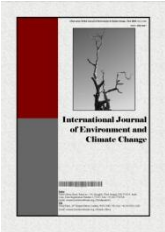

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Correlation and Path Analysis in Early Maturing Sugarcane: Climate Change and Environmental Impact

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An investigation was undertaken to identify early maturing sugarcane genotypes for higher sugar yield at the Research Farm of DRPCAU, Pusa, Samastipur, Bihar during the spring season of 2018, the experiment was carried out in Randomized Block Climate change is expected to have important consequences for sugarcane production in the world, especially in the developing countries because of relatively low adaptive capacity, high vulnerability to natural hazards, and poor forecasting systems and mitigating strategies. Sugarcane production may have been negatively affected and will continue to be considerably affected by increases in the frequency and intensity of extreme environmental conditions due to climate change. Design with three replications. Correlation and path analysis in twelve genotypes of sugarcane for twenty one different morphological and juice quality characters were studied in relation to the checks *viz*. CoLk94184 and CoSe95422. Analysis of correlation revealed that the character sugar yield had highly positive genotypic correlation with traits number of millable canes at harvest (0.977), followed by cane yield at harvest (0.963). However, it was negatively correlated with purity

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percentage at the 8th month stage (-0.491), cane diameter at harvest (-0.363), number of internodes at harvest (-0.263), length of internodes at harvest (-0.081) and fibre percentage at harvest (-0.039). The trait cane yield at harvest (0.955**) was found to have a highly significant and positive phenotypic association, followed by single cane weight at harvest (0.820**) and germination percentage at 45 DAP (0.510**).On the other hand, it was found that the traits cane diameter at harvest (-0.236), number of internodes at harvest (-0.151) and length of internodes at harvest (-0.099) had non-significant negative phenotypic associations with sugar yield. Positive direct effect on sugar yield at phenotypic level was exerted maximally by cane yield at harvest (t/ha) (1.51) followed by CCS percentage at 10th month stage (0.29) and pol in juice at 10th month stage (0.21), germination Percentage at 45 DAP (%), cane diameter (cm) and length of internode (cm), whereas at genotypic level maximum positive direct effect was observed in the case of pol percentage in cane at harvest followed by single cane weight (kg) and brix percentage at 10th month.

Keywords: Correlation; genotypic; path coefficient analysis; phenotypic; sugar yield sugarcane.

1. INTRODUCTION

Sugarcane is one of the oldest known crop grown in tropical and sub-tropical regions of the world. It is grown as a perennial monocotyledonous grass which is also a glycophyte and is rich in sucrose. Sugarcane (*Saccharum officinarum* L.) belongs to the Family: Poaceae, of tribe: Andropogoneae and sub-tribe: Saccharinae. It is an important cash crop in the entire world including India. It contributes to 75% of the worldwide sugar trade. It is the second most important industrial crop in India, sustaining millions of sugarcane farmers and livelihoods on sugarcane production. It is grown in 46.03 lakh hectares in India, with a total production of 370–371 million tonnes and a productivity of 80.50 t/ha (ICAR-sugarcane statistics 2019-2020), whereas it is grown in 2.19 lakh hectares in Bihar, with a production of 1.50 million tonnes and a productivity of 68.43 t/ha (ICAR-sugarcane statistics 2020-2021). Agriculture is vulnerable to climate change through the direct effects of changing climate conditions (e.g., changes in temperature and/or precipitation), as well as through the indirect effects arising from changes in the severity of pest pressures, availability of pollination services, and performance of other ecosystem services that affect agricultural productivity. Reduction of crop productivity is universally predicted in most status reports on effects of climate change. A negative effect of increased temperature may occur in the tropical regions where cool winters are required to slow plant growth and increase sucrose storage. Probably the most dramatic effect of climate change on sugarcane production in Australia would be from the increase in sea level [1]. Early maturing clones of sugarcane play an important role in enhancing cane and sugar yield. To improving yield rationally, component traits of yield should be selected. The correlation of different yield components with yield is considered to be highly significant based on indirect selection. Simple phenotypic correlation is an indication of the type of correlation among the different traits but is not at all a reliable basis for selection. Therefore, a genotypic correlation which is based upon the inheritance of the observed variation enables the assessment of the pattern of inherent relationship existing among the various traits.

Path coefficient analysis is used to partition the association among characters into direct and indirect effects and measures the relative importance of the causal factors involved. It is simply a standardized partial regression coefficient and as such, measures the direct influence of one variable upon another. The characters associated can be considered together as criteria for selection by plant breeders to identify traits that are useful as selection criteria to improve the cane yield.

