with 25 l of prepared GA_3 using a knapsack sprayer after 120 days from planting. To provide an equal mist, sprayer nozzles were adjusted to the finest setting. Plants were sprayed until the run-off point with the GA_3 solution applied to both the upper and lower surfaces of the leaves, with 1 ml^{-1} of Tween 20 as a surfactant to improve the efficiency of the foliar spray. Spraying was done every morning at 8 A.M. at the same time, the control treatment was sprayed with 1 ml^{-1} of tap water containing Tween 20. With three replications, a randomized complete block design was applied. Three-budded cuttings of each

Table 1. Origin of evaluated sugarcane genotypes

Genotype	Origin	Genotype	Origin
SP 59-56	Brazil, Sao Paulo	L62-96	USA (Louisiana)
Co 214	India, Coimbatore	Nco 339	South Africa (Natal)
CP 72-35	USA (Florida, Canal Point)	Co 775	India, Coimbatore
Co 662	India, Coimbatore	Co1129	India, Coimbatore
CP 57-614	USA (Florida, Canal Point)	Co 281	India, Coimbatore
CP 63-46	USA (Florida, Canal Point)	CP 43-44	USA (Florida, Canal Point)
Co 475	India, Coimbatore	CP 63-588	USA (Florida, Canal Point)
CP 31-294	USA (Florida, Canal Point)	CP 63-33	USA (Florida, Canal Point)
MEX2001-80	Mexico	CP 48-103	USA (Florida, Canal Point)
H86.37	USA, Hawaii	CP 44-105	USA (Florida, Canal Point)

Table 2. Day length in the natural flowering condition at Sabahia Station in Alexandria

Date	August	September	October	November	December
1	13:39:15	12:48:15	11:52:16	10:56:30	10:16:39
2	13:37:50	12:46:26	11:50:24	10:54:51	10:15:47
3	13:36:24	12:44:37	11:48:31	10:53:13	10:14:58
4	13:34:57	12:42:47	11:46:39	10:51:36	10:14:10
5	13:33:29	12:40:57	11:44:47	10:50:00	10:13:25
6	13:32:00	12:39:07	11:42:55	10:48:25	10:12:42
7	13:30:29	12:37:16	11:41:03	10:46:51	10:12:02
8	13:28:58	12:35:25	11:39:11	10:45:19	10:11:24
9	13:27:25	12:33:34	11:37:19	10:43:47	10:10:49
10	13:25:51	12:31:43	11:35:28	10:42:17	10:10:16
11	13:24:17	12:29:51	11:33:37	10:40:48	10:09:46
12	13:22:41	12:27:59	11:31:46	10:39:20	10:09:18
13	13:21:05	12:26:07	11:29:56	10:37:53	10:08:53
14	13:19:27	12:24:15	11:28:06	10:36:28	10:08:31
15	13:17:49	12:22:23	11:26:16	10:35:04	10:08:11
16	13:16:10	12:20:30	11:24:27	10:33:42	10:07:54
17	13:14:30	12:18:38	11:22:38	10:32:21	10:07:40
18	13:12:49	12:16:45	11:20:49	10:31:02	10:07:28
19	13:11:08	12:14:52	11:19:01	10:29:45	10:07:19
20	13:09:25	12:12:59	11:17:13	10:28:29	10:07:13
21	13:07:43	12:11:06	11:15:26	10:27:15	10:07:10
22	13:05:59	12:09:13	11:13:40	10:26:03	10:07:09
23	13:04:15	12:07:20	11:11:54	10:24:52	10:07:12
24	13:02:30	12:05:27	11:10:08	10:23:44	10:07:16
25	13:00:45	12:03:34	11:08:23	10:22:37	10:07:24
26	12:58:59	12:01:41	11:06:39	10:21:32	10:07:34
27	12:57:13	11:59:48	11:04:56	10:20:29	10:07:48
28	12:55:26	11:57:55	11:03:13	10:19:29	10:08:03
29	12:53:39	11:56:02	11:01:31	10:18:30	10:08:22
30	12:51:51	11:54:09	10:59:50	10:17:34	10:08:43
31	12:50:03		10:58:09		10:09:07

genotype were planted in a plot with a 15 m² area, three ridge plots, and ridge distances of 1 m between each ridge. This was done in the middle of March 2020. All recommended agricultural practices were followed to raise the crop for normal growth and development during 2020 to 2022. Induction of flowering took place in September, as day length ranges between 11:54 and 12.48 hours at Sabahia Station in Alexandria under natural

flowering environments, as shown in Table 2. Furthermore, as illustrated in Figures 1 and 2, temperature and relative humidity promoted flowering.

The following data on flowering and growth traits were recorded:

1. Plant height (cm) measured from soil surface to the visible dewlap.

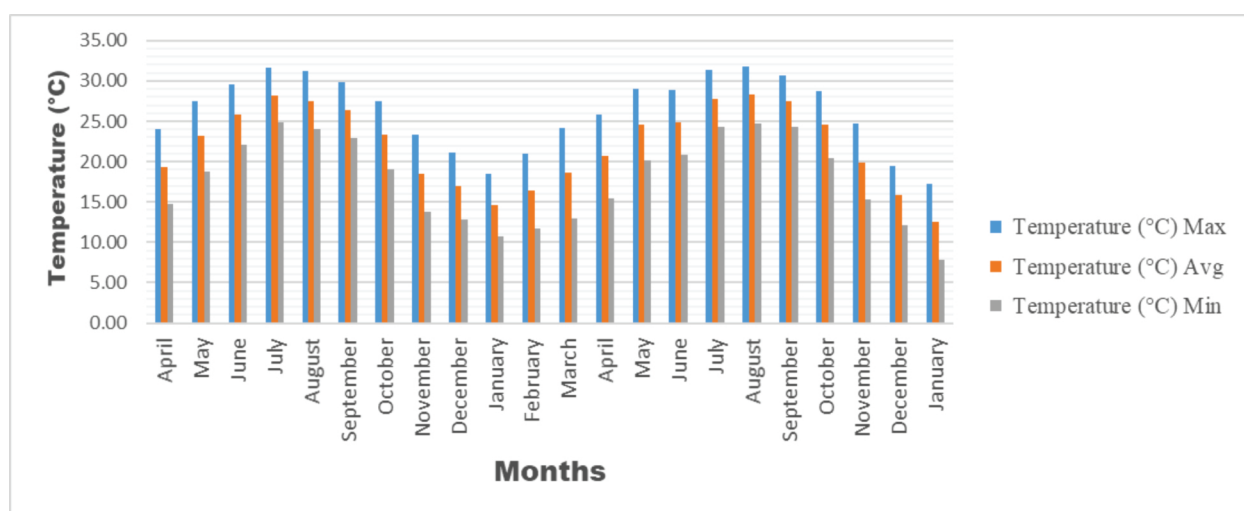


Figure 1. Temperature in Alexandria during plant cane (2020/2021) and first ratoon (2021/2022).

