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Full-Length Research Paper

Flowering performance of sugarcane genotypes under natural and artificial conditions

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ABSTRACT: This study included three experiments: two at El-Sabahia Research Station, Sugar Crops Research Institute, ARC, Egypt (31° 12 N) during the 2019/2020 (plant cane) and 2020/2021 (first ratoon) seasons, and one at Sugar Crops Research Institute, Agricultural Research Center (ARC), Giza, Egypt under artificial conditions. According to the results, the eleven sugarcane genotypes studied under natural and artificial flowering could be classified into four groups. The first group included four genotypes that flowered under both natural and artificial flowering conditions, namely ph8013, Bo 19, L61-49, and Bo 3. The four sugarcane genotypes that responded and achieved full flowering under natural and artificial flowering conditions could be classified as easy to flower genotypes. The second group consisted of four genotypes that only flowered during natural flowering conditions; Crystallina, CP44-105, CO 301, and GT 54-9 (the commercial variety). The third group included two genotypes that flowered only under artificial flowering conditions, F 161 and ROC 10. The fourth group included one genotype that did not respond to either natural or artificial flowering. The genotype is SP 79-2233. Furthermore, the results revealed that each of the genotypes that responded has its own characteristics in terms of pre-flag leaf stage duration, flag leaf stage duration, and emergence stage. Furthermore, each genotype has an optimal number of inductive cycles for flowering induction. The minimum and the maximum number of days to flower and the duration of the flowering period determine the crossing time of the genotypes studied and the possibility of synchronizing flowering of these genotypes with each other or with other genotypes.

Keyword: Sugarcane, plant cane, ratoon, flowering

INTRODUCTION

Flowering is the first step in creating new sugarcane varieties. Controlling flowering is essential in breeding programmes for the development of new varieties. As a result, understanding the factors that influence flowering is beneficial for plant breeders, who must be able to precisely control flowering timing. The improved sugarcane varieties that have resulted from controlled crosses have been greatly extended and accelerated in recent decades, with the majority of the current commercial varieties having been originated in this manner. Sugarcane breeders are very interested in inducing flowering in Egypt because there is a strong argument for establishing a successful long-term breeding program to produce improved varieties. In genetic introgression programmes, in which floral synchronicity is required, flowering is an essential element. The flowering differs in different planting dates with different conditions because of different weather conditions (Ghonema, 2017). Natural sugarcane flowering is important for the development of new clones. Sugarcane flowering is a complex physiological measure that consists of several stages of development, each with its own set of natural and physiological requirements. In recent years, cane flowering has been highly variable and

irregular in tropical environments, posing a significant challenge to breeding improvement programmes, as mentioned by Shanmugavadivu and Rao (2009).

Artificial photoperiod regimes, on the other hand, have made planned sugarcane crosses possible rather than opportunistic sugarcane crosses possible (Nuss and Berding, 1999).

Taiz and Zeiger (2010) reported that sugarcane is a short-day plant, and that flowering is induced by a series of long nights.

Thompson (1984) also demonstrated that sugarcane is generally thought to be a short-day plant, but that certain genotypes will only tassel when the photoperiod happens within a very narrow range.

Floral synchronization of genotypes or species, as well as timely and abundant flowering, are required for a successful hybridization program. Sugarcane's unreliable flowering behavior makes meaningful hybridization difficult in subtropical climates.

The main factors that dictate and control the process are the length of the day and the temperature (Srivastava et al., 2006). With considerable effort, Rao et al. (1973) partially succeeded in producing a small number of sugarcane varieties as a result of open pollination among the available parents under the natural conditions of Alexandria, Egypt.

However, both cane growers and manufacturers were dissatisfied with those varieties. Actually, their limited success could be attributed to the variability of flowering time of cane varieties, which are classified as early, intermediate, or late flowering in nature.

As a result, any defined parental genotypes cannot simply be crossed. As a result, different treatments such as controlled photoperiod must be used to modify flowering dates (James, 1972).

Artificial photoperiod regimes are frequently achieved by building photoperiod chambers in which sugarcane breeding genotypes can be rolled in and out at specific times to achieve the desired amount of day length. Sugarcane flowering is initiated by a small reduction of 30 to 60 seconds per day from about 12 hours and 30 minutes (Mehareb et al., 2021).

