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P Sri Lokesh
SV Agricultural College, ANGRAU, Tirupati, Andhra Pradesh, India

KR Tagore
SV Agricultural College, ANGRAU, Tirupati, Andhra Pradesh, India

D Mohan Reddy
S.V. Agricultural College, ANGRAU, Tirupati, Andhra Pradesh, India

SK Naffez Umar
SV Agricultural College, ANGRAU, Tirupati, Andhra Pradesh, India

Corresponding Author:
P Sri Lokesh
SV Agricultural College, ANGRAU, Tirupati, Andhra Pradesh, India

Character association studies and path analysis on yield, yield attributing traits in early clones of sugarcane (*Saccharum* spp.)

P Sri Lokesh, KR Tagore, D Mohan Reddy and SK Naffez Umar

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Abstract
Seven early clones of sugarcane were evaluated in a randomized block design with three replications which were planted in plots at Agricultural Research Station (ARS), Perumallapalle, Tirupati, during cropping season 2022-23, so as to evaluate the variation and association between the cane yield and its components and to estimate the direct and indirect effects on cane yield. In this study Cane length, NMC, SCW, brix, Sucrose, CCS% and CCS yield showed positive and significant association with cane yield and also among them. Path analysis revealed that the characters *viz.,* NMC and SCW exhibited high positive direct effects on cane yield in early trial. Direct selection of above characters would be helpful for the improvement of cane yield.

Keywords: Sugarcane, early clones, character association, path analysis

Introduction

Sugarcane (*Saccharum spp.*) is a tall, perennial grass in the tropics, belongs to poaceae family, subfamily panicoideae, and order poales. It is a cross-pollinated crop with 2n=80-120. After Brazil, India is the second-largest producer of sugar. Papua New Guinea is the original home of sugarcane, which there has been farmed for thousands of years. *Saccharum spontaneum* and *S. officinarum* (*Saccharum spp*.) interspecific hybrids that were repeatedly backcrossed with *S. officinarum* are the basis of modern varieties of sugarcane that are grown for sugarcane production. Approximately 80% of sugar made from sugarcane, with the cultivation of sugar beets providing the remaining 20%. A typical person consumes roughly 24 kilograms of sugar annually. More than 120 nations are said to be growing sugarcane on a big scale for both domestic use and export.

Sugarcane is also used to make particle board, paper, alcohol, cogen, and jaggery. Molasses and bagasse are the primary by-products of the sector of sugarcane. Molasses is utilised in distilleries making butyl alcohol, ethyl alcohol, citric acid, etc., whereas bagasse is mostly used as fuel.

Correlation coefficients play a significant role in understanding the relationship between the characters. In the field of agriculture, sugarcane production is influenced by numerous factors, including weather conditions, soil properties, nutrient levels, and management practices. Correlation coefficients provide a quantitative measure of the strength and direction of the relationships between these characters, allowing researchers and farmers to gain valuable insights. By understanding the correlation between the characters in sugarcane, breeders can select genotypes with desirable traits with less efforts. This can result in sugarcane varieties that are more productive, profitable, and resistant to disease.

Path analysis is a valuable statistical technique used in the field of sugarcane research to investigate the complex relationships between various factors and their effects on sugarcane growth and productivity. By examining the direct and indirect effects of multiple variables, path analysis helps researchers understand the underlying mechanisms and pathways through which these factors interact and influence the final outcomes. (Brasileiro *et al.* 2013) [6].

Materials and Methods
The experimental material for the present investigation consisted of seven early clones selected from clonal population. The experiment was laid in RBD with three replications and all the recommended package of practices for cultivation of sugarcane crop was followed. The three replications data were recorded for the following characters *viz.*, Germination at 30 DAP, tillers at 120 DAP, shoots at 240 DAP, number of milliable canes, single cane weight, cane length, cane diameter, juice extraction at 8th month, brix% at 8th month, sucrose % at 8th month, purity % at 8th month, Commercial cane sugar% at 8th month, juice extraction at 10th month, brix % at 10th month, sucrose % at 10th month, purity % at 10th month, Commercial cane sugar % at 10th month, reducing sugars at 10th month, top leaf weight at harvest, fibre % at 10th month, Commercial cane sugar yield (t/ha) and cane yield (t/ha). The data were statistically analysed to estimate phenotypic correlation coefficients (Johnson *et al.* 1955) [11] and phenotypic path coefficient analysis (Dewey and Lu, 1959) [8].

