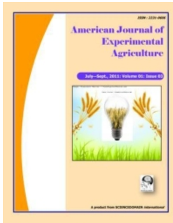

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Character Association and Selection Indices in Sugarcane

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Authors' contributions

This work was carried out in collaboration between all authors. Author MT designed the experiments, conducted the study, analyzed the results, and lead in writing the manuscript. Author IHK supervised the research project/relevant literature search. Authors PHM and BG contributed to the writing of the manuscript.

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ABSTRACT

Sugarcane is an important crop of Khyber Pakhtunkhwa province of Pakistan. However, the yield per unit area is below some advanced sugarcane growing areas of the world, and the national average of Pakistan. Improved methods of selection resulting in higher yielding sugarcane cultivars would help in increased yield. Information about direct and indirect effects of yield contributing characters and subsequently developing a selection index would greatly improve the process of cultivar development. An experiment comprising 26 sugarcane genotypes coupled with 2 check cultivars was grown in a randomized complete block design with 3 replications at Sugar Crops Research Institute, Mardan, Pakistan during 2011-2013. Data were collected on stalk and yield attributes. Genotypic path coefficients revealed that Tiller2, growth2, and Pol had positive direct effects on cane yield. Selection indices based on growth2, Pol, tiller2, and cane yield showed that individuals selected based on these characters simultaneously gave a genetic advance of above 60. CPF-225, MS-2003-CR5-245, MS-2003-CR7-243, and MS-2003-CR8-407 could be selected as the best genotypes according to these selection indices. This study showed that applying path coefficient analyses followed by development of selection index could be a worthwhile selection strategy.

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1. INTRODUCTION

In Pakistan, sugarcane is grown on an area of around one million ha with a production of 52.8 million tonnes. In Khyber Pakhtunkhwa province, sugarcane occupies an area of 94,000 ha with a total cane production of 4.6 million tonnes and per ha yield of 49 tonnes [1]. However, the per unit area yield of the crop is not commensurate with some of the advanced areas of the world. In the crop year 2009-10, cane yield for other countries was 73 tonnes ha^{-1} (Brazil), 59 tonnes ha^{-1} (India), 64 tonnes ha^{-1} (China), and 71 tonnes ha^{-1} (USA) [2]. Sugarcane breeding and better agronomic practices made a substantial contribution to improved sugarcane yields in the last 30 years [3]. We propose that in Khyber Pakhtunkhwa province, there are still substantial potential gains for increasing per ha yields of sugarcane through improved methods of genotype selection.

Hence, there is a need to develop new high yielding cultivars which would boost provincial as well as national cane yields. Information about the contribution of various cane and quality characters to cane yield is vital for development of new high yielding sugarcane cultivars. This could be achieved using the methods of path coefficients which partitions correlations among the traits into components of direct and indirect effects on the dependent variable [4]. These would be followed by development of selection criteria comprising the traits with high direct effects for selection of sugarcane genotypes manifesting a higher yield advantage.

Path analysis done by Hussein et al. [5] showed that the number of cane stalks m^{-2} was the most important character with the highest direct and indirect effects on sucrose yield followed by sucrose% and stalk weight. Cane yield was found by Abdelmahmood et al. [6] to be positively correlated with millable stalks, stalk height, internode number per stalk, and single stalk weight. They, however, noted negative association of cane yield with stalk diameter, juice pol, and purity%.

The potential advantage of selection indices is that several traits are improved simultaneously [7]. De Sousa and Milligan [8] reported that irrespective of the plant spacing, selection indices increased the efficiency over direct selection for plant height when the following four traits, stalk number, stalk length, stalk diameter, and stalk weight, were included with plant height. The efficiency of selection decreased when indices were based on fewer traits. Singh and Khan [9] constructed various selection indices for cane yield in a population of 22 sugarcane genotypes in an advanced selection stage. The selection index (SI) with number of millable canes (NMC), stalk height, stalk weight, and juice extraction per cent and cane yield itself had maximum genetic gain (19.47%) over straight selection for cane yield. The genetic gain of SI's above selected based on those five characters plus cane thickness (individually) was 18.44 percent. They concluded that selection based on NMC, cane yield, stalk height, and juice extraction percent was important for maximum improvement in cane yield. A general index involving millable canes per stool, cane diameter, cane height, and hand refractometer Brix (HR Brix) was studied by Bakhshi et al. [10]. They found selection based on number of millable canes was best, followed by selection based on selection index and cane height in ratoon crop. All selection criteria, except selection based on HR Brix, gave similar responses for Brix yield.