The initiation of the tassels occurs after the sugarcane breeding genotypes have been subjected to an allotted number of inductive cycles of the artificial photoperiod regimes. In the early days of local flowering induction research, little was known about the factors that control tasseling.

The majority of the work was devoted to determining the optimal day length for tassel induction. Meanwhile, scientists agree that photoperiod is the most important factor in cane flowering.

The purpose of this work was to investigate the flowering performance of some sugarcane genotypes under natural and artificial conditions.

MATERIALS AND METHODS

This study consisted of three experiments; two experiments that were carried out under natural conditions at El-Sabahia Research Station, Sugar Crops Research Institute, ARC, Egypt (31^{o} 12 N) during 2019/2020 (plant cane) and 2020/2021 (first ratoon) seasons and the third experiment was carried out under artificial conditions at Sugar Crop Research Institute, Agricultural Research Center (ARC), Giza, Egypt, during 2018-2019 season to study the flowering performance of eleven genotypes from different origins (Table 1).

Table 1: Origin of tested sugarcane genotypes

Genotype	Origin
F 161	Taiwan
ROC 1	China
Crystallina	New Guinea
CO 301	India, Coimbatore
BO3	India, Bihar, Orissa
BO19	India, Bihar, Orissa
CP44-105	USA, Florida
L61-49	USA, Louisiana
Ph8013	Philippine
GT 54-9	Egypt
SP 79-2233	Brazil, Sao Paulo

Experiment one and two under Natural conditions

In the middle of March 2019 two–budded/cuttings for each genotype were planted in 3 ridge plots. Each ridge was 4m long and1.25apart. All the cultural practices and fertilizer were carried out as recommended to induce flowering. The experimental design used was randomized complete blocks with three replications. Under natural flowering conditions in sabahia station, Alexandria, flowering induction occurred during first 15th days in September, when day length ranges between 12:15-12.40 hrs, in addition to, fit temperatures and humidity are available as shown in (Table 2 and Figures 1 and 2).

Experiment three under artificial flowering

An experiment was carried out at Sugar Crop Research Institute, Agricultural Research Center (ARC), Giza, Egypt, during 2018/2019 season.

Facilities

Photoperiod rooms were used to provide the potted canes with the scheduled photo-inductive cycles. Each photoperiod room could hold a total of 60 pots placed on

Table 2: Day length in Alexandria from 1 to 30 September

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

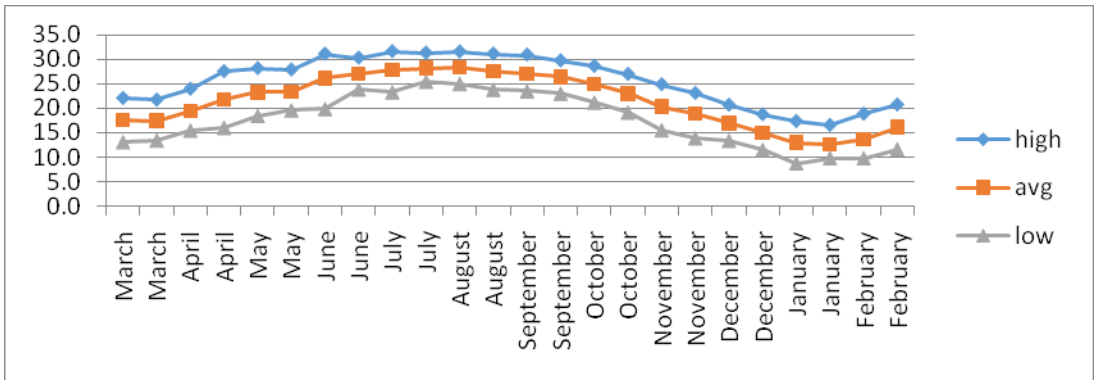

Figure 1: Air temperature in Alexandria (mean of two years, 2019/2020 (Plant cane) and 2020/2021 (first ratoon).

