Indian Journal of Agricultural Sciences **95** (2): 167–172, February 2025/Article
https://doi.org/10.56093/ijas.v95i2.132881

Cane productivity and attributes, and yield gaps of different sugarcane (*Saccharum officinarum*) varieties in south-western Punjab, India

AMARJEET SINGH SANDHU[1], PRITPAL SINGH[1]* AND NAVNEET KAUR[1]

Farm Advisory Service Centre, Bathinda, Punjab 151 001, India

Received: 03 February 2023; Accepted: 24 December 2024

ABSTRACT

Sugarcane (*Saccharum officinarum* L.) varieties differ significantly for agronomic attributes which affect their yield potential in response to management practices. The present study was carried out during 2020–21 and 2021–22 at four different locations in Bhatinda (Sukha Singh Wala, Bhai Roopa, Dayalpura Mirza and Mehta villages), Punjab to investigate the variation in agronomic attributes of three early maturing (Co J-85, Co J-64, Co Pb-96) and two late maturing (Co Pb-98 and Co J-88) sugarcane varieties at four different locations. These results revealed that variety Co Pb-98 outperformed with significantly (P<0.05) higher cane height (23.8%), stalk diameter (17.9%), number of tillers/plant (34.4%), stalk height (22.8%), number of internodes (26.7%) and internode length (42.9%) over Co J-64, which contribute towards cane productivity. The cane productivity exhibited a linear significant relationship with single cane weight (R^2=0.753; P<0.05). These results revealed existence of yield gaps of 2.9-8.9 Mg/ha over the state average yield; the highest for Co J-85 (~207%) than the Co Pb-98 variety. Regardless of the sugarcane variety, a significantly higher single cane weight (17.1%) and cane productivity (11.1%) at Dayalpura Mirza as compared to at Sukha Singh Wala showed that high soil salinity was responsible for decreased cane productivity.

Keywords: Cane productivity, Soil salinity, Sugarcane varieties, Yield contributing attributes, Yield gap

Sugarcane (*Saccharum officinarum* L.) is grown in more than 120 countries for the production of sugar and ethanol (Aquino *et al.* 2017). It has been estimated that over 80% of the sugar produced in the world is obtained from sugarcane, whereas Brazil, India, China and Thailand account for ~60% of the total production (FAO 2016). In India, sugarcane is cultivated in wide range of agro-climatic conditions in tropical and sub-tropical regions (Tyagi *et al.* 2011, Singh and Saini 2011, Singh *et al.* 2023a, b). In the sub-tropical region of Punjab, sugarcane occupies ~89 thousand ha with average cane productivity of ~8.4 Mg/ha (Anonymous 2022). In this region, several varieties are cultivated with large differences in productivity (Singh *et al.* 2023a, b). It is known that the productivity of sugarcane could be enhanced by appropriate selection of suitable varieties depending upon their adaptability to the regional agro-climatic conditions (Saini *et al.* 2012, Ellail *et al.* 2020). The quality sugar can be recovered from the high yielding and high-sugarcane varieties (Singh *et al.* 2023a, b). To achieve sugar recovery throughout the crushing season, both early and mid-late maturing varieties should be selected as crushing in India starts from end-October to the first fortnight of November, and continues until March–April. The scheduling of early, mid and late season varieties results in longer crushing periods with higher sugar recovery (Singh *et al.* 2017). Therefore, appropriate sowing time, selection of varieties and harvesting schedule helps growers and millers attain higher yields and profit. There are several factors of which varieties and soil type has a significant impact on cane yield and yield attributes (Liu and Bull 2001, Singh *et al.* 2023a, b). The present study was therefore, conducted to investigate the performance of different sugarcane varieties (early and late maturing) based on agronomic attributes and their contribution towards cane productivity in salt-affected sandy loam soil in south-western Punjab.