2. MATERIALS AND METHODS

The present investigation was carried out in the nursery block of the research farm of DRPCAU, Pusa, Samastipur, Bihar in RBD design with 3 replications during the spring season of 2018-19. The studied material for the experiment consists of 12 clones viz. CoBln15501, CoLk15466, CoLk15467, CoP15436, CoP15437, CoSe15451, CoSe15452, CoSe15455, CoSe15456, CoSe01421, CoLk94184 and CoSe95422. The plot size was 6 rows of 6 meters length each and spacing of 0.90 meter between rows. 150 three budded sets in every plot each genotype was separately planted in all three replications follow all recommended package and practices to raise good crop. The following 21 traits were observed and recorded: Germination percentage at 45 DAP (Days After Planting), Number of shoots per hectare at 120 DAP (000/ha), Plant height at harvest (cm), Cane diameter at harvest (cm), Number of millable canes at harvest (000/ha), Number of internodes at harvest, Length of internode at harvest (cm), Single cane weight (kg), Brix at 8th month stage (%), Pol in juice at 8th month stage (%), Purity at 8th month stage (%), Brix at 10th month stage (%), Pol in juice at 10th month stage (%), Purity at 10th month stage (%), CCS at 8th month stage (%), CCS at 10th month stage (%), Cane yield (t/ha), Sugar yield (CCS) at harvest (t/ha), Extraction % at harvest, Fibre % at harvest, Pol % in cane at harvest. Five representative clones were randomly selected from each plot in each replication for the cane characteristics such as cane diameter, single cane weight, plant height, number of internodes etc. whereas a number of millable canes, sugar yield and cane yield at harvest were recorded on a per plot basis and then converted into per hectare basis. Correlation and path analysis in twelve varieties of sugarcane for twenty-one different morphological and juice quality characters were studied in relation with the checks *viz.* CoLk94184 and CoSe95422.

2.1 Correlation Coefficient Analysis

The Correlation coefficient is the degree and direction of association between two variables. Simple correlation coefficients were evaluated at genotypic and phenotypic levels between pairs of characters by applying following formula given by Al-Jibouri et al*.* [2] as well as Panse and Sukhatme [3].

2.2 Genotypic Correlation Coefficient

Genotypic correlation between traits x and y:

$$r_{xy}(g) = \frac{\sigma g2\ (xy)}{\sqrt{\sigma g2\ (x)\ x\sigma g2\ (y)}}$$

2.3 Phenotypic Correlation Coefficient

Phenotypic correlation between traits x and y:

$$r_{xy}(p) = \frac{\sigma g2\ (xy)}{\sqrt{\sigma g2\ (x)\ x\sigma g2\ (y)}}$$

Where,

σ^2_g (x,y) = genotypic covariance between traits x and y

σ^2_p (x,y) = phenotypic covariance between traits x and y

2.4 Test of Significance

In order to test the significance of correlation coefficient, the estimated values were compared with table value of correlation coefficient at (n-2) treatment with degrees of freedom at 5 per cent and 1 per cent level of significance. If the evaluated value or correlation coefficient was greater than tabulated value, it is considered to be statistically significant.

2.5 Path Coefficient Analysis

Simple correlation coefficients could not explain the cause and effect of relationship between two variables. Therefore, standard regression analysis known as path analysis of the data were done in order to analyze whether the association of different traits with yield was due to their direct effect or was a consequence of their indirect effect via some other traits. The procedure was adopted from Wright [4], Dewey and Lu [5].

The genotypic correlations among sixteen characters were partitioned into their direct and indirect effects on cane yield.

Causal variable and their direct and indirect effects on cane yield were estimated as under.

The path coefficients were obtained by solving a set of simultaneous equations as below:

$$r_{ny} = P_{ny} + r_{n2}.\ P_{2y} + r_{n3}.\ P_{3y} + \ldots. + r_{nx}.\ P_{xy}$$

Where,

r_{ny} = Represents correlation coefficient between one component character and Yield,

p_{ny} = Represents the path coefficient between the character and yield,

r_{n2}, R_{n3},…,r_{me} = Represents correlation coefficients between that character and other yield component in turn.

The following genotypic correlation matrix was formed.

$$\begin{bmatrix} r_{1y} \\ r_{2y} \\ r_{3y} \\ . \\ . \\ . \\ r_{ny} \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & r_{13} & . & . & r_{n1} \\ r_{21} & r_{22} & r_{23} & . & . & r_{n2} \\ r_{31} & r_{32} & r_{33} & . & . & r_{n3} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ r_{n1} & r_{n2} & r_{n3} & . & . & r_{nn} \end{bmatrix} \quad X \quad \begin{bmatrix} p_{1y} \\ p_{2y} \\ p_{3y} \\ . \\ . \\ . \\ p_{ny} \end{bmatrix}$$

or, A = B x C

Where,

$r_{12} = r_{21}$ and so on and
r_{1y} = Correlation between first component character and yield.

The technique discovered by Goulden [6] was followed for inversion of the "B" matrix using partitioning method of matrix inversing the following correlation matrix as per Doolittle method given by Steel and Torrie [7].

Path coefficient (P_{ij}) was obtained as follows:

$$P_{ij} = (B^{-1}) \times A$$

Where,

(B^{-1}) is the inverse of mutual correlation matrix of character.