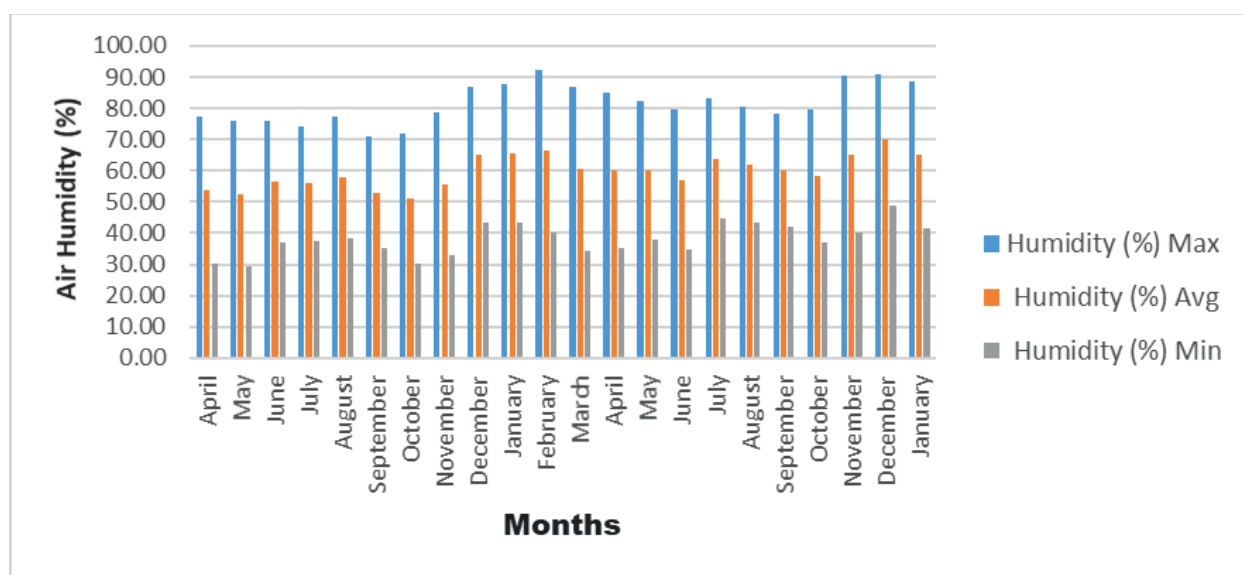


Figure 2. Relative humidity % in Alexandria during plant cane (2020/2021) and first ratoon (2021/2022)

2. Plant diameter (cm) measured as the stalk diameter of all the plants per plot at the fifth internode in the middle of the stalk.
3. Tiller numbers obtained by counting primary, secondary, and tertiary shoots of each plant at the age of 6 months.
4. Leaf area index (LAI) calculated according to Hall et al. (1993) as an equation:

Leaf area index = leaf area per plant/ground area occupied by the plant.

5. Development stage was determined as the number of days between the peak flowering period (September 5, when day lengths vary from 12.41 to 12.15 h) and the end of leaf growth and the start of flag leaf development, according to Abu-Ellail and McCord (2019).
6. Flag leaf stage calculated as the number of days from the start of flag leaf production and the time the inflorescence first emerged from the flag leaf sheath.
7. Tip emergence stage calculated as the number of days between the appearance of the flag leaf sheath and the start of inflorescence emergence.
8. Full emergence stage calculated as the number of days between the inflorescence's tip emergence and its full expansion.
9. Number of genotypes flowered and non-flowered under each level of gibberellic acid was count.
10. Percent of total flowering calculated as an equation:

Number of flowered plants / Number of plants per plot $\times$ 100

Statistical analysis

Each season's data subjected to a variance analysis.

Before doing the combined analysis, the assumption of homogeneity of variances was tested using Bartlett's homogeneity across the two seasons to test significance of differences among the twenty sugarcane genotypes. These analyses were conducted by using SPSS software (version 15). A measure of similarity levels and Euclidean distance were used in the cluster analysis (Everitt 1993). The genotype by trait (GT) biplot, by Yan and Rajcan (2002), was utilized to analyze the genotype by trait data. The significance of genotypic correlation coefficient was tested according to Robertson (1959).

Results and discussion

Effects of gibberellic acid on growth traits

Combined analysis of variance over the two seasons (Table 3) revealed that all studied growth traits of sugarcane increased significantly with increasing gibberellic acid levels. Raising the applied level of gibberellic acid to 50 and 100 mg l⁻¹ increased cane stalk height and diameter by (24.32 and 44.25 cm) and (0.26 and 0.46 cm), compared to that of the untreated canes, respectively. Similarly, Yadav et al. (2016) found that as the applied gibberellic acid levels were increased, the stalk height increased as well. According to Patel and Chaudhary (2003), one of the benefits of gibberellic acid given in the right amounts is an extended stem diameter, which could account for the increase in stalk height reported: "Gibberellic acid was observed to show a hyponastic response as a result of increased cell elongation." Gibberellic acid concentrations application also showed statistical differences ($P \leq 0.05$), with 100 mg l⁻¹ being superior in growth traits like tillers numbers and leaf area index, with an enhancement with of 8.38 and 4.75%, respectively. These values were significantly higher than the zero ppm as control by

Table 3 Effect of gibberellic acid on Growth traits of twenty sugar cane genotypes under natural flowering during combined two seasons (2020/2021 and 2021/2022).

