*Indian Journal of Agricultural Sciences* **92** (7): 842–6, July 2022/Article
https://doi.org/10.56093/ijas.v92i7.105840

# Evaluation of sugarcane (*Saccharum officinarum*) germplasm for quality, yield traits and effects of flowering on cane traits

JASWANT S KHOKHAR[1]*, NAVDEEP S JAMWAL[1], GULZAR S SANGHERA[1] and PARAMJIT SINGH[1]

*Punjab Agricultural University, Regional Research Station, Kapurthala, Punjab 144 601, India,*

Received: 10 October 2020; Accepted: 29 March 2022

ABSTRACT

Sugarcane (*Saccharum officinarum* L.) is an important commercial crop grown globally for its sugar-rich stalk. Low genetic variations and unwanted flowering in modern sugarcane varieties affect sugarcane quality and production. Therefore, a panel of 628 genetically diverse sugarcane clones were evaluated under field conditions at the Regional Research Station, Kapurthala, Punjab Agricultural University during 2019–20, for quality, yield and yield traits. The effect of flowering on quality and yield traits on a sub-set of 34 flowering sugarcane clones was also studied. A panel of 628 sugarcane clones showed greater genetic diversity for all the traits. HR brix per cent varied from 14–24%, number of millable cane (NMC) varied from 13–80 and single cane weight varied from 0.4–2.6 kg in 628 clones under field conditions. Non-flowering sugarcane clones' mean performance was greater than flowering clones for most of the traits. However, no significant differences in quality traits among the clones at different flowering stages (flag leaf, tip emergence and complete flowering) were observed. Therefore, there is a huge genetic diversity in sugarcane germplasm for quality and yield traits and it should be exploited by breeding community for the development of sugarcane varieties with improved yield and better quality.

**Keywords**: Cane, Quality, Sugarcane germplasm, Yield traits

Sugarcane (*Saccharum officinarum* L.) is an important commercial crop grown in tropical and sub-tropical regions of India. Genetic improvement has played an important role in the development of sugarcane varieties with improved cane yield and sugar content (Ming *et al.* 2010). But, in last two decades, no substantial improvement in cane yield and sugar recovery have been seen in many top sugarcane producing countries, including India and we are facing yield plateaus. This could be due the narrow genetic variation present in the sugarcane gene pool used in the development of modern sugarcane varieties.

In India, most modern sugarcane cultivars under cultivation are interspecific hybrids of *Saccharum officinarum*, *S. barberi* and *S. spontaneum* with variable chromosome numbers (2n = 80 to 120) and more than 50 years old genetic material is still used in modern breeding programs in the development of new sugarcane varieties. This leaves us with less opportunity for new chromosomal recombinations from the original wild parents (Aitken *et al*. 2006), and halts further improvement of cane yield and quality traits (Shrivastava and Srivastava 2016). Therefore, genetic variability could be reintroduced in the modern sugarcane cultivars by using the sugarcane wild parents and clones derived from the interspecific crosses. A panel of 112 sugarcane clones, derived from highly diverse genetic material, was evaluated under field conditions in India, it showed greater variation in cane yield and sucrose concentration compared to commercially released sugarcane varieties (Sanghera and Jamwal 2019). In addition to narrow genetic diversity in modern sugarcane varieties, flowering in sugarcane also plays an important role in affecting the cane yield and quality traits.Though flowering in sugarcane is essential for breeding programs, uncontrolled flowering in commercial fields poses a serious problem for sugarcane farmers and millers with a considerable loss in cane production and sugar yield (Miah and Sarkar 1980).

Thus, the objectives of present study were to evaluate a panel of 628 genetically diverse sugarcane clones for quality, yield and yield traits, and to also study the effect of flowering on quality and yield traits on a sub-set of 34 flowering sugarcane clones under field conditions.

## MATERIALS AND METHODS

The present experiment was conducted at the Punjab Agricultural University, Regional Research Station, Kapurthala, Punjab, India (latitude 31°23'16.4"N, longitude 75°21'25.2"E, altitude of 219 m amsl during 2019–20. A panel of 628 sugarcane clones was evaluated for sugarcane

[1]Punjab Agricultural University, Regional Research Station, Kapurthala, Punjab. *Corresponding author email: khokharjaswant@gmail.com

quality, yield and yield traits under field condition during 2019–20. Clones were derived from 21 bi-parental crosses (n=506), three poly-crosses (n=12), two self-crosses (n=57) and four crosses were of general collection (n=53). Each clone was grown in two rows of 2 m length, space between the rows was 90 cm planted in augmented design. After field operations, like harrowing and levelling, three budded sets were placed in open furrows and then covered with soil. Sugarcane quality and field traits like hand refractometer HR brix (%), pol (%), purity (%), commercial cane sugar CCS (%), cane length (cm), cane diameter (cm), number of millable canes (NMC), and single cane weight (kg) were measured 300–320 days after sugarcane planting in the field. Traits were measured from two canes randomly selected from each row.