Results and Discussion
In the present study from Table-1, Germination at 30 DAP expressed positive and highly significant association with juice extraction (0.766**). It had positive association with shoots at 240 DAP (0.080), cane diameter (0.139) and fibre (0.195). It had negative association with tillers at 120 DAP (-0.365), cane length (-0.237), SCW (-0.271), purity (-0.138), reducing sugars (-0.261) and Top leaf weight (-0.024). It had negative and highly significant association with NMC (-0.798**), brix (-0.584**) and CCS yield t/ha (-0.583**). It also had negative and significant association with sucrose (-0.519*) and CCS (-0.471*). The Germination% showed negative and significant association with cane yield (-0.496*) may be due to negative significant association of NMC, Brix%, Sucrose%, CCS% and CCS yield characters. Above correlation results are in accordance with Pandya and Patel (2017) [17], Gowda *et al.* (2016) [9] and Kumar *et al.* (2021) [12]. Tiller count at 120 DAP expressed positive and significant association with shoots at 240 DAP (0.482*), reducing sugars (0.452*) and fibre (0.438*). It had positive association with cane diameter (0.128), NMC (0.378), SCW (0.213) brix (0.141) and CCSY (0.131). It had negative and significant association with Purity (-0.474*). It had negative association with cane length (-0.050), juice extraction (-0.285), sucrose (-0.132), CCS (-0.214) and TLW (-0.021). The T-120 DAP showed positive association with cane yield (0.301) may be due to positive association of CD, NMC, SCW, Brix% and CCS yield characters. Above correlation results are in accordance with Agarwal and Kumar (2018) [2], Pandya and Patel (2017) [17], Ahmed (2010) [3] and Kumar *et al.* (2021) [12].
Shoot count at 240 DAP expressed positive association with SCW (0.346) juice extraction % (0.070), brix (0.056), CCSY (0.076), reducing sugars (0.030) and fibre % (0.024). It had negative association with cane length (-0.370), cane diameter (-0.036), NMC (-0.114), sucrose (-0.104), purity (-0.289), CCS (-0.152) and TLW (-0.159). The S-240DAP showed positive association with cane yield (0.197) may be due to positive association of SCW, Juice extraction%, Brix%, CCS yield, Reducing sugars% and fibre% characters. The experimental results are in accordance with Agarwal and Kumar (2018) [2], Pandya and Patel (2017) [17] and Kumar *et al.* (2021) [12].
Cane length at harvest expressed positive and highly significant association with CCSY (0.573**). It also had positive and significant association with cane diameter (0.523*), SCW (0.468*), sucrose (0.508*), purity (0.492*), CCS (0.529*) and TLW (0.459*). It had positive association with NMC (0.223), brix (0.340) and fibre (0.360). It had negative association with juice extraction (-0.282) and reducing sugars (-0.230). The cane length showed positive and significant association with cane yield (0.485*) may be due to positive and significant association of CD, SCW, Sucrose %, Purity %, CCS, CCS yield and TLW characters. The experimental results here presented are in accordance with Tyagi and Lal (2007) [22], and Tena *et al.* (2022) [24].
Cane diameter at harvest expressed positive and highly significant association with fibre (0.572**). It had positive association with SCW (0.415), juice extraction (0.212), brix (0.054), CCSY (0.201) and TLW (0.329). It had negative association with NMC (-0.102), sucrose (-0.019), purity (-0.119), CCS (-0.040) and reducing sugars (-0.037). The cane diameter showed positive association with cane yield (0.323) may be due to positive association of SCW, juice extraction%, Brix% and CCS yield characters. The experimental results here presented are in accordance with Tyagi and Lal (2007) [22], Agarwal and Kumar (2018) [2], and Tena *et al.* (2022) [24].
NMC at harvest expressed positive and highly significant association with CCSY (0.598**). It had positive and significant association with brix (0.516*). It had positive association with SCW (0.305), sucrose (0.386), CCS (0.320), reducing sugars (0.299) and TLW (0.027). It had negative and highly significant association with juice extraction (-0.607**). It also had negative association with purity (-0.024) and fibre (-0.148). The NMC showed positive and significant association with cane yield (0.631**) may be due to positive and significant association of Brix% and CCS yield characters. The experimental results here presented are in accordance with Tyagi and Lal (2007) [22], and Tena *et al.* (2022) [24].
SCW expressed highly significant positive association with brix (0.604**) and CCSY (0.764**). It had positive and significant association with sucrose (0.515*) and CCS (0.458*). It had positive association with purity (0.102), fibre (0.020) and TLW (0.380). It also had negative association with juice extraction (-0.230) and reducing sugars (-0.316). The single cane weight showed positive and significant association with cane yield (0.920**) may be due to positive and significant association of Brix%, Sucrose%, CCS% and CCS yield characters. Similar kind of results was obtained by Gowda *et al.* (2016) [9], Ahmed *et al.* (2010) [3] and Kumar *et al.* (2021) [12].
Juice extraction% expressed negative and significant association with brix % (-0.463*), sucrose (-0.502*), CCS (-0.482*) and CCSY (-0.496*). It also had positive association with fibre (0.345), TLW (0.277). It also had negative association with purity (-0.294) and reducing sugars (-0.198). Juice extraction% showed negative association with cane yield (-0.380) may be due to negative association of Purity % and reducing sugars% characters. The similar kind of results were obtained by Kumar and Agarwal (2018) [2], Tyagi and Lal (2007) [22] and Singh *et al.* (2020) [20].
Brix % expressed positive and highly significant association with sucrose % (0.870**), CCS % (0.786**) and CCS yield t/ha (0.817**). It also had positive association with purity