The present study was designed to assess the direct and indirect effects of different yield and quality contributing traits on cane yield and then develop and compare a selection index which would maximize genetic gain from selection.

2. MATERIALS AND METHODS

Twenty-eight (including two checks) sugarcane genotypes were grown in the experimental fields of Sugar Crops Research Institute, Mardan, KPK, Pakistan, during 2010-2013. The design used was a randomized complete block with 3 replications. The experimental material in the present study was advanced from previous selection stages on the basis of better agronomic and phenotypic characters.

The plant-cane crop was planted in September 2010, while in 2012 both plant-cane and ratoon crops were maintained. Plot size was 6.7 x 10 meters (67 m^2). There were 7 rows per plot, 0.90 meters apart with a row length of 10 meters. The number of buds in the central row was maintained at 150.

In the plant-cane crop, N, P_2O_5, and K_2O fertilizers at rates of 150-100-100 kg ha^{-1}, respectively, were applied in the form of urea, Di Ammonium Phosphate (DAP), and Sulphate of Potash (SOP). The DAP was applied at a rate of 217 kg ha^{-1} at planting time. The SOP (217 kg ha^{-1}) and urea (121 kg ha^{-1}) were applied in March/April, with an additional 121 kg ha^{-1} of urea at earthing up. For the ratoon crop, 175-100-100 kg ha^{-1} N, P_2O_5, and K_2O were applied. Both DAP, and SOP were applied at 217 kg ha^{-1} and urea was applied at 100 kg ha^{-1} in March/April, with an additional 195 kg ha^{-1} urea at earthing up in March.

Thiodon (2.5 l ha^{-1}) was sprayed at planting time, to control termites. Ametrin + Atrazine (both at 1.5 kg ha^{-1}) were applied one month after planting for the control of weeds. Other cultural practices such as cultivation, earthing up, and irrigation were kept uniform for all the genotypes.

Data were recorded on the stalk, yield, and quality characters.

Stalk and yield Characters

1. Second Tillering (Till2): It was recorded by counting the number of tillers 10 m^{-1} central row, one month after the first tillering.
2. First Growth (Gr1): It was recorded as length of the standing plant from the ground to the top (rosette of leaves) in centimeters, recorded during the first week of July.
3. Second Growth (Gr2): Height of the standing plant from the ground to the top in cm, measured one month after the first growth.
4. Stalk height: in cm to the point where tops are easily removable. It was measured on maturity of the crop.
5. Stalk diameter (cm): Diameter in cm was measured with the use of a digital Vernier caliper for 5 stalks.
6. Millable canes: The number of millable canes (i.e. excluding the tillers which have not developed into mature stalks) in the center row of the plot.
7. Cane yield (tons ha^{-1}): It was recorded by weighing the stalks per whole plot without trash and converting to tons ha^{-1} as follows:

$CaneYield = \left(\frac{xX\ 10000}{6.7\ X\ 1000}\right)$; where x = cane yield in kg $plot^{-1}$.

Quality characters

1. Brix percentage: Juice Brix refers to the total soluble solids content present in the juice expressed as a percentage. Brix includes sugars as well as non-sugars. Five stalks per sample were crushed using a cane crusher for estimation of Brix. Both Brix and temperature reading were taken with a hydrometer. Then, corrected Brix % was calculated using a Schmitz table [11] for a particular temperature.
2. Pol %: The juice sucrose percentage is the measurement referring to the proportion of the juice made up of sucrose. Since it is measured using a polarimeter, it is referred to as Pol %. Cane juice left from Brix reading was augmented with 1.5 g lead acetate and filtered. The filtered juice was then placed in a tube in a polarimeter. The reading taken was Pol% which was corrected for a particular Brix using a Schmitz table [11] to obtain the corrected pol%. For all practical purposes, pol% and sucrose% are synonymous.
3. Purity %: Purity % refers to the percentage of sucrose present in the total soluble solids content (Brix) in the juice. A higher purity indicates the presence of higher sucrose content out of the total Brix present in the juice. Purity is calculated by the following formula:

$$Purity\ \% = \frac{Pol\ \%}{CorrectedBrix} X\ 100$$

Where Corrected Brix was the Brix adjusted with the ambient temperature.

4. Recovery %: Calculated by the following formula:
   Recovery %= [Pol% - 0.5 (C. Brix – Pol%)] x 0.7

2.1 Statistical Analyses

Correlation is a measure of association between two traits. It may be due to genetic causes (genotypic correlation) or genetic plus environment (phenotypic correlation). Genotypic correlation is more important in selection as selecting one character has an effect in the other character and this response to change by genetic association is called correlated response [12]. Phenotypic and genotypic correlations were estimated using PLABSTAT-computer software for statistical analysis of plant breeding experiments, version 3A [13].

When there is a perfect or exact correlation between the regression exploratory variables, the problem of multicollinearity arises. It increases the standard errors, and R-squares, which in turn will affect goodness of fit of the model [14]. Since path analysis uses standardized partial regression coefficients, therefore, test of multicollinearity was carried out. Variance inflation factor and tolerance are parameters used for detecting multicollinearity. The characters were analyzed for multicollinearity using the REG procedure in SAS version 9.1 [15], with the variance inflation factor (VIF) and tolerance (TOL) options.

After removing variables that displayed significant multicollinearity, the phenotypic and genotypic correlations were subjected to path coefficient analysis [16]. This was performed using the ‘agricolae’ package [17] of R version 3.0.1 [18], which carries out path analysis according to the method of Singh and Chaudhary [19]. Cane yield was kept as the dependent variable, with the other characters as independent (causal) factors.

2.2 Selection Indices

Phenotypic and genotypic variances and covariances were computed as described by Singh and Chaudhary [19] and De Sousa and Milligan [8]. Then, index weights (b_i values) were calculated from pooled data. The Smith's [20] selection index was calculated as follows:

$$I = b_1X_1 + b_2X_2 + \ldots + b_nX_n$$

Where X_i = Observed phenotypic value of the i^{th} trait.

b_i = weight assigned to that trait in the selection index.

and

$$b = P^{-1} G a$$

Where b= vector of index coefficients,

P^{-1}= inverse of the phenotypic variance-covariance matrix,
G= genotypic variance covariance matrix, and
a= vector of relative economic values or weights

Expected genetic gain was calculated using the following formula given by Singh and Chaudhary [19].

Expected Genetic Gain: $\Delta G = \left(\frac{Z}{v}\right) * W/\sqrt{V_p}$

Where $W = \Sigma\Sigma a_i b_i G_{ij}$

And $V_p = \Sigma\Sigma a_i b_i P_{ij}$

Here Z/v is the standardized selection differential (s), indicating intensity of selection (*i*),

a_i= Economic weightage
b_i= Regression coefficient
G_{ij}= Genotypic Variance-Covariance matrix
P_{ij}= Phenotypic Variance-Covariance matrix

3. RESULTS AND DISCUSSION

3.1 Character association

3.1.1 Phenotypic and genotypic correlations among characters

3.1.1.1 Phenotypic correlations

Tiller2 had a highly significant and positive correlation (r = 0.66) with millable canes, and a significant negative correlation (r = -0.52) with stalk diameter (Table 1). Growth1 had a highly significant positive correlation (r = 0.92) with growth2, as well as significant and positive correlations with Stalk height (r = 0.41) and cane yield (r = 0.44). Growth2 had a highly significant correlation with stalk height (r = 0.56), and significant correlations with millable canes (r = 0.43) and cane yield (r = 0.38). Stalk height had the only highly significant correlation (r = 0.50) with millable canes. Stalk diameter had significant correlations with POL (r = 0.52), recovery (r = 0.53), purity (r = 0.47), and millable canes (r = -0.39). Brix was strongly associated with purity (r = 0.80) and recovery (r = 0.98), and purity was highly and significantly correlated with recovery (r=0.89).