Out of 628 clones, a set of 34 clones was characterised for sugarcane quality, yield and yield traits at different flowering stages: at flag leaf, tip emergence and 100% flowering (flowering group), and compared with ten non-flowering sugarcane commercial released varieties for all the measured traits. In addition to HR brix, juice brix of 34 flowering and 10 non-flowering clones were also measured 360–370 days after planting with sucrose analyser. Weather data was recorded during 2019–20. Briefly, minimum temperature varied from 0°C (December) to 22°C (July) and maximum temperature varied from 28ºC (February) to 46ºC (June). To get maximum crop potential, crop stand was maintained according to the Punjab Agricultural University's recommended package and practices for sugarcane crop cultivation. All the data collected for cane yield and quality traits were analysed by using CPCS statistics software (Cheema and Singh 1993).

## RESULTS AND DISCUSSION

*Genetic variation in 628 sugarcane clones for quality, yield and yield traits*: The mean HR brix of a panel of 628 sugarcane clones was 17.3% and varied from 14–24% under field conditions (Table 1). Our results are in agreement with Shadmehr *et al.* (2017) who reported brix per cent from 11.5–21% in 253 sugarcane accessions grown under field conditions in Iran. Similarly, Mehareb and Mansoub (2020) and Sumbele *et al.* (2021) reported similar variation in HR brix per cent among 18 and 40 clones, respectively, when tested under field conditions.

The mean number of millable canes (NMC) was 40.7 which varied from 13 to 80, across all the clones. The mean cane diameter was 2.42 cm and varied from 1.5–3.7 cm across all the clones. The mean single cane weight (SCW) was 1.13 kg and ranged between 0.42–2.56 kg, across all the clones (Table 1). Among the yield traits, six fold variation was observed in both number of millable canes and single cane weight, and two fold variation for cane girth, in a panel of 628 clones under field conditions. Our results are in agreement with Elenen *et al.* (2018), who reported cane diameter from 1.2–3.62 cm in 294 sugarcane clones under field conditions in Egypt. While analyzing the cane diameter of 18 diverse clones the range laid between 2.57–3.17 cm observed by Mehareb and Mansoub (2020). Similarly, Sanghera and Jamwal (2019), reported similar variations for brix per cent, number of millable canes, single cane weight and cane diameter in 4717 sugarcane clones under field conditions in India. In another study, Sumbele *et al.* (2021) also reported variation in 40 diverse African sugarcane clones for number of millable cane (10.40 to 23.20) and cane length (220 to 385 cm). The variation among clones for yield traits could be due to the involvement of different parents in the development of these clones.

Among the 30 different crosses including 20 bi-parental crosses, three poly-crosses, 2 self-crosses and 4 general collection crosses , clones from a bi-parental cross of LG 95053 × CoS 510 showed the highest mean HR brix per cent (19.5%; n=6)) while clones from CoJ 83 × CoPant 97222 showed the least mean HR brix per cent (15.8%; n=21) in sugarcane. The variation among clones for yield traits could be due to the involvement of different parents in the development of these clones. For example, clones developed from bi-parental crosses showed greater brix per cent than clones derived from poly-crosses (one female parent pollinated with many male parents) and self-crosses. For number of millable canes (NMC), clones from poly-cross of CoJ 83 showed the highest mean NMC (57.5; n=5) while least mean NMC (27.3; n=34) was recorded in a bi-parental cross, CoS 08272 × CoS 510. Clones from general collection cross of Co11015 showed the highest mean cane diameter (3.28 cm; n=4) whilst least mean cane diameter (2.14 cm) was shown by clones of three different bi-parental crosses, viz. LG 95053 × Co 62198 (n=3), CoPant 84212 × CoH 98 (n=21) and CoPb 12181 × Co 1158 (n=15). Clones from a self-cross of CoH 70 showed the highest mean single cane weight (1.60 kg; n=28) whilst the least mean single cane weight (0.79 kg; n=4) was shown by clones of a ploy-cross Co 238 (Table 1). In another study, Sanghera and Jamwal (2019) reported variation in biparental crosses, general collections, poly-crosses and self-crosses for HR brix per cent, cane diameter, no. of millable canes and single cane weight.