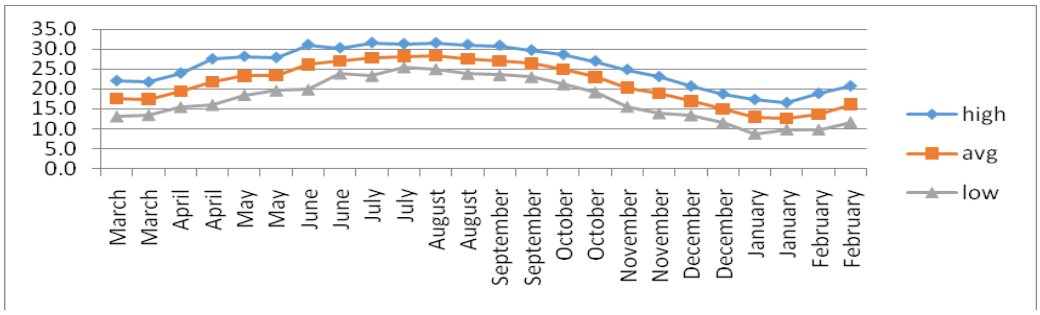

Figure 2: Air relative high humidity % in Alexandria (mean of two years, 2019/2020 (Plant cane) and 2020/2021 (first ratoon).

two carts. There are two photoperiod rooms at the station. Each pot could hold up to 4 sugarcane stalks. The size of each room is 8.1 × 3.35 × 6.5 m, and the room temperature was controlled by an air condition system to keep the room temperature up to 24°c during the cold nights. A supplementary artificial twilight was obtained by using twelve (12) incandescent lamps of 250 watts each for controlling the photoperiodic treatments.

These lamps were placed about 1.25 meter above the upper stalk leaves. The out-of-door misting system consisted of nozzles delivering tap water in the form of a fine mist spray. The canes in pots on each cart when pushed outside the photoperiod rooms were positioned directly under water sprays fixed at a height of about 5 m above the ground level. Water sprays operated daily from 10 am to 5 pm. Four single-eye cuttings from each of eleven sugarcane genotypes (Table1) were planted in 40-liter plastic pot on 15th of September 2018. All pots were filled with the prepared soil 3:1 mixture of clay and sand up to 1st upper inch, making about 15 kg as recommended by Viveros and Cassalett (1990). During growing time, the potted plants received recommended cultural practices to maintain full active growth. Regular irrigation and fertilizers were applied to all pots. Nutrient solution consisted of 38 g urea (46 % N), 48 g superphosphate (15.5% P_2O_5) and 34 g Potassium sulphate (48 % K_2O) in 100 L of water (Mohamed, 1996), was used. Each pot received 2 L of this nutrient solution weekly up to one month (May 2019) before the beginning of photoperiodic treatments. During the winter months, the pots were transferred to a greenhouse to maintain normal growth required to pass the juvenile phase. Tillers were removed whenever appeared leaving only the mother stalk per planted bud. On June 1, 2019, the previously described pots were arranged in randomized complete Block Design with two replicates. These pots were placed on carts to facilitate moving pots inside and outside the photoperiod rooms. Pots exposed specific photo-inductive treatment, where genotypes received constant photoperiod of 12:30 day light hours for 30 days from 15th of June to 15th of July. Thereafter, the photo-inductive cycles were followed by declining day length at a rate of 30 sec./day until reached 11.30 hours (120 days). The treatment ended in 12th of November for this experiment.

The following measurements were recorded in the three experiments

(i) Number of genotypes flowered under natural and artificial inductive photoperiod.
(ii) Duration of Pre flag leaf stage: This stage was calculated as a number of days from the start of photoperiod treatment until stopping formation of new leaves and beginning of the flag leaf formation. But under natural flowering from optimum days for flowering (September 5) to until stopping formation of new leaves and beginning of the flag leaf formation
(iii) Duration of flag leaf stage was calculated as a number of days from the beginning of flag leaf formation to as soon as the emergence of the inflorescence form flag leaf sheath occurred.
(iv) Duration of emergence stage was calculated from the starting of emergence of the inflorescence from flag leaf until its full extension completed.
(v) Minimum days to flower: the number of days from the beginning of natural inductive photoperiod or the beginning of the photoperiod treatment until flowering of the first stalk per pot appeared.
(vi) Maximum days to flower: the number of days from the beginning of natural inductive photoperiod or the beginning of photoperiod treatment until flowering of last stalk per pot was appeared.
(vii) Mean days to flower: The average days required to flower of a genotype. From the beginning of natural inductive photoperiod or the beginning of photoperiod treatment until flowering of last stalk per pot was appeared.
(viii) Duration of flowering period: maximum days to flower -minimum days to flower + 1.