(0.193) and TLW (0.182) It also had negative association with reducing sugars (-0.416) and fibre (-0.316). Brix% showed positive and significant association with cane yield (0.654**) may be due to positive and significant association of Sucrose%, CCS% and CCS yield characters. The similar kind of results were obtained by Kumar and Agarwal (2018) [2], Tyagi and Lal (2007) [22] and Singh *et al.* (2020) [20].

Sucrose % expressed positive and highly significant association with purity (0.652**), CCS % (0.989**) and CCS yield t/ha (0.826**). It also had negative and highly significant association with reducing sugars (-0.584**). It also had positive association with TLW (0.313). It also had negative association with fibre (-0.371). Sucrose% showed positive and significant association with cane yield (0.543*) may be due to positive and significant association of Purity%, CCS% and CCS yield characters. The similar kinds of results were obtained by Tena *et al.* (2022) [24].

Purity expressed positive and highly significant association with CCS (0.757**). It also had negative and significant association with reducing sugars (- 0.519*). It had positive association with CCSY (0.390) and TLW (0.340). It also had negative association with fibre (-0.251). The Purity% showed low positive association with cane yield (0.079) may be due to low positive association of CCS yield and TLW characters. The similar kind of results was obtained by Pandya and Patel (2017) [17], Singh *et al.* (2020) [20] and Tena *et al.* (2022) [24].

CCS % expressed positive and highly significant association with CCS yield t/ha (0.782**). It also had positive association with TLW (0.338). It also had negative and highly significant association with reducing sugars (-0.606**). It also had negative association with fibre (-0.372). CCS% showed positive and significant association with cane yield (0.475*) may be because of positive and significant association of CCS yield character. The similar kind of results was obtained by Pandya and Patel (2017) [17] and Singh *et al.* (2020) [20].