The indirect effect for particular characters through other characters was estimated by multiplication of direct path and particular correlation coefficient between those two characters, respectively.

Indirect effect = $r_{ij} \times p_{ij}$

Where,

i = 1, 2, 3,……,n
j = 1, 2, 3,…….,n
$P_{ij} = P_{1y} x P_{2y} x P_{3y} x ……. x P_{ny}$

The direct and indirect effects are rated as follows –

0.00–0.09 – Negligible
0.10–0.29 – Low
0.20–0.29 – Moderate
0.30–1.00 – High
More than 1.00– Very high Significant

2.6 Residual Effect

Residual factor $=\sqrt{1-R^2}$

Where,

$$R2 = \sum_{i=j}^{I} P^2 iy + 2 \sum_{i=j=1}^{I} P_{iy} P_{jy} .r_{ij}$$

R^2 - denotes coefficient of determination

I - denotes the number of independent characters

P_{iy} - denotes direct effect of i^th^ character over yield.

P_{ij} - denotes the direct effect of j^th^ character over yield, and

r_{ij} - denotes the correlation coefficients between i^th^ and j^th^ characters.

3. RESULTS AND DISCUSSION

Correlation analysis showed genotypic and phenotypic correlation for most of the character pairs were in same direction and genotypic estimates were higher than the phenotypic one, indicating inherent association between the characters and elimination of environmental effects. The correlation coefficient analysis of different traits was presented in Tables 1 and 2 respectively.

From the Table 1, it is evident that the highest and positive genotypic correlation of sugar yield was exhibited by the character number of millable canes at harvest (0.976) followed by cane yield at harvest (0.963), single cane weight (0.972), extraction percentage at harvest (0.617), germination percentage at 45 DAP (0.569), purity percentage at 10th month stage (0.554), brix at 8th month stage (0.533), CCS at 8th month stage (0.500), pol percentage in cane at harvest (0.486), pol percentage in juice at 10th month stage (0.478), pol at 8th months (0.472), CCS at

10th month stage (0.436), brix percentage at 10th months (0.429), plant height at harvest (0.254) and number of shoots at 120 DAP (0.035). However, it was negatively correlated with purity percentage at 8th months stage (-0.491), cane diameter at harvest (-0.363), number of internodes at harvest (-0.263), length of internodes at harvest (-0.081) and fibre percentage at harvest (-0.039). From the Table 2, it is evident that highly significant and positive association were observed for the traits cane yield at harvest (0.955**) followed by single cane weight at harvest (0.820**), Number of millable cane at harvest (0.758**), Extraction percentage at harvest (0.534**), germination percentage at 45 DAP (0.510**), pol at 10th month stage (0.465**), sugar yield at harvest (0.459**) and brix at 8th month stage (0.451**) and brix at 10th month stage (0.418**) whereas CCS at 10th month stage (0.405*), CCS at 8th month stage (0.395*) and pol at 8th month stage (0.390*) had significant and positive association with sugar yield at harvest while non-significant and positive association were observed for the traits purity at 8th month stage (0.228) followed by plant height (0.194), purity at 10th month stage (0.180) and fibre percentage at harvest (0.160). It was found that the traits cane diameter at harvest (-0.236), number of internodes at harvest (-0.151) and length of internodes at harvest (-0.099) had shown non-significant negative association with sugar yield.

In Table 3, it was found that at genotypic level, the maximum positive direct effect on sugar yield was observed in case of pol percentage in cane at harvest (3.49) followed by CCS at 10th months stage (%) (0.875), single cane weight (kg) (0.759), number of millable cane at harvest (0.385), brix at 10th month stage (0.334), fibre percentage at harvest (0.299), CCS at 8th month stage (0.208), cane diameter (0.148) and brix at 8th month stage (0.132) while pol at 10th month stage, pol at 8th month stage, plant height at harvest, purity at 10th month stage and extraction percentage at harvest while number of shoots at 120 DAP had direct and negative effect on sugar yield at harvest. Whereas at phenotypic level in Table 4, revealed that positive direct effect on sugar yield was exerted maximally by cane yield at harvest (t/ha) (1.51) followed by CCS percentage at 10th month stage (0.29), pol in juice at 10th month stage (0.21), germination Percentage at 45 DAP (%), cane diameter (cm), length of internode (cm), extraction percentage at harvest (%), pol in juice at 8th month stage and purity at 8th month stage while rest of all the traits had direct and negative effect on sugar yield.

