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Qualitative and quantitative response of sugarcane cultivars under different planting geometry

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Planting geometry could be an important factor in harvesting sugarcane's maximum production in Pakistan's irrigated agriculture. Therefore, the present experiment was designed to investigate the potential effects of two planting geometry (i.e., 75 cm apart single row trench, farmers' practice, and 120 cm apart dual rows trench plantings, recommended practices by Agricultural Research Wing) on three high yielding cultivars of sugarcane (e.g., HSF 240, CP 77-400 and CPF 249) at farm area of Sugarcane Research Institute (SRI), Ayub Agricultural Research Institute (AARI), Faisalabad during 2019-20. The treatments were randomized in Complete Block Design (CBD) under split-plot arrangements using three replications. The results showed that planting geometry of 120 cm apart dual rows trench planting produced significantly higher tillers (15.32 m^{-2}), millable canes (103085 ha^{-1}), total fresh biomass (123.41 t ha^{-1}), average cane weight (0.95 kg) cane yield (97.94 t ha^{-1}), and harvest index (79.29 %). Among the cultivars, the highest tillers (16.16 m^{-2}) were recorded by HSF 240, but maximum millable canes (104195 ha^{-1}), total fresh biomass (128.70 t ha^{-1}), average cane weight (0.98 kg) and cane yield (101.95 t ha^{-1}) were observed in CP 77-400. Furthermore, a higher sugar recovery (12.66%) was obtained from CPF 249 compared to HSF 240 and CP 77-400. Planting geometry had no impact on the sugar recovery of the cultivars.
Keyword: Planting geometry, cultivars, cane yield.

INTRODUCTION

Sugarcane is the world's most important sugar and cash crop, which provides about 86% of the total world sugar (OECD-FAO, 2020). In Pakistan, it offers raw materials for the sugar (second largest industry) and a cottage industry of Jaggery (*Gur)* to fulfill the sugar demand of the increasing population. Being a cash crop, sugarcane shares about 2.9% in agriculture and 0.6% in the GDP of Pakistan. The cultivation area under sugarcane is 1.104Mha, with an average yield of 64.31tonnes ha^{-1} (Govt. of Pakistan, 2020). Cane yield in Pakistan is far below the other cane-producing countries like Peru (123.76 t ha^{-1}), Senegal (114.19 t ha^{-1}), Guatemala (112.94 t ha^{-1}), Egypt (109.82 t ha^{-1}) and Nicaragua (109.79 t ha^{-1}) etc. (FAOSTAT, 2020) and the main causes of this low yield are shifting of the climate, labor shortage, improper management practices, weeds, insects and diseases attack, moisture stress at critical growth stages, lack of research, early or late harvesting and especially conventional planting methods/geometry and defective varieties etc.

Suggu *et al.* (2010) stated that faulty planting techniques and improper use of nutrients were the main causes for reducing the final cane yield. Planting techniques are very helpful in conserving soil moisture to enhance the stand establishment (Bhullar *et al.*, 2002). Wider row spacing (i.e., 120 – 150 cm) helps the crop to harvest more sunlight to produce more cane yield, facilitates the intercropping and intercultural operations by providing more space, and also enhances the productivity after adopting the efficient mechanization (Panghal, 2010; Chaudhari *et al.*, 2010). Now a days, the only option to increase cane production with the less cultivable area is to enhance the vertical growth by proper crop management practices (Manimaran *et al.*, 2009), including appropriate planting geometry and high-yielding genotypes of sugarcane. Furthermore, the genotypes with desirable characteristics are suitable to perform best under different planting geometries in different agro-ecological zones. Tayade *et al.* (2017)

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reported that cane yield, sugar purity and brix (%) highly depended on variety selection. Due to variable tillering potential, varieties perform differently in producing tillers and thus affect the cane yield per unit area. The production of tillers and millable canes are mainly under the control of parent materials of the varieties (Kumar *et al.*, 2012) which ultimately affects the growth and the final cane yield at harvesting.

Therefore, the present study was designed to examine the effect of row spacings on the yield and yield components of different sugarcane cultivars.

MATERIALS AND METHODS

A field experiment comprised of two planting geometry (75 cm apart single row trench, farmers' practice, and 120 cm apart dual rows trench plantings, recommended practices by Agricultural Research Wing) and three cultivars of sugarcane (HSF 240, CP 77-400 and CPF 249) was conducted at farm area of Sugarcane Research Institute (SRI), Ayub Agricultural Research Institute (AARI), Faisalabad during 2019-20. The experimental design was Randomized Complete Block Design (RCBD) under split-plot arrangements using three replications. The net plot size was 12 m × 6 m.

