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Short Communication

CLONAL SELECTION STRATEGY IN SUGARCANE (*SACCHARUM OFFICINARUM* L.) BASED ON THE ASSOCIATION OF QUALITY TRAITS AND CANE YIELD

A. Ali[1], S. A. Khan[2], M. Tahir[1], A. Farid[2], A. Khan[2], S. M. Khan[2] and N. Ali[2]

[1]Sugar Crops Research Institute Mardan, Khyber Pakhtunkhwa, Pakistan; [2]Department of Agricultural Sciences, University of Haripur, Khyber Pakhtunkhwa, Pakistan
Corresponding author's email:srobreeding@gmail.com

ABSTRACT

Quality traits play an important role in sugarcane clonal selection programs. The present investigation was carried out to study the association of quality traits with cane yield to establish an appropriate selection strategy based on quality characters. Sixteen sugarcane genotypes comprising two check cultivars were studied at Sugar Crops Research Institute Mardan, Khyber Pakhtunkhwa (KP), Pakistan. Positive phenotypic and genotypic correlations were observed for all the traits with cane yield (t ha^{-1}) except purity %. Similarly brix % and polarized sugar % showed highly significant and positive correlation with sugar recovery % at genotypic (0.66^{**}, 0.74^{**}) and phenotypic (0.67^{**}, 0.79^{**}) levels. Highly significant correlation of brix % with polarized sugar % at genotypic (1.00^{**}) and phenotypic (0.95^{**}) levels were observed. Path analysis showed that highest positive direct effect on cane yield (t ha^{-1}) is exerted by sugar recovery % at genotypic (0.42) and phenotypic (1.94) levels. It is suggested that the quality parameters should be taken in to consideration in clonal selection program for evolving improved sugarcane genotypes. Moreover the genotypes (MS-92-CP-99, MS-2000-Ho-360, MS-2003-HS-274 and MS-91-CP-523) with high cane yield and sugar recovery should be evaluated further.

Key words: correlations, path analysis, multicollinearity, plant and ratoon crop

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is world's largest crop with respect to total production and one of the important cash crops of Pakistan (Khan *et al.,* 2018). In Pakistan during 2016-17 area cultivated for sugarcane crop reached 1217 thousand hectares with a production of 63607 thousand tones and an average yield of 60428kg/ha. (Pakistan Economic Survey 2016-17). Cane yield and sugar recovery are two important characters in sugarcane breeding programme (Khan *et al*., 2012). Cane yield is influenced by several quality characters i.e. brix, polarized sugar and recovery (Singh *et al.,* 2003). To increase cane and sugar yield through selection for yield attributing and quality characters, the knowledge of association of various characters is important (Tahir *et al.,* 2014b). Therefore the study of relationship of different characters with cane yield is essential, so that an appropriate and efficient selection strategy could be adopted for improvement. In Pakistan we need high yielding and high quality varieties of sugarcane. Therefore the knowledge about the associations that occur among different quality traits and cane yield is important. Complex characters i.e. cane yield can be studied better by knowing the direct and indirect effect of interrelated components through path analysis. (Kang *et al.,* 1989). Suitable genotypes for a locality can be identified when selection criteria based on the characters having important contribution for the desired characters are made. Inter association of different quality traits of sugarcane, their effect on cane yield and appropriate selection strategy based on quality traits were worked in the study. Similarly the genotypes with high cane yield and quality traits were studied and selected for further investigation.

MATERIALS AND METHODS

Experimental site: The study was conducted at the Sugar Crops Research Institute Mardan, KP, Pakistan, located at 34ºNorth latitude, 72º East longitude, 283 meteraltitude,696mm (summer 488mm, winter 208mm) total rainfall, 39.8ºC summer mean temperature, 1.33ºC winter mean temperature and 60.8% mean relative humidity.