In present investigation, genotypic and phenotypic correlation coefficient indicated that sugar yield had highly significant and positive correlation with cane yield at harvest followed by single cane weight at harvest, Number of millable cane at harvest, extraction percentage at harvest germination percentage at 45 DAP, pol at 10th month stage, sugar yield at harvest and brix % at 8th month stage and whereas brix % at 10th month stage, CCS % at 10th month stage, CCS % at 8th month stage and pol in juice % at 8th month stage had significant and positive association with sugar yield at harvest. On the other hand, characters like number of shoots at 120 DAP, plant height at harvest, fibre percentage at harvest, purity percentage at 8th month stage, purity percentage at 10th month stage showed non-significant and positive association with sugar yield, but in case of phenotypic correlation cane diameter at harvest, number of internodes at harvest and length of internodes at harvest showed non-significant and negative association with sugar yield and in case of genotypic correlation coefficient cane diameter at harvest, number of internode at harvest, fibre percentage at harvest, purity % at 8th month stage and length of internodes at harvest showed non-significant and negative association with sugar yield.

Similar results were found by Patel [8], Tahir et al. [9], Pandya et al. [10] and Shahzad et al. [11] who reported the positive and highly significant correlation with single cane weight, cane yield. Tena et al. [12] reported cane yield showed strong positive and highly significant correlation with number of millable cane, single cane weight, stalk height and sugar yield. There was also positive significant correlation of cane diameter with cane yield. Alam [13] reported high and positive significant correlation with cane diameter at harvest, length of internodes and plant height. Bora [14] reported highly significant and positive correlation with cane yield, number of milliable canes at harvest, germination percentage at 45 DAP, plant height at harvest and single cane weight. Kumar et al. [15] reported highest significant positive association with cane yield, cane diameter, plant height at 150 DAP, number of milliable canes, plant height at 240 DAP and single cane weight. Ali et al. [16] reported highly significant and positive correlation with sugar recovery percentage at genotypic and phenotypic level.

Table 1. Genotypic correlation matrix of the productive traits of early maturing sugarcane clones on sugar yield

Traits	GP 45	NS120	PH	CD	NMC	NI	LI	SCW	Fibre	CY	B8M	P8M	Pu8M	CCS8M	B10M	P10M	Pu10M	CCS10M	PolH	EH
NS120	0.274	**1.000**																		
PH	0.720	0.745	**1.000**																	
CD	-0.484	0.120	-0.082	**1.000**																
NMC	0.832	0.112	0.100	-0.579	**1.000**															
NI	0.177	0.537	0.471	0.516	-0.211	**1.000**														
LI	-0.284	0.355	0.472	0.035	-0.267	0.223	**1.000**													
SCW	0.491	0.161	0.514	-0.192	-0.867	-0.086	0.114	**1.000**												
Fibre	0.062	-0.742	-0.383	-0.258	-0.093	-0.098	-0.664	0.063	**1.000**											
CY	0.598	0.168	0.437	-0.270	0.913	-0.098	0.041	0.994	-0.012	**1.000**										
B8M	0.161	-0.260	-0.552	-0.213	0.774	-0.192	-0.620	0.131	0.129	0.292	**1.000**									
P8M	0.216	-0.266	-0.522	-0.157	0.688	-0.188	-0.741	0.090	0.226	0.241	0.958	**1.000**								
Pu8M	0.055	0.981	0.949	0.649	-0.250	0.910	0.966	-0.208	-0.062	-0.170	-0.677	-0.575	**1.000**							
CCS8M	0.277	-0.271	-0.469	-0.128	0.696	-0.232	-0.771	0.122	0.235	0.272	0.979	0.901	-0.507	**1.000**						
B10M	0.248	-0.267	-0.517	-0.618	0.733	-0.481	-0.489	0.008	0.134	0.179	0.789	0.756	-0.109	0.737	**1.000**					
P10M	0.221	-0.278	-0.515	-0.589	0.722	-0.569	-0.507	0.087	0.111	0.241	0.860	0.812	-0.116	0.792	0.918	**1.000**				
Pu10M	0.814	0.548	-0.168	-0.173	0.918	0.562	-0.435	0.092	-0.429	0.454	0.712	0.753	-0.311	0.796	0.625	0.664	**1.000**			
CCS10M	0.122	-0.380	-0.551	-0.539	0.551	-0.678	-0.499	0.072	0.011	0.181	0.935	0.827	-0.288	0.907	0.909	0.969	0.475	**1.000**		
PolH	0.230	-0.203	-0.475	-0.583	0.737	-0.560	-0.441	0.085	0.008	0.247	0.843	0.785	-0.067	0.764	0.912	0.994	0.728	0.967	**1.000**	
EH	0.103	-0.023	0.106	0.055	0.408	0.003	0.053	0.549	-0.321	0.521	0.573	0.492	-0.038	0.489	0.296	0.309	-0.177	0.445	0.329	**1.000**
CCSH	0.569	0.035	0.254	-0.363	0.976	-0.262	-0.080	0.927	-0.039	0.963	0.533	0.472	-0.490	0.499	0.429	0.478	0.553	0.436	0.486	0.617