Statistical analysis

A aspirate analysis of variance for each season (two seasons for natural flowering and one season for artificial flowering) were conducted according to Snedecor and Cochran. (1967). The duration of pre flag leaf stage, duration of flag leaf stage, duration of emergence stage and the percentage values for total flowered stalks, were transformed to the corresponding angle values in degrees ARC-Sin according to Evwin et al. (1966). Means were compared using LSD at 5% level of probability according to Waller and Duncan (1969).

RESULTS AND DISCUSSION

Number of genotypes flowered under natural and artificial inductive photoperiod

The flowering behavior of eleven sugarcane genotypes exposed to natural flowering induction in Alexandria during the 2019/2020 (plant cane) and 2020/2021 (first ratoon) seasons for two seasons, as well as artificial flowering exposed to 30 inductive cycles at Sugar Crop Research Institute, Agricultural Research Center (ARC), Giza, Egypt, during the 2018/2019 season, is presented in (Table 3 and Figure 3).

According to the results in (Table 3), the eleven sugarcane genotypes studied under natural and artificial flowering could be classified into four groups. The first group included four genotypes that flowered under both natural and artificial lowering conditions, and these genotypes. Specifically, ph8013, Bo19, Bo19, L61-49, and Bo3.

The four sugarcane genotypes that responded and achieved full flowering under natural and artificial flowering

Table 3: Distribution of the studied sugarcane genotypes according to their flowering response under natural and artificial conditions.

Genotypes flowered under			Non flowered genotypes
Artificial flowering	**Natural flowering**	**Natural and artificial flowering**	
F 161 Roc10	Crystalina CP44-105 CO 301 GT 54-9	Ph 8013 Bo 19 L61-49 Bo 3	SP79-2233

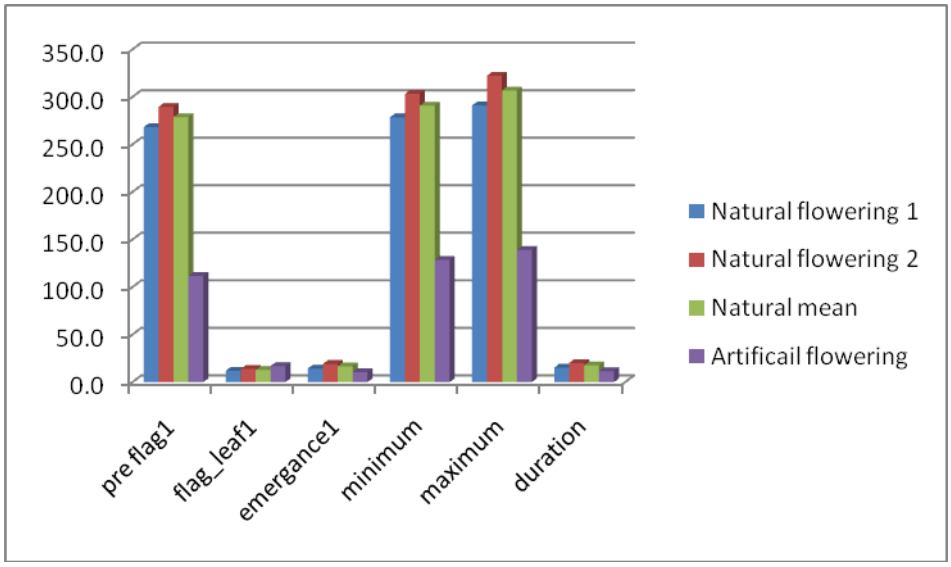

Figure 3: Sugarcane flowering stages under natural flowering in 2019/2020 and 2020/2021and artificial flowering.

conditions could be classified as easy to flower genotypes. The second group consisted of four genotypes that only flowered during natural flowering. These four genotypes are crystalina CP44-105, CO301, and commercial variety (GT 54-9), indicating that the inductive cycles used in artificial flowering were greater than what was required for these genotypes.

The third group included two genotypes that flowered only under artificial flowering, F 161 and ROC 1, implying that the natural inductive cycles were shorter than those required to induce these genotypes. The fourth group included one genotype, SP 79-2233, which did not respond to either natural or artificial flowering. These findings indicate that the eleven genotypes studied differ significantly in their response to flowering under natural and artificial flowering conditions. Flowering varieties require a minimum of 15 inductive days, according to LaBorde et al. (2014). Genotypes that flowered as a result of natural or artificial induction could be classified as easy to flower genotypes. The genotype that did not respond to artificial or natural inductive photoperiod may be considered medium-hard to flower and requires inductive days longer than 30.