Sugarcane Genotypes	Stalk height (cm)		Stalk diameter (cm)				Tillers number				LAI					
	GA ₃ levels (mg l ⁻¹)		GA ₃ levels (mg l ⁻¹)				GA ₃ levels (mg l ⁻¹)				GA ₃ levels (mg l ⁻¹)					
	0	50	100	Mean	0	50	100	Mean	0	50	100	Mean	0	50	100	Mean
SP59-56	211.3	224.3	259.0	231.6	2.4	2.6	2.6	2.5	5.61	7.26	8.12	7.00	1.97	2.40	3.56	2.64
CO.214	221.0	239.7	262.0	240.9	2.0	2.0	2.3	2.1	6.22	6.93	7.83	6.99	2.30	3.30	4.74	3.45
CP72-35	255.3	223.7	276.0	251.7	1.8	2.0	2.2	2.0	5.33	6.48	7.22	6.34	2.00	2.29	3.25	2.51
CO.662	206.0	277.0	302.7	261.9	2.3	2.5	2.8	2.5	6.66	7.67	8.33	7.55	6.35	6.48	7.22	6.68
CP57-614	233.0	256.7	281.0	256.9	1.8	2.2	2.4	2.2	7.48	8.49	9.78	8.58	6.11	7.26	8.12	7.16
CP.63-46	153.7	211.0	241.7	202.1	1.7	1.8	2.2	1.9	4.88	5.83	7.28	6.00	6.93	6.99	7.83	7.25
CO475	205.3	224.3	245.3	225.0	1.8	2.0	2.4	2.1	5.33	6.78	8.55	6.89	1.85	2.22	3.31	2.46
CP.31-294	247.3	270.7	287.7	268.6	2.0	2.2	2.4	2.2	6.07	7.55	7.78	7.13	2.10	2.41	3.14	2.55
MEX2001-80	242.3	259.0	277.3	259.6	1.9	2.1	2.4	2.1	7.15	8.22	8.72	8.03	2.31	3.33	4.31	3.32
H86.37	234.7	248.3	282.3	255.1	2.0	2.1	2.2	2.1	5.34	6.11	8.44	6.63	3.10	4.22	5.36	4.23
L62-96	221.0	249.7	265.3	245.3	1.9	2.1	2.5	2.2	4.11	5.22	7.89	5.74	2.56	2.89	3.62	3.02
NCO339	196.3	235.7	253.7	228.6	2.0	2.1	2.4	2.2	4.71	5.11	6.82	5.55	2.07	3.31	4.77	3.38
CO775	200.7	212.3	244.3	219.1	2.0	2.2	2.6	2.3	7.04	7.67	8.11	7.61	2.61	3.17	4.65	3.48
CO1129	214.0	220.7	239.7	224.8	1.9	2.1	2.5	2.2	6.11	7.44	8.23	7.26	4.10	5.89	6.22	5.40
CO281	207.3	234.0	252.0	231.1	1.8	2.1	2.4	2.1	5.63	7.33	8.44	7.13	1.87	2.34	3.65	2.62
CP43-44	189.3	207.0	238.0	211.4	1.7	2.0	2.3	2.0	6.15	8.33	9.33	7.93	2.42	3.36	4.27	3.35
CP63-588	195.0	204.3	228.7	209.3	1.9	2.1	2.4	2.1	7.04	8.11	9.33	8.16	1.93	2.49	3.52	2.65
CP63-33	213.0	221.0	244.3	226.1	2.1	2.3	2.6	2.3	6.06	7.33	8.62	7.34	2.32	3.82	4.30	3.48
CP48-103	252.7	262.0	268.0	260.9	2.4	2.6	2.7	2.5	6.18	8.33	9.55	8.02	3.22	4.86	5.36	4.48
CP44-105	204.7	221.3	240.0	222.0	2.3	2.5	2.7	2.5	7.14	8.00	9.22	8.12	2.01	2.26	3.85	2.71
Mean	215.2	235.1	259.5	236.6	2.0	2.2	2.4	2.2	6.01	7.21	8.38	7.20	3.01	3.76	4.75	3.84
LSD 0.05%																
GA ₃				2.37				0.10				0.67				0.60
Genotypes				3.12				0.16				1.01				1.12
GA ₃ x G ₃				5.21				0.23				1.49				0.72

about 39.44 and 57.81 percent. Other studies (Wang et al. 2017; Benny et al. 2017) found that exogenous gibberellic acid treatments had a positive impact on the number of tillers and the size of the leaves when applied topically during the early growth stages. According to Ashraf et al. (2002) the administration of gibberellic acid resulted in an increase in all plant growth parameters.

The results revealed significant differences ($P \leq 0.05$) in growth traits between sugarcane genotypes. The average stalk length for the tallest genotype (CP.31-294) was 268.56 cm, which was significantly higher than the shortest one, genotype (CP57-614) by 66.45 cm. CP 48-103 variety was the biggest stalk diameter (2.53 cm) while the CP57-614 variety was the smallest one (1.90 cm). Meanwhile, the same smallest diameter genotype had the highest number of tillers (8.43). CP 63-46 variety recorded the highest leaf area index with a value of 7.25, while Co 662 variety had the least one (4.49). The variation in height could be a result of genetic differences in which some sugarcane varieties respond to plant growth hormones. As a result, the forty sugarcane genotypes that were tested varied greatly from one another in how they responded to flowering under GA_3 . The study is consistent with the findings of the work by Nguyen et al. (2019), which showed that the use of gibberellins caused sugarcane genotypes to grow rapidly and had an increase in their growth characteristics. Furthermore, Rai et al. (2019) and Patel and Chaudhary (2003) reported that the use of gibberellic acid-induced an increase in the height and diameter of the sugarcane genotype stalks. According to Miceli et al. (2019), Gibberellic acid administration reportedly boosted leaf development and growth.

The interaction between the tested sugarcane genotypes and gibberellic acid rates was a

significant effect on stalk length, stalk diameter, tillers number, and leaf area index. Genotype (Co 662) was recorded as the tallest stalk treated by 50 and 100 mg l⁻¹ (277.00 and 302.67 cm, respectively), while genotype (CP44-105) registered the biggest diameter under 50 and 100 mg l⁻¹ (2.52 and 2.67 cm). Furthermore, genotype (CP57-614) recorded the highest tillers number and leaf area index (8.49 and 9.78) (7.26 and 8.12) under 50 and 100 mg l⁻¹, however, the lowest value was recorded under zero mg l⁻¹ of GA_3 . These results indicated that sugarcane genotypes behaved differently when they were exposed to different gibberellic acid levels. Gibberellic acid concentration of 100 mg l⁻¹ was the most superior increasing however, at zero mg l⁻¹ of GA_3 (control) which was the lowest level of application had the least growth traits at all stages which is an indication that application of sufficient levels of GA_3 influences growth of sugarcane. According to Mesejo et al. (2016), who showed a difference in the response of the stalk growth (width and height) and tillers number, there is interaction diversity in how sugarcane genotypes respond to the administration of gibberellic acid. The results showed that one of the causes of the increase in stem diameter was due to gibberellic acid, which is linked to growth stimulation during the vegetative phase (Gad et al. 2016). According to Ren Gao and Chen (2007), gibberellins' capacity to improve sink strength may be related to their effect on leaf growth.

Effects of gibberellic acid on flowering traits

The results of the combined analysis of variance over the two seasons in (Table 4) show significant differences between gibberellic acid levels for all traits. Increasing the concentration of gibberellic acid was decreasing the days needed to reach all flowering stages. Concerning results of gibberellic acid (GA_3) concentration, it was noted that the

Table 4 Effect of gibberellic acid on Flowering traits of twenty sugar cane genotypes under natural flowering during combined two seasons (2020/2021 and 2021/2022).