GP45- Germination Percentage at 45 DAP (%), NS120- Number of shoots at 120 DAP (000/ha) , PH- Plant height at harvest (cm) , CD- Cane diameter (cm), NMC- Number of millable cane at harvest (000/ha) , NI- Number of internode, LI- Length of internode (cm), SCW- Single cane weight at harvest (kg), Fibre- Fibre percentage at harvest (%), CY- Cane yield at harvest, B8M- Brix at 8th month stage (%), P8M- Pol in juice at 8th month stage (%), Pu8M- Purity at 8th month stage (%), CCS8M- CCS at 8th month stage (%), B10M- Brix at 10th month stage (%) , P10M- Pol in juice at 10th month stage (%), Pu10M- Purity at 10th month stage (%), CCS10M- CCS at 10th month stage (%), PolH- Pol in cane at Harvest (%), EH- Extraction Percentage at Harvest (%), CCSH- Sugar yield at harvest (t/ha)

Table 2. Phenotypic correlation matrix of the productive traits of early maturing sugarcane clones on sugar yield

Traits	GP 45	NS120	PH	CD	NMC	NI	LI	SCW	Fibre	CY	B8M	P8M	Pu8M	CCS8M	B10M	P10M	Pu10M	CCS10M	PolH	EH
GP45	**1.00**																			
NS120	0.29	**1.000**																		
PH	0.43**	0.48**	**1.000**																	
CD	-0.43**	0.03	-0.04	**1.000**																
NMC	0.49**	0.02	0.06	-0.26	**1.000**															
NI	0.16	0.26	0.17	0.32	0.084	**1.000**														
LI	-0.20	0.28	0.42*	0.08	-0.243	0.003	**1.000**													
SCW	0.43**	0.12	0.43**	-0.12	0.343*	-0.152	0.143	**1.000**												
Fibre	0.14	-0.30	-0.30	-0.10	0.278	0.083	-0.476**	0.050	**1.000**											
CY	0.54**	0.11	0.37*	-0.17	0.701**	-0.062	0.021	0.907**	0.151	**1.000**										
B8M	0.14	-0.18	-0.36*	-0.14	0.384*	-0.191	-0.442**	0.161	0.066	0.268	**1.000**									
P8M	0.16	-0.22	-0.37*	-0.10	0.326	-0.125	-0.551**	0.101	0.142	0.196	0.924**	**1.0000**								
Pu8M	-0.14	-0.14	-0.37*	0.03	0.233	-0.059	-0.255	-0.001	0.179	0.077	0.440**	0.452**	**1.0000**							
CCS8M	0.21	-0.26	-0.32	-0.06	0.319	-0.094	-0.562**	0.112	0.112	0.206	0.849**	0.974**	0.436**	**1.000**						
B10M	0.21	-0.22	-0.38*	-0.51**	0.503**	-0.270	-0.462**	0.010	0.155	0.213	0.687**	0.629**	0.308	0.579**	**1.000**					
P10M	0.17	-0.23	-0.45**	-0.44**	0.485**	-0.311	-0.505**	0.029	0.187	0.215	0.708**	0.701**	0.414*	0.667**	0.918**	**1.000**				
Pu10M	0.27	0.04	-0.05	-0.049	0.415*	0.199	-0.153	-0.042	0.082	0.158	0.323	0.220	-0.135	0.186	0.281	0.236	**1.000**			
CCS10M	0.06	-0.29	-0.49**	-0.33*	0.375*	-0.305	-0.474**	-0.022	0.142	0.125	0.699**	0.719**	0.542**	0.698**	0.777**	0.938**	0.130	**1.000**		
PolH	0.16	-0.18	-0.40*	-0.44**	0.471**	-0.321	-0.445**	0.026	0.071	0.209	0.701**	0.682**	0.401*	0.652**	0.916**	0.992**	0.235	0.930**	**1.000**	
EH	0.09	-0.01	0.10	0.070	0.299	0.070	0.011	0.453**	-0.142	0.460**	0.491**	0.472**	0.263	0.455**	0.231	0.244	-0101	0.325	0.259	**1.000**
CCSH	0.510**	0.004	0.194	-0.236	0.758**	-0.150	-0.099	0.820**	0.160	0.955**	0.451**	0.390*	0.228	0.395*	0.418*	0.465**	0.180	0.405*	0.459**	0.533**

GP45- Germination Percentage at 45 DAP (%), NS120- Number of shoots at 120 DAP (000/ha) , PH- Plant height at harvest (cm), CD- Cane diameter (cm), NMC- Number of millable cane at harvest (000/ha) , NI- Number of internode, LI- Length of internode (cm), SCW- Single cane weight at harvest (kg), Fibre- Fibre percentage at harvest (%), CY- Cane yield at harvest, B8M- Brix at 8th month stage (%), P8M- Pol in juice at 8th month stage (%), Pu8M- Purity at 8th month stage (%), CCS8M- CCS at 8th month stage (%), B10M- Brix at 10th month stage (%) , P10M- Pol in juice at 10th month stage (%), Pu10M- Purity at 10th month stage (%), CCS10M- CCS at 10th month stage (%), PolH- Pol in cane at Harvest (%), EH- Extraction Percentage at Harvest (%), CCSH- Sugar yield at harvest (t/ha)