Experimental detail: The trials were conducted during 2012-13 (Plant crop), 2013-14 (Plant and ratoon crops) and 2014-15 (Ratoon crop). Fourteen sugarcane genotypes and two check cultivars (CP-77/400 and Mardan-93) were used. The experiments were arranged in randomized complete block design with three replications. Size of plot for each genotype was 10 m long and 6.7m wide, having 7 rows (150 buds per row) with a row-to-row distance of 90 cm. All recommended agronomic practices were carried out when required. For plant crop N, P_2O_5, and K_2O at the rate of 150-100-100 kg ha^{-1} were applied in the form of Urea, DAP and SOP. Similarly in ratoon Crop 175-100-100 kg ha^{-1} N, P_2O_5, and K_2O were applied. Thiodon at the rate of 2.5 l ha^{-1}

was sprayed at planting time, for control of termites. Ametrin + Atrazine at the rate of 1.5 kg ha^{-1} were applied one month after plantation for the control of weeds. Other cultural practices like hoeing, earthling up, and irrigation were kept uniform for all the genotypes. The quality parameters were studied in the analytical laboratory of Sugar Crops Research Institute Mardan.

Brix %: Brix % was taken by measuring total soluble solids using hydrometer. Five canes per samples were obtained for estimation of brix percentage. Both brix and temperature reading were noted. Then, corrected brix % was calculated using Schmitz table for a particular temperature.

Polarized sugar %: Polarimeter is used to determine it. Cane juice was augmented with 1.5 g lead acetate and filtered. The filtered juice was then placed in a tube in polarimeter. The reading taken was polarized sugar %. (Tahir *et al*., 2014a)

Purity %: Purity % is calculated by the following formula:

$$Purity\,\% = \frac{POL\%}{Corrected\ Brix} \times 100$$

Sugar Recovery %: Calculated by the following formula 00.7 × [Polarized sugar % - 0.5 (Corrected brix – polarized sugar %)] (Spencer and Meade, 1948)

Cane yield (t ha^{-1}): This data was taken by weighing the cane without trash per plot in kilograms and converting in to tons / ha by the following formula.

$$Caneyield = \left(\frac{x \times 10000}{plot\ size \times 1000}\right)$$

Where "*x*" is the yield in kg per plot (Khalid *et al.,* 2018).

Statistical analysis: Analysis of variance was carried out as suggested by (Gomez & Gomez, 1984). Version 3A of PLABSTAT software of plant breeding experiments (Utz, 2011) was used to determine phenotypic and genotypic correlations. Path analysis was performed by using these correlations as described by Singh and Chaudhary (1979). Multicollinearity analysis was performed before determining path coefficient analysis for the characters under study. Procedure Regression in SAS Version 9.3 (SAS Institute, 2003) was used for determining multicollinearity analysis.

RESULTS AND DISCUSSION

ANOVA and Mean performance: Crops, genotypes and genotype × crop interactions showed varying levels of significance. Mean squares for crops were highly significant for all traits except brix %. Among genotypes highly significant differences were present for brix (%), polarized sugar (%) and cane yield (t ha^{-1}) while significant differences were present for sugar recovery (%) and non-significant differences for purity (%). The effect of genotype × crop interaction was highly significant for cane yield (t ha^{-1}) while non-significant for other characters (Table 1). The genotypic mean squares were of higher magnitudes suggesting genetic control on the traits (Table 1). Highly significant differences for cropping year revels the importance of different years. The crop × genotype effect is non-significant for quality traits which suggested that only one year trial is sufficient and no need of separate selection for these traits. These findings are in agreement with the study of Tahir *et al.,* (2014a) who described similar kind of crops/years, genotypes and genotypes × crops interaction. Significant genotype × environment interaction was also reported by Khalid *et al.,* (2018).