3.1.1.2 Genotypic correlations

Tiller2 showed a highly significant positive correlation with millable canes (r = 0.70), and a negative correlation with stalk diameter (r = -0.55) (Table 2). Growth1 showed highly significant and positive correlations with growth2 (r = 0.95), stalk height (r = 0.47), and cane yield (r = 0.52). Similarly, growth2 had highly significant correlations with stalk height (r = 0.60), millable canes (r = 0.50) and cane yield (r = 0.47). Stalk height was strongly correlated with millable canes (r = 0.63), while stalk diameter had highly significant genotypic correlations with Pol (r = 0.67), purity (r = 0.66), and recovery (r = 0.69), and was moderately correlated with Brix (r=0.43). Cane yield was negatively correlated with millable canes (r = -0.48). Brix had highly significant genotypic correlations with Pol (r = 0.82) and recovery (r = 0.71). Pol had highly significant correlation with purity and recovery (r = 0.79 and 0.98), respectively. Purity was highly correlated with recovery (r = 0.88). These results were in conformity with Abdelmahmoud et al. [6] who found cane yield to be positively correlated with millable stalks, stalk height, intermodal number per stalk, and single stalk weight. The results further indicate that growth1 and growth2 were significantly correlated with cane yield. It shows that these are important characters in cane yield determination. Tiller2 also was positively correlated with yield though non-significant. However, it had a strong association with millable canes. That is also logical as the more number of tillers, the more are number of millable canes. However, stalk diameter decreases as the number of tillers increases.

The results reported by Tyagi et al. [21] revealed that cane yield had a positive association with its components. They concluded that cane yield components like number of stalks, stalk weight, and stalk height were desirable traits for selection criteria in a sugarcane cultivar development program. In addition, they noted a low negative correlation of sucrose with cane and sucrose yield, which implied that cane yield and sucrose could be selected simultaneously. On the contrary, our results show that Pol was positively correlated with yield, though its magnitude was very low. It means that it could be selected with other components simultaneously.

Table 1. Phenotypic correlations of 11 characters in 28 sugarcane genotypes

	Till2	Gr1	Gr2	Slen	Sdia	Brix	Pol	Pur	Rec	Mcanes	Cyield
Till2	1	-0.02	0.13	0.34	-0.52**	-0.04	0.00	0.05	0.01	0.66**	0.29
Gr1		1	0.92**	0.41*	0.26	0.03	0.07	0.09	0.08	0.26	0.44*
Gr2			1	0.56**	0.20	0.01	0.11	0.16	0.13	0.43*	0.38*
Slen				1	-0.08	-0.1	0.05	0.18	0.09	0.50**	0.24
Sdia					1	0.37	0.52**	0.47*	0.53**	-0.39*	-0.16
Brix						1	0.81**	0.29	0.69**	-0.1	-0.08
POL							1	0.80**	0.98**	-0.04	0.05
Pur								1	0.89**	0.04	0.18
Rec									1	-0.02	0.09
Mcanes										1	0.33
Cyield											1

*Till= Tillers. Gr= Growth. Slen= Stalk height. Sdia= Stalk diameter. Pur: Purity. Rec: Recovery. Mcanes= Number of Millable Canes. Cyield: Cane Yield; *: Values greater than standard error; **: Values greater than double the standard error. Standard errors for both the correlations are computed by the PLABSTAT software using the method described by Mode and Robinson (1959).*