Table 3. Genotypic Path correlation matrix of the productive traits of early maturing sugarcane clones on sugar yield

Traits	GP 45	NS120	PH	CD	NMC	NI	LI	SCW	Fibre	CY	B8M	P8M	Pu8M	CCS8M	B10M	P10M	Pu10M	CCS10M	PolH	EH
GP45	**0.121**	0.033	0.087	-0.058	0.101	0.021	-0.034	0.059	0.008	0.072	0.020	0.026	0.007	0.034	0.030	0.027	0.098	0.015	0.028	0.012
NS120	-0.015	**-0.055**	-0.041	-0.007	-0.006	-0.030	-0.020	-0.009	0.041	-0.009	0.014	0.015	-0.065	0.015	0.015	0.015	-0.030	0.021	0.011	0.001
PH	-0.100	-0.104	**-0.139**	0.012	-0.014	-0.066	-0.066	-0.072	0.053	-0.061	0.077	0.073	-0.146	0.065	0.072	0.072	0.023	0.077	0.066	-0.015
CD	-0.072	0.018	-0.012	**0.148**	-0.086	0.077	0.005	-0.029	-0.038	-0.040	-0.032	-0.023	0.096	-0.019	-0.092	-0.087	-0.026	-0.080	-0.086	0.008
NMC	0.320	0.043	0.039	-0.223	**0.385**	-0.082	-0.103	0.334	-0.036	0.352	0.298	0.265	-0.096	0.268	0.282	0.278	0.508	0.212	0.284	0.157
NI	0.000	0.001	0.001	0.001	-0.001	**0.002**	0.001	0.000	0.000	0.000	-0.001	-0.001	0.003	-0.001	-0.001	-0.001	0.001	-0.002	-0.001	0.000
LI	-0.024	0.029	0.039	0.003	-0.022	0.018	**0.083**	0.009	-0.055	0.003	-0.051	-0.061	0.080	-0.064	-0.040	-0.042	-0.036	-0.041	-0.036	0.004
SCW	0.373	0.122	0.390	-0.146	0.658	-0.065	0.087	**0.759**	0.048	0.754	0.100	0.069	-0.159	0.093	0.006	0.066	0.070	0.055	0.065	0.417
Fibre	0.019	-0.222	-0.115	-0.077	-0.028	-0.029	-0.199	0.019	**0.299**	-0.004	0.039	0.068	-0.019	0.070	0.040	0.033	-0.128	0.003	0.002	-0.096
CY	-0.049	-0.014	-0.036	0.022	-0.075	0.008	-0.003	-0.082	0.001	**-0.082**	-0.024	-0.020	0.014	-0.022	-0.015	-0.020	-0.037	-0.015	-0.020	-0.043
B8M	0.021	-0.035	-0.073	-0.028	0.103	-0.026	-0.082	0.017	0.017	0.039	**0.132**	0.134	-0.222	0.134	0.104	0.114	0.094	0.130	0.112	0.076
P8M	-0.049	0.060	0.118	0.036	-0.156	0.043	0.168	-0.020	-0.051	-0.055	-0.229	**-0.227**	0.357	-0.227	-0.171	-0.184	-0.171	-0.210	-0.178	-0.112
Pu8M	0.007	0.143	0.127	0.079	-0.030	0.135	0.117	-0.025	-0.008	-0.021	-0.203	-0.191	**0.121**	-0.183	-0.134	-0.135	-0.159	-0.156	-0.129	-0.114
CCS8M	0.058	-0.057	-0.098	-0.027	0.145	-0.048	-0.161	0.026	0.049	0.057	0.212	0.209	-0.314	**0.208**	0.154	0.165	0.166	0.189	0.159	0.102
B10M	0.083	-0.089	-0.173	-0.206	0.245	-0.161	-0.163	0.003	0.045	0.060	0.263	0.252	-0.370	0.246	**0.334**	0.340	0.209	0.334	0.338	0.099
P10M	-0.982	1.237	2.284	2.615	-3.203	2.526	2.250	-0.387	-0.495	-1.068	-3.815	-3.600	4.952	-3.512	-4.518	**-4.434**	-2.945	-4.300	-4.411	-1.374
Pu10M	-0.048	-0.032	0.010	0.010	-0.078	-0.033	0.026	-0.006	0.025	-0.027	-0.042	-0.045	0.077	-0.047	-0.037	-0.039	**-0.059**	-0.028	-0.043	0.011
CCS10M	0.107	-0.333	-0.482	-0.472	0.482	-0.593	-0.437	0.063	0.010	0.159	0.856	0.811	-1.127	0.794	0.875	0.848	0.416	**0.875**	0.846	0.390
PolH	0.805	-0.714	-1.665	-2.040	2.582	-1.960	-1.546	0.301	0.028	0.866	2.953	2.749	-3.736	2.676	3.543	3.481	2.548	3.385	**3.499**	1.152
EH	-0.006	0.001	-0.006	-0.003	-0.025	0.000	-0.003	-0.033	0.019	-0.031	-0.034	-0.030	0.056	-0.029	-0.018	-0.019	0.011	-0.027	-0.020	**-0.060**
CCSH	0.569	0.035	0.255	-0.363	0.977	-0.263	-0.081	0.927	-0.039	0.963	0.533	0.472	-0.491	0.500	0.429	0.478	0.554	0.436	0.486	0.617