Genotypes	Development stage (days)				Flag leaf stage (days)				Tip stage (days)				Emergence stage (days)			
	GA ₃ Levels (mg l ⁻¹)		Mean		GA ₃ Levels (mg l ⁻¹)		Mean		GA ₃ Levels (mg l ⁻¹)		Mean		GA ₃ Levels (mg l ⁻¹)		Mean	
	0	50	100	100	0	50	100	100	0	50	100	100	0	50	100	100
SP59-56	118.00	113.33	109.67	113.67	125.67	122.00	117.33	121.67	127.50	125.33	123.50	125.44	128.67	127.67	125.33	127.22
CO.214	-	-	143.00	143.0	-	-	154.67	154.6	-	-	161.50	161.5	-	-	162.33	162.3
CP72-35	119.00	117.00	113.00	116.33	137.67	136.00	135.33	136.33	145.00	145.00	144.00	144.67	161.67	151.67	145.67	153.00
CO.662	106.00	104.00	102.00	104.00	130.33	129.00	127.67	129.00	139.00	137.50	133.50	136.67	144.67	143.00	141.33	143.00
CP57-614	-	-	127.67	127.6	-	-	135.67	135.6	-	-	145.00	145.0	-	-	161.67	161.6
CP.63-46	81.33	80.00	79.67	80.33	96.33	93.00	91.67	93.67	110.00	108.00	105.50	107.83	123.67	120.33	118.33	120.78
CO475	-	110.33	105.00	107.67	-	-	119.00	119.0	-	-	132.00	132.0	-	-	137.00	137.0
CP.31-294	139.33	134.00	77.00	116.78	-	103.67	78.67	91.17	-	151.33	93.67	122.50	-	152	154.00	153.00
MEX2001-80	66.33	61.00	56.67	61.33	91.33	88.33	81.00	86.88	94.00	91.50	81.33	88.94	99.33	96.33	93.67	96.44
H86.37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L62-96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NCO339	147.33	143.00	141.00	143.78	159.33	152.67	150.67	154.22	167.00	163.50	160.00	163.50	174.00	171.67	169.67	171.78
CO775	133.67	84.67	74.33	97.56	156.67	83.33	81.33	107.11	165.67	84.50	81.33	110.50	-	-	178.00	178.0
CO1129	83.00	79.00	76.00	79.33	102.33	99.67	98.00	100.00	108.00	105.50	103.00	105.50	120.00	118.00	110.00	116.00
CO281	98.00	93.33	91.67	94.33	109.00	105.50	103.67	106.06	114.50	109.50	107.00	110.33	125.67	122.00	119.67	122.45
CP43-44	143.67	141.00	139.00	141.22	-	147.00	144.50	145.75	-	-	150.50	150.5	-	-	-	-
CP63-588	102.33	98.00	95.33	98.55	141.50	136.50	134.00	137.33	-	131.50	135.00	133.25	151.00	149.67	145.67	148.78
CP63-33	-	146.67	137.33	142.00	-	-	147.67	147.6	-	-	-	-	-	-	-	-
CP48-103	-	-	149.0	149.0	-	-	-	-	-	-	-	-	-	-	-	-
CP44-105	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Responded	12	14	17	14.33	10	12	16	12.67	9	11	15	11.67	9	10	14	11.00

LSD 0.0 5%

GA₃

Genotypes

GA₃ × G₄

2.29

3.46

5.14

2.75

3.16

3.88

1.58

1.46

3.00

highest application (100 mg l⁻¹) decreased the number of days required for the beginning of the development stage and the rest of the stages i.e. flag, tip, and full emergency required after (September 5, day length = from 12.41 to 12.15 h). Compared to the lowest application of zero mg l⁻¹ of GA₃ concentration the number of days needed to reach the development stage, flag leaf, tip, and full emergence stages was increased. The successfully induced flowering followed by the application of gibberellic acid (GA₃) for increased flowering initiation (Bora and Bohra 1989). Gibberellins control growth and have an impact on a number of developmental processes, including stem elongation, blooming, leaf growth, and the induction of flowering enzymes (Vishwakarma 2010). The response of plants in terms of growth and development are determined by this regulator's concentration and the sensitivity of plant tissue to this molecule (Buchanan et al. 2015). These results are in a harmony with those of Julien (1969), who studied the effect of gibberellic acid (GA₃) on sugarcane flowering and suggested that there are two metabolic pathways for the action of GA₃, one for growth and the other for floral initiation.

Data in Table 4 indicated that sugarcane genotypes behaved differently when they were exposed to different gibberellic acid levels. The number of flowering genotypes increased with increasing gibberellic acid (100 mg l⁻¹ GA₃) concentrations compared with the control (zero GA₃). The MEX2001-80 genotype was the earliest flowering compared to the last NCo339 genotype during the different flowering stages, where the mean percentage of days to the development stage, flag stage, tip stage, and full emergence stage decreased by about 57, 43, 44, and 44%, respectively. Sugarcane genotypes differ in flowering, and other attributes owing to genotypic differences between

genotypes. Flowering shows a range of variations among the genotypes (Yoder 2001).

These differences between tested varieties may be due to the variation in genetic constitution of the tested varieties. These differences in flowering cane varieties may be also due to the differences in the concentration of flowering substance as denoted by Vijayasradhy and Narasimhan (1953). According to Cobas et al. (1984), Correa et al. (1972) found that in sugarcane varieties, levels of gibberellin-like substances were found in the apices of plants that had been induced to flower. This suggests that the reason for the variations in flowering stages could be attributed to increased GA₃ application. The interaction between sugarcane genotypes and gibberellic acid (GA₃) concentration in the combined two seasons had a significant effect during the four measured flowering stages. The most effective interaction between genotypes and GA₃ concentration was on the genotype MEX2001-80, which achieved the lowest values of responded days to reach the flowering stages with 100 mg l⁻¹ of GA₃ concentration 56.67, 81.33, 81.00, and 93.67 days during development, flag, tip, and full emergence stage, respectively. To better utilize these resources in breeding programs, it is necessary to study the breeding germplasm in order to identify such a reaction. These results are consistent with those of Rizk et al. (2002), who reported that, according to their findings; the pre-flag leaf stage lasts much longer than the other flowering stages because it includes the time needed for the meristem to be diverted from producing leaves to producing flowerers. Additionally, some sugarcane genotypes had high GA₃ concentrations that were very favorable to growth and improved the flowering apices of sugarcane plants and also showed significant flowering activity (Moore et al. 1986).

Effects of gibberellic acid on flowering intensity

The flowering behavior of 20 sugarcane genotypes, when treated with different gibberellic acid levels, is presented in Table (5). The flowering percentage increased with increasing GA_3 concentration levels. Results indicated that the percent (%) of total flowered genotypes was significant under 0 mg l^{-1} GA_3 reaching 45%, whereas the percentage of total flowered genotypes under the first 50 GA_3 reached 50%, while the highest levels of GA_3 100 mg l^{-1} recorded the highest flowering percentage genotypes (70%). An effective hybridization program needs genotype or species floral intensity as well as timely and profuse flowering (Sujatha et al. 2018; Ren 2007).