MATERIALS AND METHODS

Description of study area: The present study was carried out during 2020–21 and 2021–22 at four different locations in Bhatinda (Sukha Singh Wala, Bhai Roopa, Dayalpura Mirza and Mehta villages), Punjab. The study area in Bathinda district falls in south-western Punjab, comprises an area of ~3385 km^2, and has been divided into 4 tehsils, viz. Bathinda, Rampura Phul, Maur and Talwandi Sabo (9 administrative blocks). The region is characterized by semi-arid climate with large variations between summer and winter temperatures (Singh *et al.* 2018). The maximum and minimum temperatures showed considerable variation

[1]Farm Advisory Service Centre (Punjab Agricultural University, Ludhiana, Punjab), Bathinda, Punjab. *Corresponding author email: jasppsingh@gmail.com

during both summer and winter seasons (Kaur *et al.* 2024). Maximum temperature goes above 48°C during summer, while temperature below 3°C accompanied by frosty spells during the winter months of December and January. The average annual rainfall in zone is approximately 420 mm, most of which ~75-80% is received during the monsoon season extending between July and September (Singh *et al.* 2019a, b). The soils of the study regions were sandy, calcareous and alluvial, which is an admixture of sand, gravel and silt in varying proportions. The important properties of surface (0–15 cm) soils at different locations are given in Table 1.

Details of technology demonstrated: At each location, three cane budded sets of five sugarcane varieties viz. three early maturing (Co J-85, Co J-64, Co Pb-96) and two late maturing (Co Pb-98 and Co J-88) were evaluated. Cane planting was done between mid-february to end-march. Three-budded cane sets (at 50 thousand/ha) were planted in rows 75 cm apart while maintaining trenches of 20–25 cm depth. Plot size varied between 500–700 m^2, depending upon availability of land at farmer's field. A recommended dose of fertilizers-N (150 kg N/ha) was applied in two equal splits; half of total fertilizer-N was top dressed alongside the cane rows with first irrigation to crop after germination, and the remaining half N was applied alongside the cane rows in mid-May. Since the soils at experimental sites were medium in available-P, therefore, fertilizer-P application was skipped. The crop was irrigated at 7–10 days interval during hot and dry period of April–June. However, during rainy season, the frequency of irrigation depends upon rainfall. During winter months (November–January), crop was irrigated in monthly intervals. During frost period, to protect from frost injury the crop was irrigated. For weed control, pre-emergence herbicide Atrataf 50 WP (Atrazine) @2.0 kg/ha was applied using 500 L of water 2–3 days after planting (DAP). For control of *dila* and *motha*, 2, 4-D sodium salt 80 WP @2.0 kg/ha was applied as post-emergence herbicide (at 3–5 leaf stage of weeds). For the control of top borer, 25 kg/ha granules of Ferterra 0.4 GR (Carbofuran) were applied at the base of the shoots in the first week of July (only when the damage of borer exceeds 5% level).

Data collection and calculations: In each plot, three pseudo-replications were created for gathering more precised information. The number of tillers was assessed by counting the total number of single plant tillers in a randomly selected 15 plants within each plot. Cane diameter (i.e. stalk diameter) was recorded at ground surface (2–3 cm above ground surface) and at breast height using vernier caliper. Cane length at breast height, number of internodes/cane and the internode length were measured from 10 randomly selected canes from each replicated plot. For measuring weight of single cane, 10 randomly selected canes with in each replication were harvested near the ground surface and weighed. The weight of all sugarcane stalks in each plot was measured at harvest and expressed as cane yield. The yield gap was estimated based on demonstration yield and state potential yield:

Yield gap over potential yield (Mg/ha) = Demonstration yield (Mg/ha) - State average yield (Mg/ha) (1)

Statistical analysis: The data collected on various aspects of investigation were analyzed using CPCS-1 software developed by Punjab Agricultural University, Ludhiana, Punjab, India (Cheema and Singh 1991). The data was subjected to analysis of variance (ANOVA) for the randomized complete block design (RCBD) to test the significance at $P<0.05$ using least significant difference (LSD) test. Correlation matrix was developed using SPSS software, and correlations significant at $P<0.05$ and $P<0.01$ were marked as * and **, respectively.