The highest cane yield (74.92 t ha^{-1}) was given by genotype MS-92-CP-99 followed by MS-2000-Ho-360 (72.13t ha^{-1}), MS-2003-HS-274 (72.04t ha^{-1}) and MS-91-CP-523 (71.58t ha^{-1}) (Table 2). The cane yield is the result of a number of independent traits which include cane height, cane diameter, internode length and number of nodes (Khan *et al*., 2018). Regarding qualitative traits genotype MS-92-CP-99 performed better as compared to other genotypes. The highest sugar recovery was given by genotype MS-92-CP-99 (12.44%) followed by MS-2000-Ho-360 (11.89%), MS-99-Ho-6 (11.89%), S-98-SSG-612 (11.88%), CP-77-400 (11.87%), S-98-SSG-363(11.85%), S-92-US-72 (11.84%), MS-91-CP-248 (11.81%) and Mardan-93 (11.75%). Whereas the highest polarized sugar was given by genotype MS-92-CP-99 (18.38 %) followed by S-98-SSG-612 (18.26%), MS-2000-Ho-535 (18.22%), S-98-SSG-363 (18.18%), MS-91-CP-248 (18.12%) and MS-2000-Ho-115 (18.10%). Maximum brix (20.41%) was observed for genotype MS-92-CP-99 followed by MS-2000-Ho-115 (20.37%), MS-91-CP-248 (20.30%), S-98-SSG-612 (20.24%), CP-77/400 (20.18%) and MS-2000-Ho-535 (20.17%) (Table 2). According to Khan *et al.,* (2018) it is very difficult to achieve high cane yields and sugar recovery, in the same genotype. It has been observed over the years that improvement in one trait results impact on many others (Chaudhary and Joshi, 2005). Genotypes MS-92-CP-99, MS-2000-Ho-360, MS-2003-HS-274 and MS-91-CP-523 performed better and were selected for further testing.

Character association: The degree of association among the traits showed highly significant correlation of brix % with polarized sugar % (rp= 0.95**, rg = 1**) and sugar recovery % (rp = 0.67**, rg = 0.66**) both at genotypic and phenotypic levels. Polarized sugar % had a highly significant correlation with sugar recovery % (rp = 0.79**, rg = 0.74**) at phenotypic and genotypic levels while its association with purity at phenotypic level is positive (rp = 0.30) (Table 3). Purity % had positive correlation with sugar recovery % (rp = 0.41) at phenotypic level. Sugar recovery % had highly significant correlation with cane yield (t ha^{-1}) at genotypic level ($rg = 0.70^{**}$) while its correlation with cane yield at phenotypic level was positive (rp = 0.47) (Table 3). Most of the correlation of the quality characters is seen to be positive or significant in association with each other. In our findings the association of sugar recovery is positive and significant with cane yield as compared with other quality traits, which will help in development of better performing sugarcane variety in the materials tested. Tahir *et al.,* (2014b) reported negative phenotypic and genotypic correlation of brix with cane yield. Results of Smiullah *et al.,* (2013) were contradictory to our findings who reported positive association of yield with brix. Likewise, Tyagi *et al.,* (2012) reported significant positive phenotypic and genotypic correlations of number of canes per plot and cane yield with sucrose %. They suggested that these characters could be selected for improving cane yield.

Path analysis: Before path coefficient analysis, multicollinearity was carried out and the character with VIF (Variance inflation factor) value higher than 10 was removed i.e. Polarized sugar % (Table 4).

Analysis of multicollinearity of the characters under study is very important before conducting path coefficients analyses. For conformation of collinearity three criteria's persist. They included variance inflation factor, tolerance and condition index. The characters are decided to be collinear when VIF and tolerance values are > 10, and reduction in multicollinearity can occur by eliminating the correlated parameter. Values from 100 to 1000 for condition index show moderate to high multicollinearity.