CCS yield (t/ha) expressed positive significant association with TLW (0.385). It also had negative association with reducing sugars (-0.354) and fibre (-0.160). CCS yield showed positive and significant association with cane yield (0.919**) may be due to positive and significant association of TLW character. The similar kind of results was obtained by Pandya and Patel (2017) [17] and Singh *et al.* (2020) [20].

Reducing sugars at harvested expressed positive association with fibre (0.327). It also had negative association with TLW (-0.312) and Reducing sugars% showed negative association with cane yield (-0.134) may be due to negative association of TLW character. The experimental results here presented are in accordance with Pandya and Patel (2017) [17], Mali and Patel (2013) [15] and Kumar *et al.* (2021) [12].

Fibre % expressed positive association with TLW (0.315). The fibre% showed positive association with cane yield (0.013) may be due to positive association of TLW character. The similar kind of results was obtained by Pandya and Patel (2017) [17], Mali and Patel (2013) [15] and Kumar *et al.* (2021) [12]. In the present study, it was observed that the single cane weight (0.901) had positive and high direct effect on cane yield followed by NMC (0.438).

Conversely, negative and low direct effect on cane yield was exhibited by cane length (-0.114) and brix (-0.126). The above results were in accordance with Hiremath *et al.* (2015) [10], Priya (2013) [18] and Kumar *et al.* (2021) [12].

Cane length had low negative and direct effect on cane yield per hectare (-0.114). It has positive and indirect effects through NMC (0.097) and single cane weight (0.421). The obtained results nullifies the negative direct effects through its positive indirect effects and resulted in the positive and significant correlation with cane yield (0.485*). Similar type of negative and direct effect of cane length were given by Pandya and Patel (2017) [17] and Singh *et al.* (2020) [20].

NMC had high positive and direct effect on cane yield (0.438). However it has indirect high positive effect *via* SCW (0.274). Significant positive association with cane yield per hectare (0.631**) was due to its high positive direct effect. Similar type of high positive and direct effect of NMC were given by Priya (2013) [18], Agarwal and Kumar (2018) [2] and Singh *et al.* (2020) [20].

Single cane weight had high positive and direct effect on cane yield (0.901). It shows significant positive association with cane yield per hectare (0.920**) which was due to its high positive direct effect. Similar type of high positive effect of single cane weight was given by Priya (2013) [18] and Kumari *et al.* (2020) [20].

Brix had low and negative direct effect on cane yield (-0.126). It has positive and indirect effects through NMC (0.226), SCW (0.543) and Sucrose (0.128). It shows significant positive association with cane yield per hectare (0.654*) which was due to positive indirect Effects. Therefore, nullifies the low negative direct effect. Similar kinds of results for low negative direct effect of brix were given by Kumar (2014) [13] and Singh *et al.* (2022) [21].

Sucrose had low positive and direct effect on cane yield per hectare (0.147). It has positive and indirect effects through SCW (0.463). It shows positive and significant correlation with cane yield (0.543*). Similar type of positive and direct effect of sucrose were given by Pandya and Patel (2017) [17] and Singh *et al.* (2022) [21].

Conclusion

The correlation studies in early clones revealed that cane length, number of millable canes, single cane weight, brix%, sucrose%, CCS% and CCS yield (t/ha) showed positive and significant association with cane yield and also among themselves indicating that simultaneous selection for these characters would result in the improvement of cane yield in sugarcane. Characters like germination at 30 DAP show significant negative association with cane yield. Characters like tillers at 120 DAP, shoots at 240 DAP, and cane diameter, purity%, fibre% and top leaf weight show positive association with cane yield. Characters like juice extraction% and reducing sugars% show negative association with cane yield. Path analysis revealed that the characters *viz.*, single cane weight, number of millable canes, juice extraction%, sucrose% and fibre% exhibited high positive direct effects on cane yield and the other characters also exhibited their indirect positive effects on cane yield *via*, these characters, indicating that these were the major contributing characters to cane yield in sugarcane. Hence, direct selection for these characters like single cane weight, number of millable canes, juice extraction%, sucrose% and fibre% would be helpful for the improvement of cane yield. The phenotypic residual effect was 0.123 indicating that the characters included in the present study are contributing 87.7 per cent of variability pertaining to the dependent variable is *i.e.* cane yield per hectare. Hence, the characters under the consideration, some other characters should be included in further studies.