Land was prepared using crosswise subsoiling twice followed by two cultivations and planking. Then, ridges were made at 75 cm and 120 cm apart using a normal ridger and a specially designed sugarcane ridger, respectively. Crop was planted on March 15th, 2019, with seed rate of 15,0000 buds ha^{-1} through triple budded setts. The recommended amount of phosphorous (112 kg ha^{-1}) and potassium (112 kg ha^{-1}) was applied in furrows at planting. However, nitrogen (168 kg ha^{-1}) was applied in three equal splits; 1st split at 50 days after planting, 2nd dose at 75 days after planting and 3rd split at 100 days after planting (before earthing up). Earthing up was done after 100 days of planting. Harvesting was done manually on January 15th, 2020, to record yield and related observations and quality analysis. All the remaining practices, such as irrigations, weedicides, granular application etc., were kept the same for all experimental plots.

Phenological parameters

***Days to emergence*:** Bud sprouts from three rows of each experimental unit were counted daily. When the number of plants became constant, average days taken to emergence were calculated.

***Days to tillering*:** Same rows from each experimental unit were used for observing days to tillering, days were counted from completion of germination till earthing up and then average days were calculated.

Agronomic and yield parameters

***Number of plants (m^{-2})*:** After constant number of days to emergence, all the seedlings were counted and converted to m^{-2}.

***Number of tillers (m^{-2})*:**Before earthing up, the number of tillers were calculated by selecting three rows in each plot and then converted into m^{-2}.

***Number of millable canes (ha^{-1})*:**After harvesting three rows, the matured canes were counted and converted to per hectare.

***Total fresh biomass (t ha^{-1})*:** At harvesting, the total fresh biomass was calculated by weighing canes with their top trash and converted to t ha^{-1}.

***Top trash weight (t ha^{-1})*:**The harvested canes were de-trashed and de-topped. Top& trash were weighed and then converted to t ha^{-1}.

***Cane yield (t ha^{-1})*:** The canes without top and trash were weighed and converted to t ha^{-1}.

***Biological yield (t ha^{-1})*:** At harvesting, leaves and canes were separated and sub-samples of each fraction were taken. The subsamples of leaves and canes were sun dried for two days and then oven dried till constant weight. The weight was then converted into t ha^{-1}.

***Average cane weight (kg)*:** Average cane weight is the ratio of cane yield (kg) and number of millable canes. It was figured out using following formula:

$$Average\ cane\ weight = \frac{Cane\ yield}{Number\ of\ millable\ canes}\,(kg)$$

***Harvest index (%)*:** It is the proportion of cane yield to the total fresh biomass. It is presented in percentage (%) and was calculated by following formula:

$$Harvest\ index = \frac{Cane\ yield}{Total\ fresh\ biomass} \times 100\ (\%)$$

Where, total fresh biomass included cane yield and top trash weight.

***Quality parameters Sugar recovery (%)*:**

Sugar recovery shows the amount of sugar extracted from sugarcane. It is usually represented in percent (%) and was calculated by formula;

$$Sugar\ recovery\ (\%) = Commercial\ cane\ sugar\ (\%) \times 0.94$$

Where, 0.94 was a factor which represents sugar losses.

***Statistical analysis*:** Analysis of recorded data was done in statistical software (statistics 8.1) and for treatment's means comparison, the Tukey Honestly Significant Difference (HSD) test at probability level of 5% was used.

RESULTS

***Phenological parameters days to emergence*:** Table 1 shows that sprouts of each cultivar took statistically similar days to emergence in both planting geometry. However, days taken to emergence were ranged from 42.78 to 43.00 days under both planting geometry, while in the case of cultivars they were ranged from 42.50 to 43.67 days. Interaction of planting geometry and varieties also exhibited similar results.

***Days to tillering*:** Planting geometry performed statistically similarly to days taken to tillering (Table 1). These were ranged from 104.67 and 105.11 days. Among cultivars, HSF 240 took significantly more days from planting to tillering (107.17 days) and was at par with CPF 249 (106.17 days). Both cultivars are referred as medium maturing varieties, while minimum days taken to tillering were recorded in CP 77-400 (93.67 days), known as an early maturing genotype. Additionally, the interactive effect of planting geometry and cultivars for days taken to tillering was found non-significant.

Table 1. Effect of planting geometry and varieties on phenology of sugarcane.