Data in Table 5 show the sugarcane genotype's inconsistent flowering behavior and intensity under zero gibberellic acid (GA_3) concentration, in

subtropical climates like Alexandria,. Therefore, unless the flowering dates are delayed and the intensity is managed with GA_3 , it becomes challenging to flower. Results indicated that the flowering date decreased with increasing GA_3 concentration. Under 100 mg l^{-1} GA_3 concentration, some genotypes exhibit early flowering than normal (MEX2001-80, Co 1129, and CP 63-46, respectively), and some are mid-flowering (SP59-56, Co 475, and Co 662, respectively) and some are late (Co 775, Nco 339 and Co 214, respectively) most of these genotypes were nil flowering under normal. Results are consistent with Moore et al. (1986), and El-Maghraby et al. (2008) who found a significant flowering intensity was attained with some sugarcane genotypes within GA_3 concentrations highly favorable to growth and may enhance flowering apices of sugarcane plants.

Table 5. Flowering intensity percentage and distribution of the treated sugarcane genotypes according to their flowering response under GA_3 concentrations

Genotype No.	Not flowering	Flowering under $GA_3\text{ }30\text{ mg l}^{-1}$	Flowering under $GA_3\text{ }50\text{ mg l}^{-1}$	Flowering under $GA_3\text{ }100\text{ mg l}^{-1}$
1	H86.37	SP 59-56	SP 59-56	SP 59-56
2	L62-96	CP 72-35	CP 72-35	Co 214
3	CP 43-44	Co 662	Co 662	CP 72-35
4	CP 63-33	CP 63-46	CP 63-46	Co 662
5	CP 48-103	MEX2001-80	CP 31-294	CP 57-614
6	CP 44-105	NCo 339	MEX2001-80	CP 63-46
7		Co 1129	NCo 339	Co 475
8		Co 281	Co 1129	CP 31-294
9		CP 63-588	Co 281	MEX2001-80
10			CP 63-588	NCo 339
11				Co 775
12				Co 1129
13				Co 281
14				CP 63-588
Total	6	9	10	14
Flowering intensity	30%	45%	50%	70%

Cluster analysis (CA): flowering under different concentrations of GA₃.

Figure 3 shows how cluster composition is generated. The genotype distribution pattern

distance (252.66). Clusters 1 and 3 were found to have the smallest distance (150.61), implying that proving their close relationship would not produce the intended results.

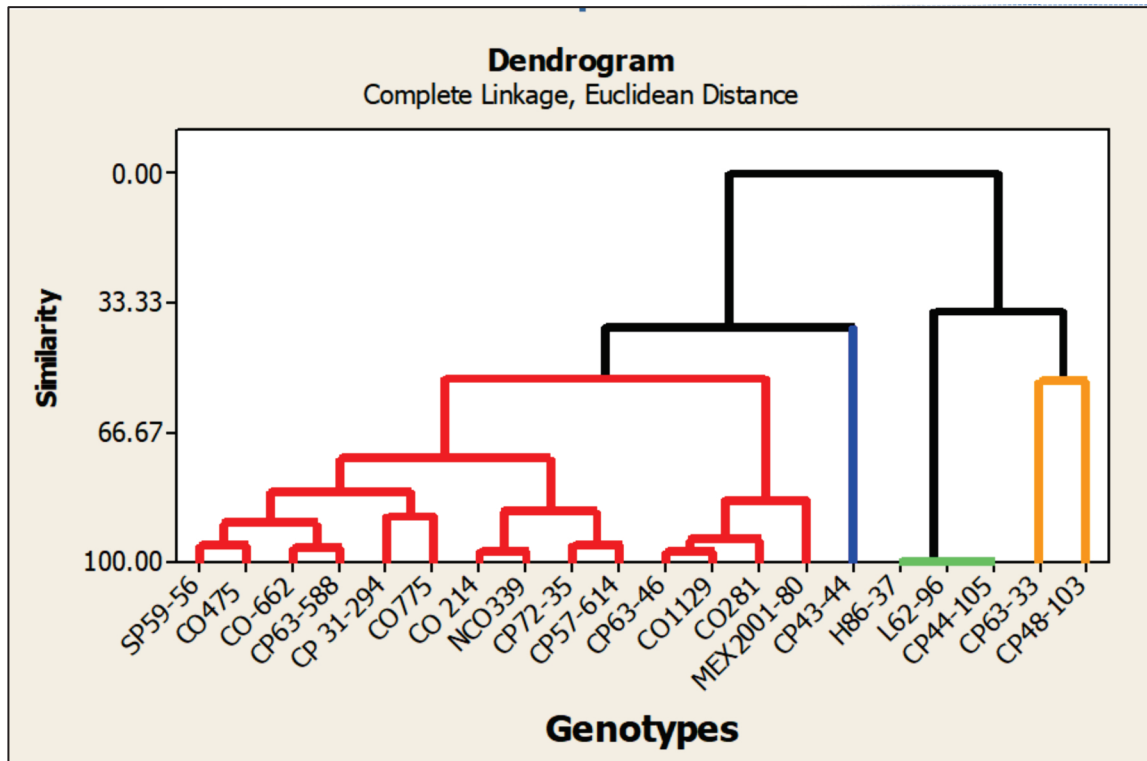


Figure 3. Dendrogram showing the distance among twenty sugarcane genotypes based on flowering ability percent and its related attributes.

revealed that cluster 1 had the most genotypes (14) followed by clusters 2 and 3, which each had three and two genotypes, respectively, and then cluster 4, which had the fewest genotypes (one). Items are arranged according to their inter- and suggestions. Based on flowering statistics, Table 6 indicated that twenty sugarcane genotypes were divided into four clusters, with the distances between genotypes within a cluster varying from 0.00 to 81.60. The clusters 2 and 3 had the maximum inter-cluster

Four different clusters were formed from the sugarcane genotypes. Based on Euclidean distance, the examined genotypes in the current study were distinguished as shown in Figure 3. and calculated blooming and its related features. The mean values for the flag leaf, emergence, development, and tip stages were: Cluster 4 had the greatest pre-flag stage value (145.5 days), whereas Cluster 2 had the lowest value (0.00 days). The development stage of Cluster 4 is superior to the

Table 6. Distance between cluster centroids for genotypes were treated by GA₃ for flowering

No.	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Cluster 1	0.000			
Cluster 2	249.09	0.000		
Cluster 3	150.60	252.66	0.000	
Cluster 4	200.45	163.15	166.87	0.000

other three Clusters because it began 39.48, 145.5, and 4.28 days earlier than Clusters 1, 2, and 3, respectively in the pre-flag stage. According to the results, Cluster 3 had the best value for the flag stage (145.75 days), while Cluster 2 had the worst value (0.00 days). Additionally, Cluster 3 has a better tip emergence stage than the other three Clusters. While Clusters 2 and 4 recorded the lowest value (0.0 days), Cluster 3 recorded the longest amount of time (150.50 days) at the tip emergence stage. Additionally, the results showed that Cluster 1 recorded the highest value of full emergence (142.24 days), whereas Clusters 2, 3, and 4 recorded the lowest value of this attribute (0.0 days). In addition, it was shown that Cluster 1's dominance in longevity is mostly attributable to its supremacy in the entire emergence stage. According to Cordeiro et al. (2003), the sugarcane germplasm was varied. When tested on 30 or 40 sugarcane varieties, Ahmed and Khaled (2009) discovered similarities ranging from 0.324 to 0.834.