*Comparison between flowering and non-flowering clones for quality, yield and yield traits*: Out of 628, only 34 clones (5.41% of the total clones) showed flowering traits. Furthermore, 34 clones were divided in to three sub-categories on the basis of initiation of different flowering stages, for example, flag leaf, tip emergence and 100% flowering. Non-flowering clones mean performance for different quality, yield and yield traits were better than flowering clones. No significant differences in quality and yield traits among the clones at flag leaf, tip emergence and flowering stages were observed. Flowering in sugarcane varies with genetic make-up of the variety, photoperiod, temperature and moisture status of the soil (Mehareb *et al.* 2016 and Dong *et al*. 2021).

The mean juice brix of non-flowering and flowering clones was 19.5 (n=10) and 18.50% (n=34), respectively. It varied from 17.6–20.5% in non-flowering clones and from 13.3–20.8% in flowering clones (Fig 1a). The mean pol of

Table 1 Mean and range of sugarcane clones, derived from different crosses (bi-parental BP; poly-crosses PC; self and general collection GC) for quality and yield related traits during 2019–20

| Parentage | Type of cross | No. of clones | HR brix (%) | | Number of millable canes (NMC) | | Cane diameter (cm) | | Single cane weight (kg) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| CoLK 8102 × ISH 176 | BP | 13 | 15.90 | 14-19 | 29.67 | 13-47 | 2.39 | 1.5-2.9 | 1.10 | 0.49-2.02 |
| CoS 08272 × CoS 510 | BP | 42 | 18.60* | 17-22 | 55.94* | 35-73 | 2.41 | 1.6-2.5 | 1.05 | 0.98-1.75 |
| CoSe 01434 × CoH 70 | BP | 15 | 15.80 | 14-18 | 34.20 | 26-52 | 2.33 | 2.0-3.3 | 1.28* | 0.83-2.17 |
| CoPb 13182 × Co 62198 | BP | 67 | 17.90* | 15-21 | 37.34 | 30-63 | 2.36 | 2.1-2.7 | 1.23* | 0.95-1.78 |
| CoPant 84212 × CoS 510 | BP | 24 | 17.10 | 14-20 | 37.82 | 25-57 | 2.23 | 1.8-3.1 | 0.92 | 0.66-1.31 |
| CoPant 84212 × CoH 98 | BP | 3 | 17.30 | 16-18 | 29.03 | 26-51 | 2.14 | 2.3-3.5 | 0.95 | 0.72-1.66 |
| CoPant 84212 × CoSe 01434 | BP | 18 | 18.40* | 17-23 | 36.96 | 21-40 | 2.41 | 2.1-3.3 | 1.10 | 0.68-1.49 |
| CoPant 84212 × CoS 510 | BP | 15 | 19.20* | 16-24 | 45.02 | 14-63 | 2.43 | 2.0-2.6 | 1.02 | 0.89-1.84 |