	Days to emergence	Days to tillering
Planting geometry		
75 cm	43.00	102.89
120 cm	42.78	101.78
HSD (5%)	NS	NS
Cultivars		
HSF 240	42.50	107.17 A
CP 77- 400	42.50	93.67 B
CPF 249	43.67	106.17 A
HSD (5%)	NS	6.15

***Agronomic and yield parameters number of plants (m^{-2})*:** Effect of planting geometry on number of plants (m^{-2}) was non-significant as shown in Table 2. In the beginning of planting, moisture was sufficient for all sugarcane buds due to which differences in number of plants were non-significant. On the other hand, cultivars and interaction were also non-significant (Table 2). But in varieties, the number of plants (m^{-2}) were ranged from 7.65 to 8.20.

***Number of tillers (m^{-2})*:** Data of tillers (m^{-2}) are given in Table 2. Planting geometry of 120 cm apart dual rows trench planting method produced a significantly higher number of tillers (15.32 m^{-2}) as compared to 75 cm apart single row trench planting (13.93 m^{-2}). The highly significant difference in the number of tillers was also observed among cultivars. Higher number of tillers were recorded in HSF 240 (16.16 m^{-2}) followed by CP 77-400 (14.61 m^{-2}), while the minimum in variety CPF 249 (13.09 m^{-2}). Interaction of planting geometry and cultivars was found to be non-significant.

***Number of millable canes (ha^{-1})*:** Millable canes significantly differ in planting geometry (Table 2). Dual rows trench treatment produced a significantly higher number of millable canes (103085 ha^{-1}) than single row trench treatment (97116 ha^{-1}) which might be due to higher number of tillers in wider trench planting. On the other hand, maximum millable canes were recorded in CP 77-400 (104195 ha^{-1}) followed by CPF 249 (100305 ha^{-1}), While minimum were obtained in HSF 240 (95801 ha^{-1}). However, the interaction of planting geometry with cultivars was found non-significant.

***Total fresh biomass (t ha^{-1})*:** Highly significant difference in total fresh biomass was observed in planting geometry as well as among varieties (Table 2). Dual rows trench planting treatment resulted in higher total fresh biomass (123.41 t ha^{-1}) than single row trench treatment (106.23 t ha^{-1}). Among cultivars, maximum total fresh biomass (128.70 t ha^{-1}) was recorded in CP 77-400, and minimum (105.85 t ha^{-1}) in HSF 240, which was at par with CPF 249 (109.92 t ha^{-1}). While the interaction was found to be non-significant for total fresh biomass.

***Top trash weight (t ha^{-1})*:** Results regarding top trash weights are given in Table 2. Significantly higher top trash weight (25.46 t ha^{-1}) was observed in dual rows trench planting as compared to single row trench planting (23.50 t ha^{-1}). Further, sugarcane cultivars also showed a significant difference in top trash weights. Maximum top trash weight (26.76 t ha^{-1}) was observed in CP 77-400 and minimum (22.14 t ha^{-1}) was

Table 2. Effect of planting geometry and varieties on yield and sugar recovery of sugarcane.

	Number of plants (m^{-2})	Number of tillers (m^{-2})	Number of millable canes (ha^{-1})	Total fresh biomass (t ha^{-1})	Top trash weight (t ha^{-1})	Cane yield (t ha^{-1})	Biological yield (t ha^{-1})	Average cane weight (kg)	Harvest index (%)	Sugar recovery (%)
Planting geometry										
75 cm	7.92	13.93B	97116B	106.23B	23.50B	82.73B	30.19B	0.85B	77.88	11.52
120 cm	7.90	15.32A	103085A	123.41A	25.46A	97.94A	33.48A	0.95A	79.36	11.64
HSD (5%)	NS	1.20	5056.70	3.52	1.69	5.20	1.33	0.02	NS	NS
Cultivars										
HSF 240	7.88	16.16A	95801B	105.85B	24.55AB	81.30B	29.57B	0.85B	76.81	10.87B
CP 77-400	7.65	14.61B	104195A	128.70A	26.76A	101.95A	34.52A	0.98A	79.22	11.22B
CPF 249	8.20	13.09C	100305AB	109.92B	22.14B	87.77B	31.42B	0.87B	79.85	12.66A
HSD (5%)	NS	1.19	6125.60	6.50	3.80	7.45	2.74	0.07	NS	0.83

recorded by CPF 249. While, non-significant difference was seen in interaction of planting geometry and cultivars.