Duration of pre flag leaf stage

The data in (Table 4) and (Figure 3) showed that the tested genotypes differed significantly in pre flag leaf stage duration, with genotype L61-49 outperforming the other genotypes in 2019/2020 under natural flowering, recording a longer duration of pre flag leaf than the same genotype under artificial flowering. In contrast, in the second season 2020/2021, genotype CO 301 produced significantly more pre-flag leaf stage than other genotypes, but this genotype (CO 301) did not respond to artificial flowering. In terms of flowering genotypes under both natural and artificial conditions, ph8013 had a longer

Table 4: Pre flag leaf and flag leaf stages duration under natural and artificial conditions.

Genotypes	Pre flag				Flag leaf			
	Natural flowering			Artificial	Natural flowering			Artificial
	2019/2020 (PC)	2020/2021(FR)	Mean*	2018/2019	2019/2020 (PC)	2020/2021(FR)	Mean*	2018/2019
Crystalina	76	152	114	--	14	21	17.3	--
GT 54-9	114	179	293.5	--	11	18	14.2	--
ph 8013	73	80	76.5	95	13	19	15.8	23
Bo 19	133	82	107.5	81	--	8	3.8	21
Bo 3	110	103	106.5	83	7	13	10.2	23
F 161	--	--	--	138	--	--	--	8
Roc10	--	--	--	150	--	--	--	11
L61-49	173	154	163.5	123	10	12	11.2	16
Co 301	97	210	153.5	--	6	6	5.7	--
Cp 44-105	151	--	151	--	23	--	11.5	--
SP 79-2233	--	--	--	--	--	--	0.0	--
LSD	16.7	12.1		1.6	3.7	5.0		1.3

* Mean: calculated from only genotypes flowered. PC (plant cane) and (FR (first ratoon)

pre flag leaf duration stage under natural conditions than under artificial conditions. However, under natural conditions, Bo19, Bo3, and L61-49 genotypes had longer pre-flag leaf duration than those under artificial conditions. This demonstrates that exposing plants of those genotypes to artificial flowering caused an early onset of pre-flag leaf development. The duration of the pre flag leaf stage is much longer than the other flowering stages, as it includes the time required for the meristem to accumulate enough stimulus to divert it from leaf production to reproductive stage, followed by a relatively long period in which no structural changes occur but the tip of the inflorescence undergoes the change from bilateral arrangement to unilateral arrangement. After that, floral differentiation takes place. According to Mehareb et al. (2021), differences in flowering dates among cultivars that require nearly the same number of inductive cycles to complete the induction stage are caused by differences in time required for their pre flag leaf stage under optimum flowering conditions.

Duration of flag leaf stage

This stage represents the developmental and elongation of the panicle from the end of pre flag leaf stage to the time of panicle emerges from the flag leaf sheath. Duration of flag leaf stage presented in (Table 4 and Figure 3) indicated that in first season, under natural conditions, ranged between six days four Co 301 genotype to 23 days for Cp44-105 while in second season, it ranged between six days for Co301 to 19 days for Ph8013. However, it ranged between 8 days for F161 genotype to 23 days for Ph8013and Bo3. These results refer that this stage is shorter than the duration of pre flag leaf.

Duration of emergence stage:

Data presented in (Table 5 and Figure 3) revealed that the studied genotypes varied significantly in duration of emergence stage with a superiority of commercial variety, GT54-9 over the other genotypes in this duration in first season and over two seasons in natural flowering, recording 19.5 days higher than that given by Ph 8013 that was the first genotype to emit the emergence stage under natural flowering in first season. In general, under natural condition the duration of this stage ranged between 6 days for ph8013 genotype to 25 days for G.T.54-9 variety in first season while it ranged between 13.3 days for Cp301 genotype and 23 days for G.T. 54/9 variety in the second season. However, under artificial conditions, it ranged between 9 days for L61-49 genotype to 13 days for Bo19 genotype. The previous results shown that each one of the responded genotypes have its own characteristic with respect to duration of pre flag leaf stage, duration of flag leaf stage and emergence stage. Additionally, each genotype has an ideal number of inductive cycles for its flowering induction. These results are in harmony with those reported by Mohamed (1996); Rizk *et al*. (2002) and Mehareb et al. (2021).