GP45- Germination Percentage at 45 DAP (%), NS120- Number of shoots at 120 DAP (000/ha) , PH- Plant height at harvest (cm), CD- Cane diameter (cm), NMC- Number of millable cane at harvest (000/ha) , NI- Number of internode, LI- Length of internode (cm), SCW- Single cane weight at harvest (kg), Fibre- Fibre percentage at harvest (%), CY- Cane yield at harvest, B8M- Brix at 8th month stage (%), P8M- Pol in juice at 8th month stage (%), Pu8M- Purity at 8th month stage (%), CCS8M- CCS at 8th month stage (%), B10M- Brix at 10th month stage (%) , P10M- Pol in juice at 10th month stage (%), Pu10M- Purity at 10th month stage (%), CCS10M- CCS at 10th month stage (%), PolH- Pol in cane at Harvest (%), EH- Extraction Percentage at Harvest (%), CCSH- Sugar yield at harvest (t/ha)

Table 4. Phenotypic path correlation matrix of the productive traits of early maturing sugarcane clones on sugar yield

Traits	GP 45	NS120	PH	CD	NMC	NI	LI	SCW	Fibre	CY	B8M	P8M	Pu8M	CCS8M	B10M	P10M	Pu10M	CCS10M	PolH	EH
GP45	0.046	0.013	0.020	-0.020	0.022	0.007	-0.009	0.019	0.006	0.025	0.006	0.008	-0.006	0.009	0.010	0.008	0.012	0.003	0.007	0.004
NS120	-0.006	-0.022	-0.010	-0.001	0.000	-0.006	-0.006	-0.003	0.007	-0.002	0.004	0.005	0.003	0.006	0.005	0.005	-0.001	0.006	0.004	0.000
PH	-0.004	-0.004	-0.008	0.000	-0.001	-0.001	-0.003	-0.004	0.003	-0.003	0.003	0.003	0.003	0.003	0.003	0.004	0.000	0.004	0.003	-0.001
CD	-0.008	0.001	-0.001	0.019	-0.005	0.006	0.002	-0.002	-0.002	-0.003	-0.003	-0.002	0.001	-0.001	-0.010	-0.008	-0.001	-0.006	-0.008	0.001
NMC	-0.121	-0.004	-0.015	0.064	-0.249	-0.021	0.061	-0.086	-0.069	-0.175	-0.096	-0.081	-0.058	-0.080	-0.126	-0.121	-0.104	-0.094	-0.117	-0.075
NI	-0.005	-0.009	-0.006	-0.011	-0.003	-0.033	0.000	0.005	-0.003	0.002	0.006	0.004	0.002	0.003	0.009	0.010	-0.007	0.010	0.011	-0.002
LI	-0.004	0.006	0.009	0.002	-0.005	0.000	0.022	0.003	-0.010	0.001	-0.010	-0.012	-0.006	-0.012	-0.010	-0.011	-0.003	-0.010	-0.010	0.000
SCW	-0.209	-0.057	-0.211	0.059	-0.169	0.075	-0.070	-0.490	-0.025	-0.445	-0.079	-0.050	0.001	-0.055	-0.005	-0.014	0.021	0.011	-0.013	-0.222
Fibre	-0.006	0.012	0.012	0.004	-0.011	-0.003	0.019	-0.002	-0.041	-0.006	-0.003	-0.006	-0.007	-0.005	-0.006	-0.008	-0.003	-0.006	-0.003	0.006
CY	0.813	0.161	0.555	-0.262	1.060	-0.094	0.033	1.371	0.229	1.512	0.406	0.297	0.117	0.312	0.322	0.326	0.239	0.189	0.315	0.696
B8M	-0.003	0.004	0.007	0.003	-0.008	0.004	0.009	-0.003	-0.001	-0.005	-0.020	-0.019	-0.009	-0.017	-0.014	-0.014	-0.007	-0.014	-0.014	-0.010
P8M	0.008	-0.011	-0.019	-0.005	0.016	-0.006	-0.028	0.005	0.007	0.010	0.047	0.050	0.023	0.049	0.032	0.035	0.011	0.036	0.034	0.024
Pu8M	-0.002	-0.003	-0.006	0.001	0.004	-0.001	-0.004	0.000	0.003	0.001	0.007	0.008	0.017	0.007	0.005	0.007	-0.002	0.009	0.007	0.004
CCS8M	-0.008	0.010	0.013	0.002	-0.013	0.004	0.023	-0.005	-0.005	-0.008	-0.034	-0.039	-0.018	-0.040	-0.023	-0.027	-0.008	-0.028	-0.026	-0.018
B10M	0.002	-0.002	-0.003	-0.004	0.004	-0.002	-0.003	0.000	0.001	0.002	0.005	0.005	0.002	0.004	0.008	0.007	0.002	0.006	0.007	0.002
P10M	0.036	-0.050	-0.097	-0.095	0.104	-0.067	-0.109	0.006	0.040	0.046	0.152	0.151	0.089	0.144	0.198	0.215	0.051	0.202	0.213	0.053
Pu10M	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	0.000	0.000	0.000
CCS10M	0.016	-0.085	-0.144	-0.097	0.110	-0.089	-0.139	-0.007	0.042	0.037	0.205	0.210	0.158	0.204	0.227	0.274	0.038	0.292	0.272	0.095
PolH	-0.038	0.043	0.094	0.102	-0.110	0.075	0.104	-0.006	-0.017	-0.049	-0.163	-0.159	-0.093	-0.152	-0.213	-0.231	-0.055	-0.217	-0.233	-0.060
EH	0.003	0.000	0.004	0.003	0.011	0.003	0.000	0.017	-0.005	0.017	0.018	0.017	0.010	0.017	0.009	0.009	-0.004	0.012	0.010	0.037
CCSH	0.510	0.004	0.194	-0.236	0.758	-0.151	-0.100	0.820	0.161	0.955	0.452	0.390	0.229	0.396	0.419	0.465	0.181	0.406	0.459	0.534