Table 2. Genotypic correlations of 11 characters in 28 sugarcane genotypes

	Till2	Gr1	Gr2	Slen	Sdia	Brix	POL	Pur	Rec	Mcanes	Cyield
Till2	1	-0.03	0.12	0.38+	-0.55++	-0.06	-0.07	-0.04	-0.07	0.70++	0.31+
Gr1		1	0.95++	0.47++	0.32+	0	0.06	0.09	0.07	0.29+	0.52++
Gr2			1	0.60++	0.25+	-0.01	0.08	0.14	0.1	0.50++	0.47++
Slen				1	-0.11	-0.15	0.03	0.19	0.07	0.63++	0.31+
Sdia					1	0.43++	0.67++	0.66++	0.69++	-0.48++	-0.07
Brix						1	0.82++	0.30+	0.71++	-0.23	-0.11
POL							1	0.79++	0.98++	-0.19	0.01
Pur								1	0.88++	-0.06	0.15
Rec									1	-0.16	0.05
Mcanes										1	0.34+
Cyield											1

Till= Tillers. Gr= Growth. Slen= Stalk height. Sdia= Stalk diameter. Pur: Purity. Rec: Recovery. Mcanes= Number of Millable Canes. Cyield: Cane Yield; +: Values greater than standard error; ++: Values greater than double the standard error. Standard errors for both the correlations are computed by the PLABSTAT software using the method described by Mode and Robinson (1959).

3.2 Test of Multicollinearity

As stated earlier in materials and methods, multicollinearity in the independent variables, reduces the reliability of the regression model. Multicollinearity is indicated by high correlation values among different variables. In our case, some correlations were particularly high, such as that of growth1 with growth2, Pol and recovery, and purity and recovery (Table 1). When such correlations are identified, tests of multicollinearity are warranted. Variance inflation faction (VIF) values for growth2 and Brix, Pol, purity, and recovery were greater than 10 (table not shown). When the VIF value for a given character is greater than 10, then multicollinearity can be corrected by removing one of the correlated characters. Thus, we removed growth1. Similarly, since purity and recovery were already derived characters, and had high correlations with brix and Pol, these variables were removed as well. Millable stalks and recovery showed a high condition index, so they were removed as well. The remaining characters had VIF value less than 10 and were subjected to path coefficient analysis to assess direct and indirect effects of different characters on yield.

3.3 Path Coefficient Analysis

Based on phenotypic path coefficients, tiller2, growth2, and Pol showed positive direct effects on cane yield, while stalk height, stalk diameter, Brix, and millable stalks exhibited negative direct effects on yield (Table 3). Growth2 showed high direct effect (0.44) on yield with a correlation of 0.38. Stalk height, stalk diameter, and Brix showed negative direct effects (-0.13, 0.32, and -0.33, respectively) on cane yield.

Table 3. Phenotypic and genotypic (in parentheses) direct (bold face) and indirect effects, based on path coefficient analyses, of 7 characters on cane yield of 28 sugarcane genotypes

	Till2	Gr2	Slen	Sdia	Brix	POL	corr with Cyield
Till2	**0.10**	0.06	-0.04	0.17	0.01	0.00	0.29
	(0.09)	(0.08)	(-0.11)	(0.27)	(0.03)	(-0.05)	(0.31)
Gr2	0.01	**0.46**	-0.07	-0.06	0.00	0.05	0.38
	(0.01)	**(0.70)**	(-0.18)	(-0.12)	(0.01)	(0.06)	(0.47)
Slen	0.03	0.26	**-0.13**	0.03	0.03	0.02	0.24
	(0.03)	(0.42)	**(-0.30)**	(0.05)	(0.08)	(0.02)	(0.31)
Sdia	-0.05	0.09	0.01	**-0.32**	-0.12	0.23	-0.16
	(-0.05)	(0.17)	(0.03)	**(-0.50)**	(-0.23)	(0.50)	(-0.07)
Brix	0.00	0.00	0.01	-0.12	**-0.33**	0.36	-0.08
	(-0.01)	(-0.01)	(0.05)	(-0.21)	**(-0.54)**	(0.61)	(-0.11)
POL	0.00	0.05	-0.01	-0.17	-0.27	**0.44**	0.05
	(-0.01)	(0.06)	(-0.01)	(-0.33)	(-0.44)	**(0.75)**	(0.01)
Residual	(P)	(0.72)					
	(G)	(0.63)					

Till= Tillers. Gr= Growth. Slen= Stalk height. Sdia= Stalk diameter. Mcanes= Number of Millable canes. Corr: Correlation. Cyield: Cane yield. P: Phenotypic. G: Genotypic.