| LG 95053 × Co 62198 | BP | 21 | 18.20* | 16-20 | 27.63 | 19-46 | 2.14 | 1.7-3.0 | 1.22 | 0.99-1.56 |
| LG 95053 × CoS 510 | BP | 36 | 16.40 | 14-19 | 51.69* | 26-75 | 2.32 | 1.7-3.7 | 0.83 | 0.56-1.98 |
| CoPb 10182 × CoS 88216 | BP | 38 | 15.90 | 14-22 | 43.19 | 15-61 | 2.18 | 1.9-2.9 | 1.38* | 1.06-1.84 |
| CoPb 10182 × BO 130 | BP | 40 | 16.80 | 14-19 | 57.45* | 45-78 | 2.30 | 1.8-3.0 | 0.95 | 0.52-1.46 |
| CoLK 8102 × BO 154 | BP | 60 | 17.50 | 15-22 | 36.55 | 16-80 | 2.28 | 1.9-2.4 | 1.30* | 1.07-2.11 |
| CoPb 12181 × Co 1158 | BP | 15 | 15.80 | 14-16 | 37.55 | 14-63 | 2.14 | 2.1-3.3 | 1.03 | 1.17-2.56 |
| CoJ 83 × CoPant 97222 | BP | 21 | 15.80 | 14-18 | 37.29 | 20-62 | 2.25 | 1.9-2.5 | 1.52* | 0.56-2.42 |
| Co 0238 × Co 89003 | BP | 5 | 16.70 | 15-18 | 28.22 | 17-57 | 2.35 | 2.4-3.6 | 1.07 | 0.65-1.49 |
| CoLK 8102 × ISH 176 | BP | 5 | 16.90 | 14-19 | 37.60 | 14-63 | 2.32 | 1.8-2.9 | 0.98 | 0.62-2.17 |
| CoS 08272 × CoS 510 | BP | 34 | 19.40* | 15-24 | 27.32 | 17-57 | 2.42 | 2.1-3.0 | 1.06 | 0.87-2.56 |
| CoSe 01434 × CoH 70 | BP | 23 | 17.80* | 16-22 | 52.01 | 19-68 | 2.30 | 1.9-3.2 | 1.02 | 0.72-1.49 |
| UP 05125 × CoH 70 | BP | 5 | 17.90* | 15-19 | 36.89 | 17-57 | 2.29 | 1.6-2.6 | 1.11 | 0.96-1.65 |
| LG 95053 × CoS 510 | BP | 6 | 19.50* | 15-24 | 37.05 | 19-68 | 2.34 | 2.1-2.8 | 0.94 | 0.84-1.48 |
| CoJ 88 | (PC) | 3 | 17.80* | 16-20 | 46.18* | 31-67 | 2.72* | 1.8-3.0 | 0.99 | 0.71-1.62 |
| CoJ 83 | (PC) | 5 | 16.20 | 14-20 | 57.52 | 21-73 | 2.68* | 1.9-2.9 | 1.25* | 0.99-1.99 |
| Co 0238 | (PC) | 4 | 17.30 | 16-21 | 35.68 | 14-63 | 3.05* | 2.6-3.4 | 0.79 | 0.42-1.37 |
| Co 775 | Self | 29 | 16.90 | 15-18 | 40.70 | 21-60 | 2.24 | 1.8-3.3 | 1.26* | 1.12-2.46 |
| CoH 70 | Self | 28 | 16.60 | 15-24 | 51.85 | 19-68 | 2.58 | 3.1-3.4 | 1.60* | 1.31-2.17 |
| Co 11015 | (GC) | 4 | 17.80* | 16-24 | 42.99 | 17-57 | 3.28 | 1.9-3.6 | 1.30* | 1.05-1.83 |
| CoT 8201 | (GC) | 5 | 16.20 | 14-18 | 40.06 | 19-68 | 2.27 | 2.1-3.3 | 1.14 | 0.85-1.73 |
| CoSe 92423 | (GC) | 22 | 17.20 | 15-22 | 55.59 | 16-68 | 3.28* | 2.9-3.6 | 1.10 | 0.96-1.75 |
| CoH 70 | (GC) | 22 | 16.80 | 15-17 | 34.49 | 21-70 | 2.27 | 2.5-3.0 | 1.53* | 1.23-2.17 |
| Total | | 628 | | | | | | | | |
| Mean | | | 17.26 | | 40.72 | | 2.42 | | 1.13 | |
| SE± | | | 0.196 | | 1.671 | | 0.055 | | 0.037 | |