RESULTS AND DISCUSSION

Agronomic attributes of sugarcane varieties: There was significant differences in agronomic attributes, viz. number of tillers/plant, number of leaves/plant, plant height, stalk diameter, stalk height, number of internodes, internode length, single cane weight and cane yield of different sugarcane varieties (Table 2). Averaged across the locations, number of tillers were significantly ($P<0.05$) lower for Co J-85, highest for Co Pb-98, while the other varieties in-between. The number of leaves (above last internode) was significantly lower for Co J-64 (by ~32.5%) than the Co J-85. Average plant height of Co J-64 was significantly lower, while it was highest for Co Pb-96. These results revealed that plant height of Co Pb-96 was significantly higher by ~24.3%, compared with Co J-64 (Table 2). Stalk diameter of Co Pb-98 and Co J-88 at ground surface was significantly higher than other varieties, although there were non-significant differences amongst these varieties. Stalk diameter of Co J-64 was significantly higher by ~6.5% than Co J-85. These results corroborate earlier research highlighted a significant differences in agronomic attributes of sugarcane varieties and their contribution in cane productivity (Singh and Singh 2004, Sanghera *et al.* 2014, Kashyap *et al.* 2019).

Stalk diameter (at breast height) was significantly higher for Co J-88, while the lowest for Co J-64. It was significantly lower by ~12.1–20.6% for Co J-64, compared to others. The stalk height of Co Pb-98 was significantly higher by ~10.2% than Co Pb-96. Average stalk height of sugarcane

Table 1 Soil properties of the surface (0–15 cm) layer at different experimental sites in south-western Punjab.

Soil properties	Sukha Singh Wala	Bhai Rupa	Dayalpura Mirza	Mehta
$p\text{H}_{1:2}$	8.33	8.19	8.22	8.29
$EC_{1:2}$ (dS/m)	0.698	0.447	0.329	0.584
Soil organic carbon (g/kg)	0.385	0.419	0.468	0.401
Available-P (mg/kg)	7.19	11.3	13.4	8.78
Available-K (mg/kg)	76.5	84.8	78.0	101.5

Table 2 Agronomic attributes of different sugarcane varieties at four experimental sites in south-western Punjab (pooled data 2020–21 and 2021–22)

Varieties/ Locations	Number of tillers/plant					Number of leaves/plant (above the last internode)				
	Sukha Singh Wala	Bhai Rupa	Dyalpura Mirja	Mehta	Mean	Sukha Singh Wala	Bhai Rupa	Dyalpura Mirja	Mehta	Mean
Co J-85	9.0	10.0	12.0	11.0	10.5	11.2	12.1	13.3	12.4	12.3
Co J-64	12.3	13.0	13.0	11.8	12.5	7.4	8.2	8.8	8.9	8.3
Co Pb-96	12.9	12.1	13.5	12.8	12.8	10.9	12.3	13.4	11.8	12.1
Co Pb-98	15.8	16.9	17.5	16.8	16.8	14.3	16.4	16.4	15.5	15.7
Co J-88	10.2	11.9	10.6	12.2	11.2	10.9	12.3	13.4	11.8	12.1
Mean	12.0	12.8	13.3	12.9		10.9	12.3	13.1	12.1	
LSD (P<0.05)	Varieties = 0.42, Location = 0.37, Varieties × Location = 0.84					Varieties = 0.37, Location = 0.33, Varieties × Location = 0.74				
	Plant height (cm)					Stalk diameter at ground surface (cm)				
Co J-85	933	972	988	948	960	1.30	1.60	1.70	1.60	1.55
Co J-64	602	1011	1072	936	905	1.60	1.70	1.70	1.60	1.65
Co Pb-96	1053	1140	1162	1146	1125	1.60	1.70	1.70	1.60	1.65
Co Pb-98	1123	1142	1158	1057	1120	1.70	1.70	1.80	1.70	1.73
Co J-88	980	1091	1095	1001	1042	1.60	1.70	1.80	1.70	1.70
Mean	938	1071	1095	1018		1.56	1.68	1.74	1.64	
LSD (P<0.05)	Varieties = 44.9, Location = 40.2, Varieties × Location = 89.8					Varieties = 0.04, Location = 0.03, Varieties × Location = 0.08				
	Stalk diameter at breast height (cm)					Stalk height (cm)				
Co J-85	1.30	1.40	1.50	1.40	1.40	469	559	585	560	543
Co J-64	1.10	1.20	1.30	1.30	1.23	493	540	542	508	521
Co Pb-96	1.40	1.40	1.50	1.40	1.43	542	593	606	581	581
Co Pb-98	1.30	1.50	1.50	1.50	1.45	621	643	660	636	640
Co J-88	1.50	1.60	1.60	1.50	1.55	514	549	564	533	540
Mean	1.32	1.42	1.48	1.42		528	577	591	564	
LSD (P<0.05)	Varieties = 0.02, Location = 0.02, Varieties × location = 0.05					Varieties = 6.9, Location = 6.3, Varieties × location = 13.9				
	Number of internodes					Average internode length (cm)				
Co J-85	20.5	20.5	22.0	21.0	21.0	10.2	10.6	11.3	10.5	10.7
Co J-64	19.5	22.0	23.0	20.0	21.1	8.9	11.1	12.2	10.4	10.7
Co Pb-96	21.5	24.0	24.5	23.5	23.4	10.1	11.0	11.2	10.4	10.7
Co Pb-98	25.5	27.5	28.5	25.0	26.6	14.4	15.7	15.9	15.2	15.3
Co J-88	20.5	22.5	23.5	21.0	21.9	9.7	10.2	11.1	10.3	10.3
Mean	21.5	23.3	24.3	22.1		10.7	11.7	12.3	11.4	
LSD (P<0.05)	Varieties = 0.40, Location = 0.36, Varieties × Location = 0.81					Varieties = 0.31, Location = 0.27, Varieties × Location = 0.61				
	Cane weight (kg/cane)					Cane yield (Mg/ha)				
Co J-85	0.96	1.12	1.13	1.05	1.07	62.6	68.9	74.7	63.5	67.4
Co J-64	1.02	1.18	1.24	1.07	1.13	64.0	76.2	76.5	71.7	72.1
Co Pb-96	1.39	1.40	1.54	1.53	1.47	90.4	92.8	94.1	91.9	92.3
Co Pb-98	1.75	2.11	2.22	1.97	2.01	92.7	99.6	100.6	95.4	97.1
Co J-88	1.35	1.43	1.43	1.34	1.39	70.2	74.1	75.9	71.9	73.0
Mean	1.29	1.45	1.51	1.39		76.0	82.3	84.4	78.9	
LSD (P<0.05)	Varieties = 0.08, Location = 0.07, Varieties × Location = 0.17					Varieties = 0.72, Location = 0.65, Varieties × Location = 1.44				