Sugarcane Genotypes by GA₃ treatments (GT) biplot graph

Results shown in Figure 4, where the polygon view of a genotype by treatments (GT) biplot graph demonstrates that, for the sugar cane dataset of flowering, the GT biplot explained 99.25% of the total variation in the combined seasons. The entire emergence (flowering) dataset was explained by the two PCs (PC1 and PC2) in 90.43 and 8.86% of the cases, respectively. This comparatively high percentage shows how well the GT biplot graph explains how the genotypes of sugar cane responded to the blooming treatments over the course of the combined trial years. The polygon view of the GT biplot can be used to identify the genotypes with good flowering responsibility for one or more GA₃ treatments. Results revealed that genotype MEX2001-80 had the earliest blooming

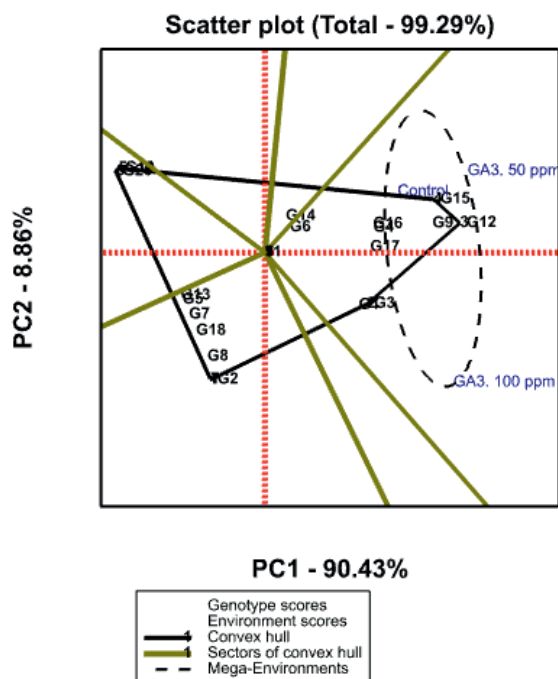


Figure 4. Polygon view of genotype (G1 to G20) × treatments (GA₃) biplot of twenty sugar cane genotypes for flowering at the combined of (1st and 2nd season)

(96.44 days) across all GA₃ concentration treatments, followed by genotype Co1129 (116 days) and genotype CP 63-46 (120.7 days). These findings concur with those of Ober et al. (2005) and Korshid (2016), who discovered that genotype trait biplots (GT) demonstrated superior genotypes with comparatively stronger expression of combinations of advantageous characteristics. The findings imply that blooming and GA₃ concentration patterns may be used to distinguish early sugar cane genotypes. These data would help to create techniques for indirectly identifying sugarcane genotypes that are most adapted to flowering in Alexandria's native agro climate.

Genotypic interrelationships for flowering traits

The genotypic correlation coefficient (r_g) among various traits calculated across two seasons is presented in Table 7. Correlations between certain stalk-related traits (stalk length, stalk diameter, and

tillers number), and leaf area index were negative and significant except for flowering traits (development stage, flag leaf stage, tip emergence stage, full emergence stage, and flowering percentage) which were positive and significant. The correlation between stalk diameter and tillers number agreed with the data of Milligan et al. (1990), who found the correlation between stalk diameter and stalk numbers was negative and significant. A positive and significant correlation was found between all flowering traits studied (development stage, flag leaf stage, tip emergence stage, and full emergence stage) and flowering percent (Table 7). Genotypic correlation indicated that emphasis should be given to the selection for the development stage, flag leaf stage, and tip emergence to improve flowering percentage. Kang et al. (1983) concluded that an artificial correlation

tended to inflate the relative importance of traits that may not be far from reality because were determined independently. Several researchers reported genotypic correlations among sugar cane traits. However, Milligan (1990) showed that the genetic variance and covariance of traits changed with selection. Thus, accurate variance-covariance estimates should be selection- stage specific. Therefore, our results of trait interrelationships may be similar or different, higher or lower than those reported from other studies. Kang et al. (1983), Milligan et al. (1990), Abu-Ellail (2015) and Tahir et al. (2014) concluded differences of correlation among studies because of differences in the degree of prior selection in the population, and differences in the environmental conditions among the studies.

Table 7. Genotypic interrelationships among different flowering traits in sugarcane genotypes

Traits	ST	SD	TN	LAI	DS	FLS	TES	FES
Stalk diameter	0.117**							
Tiller numbers	0.243**	0.733**						
Leaf area index	-	0.029**						
	0.136**		0.317**					
Development stage	0.268**	-	0.598**					
		0.637**		0.601**				
Flag leaf stage	0.234**	-	-	0.254**				
		0.052**	0.251**		0.019			
Tip emergence stage	0.302**	-		-				
		0.025**	0.055**	0.041**	0.068**	0.738**		
Full emergence stage	0.194**	-		-				
		0.036**	0.214**	0.436**	0.176**	0.167**	0.434**	
Flowering Percent	-	0.345**	0.209**	0.106**	0.291**	0.218**	0.522**	
	0.076**							0.567**

Abbreviations Stalk height: (ST), Stalk diameter: (SD), Tiller numbers: (TN), Leaf area index: (LAI), Development stage: (DS), Flag leaf stage: (FLS), Tip emergence stage: (TES), Full emergence stage: (FES), Flowering Percent: (FP)

Conclusion

Results concluded that gibberellic acid can be used to increase flowering in sugarcane genotypes. Increase in Gibberellic acid levels resulted in increased height, tillering, stem diameter, and leaf area index. Flowering and growth traits of sugarcane genotypes were significantly increased by increasing gibberellic acid concentrations. The genotypes Mex2001-80, Co 1129, and CP 63-46 showed the best results across the majority of the studied flowering parameters. There was a significant difference in flowering traits because of the gibberellic acid application. The increase in flowering percentage was between 45% and 50% and 70% when applied at 0, 50, and 100 mg l⁻¹ of GA₃ respectively.