*5% level of significance.

non-flowering and flowering clones was 17.7 (n=10) and 16.6% (n=34), respectively. It varied from 15.8 to 18.5% in non-flowering clones and from 9.9–19.2% in flowering clones (Fig 1b). The mean purity of non-flowering and flowering clones was 90.8 (n=10) and 89.4% (n=34), respectively. It varied from 89.0 to 93.4% in non-flowering clones and from 74.4 to 92.4% in flowering clones (Fig 1c). The mean CCS of non-flowering and flowering clones

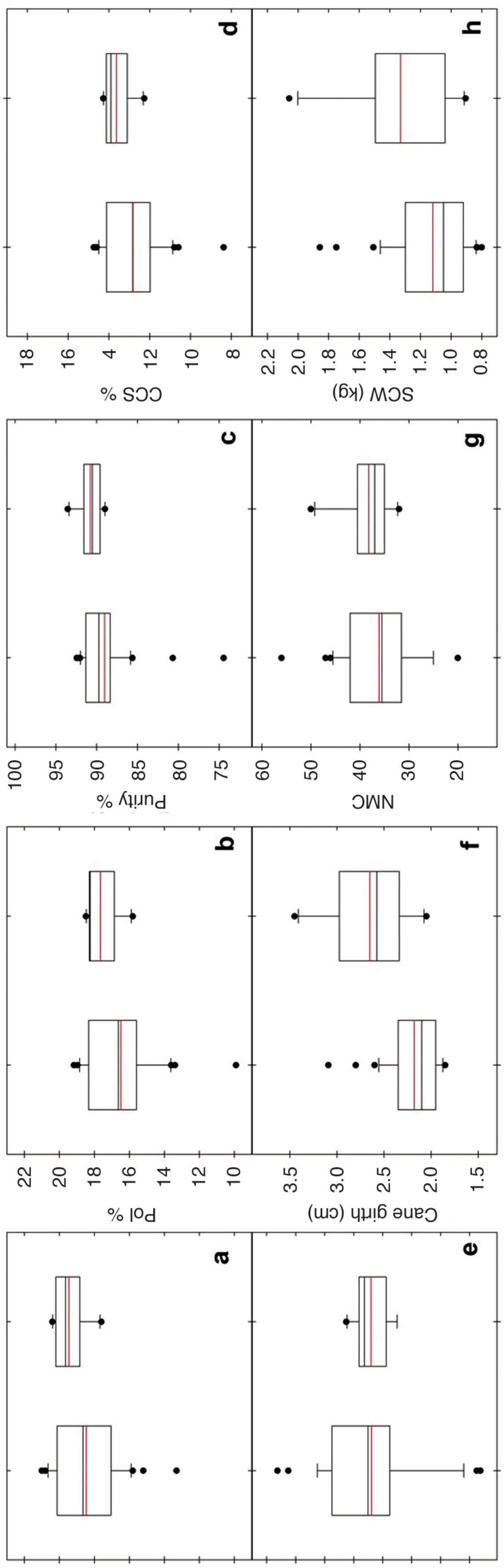


Fig 1 Sugarcane quality, yield and yield traits of flowering (n=34) and non-flowering (n=10) clones. a, juice brix; b, Pol; c, purity; d, CCS; e, cane length; f, cane girth; g, NMC; h, SCW of flowering and non-flowering clones. Data are means of two canes of each flowering and non-flowering clones. Boxes show the median (black) and mean (red) lines; whiskers are the 95% confidence limits; circle represents outliers.

was 13.6 (n=10) and 12.9 % (n=34), respectively. It varied from 12.3 to 14.3 % in non-flowering clones and from 8.4 to 14.7 % in flowering clones (Fig 1d).

The mean cane length of non-flowering and flowering clones was 268 (n=10) and 262 cm (n=34), respectively. It varied from 250 to 285 cm in non-flowering clones and from 193 to 333 cm in flowering clones (Fig 1e). The mean cane girth of non-flowering and flowering clones was 2.7 (n=10) and 2.2 cm (n=34), respectively. It varied from 2.1 to 3.5 cm in non-flowering clones and from 1.9 to 3.1 cm in flowering clones (Fig 1f). The mean number of millable canes (NMC) of non-flowering and flowering clones was 38 (n=10) and 37 (n=34), respectively. It varied from 32 to 50 in non-flowering clones and from 20 to 56 in flowering clones (Fig1g). The mean single cane weight (SCW) of non-flowering and flowering clones was 1.3 (n=10) and 1.1 kg (n=34), respectively. It varied from 0.9 to 2.1 kg in non-flowering clones and from 0.8 to 1.9 kg in flowering clones (Fig 1 h). Similar results have been reported by Rao *et al.* (1996) where increased cane yield and sucrose had been observed in clones in which flowering was inhibited. In another study, Rao and Kumar (2003) reported lower single cane weight in flowering clones. Contrasting results were reported by Miah and Sarkar (1981) where flowering clones had no effect on cane yield and quality traits compared to non flowering clones.

In present study, non-flowering sugarcane clones' mean performance for different quality, yield and yield traits were slightly better than flowering clones'. However, greater variations, for all the traits, were observed within the flowering clones than non-flowering clones (Fig 1). It could be due to the more genetically diverse parents involved in the development of flowering canes than the commercially released non-flowering sugarcane varieties. Greater diversity for quality, yield and yield traits have been reported by Sanghera and Jamwal (2019) in a panel of 4717 sugarcane clones than commercially released varieties under field conditions.