Minimum and maximum number of days to flower as well as duration of flowering period

The response of the tested sugarcane genotypes presented in (Tables 5 and 6). In natural flowering, the results showed that lowest minimum days to flower was

Table 5: Duration of emergence stage and minimum number days to flower under natural and artificial conditions.

Genotypes	Duration of emergence stage				Minimum number days to flower			
	Natural flowering			Artificial	Natural flowering			Artificial
	2019/2020 (PC)	2020/2021(FR)	Mean*	2018/2019	2019/2020 (PC)	2020/2021(FR)	Mean*	2018/2019
Crystalina	16.0	25.0	20.5	--	89.7	173.7	131.7	--
GT 54-9	25.5	26.0	25.8	--	124.5	197.5	161	--
Ph 8013	6.0	14.7	10.3	11.0	86	98.7	92.4	118.0
Bo 19	--	10.0	5.0	13.0	133.7	89.7	111.7	102.0
Bo 3	10.3	27.3	18.8	10.0	117	117	117	106.0
F 161	--	--	--	10.5	--	--	--	145.5
Roc10	--	--	--	10.0	--	--	--	160.5
L61-49	15.3	17.3	16.3	9.0	183.7	166.7	175.2	139.0
Co 301	10.3	13.3	11.8	--	103.3	215.7	159.5	--
Cp 44-105	16.3	--	8.2	--	174.3	--	174.3	--
SP 79-2233	--	--	--	--	--	--	--	--
LSD	3.2	4.5		1.3	5.43	7.19		3.0

*Mean: calculated from only genotypes flowered. PC (plant cane) and (FR (first ratoon)

Table 6: Maximum number days to flower and duration flowering period under natural and artificial conditions.

Genotypes	Maximum number days to flower				Duration flowering period			
	Natural flowering			Artificial	Natural flowering			Artificial
	2019/2020 (PC)	2020/2021 (FR)	Mean*	2018/2019	2019/2020 (PC)	2020/2021 (FR)	Mean*	2018/2019
Crystalina	105.7	198.7	152.2	--	17.0	26.0	21.5	--
GT 54-9	150	223.5	186.75	--	26.5	27.0	26.8	--
Ph 8013	92	113.3	102.65	129.0	7.0	15.7	11.3	12.0
Bo 19	133.7	99.7	116.7	115.0	1.0	11.0	6.0	14.0
Bo 3	127.3	144.3	135.8	116.0	11.3	28.3	19.8	11.0
F 161	--	--	--	156.0	--	--	--	11.5
Roc10	--	--	--	170.5	--	--	--	11.0
L61-49	199	184	191.5	148.0	16.3	18.3	17.3	10.0
Co 301	113.7	229	171.35	--	11.3	14.3	12.8	--
Cp 44-105	190.7	--	190.7	--	17.3	--	8.7	--
SP 79-2233	--	--	--	--	--	--	--	--
LSD	6.49	4.74		2.8	3.2	4.5		2.0

* Mean: calculated from only genotypes flowered. PC (plant cane) and (FR (first ratoon)

92.4 days for genotype Ph 8013, while its maximum days was 102.65 days. The highest minimum number of days was 175.2recorded by the genotype L61-49.Though its maximum days was 191.5days. By contrast, under artificial flowering, the results presented that lowest minimum days to flower was 102 days for genotype BO 19, however, its maximum days was 115 days. The highest minimum number of days was 160.5 recorded by the genotype ROC 10.However, its maximum day's were170.5 days. Duration of flowering as presented in (Table 6), represents the period from full emergence of the tassel of the first plant until full emergence of the tassel of the last plant of given genotype. Under natural flowering, this duration varied from 6 days for genotypes Bo 19 to 26.8days for commercial variety GT 54-9. Under artificial conditions, however, the duration of flowering varied from 10 days for genotypes L61-49 to 14 days for genotype Bo 19. Thus, plants belonging to commercial variety GT 54-9 under natural conditions and Bo 19 genotypes under artificial flowering recorded the longest duration of flowering, indicating the possibility of using these genotypes in a wide range of crosses.

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