GP45- Germination Percentage at 45 DAP (%), NS120- Number of shoots at 120 DAP (000/ha) , PH- Plant height at harvest (cm), CD- Cane diameter (cm), NMC- Number of millable cane at harvest (000/ha) , NI- Number of internode, LI- Length of internode (cm), SCW- Single cane weight at harvest (kg), Fibre- Fibre percentage at harvest (%), CY- Cane yield at harvest, B8M- Brix at 8th month stage (%), P8M- Pol in juice at 8th month stage (%), Pu8M- Purity at 8th month stage (%), CCS8M- CCS at 8th month stage (%), B10M- Brix at 10th month stage (%) , P10M- Pol in juice at 10th month stage (%), Pu10M- Purity at 10th month stage (%), CCS10M- CCS at 10th month stage (%), PolH- Pol in cane at Harvest (%), EH- Extraction Percentage at Harvest (%), CCSH- Sugar yield at harvest (t/ha)

Present investigation indicates that, the highest positive direct effect on sugar yield was exerted by the number of millable cane at harvest, single cane weight at harvest, brix at 10th month stage, CCS at 10th month stage and pol at harvest. In other words these characters were directly responsible for the higher sugar yield. Although, at genotypic level, number of shoots at 120 DAP, plant height at harvest, cane yield, pol at 8th month stage, pol at 10th month stage, purity at 10th month stage and extraction percentage at harvest showed a negative direct effect on sugar yield. At phenotypic level, positive direct effect on sugar yield was exerted by germination percentage at 45 DAP, cane diameter at harvest, length of internodes, cane yield, brix at 8th month stage, pol at 8th month stage, purity at 8th month stage, brix at 10th month stage, pol at 10th month stage and CCS at 10th month stage. Other characters like pol percentage in cane, purity percentage at 10th month stage, fibre percentage at harvest, plant height at harvest, number of millable canes, number of internodes, CCS percentage at 8th month stage and single cane weight at harvest at genotypic level recorded negative direct effect. Tena et al. [12] observed the highest positive direct effect of number of millable cane number on cane yield followed by single cane weight and pol percentage. Yahaya et al. [17] reported stalk length had the highest direct contribution to cause yield followed by number of millable cane at harvest. Ali et al. [16] reported highest positive direct effect on cane yield is exerted by sugar recovery.

The characters germination percentage at 45 DAP, cane diameter, length of internodes, brix at 8th month stage, purity at 8th month stage and brix at 10th month stage showed positive direct effects on sugar yield both at genotypic and phenotypic levels.

3.1 Residual Effect

The lower value of residual effect in the case of both genotypic as well as phenotypic path coefficient indicates that the all-important characters were studied.

4. CONCLUSION

The present investigation revealed that, the traits *i.e.* number of millable canes at harvest followed by cane yield at harvest and single cane weight were the most important for sugar yield improvement. These three characters had highly significant positive correlation with each other and with sugar yield. Selection based on these characters can increase the sugar yield. Path analysis revealed that the traits, pol percentage in cane at harvest followed by CCS at 10th months stage, single cane weight, number of millable cane at harvest and germination percentage at 45 DAP had positive direct effect on sugar yield at genotypic and phenotypic level. On the basis of these characters selection can be done for improvement of sugar yield.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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