The genotypes of sugarcane were separated into four groups according to full flowering. Clusters 1 and 3 had the smallest distance (150.60); demonstrating the close ties between these clusters would not yield favorable results. The results showed that Cluster 1 recorded the longest period of full emergence flowering (142.24 days), while Cluster 2 recorded the shortest period (0.0 days). It was observed that the Mex2001-80 genotype's superiority in longevity is mostly due to its superiority in the emergence stage. The genotypes with good flowering responsibility for one or more GA₃ treatments can be found using the polygon view of the GT biplot. According to genotypic correlation, in order to increase flowering percentage, selection should focus on the flag leaf stage and the tip emergence stage. Further research is recommended to evaluate the flowering of more sugarcane genotypes that were previously treated with gibberellic acid.

References

- Abu-Ellail FFB, Mohamed BD. 2020. Effects of photo initiation treatments on flowering, pollen viability and seed germinability of four sugarcane clones. *Journal of Sugarcane Research*, 9 (2): 138-149.
- Abu-Ellail FFB. 2015. Breeding for yield and quality traits in sugarcane. Ph. D Thesis, Fac. of Agric., Cairo Univ., Egypt.
- Abu-Ellail FFB, McCord PH. 2019. Temperature and relative humidity effects on sugarcane flowering ability and pollen viability under natural and semi-natural conditions. *Sugar Tech.*, 21(1):83-92.
- Ahmed AZ, Khaled KA. 2009. Detection of genetic similarity of sugarcane genotypes. *Eelectronic Journal of Gene Conserve* 31 (1): 686-697
- Ahmed MF, Siddique M, Kama N, Ahmad N. 2019. Sugarcane flowering at sugarcane breeding substation (SBSS), Murree. *Haya: The Saudi Journal of Life Sciences*, 4(6): 206-212.
- Ashraf M, Karim F, Rasul E. 2002. Interactive effects of gibberellic acid (GA₃) and salt stress on growth, ion accumulation and photosynthetic capacity of two spring wheat (*Triticum aestivum* L.) cultivars differing in salt tolerance. *Plant Growth Regulation*, 36(1): 49-59.
- Batlang U, Emongor, VE, Pule-Meulenburg F. 2006. Effect of benzyladenine plus gibberellins and gibberellic acid on yield and yield components of cucumber (*Cucumis sativus* L. cv. 'tempo'). *Journal of Agronomy*, 5(3): 418-423.
- Bendigeri AV, Hapse DG, Shaikh AA, Tiwari US. 1986. Efficacy of different growth regulators and hormones on sugarcane. *Proceeding. Thirty Sixth Ann. Convention. D.S.T.A. Pune*, pp 289-296.

- Benny JC, Devi S, Fatmi U, Jose DA. 2017. Effect of plant growth regulators, Gibberellic acid (GA₃) and Naphthalene Acetic Acid (NAA) on growth and yield of carnation (*Dianthus caryophyllus* L.) under naturally ventilated polyhouse. Plant Archives, 17(2):803-812.
- Buban T. 2000. The use of benzyl adenine in orchard fruit growing: A mini review. Plant Growth Regulation, 32, 381-390.
- Buchanan BB, Gruissem W, Jones RL. (Eds.). 2015. Biochemistry and molecular biology of plants. John Wiley & sons.
- Bora KK, Bohra SP. 1989. Effect of ethephon on growth and yield of Glycine max L. Comp. Physiological Ecology. 14: 74-77.
- Cobas DB, Dathe W, Gonzalea M. 1984. The influence of gibberellic acid on the development of young sugarcane plants. Sugarcane Research Institute, Cuba; Agricultural Sciences 18: 59-69.
- Coleman RE. 1962. Control of flowering and the use of pollen storage as techniques in a sugarcane breeding programme. In Proceedings International Society Sugarcane Technologists, 11, 533-540.
- Cordeiro GM, Yong-Bao P, Robert JH. 2003. Sugarcane microsatellites for the assessment of genetic diversity in sugarcane germplasm. Plant Science 165(1): 181-189.
- Correa NS, Perez-Antich E, Antoni H. 1972. A preliminary study of gibberellin-type substances in sugarcane apices and their relationship to photoperiodic induction. Revista Industrial y Agrícola. De Tucuman. 49(1): 1-11.
- Daniels J, Roach BT, Heinz DJ. 1987. Sugarcane improvement through breeding. Elsevier, Amsterdam, 313-342.
- El-Maghraby SS, El-Banna MN, El-Kady MS. 2006. Effects of GA₃ concentration on flowering of some sugarcane varieties. Conference: Proc. of Int. Conf. Meeting the Challenges of Sugar Crops and Integrated Industries in Developing Countries, Al Arish, Egypt, PPS-79.
- Emami H, Saeidnia M, Hatamzadeh A, Bakhshi D, Ghorbani E. 2011. The Effect of gibberellic acid and benzyladenine on growth and flowering of Lily (*Lilium longiflorum*). Advances in Environmental Biology 5(7):1606-1611.
- Everitt BS. 1993. Cluster analysis, 3rd edn. Edward Arnold, London
- Gad MM, Abdul-Hafeez EY, Ibrahim OHM. 2016. Foliar application of salicylic acid and gibberellic acid enhances growth and flowering of *Ixora coccinea* L. plants. International Journal of Plant Production, 7(1): 85-91.
- Hedden P, Thomas SG. 2012. Gibberellin biosynthesis and its regulation. Biochemical Journal, 444(1), 11-25.
- Hodges T. 1991. Temperature and water stress effects on phenology. In: Hodges, T., ed. Predicting crop phenology. Boca Raton, Florida: CRC Press, 7-13.
- Ishaq MN, Olaoye G. 2014. Effect of climate variability on sugarcane breeding in Nigeria. Nigerian Agricultural Journal, 45(1):37-45.
- Julien MHR. 1973. Physiology of flowering in *Saccharum*: I. Daylength Control of Floral Initiation and Development in *S. Spontaneum* L. Journal of Experimental Botany, 24(3):549-557.