was significantly lower for Co J-64 by ~18.6% than the Co Pb-98. There was a non-significant difference in stalk height between Co J-85 and Co J-88. The number of internodes was significantly higher for Co Pb-98, compared with the others. As compared with the Co J-64 variety, number of internodes was higher by ~26.1% for Co Pb-98 (Table 2). Average internode length did not differ significantly for Co J-85, Co J-64 and Co Pb-96, while was significantly higher for Co Pb-98. A significant variation in average stalk height of different sugarcane varieties and its contribution towards increased cane diameter has also been reported earlier (Sohu *et al.* 2008). It has been well established that stalk diameter has been important determinant of cane productivity (Sohu *et al.* 2008, Singh *et al.* 2023a). The larger stalk diameter has been reported to contribute significantly towards cane productivity and economic indices of sugarcane (Ramdoyal 1999). A large variation amongst the sugarcane varieties for number of internodes/cane has also been reported earlier (Khan *et al.* 2003).

Regardless of the sugarcane variety, significantly higher values for these agronomic attributes was recorded for Dayalpura Mirza, the lowest for Sukha Singh Wala, while the others in-between (Table 2). As compared with the Sukha Singh Wala location, the number of tillers/plant were higher by ~10.8%, number of leaves/plant by ~20.2%, plant height by ~16.7% and stalk diameter at ground surface by ~11.5% at Dayalpura Mirza. Similarly, the stalk diameter at breast height and stalk height were higher by ~12.2 and 11.9%, respectively at Dayalpura Mirza than at Sukha Singh Wala. The number of internodes and their length were significantly higher by ~13.1 and 15.0%, respectively at Dayalpura Mirza than the Sukha Singh Wala experimental site. The significantly lower cane productivity and agronomic attributes of sugarcane varieties at Sukha Singh Wala was ascribed to relatively higher concentration of soluble salts ($EC_{1:2}$=0.698 dS/m), compared with the other sites. Additionally, the general fertility status of soil at Sukha Singh Wala was lower; low soil organic C and available-P (Table 1). These results corroborate earlier research highlighting detrimental impacts of soil salinity on cane productivity and associated yield contributing agronomic attributes of sugarcane varieties (Singh *et al.* 2023a, b). Due to increased concentration of soluble salts concentration, cane productivity has been reported to decline by ~14 Mg/ha with one unit (dS/m) rise in electrical conductivity (Wiegand *et al.* 1996). Accumulation of soluble salts in rhizosphere results in reduced net photosynthetic rate and a change in enzyme activity of soils and plant system (Gomathi *et al.* 2004).