*Correlations between quality and yield traits of 34 clones*: There was a strong positive significant relationship among the quality traits. Sugarcane juice brix percentage of a set of 34 clones showed positive significant relationship with pol percentage, purity and commercial cane sugar (CCS) (r ranged from 0.62 to 0.99; P<0.001). It didn't show relationship with cane girth, number of millable canes and single cane weight (r ranged from 0.11 to 0.28; P ranged from 0.11 to 0.54). However, juice brix showed relationship with cane length (r=0.5; P=0.002). Pol % of canes of 34 clones showed positive significant relationship with purity (r=0.77; P=<0.001), commercial cane sugar (r=0.99; P=<0.001) and cane length (r=0.5; P=0.003) but not correlated with cane girth, number of millable canes and single cane weight. Purity of canes of 34 clones showed relationships with CCS (r=0.71; P=<0.001) but didn't show any relationships with cane length, cane girth, number of millable canes and single cane weight. Commercial cane sugar CCS showed relationship with cane length (r=0.5; P=0.002) but did not correlate with cane girth, number of millable canes and single cane weight of 34 clones. Within yield and yield traits, only cane girth showed positive significant relationships with single cane weight, no relationships within other yield traits of 34 clones was observed. Our results are in agreement with Shadmehr *et al.* (2017) who showed positive relationships between brix per cent and pol, purity in 253 sugarcane varieties under field conditions in Iran. Among yield traits, cane girth correlated with single cane weight which is in agreement with Shadmehr *et al.* (2017), suggesting that these traits can be included in the breeding programme to develop the high yielding sugarcane varieties.

There were no significant differences in juice brix, pol, purity and CCS between the sugarcane clones at flag leaf, tip emergence and complete flowering stages. Whereas, Rao and Kumar (2003), reported that flowering affects quality traits after three months of flowering. However, we took measurements of quality traits only at single time point for all the clones at different flowering stages. Future study investigating the effects of different time intervals on the various quality traits of sugarcane after induction of flowering are needed.

## ACKNOWLEDGEMENT

We are grateful to Punjab Agricultural University, Ludhiana for financial assistance to carry out the research work**.**

## REFERENCES

Aitken K, Jackson P and Mclntyre C. 2006. Quantitative trait loci identified for sugar related traits in a sugarcane (*Saccharum* spp.) cultivar × *Saccharum officinarum*. *Applied Genetics* **116**: 701–14.

Anonymous. 2020. Sugarcane in India: A statistical profile. Retrieved from https://sugarcane.icar.gov.in/index.php/en/sugar-stats/sugarcane-statistics, accessed on 23 September 2020.

Cheema H S and Singh B. 1993. CPCS 1: a programme package for the analysis of commonly used experimental designs. Punjab Agricultural University, Ludhiana.

Dong H, Clark L V, Jin X, Anzoua K, Bagmet L and Chebukin P. 2021. Managing flowering time in *Miscanthus* and sugarcane to facilitate intra- and intergeneric crosses. *PLoS ONE* **16**(1): e0240390.

Elenen A, Fouz F M, Mehareb E M, Groneman M A and El-Bakry A. 2018. Selection in sugarcane germplasm under the Egyptian conditions. *Journal of Agricultural Research* **3**(3): 1–13.

Mehareb E M, Salem E S R and Ghonema M A. 2016. Effects of environmental factors on sugarcane flowering under natural conditions in Egypt. *Egypt Journal of Plant Breeding* **20**(6): 1093–105

Miah M A S and Sarkar M A A.1981. The effect of flowering on the quality of sugarcane. *Bangladesh Journal of Sugarcane* **3**(24): 25–28.

Rao P N G and Kumar K N. 2003. Effect of flowering on juice quality content in sugarcane. *Sugar Tech* **5**(3): 185–87.

Rao P N G, Singh S and Naidu K M. 1996. Flowering suppression by ethephon in sugarcane and its effect on yield and juice quality. *Indian Journal of Plant Physiology* **1**(4): 307–09.

Sanghera G S and Jamwal N S.2019. Identification of potential crosses based on vigour, cane characteristics and HR Brix for first clonal selection in sugarcane. *Indian Journal of Sugarcane Technology* **34**(01): 12–16

Shadmehr A, Ramshini H, Zeinalabedini M, Almani M P, Ghaffari M R, Darbandi A I and Fooladvand M. 2017. Phenotypic variability assessment of sugarcane germplasm (*Saccharum officinarum* L.) and extraction of an applied mini-core collection. *Agriculture* **7**(55): 1–15.

Shrivastava A K and Srivastava S. 2016. Diversity of the germplasm of saccharum species and related genera available for use in directed breeding programmes for sugarcane improvement. *Current Science* **111(**3): 475–82.

Sumbele S A, Fonkeng E E, Akongte P, Ndille C N and Henry A. 2021. Characterization of sugarcane germplasm collection and its potential utilization for evaluation of quantitative trait. *African Journal of Agricultural Research* **17**(2): 273–82