- Julien MHR .1969. Investigation on the physiology of flowering. Republic of Mauritius Sugar Industry Research Institute 18: 45-53.
- Kang MS. 1994. Applied quantitative genetics. Kang Publ. Baton Rouge, LA, USA. pp157.
- Kang MS, Miller JD, Tai PYP. 1983. Genetic and phenotypic path analysis and heritability in sugarcane. *Crop Science*, 23: 643-651.
- Kanwar K, Kanwar RS. 1986. Effect of gibberellic acid on sugarcane genotypes. *Indian Sugar*. 36(2):65-66.
- LaBorde C, Kimbeng C, Gravois K, Bischoff K. 2014. Temperature effects on sugarcane tassel production under artificial photoperiod regimes. *Journal of American Society of Sugar Cane Technologists*, 34, 33-43.
- Li Y, Solomon S. 2003. Ethephon: a versatile growth regulator for sugar cane industry. *Sugar Tech*, 5(4):213-223.
- Mesejo C, Yuste R, Reig C, Martínez-Fuentes A, Iglesias DJ, Muñoz-Fambuena N, Agustí M. 2016. Gibberellin reactivates and maintains ovary-wall cell 80 division causing fruit set in parthenocarpic Citrus species. *Plant Science*, 247, 13-24.
- Miceli A, Moncada A, Sabatino L, Vetrano F. 2019. Effect of gibberellic acid on growth, yield, and quality of leaf lettuce and rocket grown in a floating system. *Agronomy*, 9(7):382.
- Milligan SB, Gravois KA, Bischoff KP, Martin FA. 1990. Crop effect on genetic relationships among sugarcane traits. *Crop Science*, 30: 927-931.
- Mohammad, F.H., S. Anwar and Z. Hussain 2006. Economics of sugarcane production in Pakistan: A Price Risk Analysis, *International Research Journal of Finance and Economics*.
- Moore PH, Pharis RP, Yoshika M. 1986. Gibberellins in apical shoot meristems of flowering and vegetative sugarcane. *Journal of Plant Growth Regulation*. 5(2): 101-109.
- Nguyen CT, Dang LH, Nguyen DT, Tran KP, Giang BL, Tran NQ .2019. Effect of GA₃ and Gly plant growth regulators on productivity and sugar content of sugarcane. *Agriculture*, 9(7):136.
- Patel D, Chaudhary MP. 2003. Influence of plant growth regulators on growth, yield and quality of sugarcane under south Gujarat. Rangaswamy R. *A Textbook of Agricultural Statistics*. 496 pp.
- Patel RG, Mankad AU. 2014. Effect of gibberellins on seed germination of *Tithoniarotundifolia* Blake. *International Journal of Innovative Research in Science, Engineering and Technology*, 3(3): 10680-10684.
- Praharaj S, Singh D, Guru SK, Meena BR. 2017. Effect of plant growth regulators on tiller dynamics and yield of sugarcane (*Saccharum officinarum*). *International Journal of Bio-resource and Stress Management*. 8(1):75-78.6.
- Rai RK, Tripathi N, Gautam D, Singh P. 2017. Exogenous application of ethrel and gibberellic acid stimulates physiological growth of late planted sugarcane with short growth period in sub-tropical India. *Journal of Plant Growth Regulation*, 36(2): 472-486.

- Rao GN, Rao NVM, Rao PH. 1960. Preliminary note on the effect of gibberellic acid on growth and tillering of sugarcane. *Ind. Jour. of Sugarcane Res.* 4(3):148.
- Rao JT, Nour AH, El-Manhaly MA .1973. Flowering of sugarcane in Egypt. *International Sugar Journal*, 75: 241 -244.
- Ren Gao, Chen. 2007. Effects of three growth regulators on growth and sucrose accumulation in sugarcane. *Journal of Guangxi Academy of Agricultural Sciences*, 9(4): 35-43.
- Rizk TY, Khalil HA, Nosaer HM. 2002. Photoperiodic response of five locally developed sugarcane varieties. *Arab Universities journal of Agriculture Science*, 10(2):619-627.
- Sartoris GB. 1939. The behavior of sugarcane in relation to length of day. *Proceedings of International Society of Sugar Cane Technologists* 6: 796-801.
- Sartoris GB. 1942. Longevity of sugarcane and corn pollen—A method for long-distance shipment of sugarcane pollen by airplane. *American Journal of Botany*. 1; 29: 395–400.
- Shanmugavadivu R, Rao PG. 2009. A comparison of flowering behaviour of sugarcane clones in two different locations. *Sugar Tech*, 11(4):401-404.
- Snedecor GW, Cochran WG. 1981. *Statistical methods*. 7th Ed. Iowa State Univ. Press, Ames Iowa, USA.
- Solamani A, Sivakumar C, Anbumani S, Suresh T, Arumugam K. 2001. Role of plant growth regulators on rice production: A review. *Agricultural Reviews*, 23:33-40.
- SPSS. 2006. *User's guide for SPSS for windows evaluation version 15.0*, Statistical Program for Social Science, Inc. USA.
- Srivastava RP, Singh SE, Singh P, Singh SB .2006. Artificial induction of flowering in sugarcane under sub-tropical conditions - A successful approach. *Sugar Tech* 8 (2&3) 184-186.
- Steel RGD, Torrie JH, Dickey DA. 1997. *Principles and procedures of statistics*. McGraw Hill Book Co. Inc, New York, USA.
- Stevenson GC. 1965. *Genetics and breeding of sugarcane*, Longmans, Green and Co. Ltd., London. 2.
- Sujatha P, Kumar BR, Naidu NV, Charumathi M, Beby P, Jayachandra K. 2018. Plant growth promoters' effect on cane, quality and yield parameters in sugarcane (*Saccharum officinarum* L.). *Indian Journal of Crop Science*, 6(3), 737-743.
- Sure S, Arooie H, Azizi M. 2012. Influence of plant growth regulators (PGRs) and planting method on growth and yield in oil pumpkin (*Cucurbita pepo* var. *Styriaca*). *Notulae Scientia Biologicae* 4(2), 101-107.
- Tahir ML, Khalil H, McCord PH, Glaz B. 2014. Character association and selection indices in sugarcane. *American Journal of Experimental Agriculture*. 4(3):336-348
- Van Staden J, Crouch R. 1996. Benzyladenine and derivatives their significance and interconversion in plants. *Plant Growth Regulator*, 19, 153-175.
- Vijayasaradhy N., Narasimhan R .1953. Control of flowering in sugarcane. *Proceedings of International Society of Sugar Cane Technologists*, 8. 371-401

- Vishwakarma AL. 2010. Studies on some biochemical changes during sprouting and tillering of sugarcane. *Indian Journal of Sugarcane Technology*, 8(1): 41-49.
- Wang Y, Ren T, Lu J, Cong R., Hou W, Liu T, Li X. 2017. Exogenously applied gibberellic acid improves the growth and yield performance of inferior rice tillers grown under different nitrogen levels. *Acta physiologiae plantarum*, 39(1), 5.
- Ward JJH. 1963. Hierarchical grouping to optimize an objective function' *Journal of the American Statistical Association*, (58), pp. 236-244.
- Yadav S, Singh S, Yadav S, Kumar A, Sharma B. 2016. Effect of ethrel and gibberellic acid on growth and yield of sugarcane (cv 'CoS 03251') with recommended agronomic practices. *Indian Journal of Sugarcane Technology*, 31(02), 65-67.
- Yan W, Rajcan IR. 2002. Biplot analysis of test sites and trait relations of soybean in Ontario. *Canadian Journal of Plant Science*, 42:11–20.
- Yoder JI, Musselman L, Westhood JH. 2001. Effect of plant growth regulators on sugarcane production in Taiwan. *Taiwan Sugar*, pp. 17-25.