Cane productivity of different sugarcane varieties: Single cane yield varied between 0.96 and 2.22 kg/cane, regardless of the location and sugarcane variety (Table 2). Single cane yield was significantly higher for Co Pb-98 by 37.4–89.0%, compared with the other varieties. Cane yield of Co Pb-96 was significantly higher by ~29.9% than Co J-64. The single cane productivity of Co Pb-96

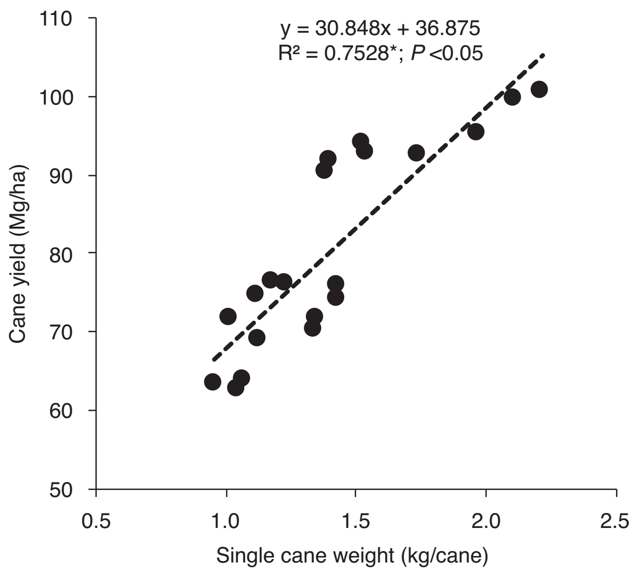

Fig. 1 Relationship between single cane weight (kg/cane) and cane yield (Mg/ha) (pooled for different sugarcane varieties and locations).

and Co J-88 did not differ significantly. Regardless of the sugarcane variety, single cane yield was significantly higher at Dayalpura Mirza than at Sukha Singh Wala. These results revealed a linear significant relationship between single cane yield and cane productivity (Fig. 1). The relationship between single cane yield and cane productivity could best described by equation 2.

$$\text{Cane yield (Mg/ha)} = 30.848x + 36.875;\ R^2 = 0.753^*;\ P<0.05$$

These results revealed that cane productivity of 97.1 Mg/ha for Co Pb-98 was significantly higher by ~32.9–44.0% than the Co J-85, Co J-64 and Co J-88 (Table 2). Cane productivity of Co J-64 and Co J-88 did not differ significantly. Averaged across the varieties, cane yield at Dayalpura Mirza was higher by ~6.9–11.2%, compared with the Sukha Singh Wala and Mehta locations. Fig 2 illustrates the yield gap of 2.9–8.9 Mg/ha over the state average yield. The highest yield gap of 8.9 Mg/ha was observed for Co J-85, which was higher by ~207% than the Co Pb-98.

Relationship between agronomic attributes and cane

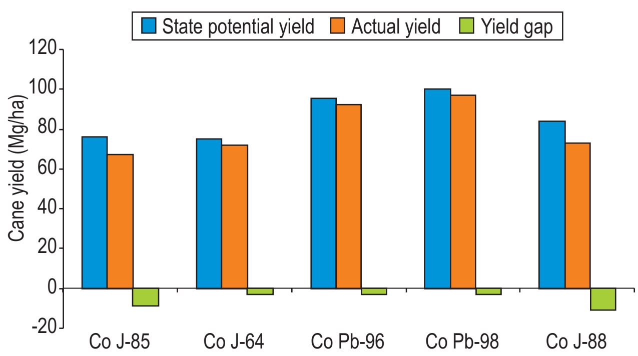

Fig. 2 Average cane yield and gaps estimated over state potential yield and actual yield for different sugarcane varieties evaluated at farmer's fields in south-western Punjab.