Genotypic path coefficients showed positive direct effects of growth2, and Pol on cane yield with values of 0.70 and 0.75, respectively. Tiller2 showed a positive indirect effect on cane yield via growth2, stalk diameter, and Brix. Growth 2 exhibited positive but low indirect effects via tiller2, Brix and Pol while Pol displayed a positive but low indirect effect on cane yield via growth2. Other characters such as stalk height, stalk diameter, and Brix showed moderate to high and negative direct effects on cane yield. For other traits, stalk height and stalk diameter had positive and significant associations with tiller2 and growth2, and stalk diameter had a strong positive association with Brix and POL. This is supported by Tyagi et al. [21] who found highly significant correlations of cane yield with cane weight, cane height, and low degree of association with cane thickness at genotypic level.

Overall, cane yield was negatively associated with stalk diameter, and Brix, and had positive but non-significant associations with tiller2, stalk height, and Pol. Olaoye and Agbana [22] also found a negative phenotypic association of tonnes of cane ha^{-1} and other quality traits. Chaudhary et al. [23] reported significant positive correlation of cane yield with stalk length, stalk weight, and internode number and length.

Path analysis of the seven traits (Table 3) showed that growth2 had the highest positive direct effect on cane yield followed by Pol and tiller2. However, stalk height and diameter, and Brix had negative direct effects on cane yield. Chaudhary et al. [23] found stalk length an important character in determining cane yield. On the contrary, Rewati and Bal [24] reported that stalk diameter and stalk length were positively correlated with yield due to indirect effect of single stalk height. Similarly, stalk height and thickness were also found important by Anand and Praduman [25], whereas stalk number, sucrose %, and stalk weight were noted to be important characters with highest direct and indirect effects by Hussein et al. [5].

In brief, tiller2, growth2, and Pol had high direct effect on cane yield and could be combined in a selection index with cane yield for selection of suitable genotypes.

3.4 Development of Smith's Selection Indices

Selection indices for cane yield were calculated using tiller2, growth2, and Pol (Table 4). Individual genetic advance for tiller2 was 48.48 and for growth2 it was 31.59. Pol and cane yield gave values of genetic advances as 0.78 and 5.36, respectively. Higher genetic advance values were recorded (more than 60) for the indices including tiller2 + growth2, tiller2 + growth2 + Pol, tiller2 + growth2 + cane yield, and tiller2 + growth2 + Pol + cane yield. The highest genetic advance was recorded for the selection index including all 4 characters.

Smith's selection indices were developed for 4 characters (Table 5), and showed that index based on individual characters yielded a genetic gain in the range of 0.78 and 48.48. Tiller2, growth2, Pol, and cane yield gave a cumulative expected genetic advance greater than 60. The individuals selected on the basis of these selection indices showed higher mean values than that of the overall means and revealed higher genetic advances. Entries CPF-225, MS-2003-CR5-245, MS-2003-CR7-243, and MS-2003-CR8-407 were selected using either of the selection indices. Singh and Khan [26] also reported an improvement in genetic gain with cane yield and quality characters viz juice extraction per cent, cane yield and commercial cane sugar, selected simultaneously than selection based on individual character. Similarly, Singh and Khan [9] suggested selection based on number of millable canes, cane yield, stalk height, stalk weight, and juice extraction percent as important characters for improvement in cane yield.