***Cane yield (t ha^{-1})*:** The highly significant difference was observed in cane yield in planting geometry treatments (Table 2). Maximum cane yield (97.94 t ha^{-1}) was found in 120 cm apart dual rows trench planting, and minimum (82.73 t ha^{-1}) cane yield was recorded in 75 cm apart single row trench planting. Among the cultivars, CP 77-400 produced more cane yield (101.95 t ha^{-1}) compared to CPF 249 (87.77 t ha^{-1}) and HSF 240 (81.30 t ha^{-1}). But results of the interaction were non-significant.

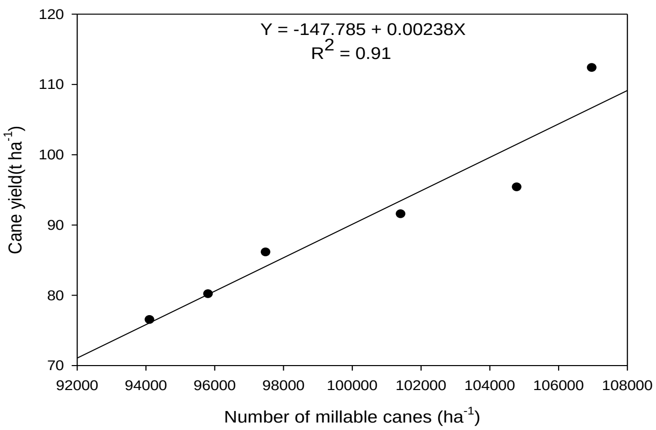

Figure 1. Relationship between number of millable canes and cane yield.

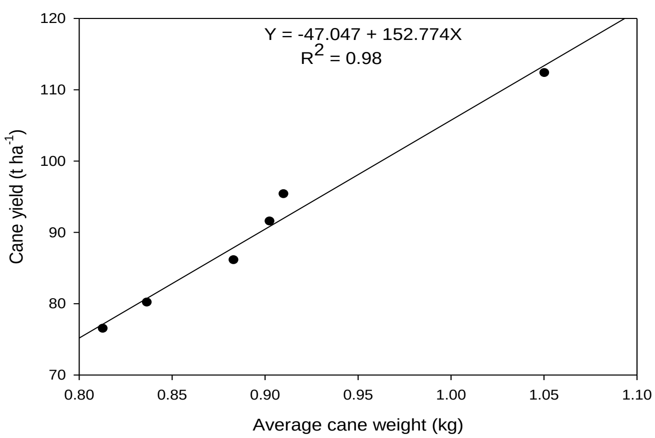

Figure 2. Relationship between average cane weight and cane yield.

***Biological yield (t ha^{-1})*:** Planting geometry 120 cm apart dual rows trench planting performed significantly superior in biological yield (33.48 t ha^{-1}) than 75 cm apart single row trench planting treatment (30.19 t ha^{-1}) as shown in Table 2. Cultivars also found significantly different in terms of biological yield. Highest biological yield was observed in CP 77-400 (34.52 t ha^{-1}) followed by CPF 249 (31.42 t ha^{-1}), While the minimum was found in HSF 240 (29.57 t ha^{-1}). On the other hand, interaction of planting geometry and cultivars was found non-significant for biological yield.

***Average cane weight (kg)*:** Average cane weight was significant in planting geometry treatments (Table 2). The recommended planting technique by Agriculture Department (Research Wing) i.e., 120 cm apart dual rows trench planting showed higher average cane weight (0.95 kg) compared to single row trench planting treatment (0.85 kg). While the cultivar CP 77-400 performed better in relation to average cane weight (0.98 kg) as compared to CPF 249 (0.87 kg) and HSF 240 (0.85 kg). Interaction of planting geometry and cultivars showed non-significant effect on average cane weight.

***Harvest index (%)*:** The planting geometry, cultivars and their interaction exhibited non-significant results for harvest index (Table 2). However, it ranged from 76.81 to 79.85%.

***Quality parameters Sugar recovery (%)*:** Sugar recovery was not affected by planting geometry, as given in Table 2. However, it was ranged from 11.52 to 11.64%. While a significant difference was recorded in sugar recovery (%) among the cultivars (Table 2). The highest sugar recovery was observed in CPF 249 (12.66 %) followed by CP 77-400 (11.22 %). The lowest sugar recovery (10.87%) was recorded in HSF 240. However, the interaction was non-significant.