Table 3 Correlation matrix depicting relationship between various agronomic attributes of sugarcane cultivated in south-western Punjab. (pooled for different sugarcane varieties and locations)

Character	Cane length	Number of internodes	Length of internodes	Diameter at ground surface	Diameter at breast height	No. of tillers/ plant	Plant height
Number of internodes	0.863**						
Length of internodes	0.775**	0.788**					
Diameter at ground surface	0.151	0.359	0.239				
Diameter at breast height	0.393	0.330	0.241	0.156			
Number of tillers/plant	0.693**	0.786**	0.851**	0.496*	0.024		
Plant height	0.581**	0.616**	0.227	0.270	0.310	0.365	
Cane yield	0.763**	0.854**	0.679**	0.346	0.287	0.785**	0.604**

* and ** are significant at P<0.05 and 0.01, respectively.

productivity: The correlation matrix showed a significant linear relationship between cane yield and number of internodes (r = 0.863**), length of internodes (r = 0.775**), number of tillers/plant (r = 0.693**) and average plant height (r = 0.581**) (Table 3). The average plant height exhibited a significant linear increase with number of internodes (r = 0.616**). These results revealed that cane yield increased linearly with increased length of internodes (r = 0.679**). Cane yield exhibited a significant linear relationship with increase average plant height (r = 0.604**). The increased cane productivity was related to combined effect of number of internodes/plant, average internode length and cane length (Raman *et al.* 1985, Kashyap *et al.* 2019). A highly positive and significant relation between cane yield and agronomic attributes, viz. cane length and number of internodes has also been reported earlier (Chaudhary and Joshi 2005).

The present study evaluated the performance of five different sugarcane varieties at four different locations. Amongst the tested varieties, Co Pb-98 has significantly higher cane height, stalk diameter, number of tillers/plant, number of internodes and internode length over Co J-64. Regardless of the variety, number of tillers/plant were higher by ~10.8%, number of leaves/plant by ~20.2%, plant height by ~16.7% and stalk diameter at ground surface by ~11.5% at Dayalpura Mirza as compared to the Sukha Singh Wala location. These results revealed ~17.1% higher single cane yield and ~11.1% cane productivity at Dayalpura Mirza as compared to Sukha Singh Wala. The lower sugarcane productivity at Sukha Singh Wala location was ascribed to higher electrical conductivity of soil ($EC_{(1:2)}$ = 0.698 dS/m). Cane productivity exhibited a linear significant relationship with number of internodes (r = 0.863**), length of internodes (r = 0.775**), number of tillers/plant (r = 0.693**) and average plant height (r = 0.581**). Cane yield exhibited a significant linear relationship with increase average plant height (r = 0.604**). These results revealed intensified extension efforts to disseminate the sugarcane production technology with special emphasis on selection of variety suitable for soils with variable concentration of soluble salts.

REFERENCES

Anonymous. 2022. *Package of Practices for Crops of Punjab*. Punjab Agricultural University, Ludhiana, Punjab.

Aqiuno G S, Medina C C, Costa D C, Shahab M and Santiago A D. 2017. Sugarcane straw management and its impact on production and development of ratoons. *Industrial Crops and Products* **102**: 58–64.

Chaudhary R R and Joshi B K. 2005. Correlation and path coefficient analysis in sugarcane. *Nepal Agricultural Research Journal* **6**: 24–27.

Cheema H S and Singh B. 1991. *Software Statistical Package CPCS-I*. Department of Statistics, Punjab Agricultural University, Ludhiana, Punjab, India.

Ellail A, Gadallah A F I and Gamal H E. 2020. Genetic variance and performance of five sugarcane varieties for physiological, yield and quality traits influenced by various harvest age. *Journal of Plant Production Mansoura Uni*versity **11**: 429–38.

FAO. 2016. Food and Agriculture Organization of the United Nations (FAO), FAOSTATS.

Gomathi R and Thandapani P V. 2004. Sugar metabolism and carbon partitioning of sugarcane genotypes under salinity stress condition. *Sugar Tech* **6**: 151–58.

Kashyap L, Sanghera G S and Anuradha. 2019. Effect of variety and season on cane yield and quality traits in sugarcane (*Saccharum* spp. Hybrid complex) under subtropical conditions. *Research Journal of Agricultural Sci*ences **10**: 8–12.