Table 4. Selection indices based on any one to four characters with expected genetic gain

Selection Index I	ΔG (Expected genetic gain at 20% selection intensity)				Total
Till2	48.48				48.48
GR2	31.59				31.59
Pol	0.78				0.78
Cyield	5.36				**5.36**
Till2 + GR2	41.51	19.26			60.76
Till2 + POL	48.57	-0.09			48.48
Till2 + Cyield	48.24	2.27			50.51
GR2 + Pol	31.60	0.05			31.66
GR2 + Cyield	31.32	3.59			34.91
Pol + Cyield	0.09	5.31			5.40
Till2 + GR2 + Pol	41.58	19.33	-0.06		60.86
Till2 + GR2 + Cyield	40.82	19.80	3.31		63.92
Till2 + Pol + Cyield	48.33	-0.09	2.28		50.51
GR2 + Pol + Cyield	31.34	0.04	3.60		34.98
Till2 + GR2 + Pol + Cyield	40.89	19.87	-0.06	3.32	64.03

Till= Tillers. Gr= Growth. Cyield: Cane Yield.

Table 5. Genotypes selected on the basis of the Smith index for different combination of characters (selection intensity i=20%)

S.I.1	Characters (mean values)			Smith's index
	Till2	Gr2		
MS-2003-CR8-407	342.06	214.93		388.28
MS-2003-CR7-243	328.17	210.90		376.01
CPF-225	351.50	179.57		368.22
MS-2003-CR5-245	318.33	198.47		360.19
CoJ-76	328.00	183.03		355.13
CP 77/400	249.94	249.58		352.66
Mean of Selected Individuals	319.67	206.08		
Mean of all Individuals	283.20	184.78		
S.I.2	**Till2**	**Gr2**	**Pol**	**Smith index**
MS-2003-CR8-407	342.06	214.93	15.95	115.52
MS-2003-CR7-243	328.17	210.90	15.71	111.64
CPF-225	351.50	179.57	17.08	107.62
MS-2003-CR5-245	318.33	198.47	16.23	105.81
MS-2003-CR2-129	284.00	215.70	15.20	103.50
CoJ-76	328.00	183.03	16.97	103.36
Mean of Selected Individuals	325.34	200.43	16.19	
Mean of all Individuals	283.20	184.78	16.07	
S.I.3	**Till2**	**Gr2**	**Cyield**	**Smith index**
MS-2003-CR8-407	342.06	214.93	75.51	388.02
MS-2003-CR7-243	328.17	210.90	74.97	376.47
CPF-225	351.50	179.57	66.72	365.70
MS-2003-CR5-245	318.33	198.47	71.78	360.54
CoJ-76	328.00	183.03	75.48	356.88

S.I.1	**Characters (mean values)**				**Smith's index**
	Till2	**Gr2**			
CP 77/400	249.94	249.58	72.82		355.13
Mean of Selected Individuals	319.67	206.08	72.88		
Mean of all Individuals	283.20	184.78	66.85		
S.I.4	**Till2**	**Gr2**	**Pol**	**Cyield**	**Smith index**
MS-2003-CR8-407	342.06	214.93	15.95	75.51	117.13
MS-2003-CR7-243	328.17	210.90	15.71	74.97	113.44
CPF-225	351.50	179.57	17.08	66.72	108.37
MS-2003-CR5-245	318.33	198.47	16.23	71.78	107.51
MS-2003-CR2-129	284.00	215.70	15.20	74.08	105.85
CoJ-76	328.00	183.03	16.97	75.48	105.53
Mean of Selected Individuals	325.34	200.43	16.19	73.09	
Mean of all Individuals	283.20	184.78	16.07	66.85	

Till= Tillers. Gr= Growth. Cyield: Cane Yield.

4. CONCLUSIONS

Path analysis revealed the importance of such characters as growth2, Pol, and tiller2. Thus, we recommend using these traits for the selection of sugarcane genotypes. However, stalk height, stalk diameter, and Brix had negative direct effects on cane yield. Smith's selection indices showed that individuals selected based on tiller2, growth2, Pol, and cane yield gave expected genetic advances greater than 60. These genetic advances were greater than those from selecting directly for cane yield alone, or indirectly on other individual characters. CPF-225, MS-2003-CR5-245, MS-2003-CR7-243, and MS-2003-CR8-407 could be selected as the best genotypes according to this selection index. These genotypes could be included in the coming advanced evaluation trials. Looking at the results of this study, it can be concluded that path analysis procedure followed by development of a selection index for selection of sugarcane genotypes could be fruitful in improving overall selection strategies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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