Table 1: Phenotypic Correlation coefficients among yield and yield attributing characters in early clones of Sugarcane

	G%	T-120	S-240	CL	CD	NMC	SCW	Juice EXTN	Brix	Sucrose	Purity	CCS	CCSY	Red. Sugars	Fibre	TLW	Cane Yield
G%	1.000	-0.365	0.080	-0.237	0.139	-0.798**	-0.271	0.766**	-0.584**	-0.519*	-0.138	-0.471*	-0.568**	-0.261	0.195	-0.024	-0.496*
T-120		1.000	0.482*	-0.050	0.128	0.378	0.213	-0.285	0.141	-0.132	-0.474*	-0.214	0.131	0.542*	0.438*	-0.021	0.301
S-240			1.000	-0.370	-0.036	-0.114	0.346	0.070	0.056	-0.104	-0.289	-0.152	0.076	0.030	0.024	-0.159	0.197
CL				1.000	0.523*	0.223	0.468*	-0.282	0.340	0.508*	0.492*	0.529*	0.573**	-0.230	0.360	0.459*	0.485*
CD					1.000	-0.102	0.415	0.212	0.054	-0.019	-0.119	-0.040	0.201	-0.037	0.572**	0.329	0.323
NMC						1.000	0.305	-0.607**	0.516*	0.386	-0.024	0.320	0.598**	0.299	-0.148	0.027	0.631**
SCW							1.000	-0.230	0.604**	0.515*	0.102	0.458*	0.851**	-0.316	0.020	0.380	0.920**
Juice EXTN								1.000	-0.463*	-0.502*	-0.294	-0.482*	-0.496*	-0.198	0.345	0.227	-0.380
Brix									1.000	0.870**	0.193	0.786**	0.817**	-0.416	-0.316	0.182	0.654**
Sucrose										1.000	0.652**	0.989**	0.826**	-0.584**	-0.371	0.313	0.543*
Purity											1.000	0.757**	0.390	-0.519*	-0.251	0.340	0.079
CCS												1.000	0.782**	- 0.606**	-0.372	0.338	0.475*
CCSY													1.000	-0.354	-0.160	0.385	0.919**
Red. Sugars														1.000	0.327	-0.312	-0.134
Fibre															1.000	0.315	0.013
TLW																1.000	0.345

*, ** Significant at 5% and 1%, respectively, G%: Germination % at 30 Days after planting; T-120: Tillers at 120 days after planting; S- 240: Shoots at 240 days after planting; CL: Cane length; CD: Cane diameter; NMC: Number of milliable canes; SCW: Single cane weight; Juice EXTN: Juice extraction%; CCS %: Commercial cane sugar %; CCSY: Commercial cane sugar yield (t/ha); Red. sugars: Reducing sugars%; TLW: Top leaf weight

Table 2: Phenotypic path co-efficient among yield and yield components of early sugarcane clones

	CL	NMC	SCW	Br	Su	Correlation with cane yield
CL	-0.114	0.097	0.421	-0.043	0.075	0.485*
NMC	-0.025	0.438	0.274	-0.065	0.057	0.631**
SCW	-0.053	0.133	0.901	-0.076	0.075	0.920**
Br	-0.038	0.226	0.543	-0.126	0.128	0.654**
Su	-0.058	0.169	0.463	-0.110	0.147	0.543*

*, ** Significant at 5% and 1%, respectively, Residual effect = 0.123
CL: Cane Length; CD: Cane diameter; NMC: Number of millable canes; SCW: Single Cane Weight; Br: Brix %; Su: Sucrose %

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