DISCUSSION

Planting geometry plays a crucial role in maximizing the cane yield by affecting different processes during whole growing season, especially sunlight harvesting. In phenological parameters, days to emergence were not affected by planting geometry and cultivars. It might be due to prevailed weather conditions under which sugarcane cultivars didn't get the advantage concerning days taken for emergence. Thus, days to tillering were not affected in both planting geometries but by cultivars because it was only controlled by parent material of the varieties. In the beginning of planting, moisture was sufficient for all the buds of sugarcane due to which differences in number of plants were non-significant as the whole cane plant of each cultivar was used for making setts and soil moisture and other environmental conditions were same, that is why, no difference in planting geometry or cultivars were found. These results align with Patel et al. (2014a) but contradict the findings of Singh *et al.* (2018) who found significantly higher number of plants in wider rows than narrow rows due to adequate moisture.

Higher number of tillers under 120 cm apart dual rows treatment could be due to the availability of more space. Singh *et al.* (2018) also found significantly higher tillers in wider trenches than conventional planting methods at all sugarcane growth stages. Due to genetic makeup, cultivars have different ability to produce tillers per unit area, therefore, each variety produces different number of tillers under the same climatic conditions. Patel *et al.* (2014a) also recorded significant difference in tillers (m^{-2}) among various cultivars due to their parent material.

Abd El-Aal *et al.* (2015) reported a significant difference in millable canes among different varieties. Due to higher number of tillers in 120 cm dual rows trench planting, millable canes were also more in wider trenches than 75 cm single row trench planting. Light interception in wider row spacing is more which leads to more tillers. Ahmed *et al.* (2018) also found maximum canes per unit area when sugarcane planting was done at 1.2 m apart rows. Dying and survival of tillers is fully under control of varietal genetic makeup; therefore, variables number of canes were noticed at harvesting stage among all cultivars.

More total fresh biomass in dual rows trenches might be due to a greater number of tillers, more millable canes and individual cane weight. Due to genetic makeup, all the cultivars can produce different numbers of tillers, millable canes and cane weight etc. Therefore, the difference in total fresh biomass might be due to their genetic makeup. Greater number of millable canes in wider spaced trenches could be the possible reason for higher top trash weight in 120 cm apart dual rows trench planting. It shows that in wider row spacing tillers to millable canes conversion is more. Variations in top trash weight among genotypes could be due to unique genetic makeup of each cultivar.

The highest cane yield in both wider rows and cultivar was due to greater number of millable canes and average cane weight. Figures 1 and 2 showed a strong regression relationship of cane yield with the number of millable canes and average cane weight with R^2 of 0.91 and 0.98, respectively. Abiy *et al.* (2016) also reported that the cane yield was mainly controlled by the number of millable canes and individual cane weight. Similar results were also reported by Singh *et al.* (2018) who found higher cane yield (23.2%) in wider spaced rows than the conventional method due to more plant height, number of canes, cane diameter and average cane weight. Abd El-Aal *et al.* (2015) studied different cane varieties and found significant results of number of canes and cane yield when grown as first or second ratoon crop. Ahmed *et al.* (2018) found maximum cane yield when sugarcane was planted at 1.2 m apart rows. Further, he also found a significant effect of different varieties on cane yield.

Higher average cane weight might be due to more diameter and height of canes in wider trenches. As all cultivars have different abilities to produce a number of tillers, cane length, and cane diameter due to their parent material, they also affect individual cane weight among different cultivars. These results are in line with Chakrawal and Kumar (2014), who also observed a significant effect of genotypes on average cane weight. Sugar recovery is an inherit character of the varieties; therefore, planting geometry did not affect the sugar recovery. Abd El-Aal *et al.* (2015) also observed significant variation in sugar recovery among all varieties.

Conclusion**:** It was concluded that planting geometry 120 cm apart dual rows trench planting performed superior in terms of number of millable canes, total fresh biomass, average cane weight, cane yield and biological yield. While, the recently approved variety CPF 249 was found better in sugar recovery than the rest of the cultivars. On the other hand, genotype CP 77-400 yielded more yield and yield-related attributes.

Author Contribution Statement**:** Tanveer Ahmad: Conducted the research and collected the data; Naeem Fiaz: Helped in data collection & manuscript write up; Ashfaq Ahmad: Supervised the research; Muhammad Shafique: Helped in literature search & manuscript write up; Muhammad Aleem Sarwar: Helped in Lab. analysis and proof reading of manuscript; Hafiz Ali Raza: Helped in data analysis & literature search.

Conflict of interest**:** Authors declare no conflict of interest.

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