Kaur G, Rajni and Sivia J S. 2024. Integrating data envelopment analysis and machine learning approaches for energy optimization, decreased carbon footprints, and wheat yield prediction across north-western India. *Journal of Soil Science Plant Nutrition* **24**: 1424–47. https://doi.org/10.1007/s42729-024-01647-7

Khan M A, Keerio H K, Junejo S, Panhwar R N, Rajput M A and Qazi B R. 2003. Evaluation of new sugarcane genotypes developed through fuzz correlation of cane yield and yield components. *Journal of Applied Sci*ences **3**: 270–73.

Liu D L and Bull T A. 2001. Simulation of biomass and sugar accumulation in sugarcane using a process-based model. *Ecological Modelling* **144**(2–3): 181–211.

Raman K, Bhat S R and Tripathi B K. 1985. Ratooning ability of sugarcane genotypes under late harvest conditions. *Indian Sugar* **35**: 445–48.

Ramdoyal K. 1999. Genetic correlation and repeatability of agronomic characters in sugarcane population in contrasting environment and different crop years. *Sugarcane* **4:** 6–12.

Saini S P, Sidhu A S and Singh P. 2012. Crop yield, efficiency and economics of autumn and spring sown single bud sugarcane intercropped with pulse crops. *International Journal of Forestry and Crop Improvement* **3**(2): 60–65.

Sanghera G S, Tyagi V, Kumar R and Thind K S. 2014. Selection indices for earliness yield and quality traits in sugarcane for sub-tropical region of India. *(In) International Conference on "Crop Productivity and Sustainability-Shaping the Future,* Baba Farid Group of Institution Bathinda, pp. 31–34.

Singh A, Singh P and Mahajan M. 2023a. Agronomic and biochemical quality attributes and economic indices of sugarcane (*Saccharum officinarum* L.) cultivation in saline vis-a-vis non-saline soils of south-western Punjab, India. *The Indian Journal of Agricultural Sciences* **93**(1): 106–09. https://doi.org/10.56093/ijas.v93i1.130246

Singh A, Singh P and Mahajan M. 2023b. Net primary production, biochemical composition and economics of sugarcane (*Saccharum officinarum* L.) cultivation in saline and non-saline soils of south-western Punjab, India. *International Journal of Plant Production* **17**(3): 557–77. https://doi.org/10.1007/s42106-023-00248-1

Singh G, Singh P and Sodhi G P S. 2018. Status of crop management practices for rice and basmati cultivation in south-western Punjab. *Journal of Community Mobilization and Sustainable Development* **13**: 457–62.

Singh P and Saini S P. 2011. Effect of rice straw mulching and irrigation intervals on sugarcane (*Saccharum officinarum*) yield and water productivity in sub-tropics of Punjab. *Crop Research* **41**: 88–93.

Singh P, Pathak S K, Singh M M, Mishra V and Sharma B L. 2017. Impact of high sugar early maturing varieties for sustainable sugar production in sub-tropical India. *Sugarcane Technology* **19**(4): 368–72.

Singh P, Singh G and Sodhi G P S. 2019a. Energy auditing and optimization approach for improving energy efficiency of rice cultivation in south-western Punjab. *Energy* **174**: 169–79. https://doi.org/10.1016/j.energy.2019.02.169

Singh P, Singh G and Sodhi G P S. 2019b. Applying DEA optimization approach for energy auditing in wheat cultivation under rice-wheat and cotton-wheat cropping systems in north-western India. *Energy* **181**: 18–28. https://doi.org/10.1016/j.energy.2019.05.147

Singh R K and Singh D N. 2004. Evaluation of early sugarcane varieties for sustaining high sugar recovery in Uttar Pradesh. *Cooperative Sugar* **31**: 797–804.

Sohu I A, Memon A H and Abro B A. 2008. Performance of sugarcane varieties in comparison with commercial varieties. *Life Sciences: An International Journal* **2:** 760–64.

Tyagi V K, Sharma S and Bhardwaj S B. 2011. A study on the nature and magnitude of variations in different traits in sugarcane. *Electronic Journal of Plant Breed*ing **2:** 334–41.

Wiegand C L, Escobar D E and Lingle S E. 1996. Growth and yield responses of sugarcane to saline soils: I. Sensing and mapping using aerial videography. *(In) Proceedings of International American Sugarcane Seminar*, pp. 15–17.