On phenotypic level brix % had negative (-0.02) direct effect on cane yield (t ha^{-1}) similarly its indirect effect via purity % was negative ($P_{(1,2)} = -0.01$) while its indirect effect via sugar recovery % was positive ($P_{(1,3)} = 0.28$) (Table 5). On genotypic level brix % had a high positive (1.16) direct effect on cane yield (t ha^{-1}). Similarly its indirect effect via sugar recovery % was also high ($P_{(1,3)} = 1.28$) (Table 6). Purity % had positive ($P_{(2,3)} = 0.17$) indirect effect via sugar recovery % on phenotypic level (Table 5). On genotypic level it had negative (-0.21) direct effect on cane yield (t ha^{-1}) (Table 6). Sugar recovery % had high positive (1.94) direct effect on cane yield (t ha^{-1}) while it's indirect effect via brix % ($P_{(3,1)} = -0.01$) and purity % ($P_{(3,2)} = -0.08$) was negative at phenotypic level (Table 5). Sugar recovery % had a direct positive (0.42) effect on cane yield (t ha^{-1}) at genotypic level while its effect via brix % was negative ($P_{(3,1)} = -0.77$) (Table 6). The characters having direct positive effects must be given importance during the selection process. In our study the highest direct effect on cane yield was noted for sugar recovery %, while brix % also had high direct effect on cane yield at genotypic level. Yield is determined by numerous agronomic, morphological, and physiological factors which further have intricate associations and interrelations (Khan *et al.,* 2012). In case of sugarcane, yield as well as sugar recovery is very important for a good variety. Varietal selection on the basis of contributing components is advantageous (Risch, 2000; Darvasi and Pisanté-Shalom; 2002). Negative direct effects of brix on cane yield were noted by Tena *et al.,* (2016) at Wonji and Metehara Estates of Sugar Corporation of Ethiopia. Singh and Khan (2003) described a negative relationship of cane yield with sucrose and suggested a combine selection approach for these traits to obtain more cane and sugar yield.

Table 1. Mean squares of sugarcane genotypes evaluated as plant and ratoon crops.

Source	DF	Brix%	Polarized sugar%	Purity%	Recovery%	Cane yield (tha^{-1})
Crops/Years	3	1.48^{ns}	21.72^{**}	270.27^{**}	28.05^{**}	7389.49^{**}
Reps (Crops)	8	0.47	1.00	3.32	0.60	115.44
Genotypes	15	3.62^{**}	3.23^{**}	5.60^{ns}	1.58^{*}	193.15^{**}
Crops x Genotypes	45	1.05^{ns}	0.90^{ns}	1.71^{ns}	0.77^{ns}	134.38^{**}
Error	120	1.45	1.48	5.87	0.90	48.71
CV%		6.10	6.85	2.69	8.31	10.38

** = Highly significant at 1 % level of probability
* = Significant at 5 % level of probability
ns = Non-significant
DF = degrees of freedom

Table 2. Mean data of sugarcane genotypes evaluated as plant and ratoon crops.

Genotypes	Source	Brix%	Polarized sugar%	Purity%	Sugar recovery%	Cane Yield (tha^{-1})
MS-2000-Ho-535	Houma, USA	20.17ab	18.22a	90.17	11.66b	63.38efg
MS-99-Ho-6	Houma, USA	19.64abcd	17.98ab	91.34	11.89ab	64.57efg
MS-2000-Ho-115	Houma, USA	20.37a	18.10ab	88.83	11.26bc	65.03efg
MS-2000-Ho-357	Houma, USA	19.68abcd	17.89ab	90.91	11.52bc	61.15fg
S-98-SSG-363	Guatemala	19.94abc	18.18a	89.88	11.85ab	66.00defg
S-98-SSG-612	Guatemala	20.24ab	18.26a	90.18	11.88ab	66.43cdef
MS-91-CP-248	Canal Point, USA	20.30ab	18.12a	89.98	11.81ab	67.60bcde
MS-91-CP-249	Canal Point, USA	18.67e	16.58d	88.74	10.88c	60.49g
S-92-US-72	Canal Point, USA	19.82abc	17.88ab	90.18	11.84ab	67.83bcde
MS-91-CP-523	Canal Point, USA	18.84de	16.88cd	89.49	11.22bc	71.58abcd
MS-92-CP-99	Canal Point, USA	20.41a	18.38a	89.49	12.44a	74.92a
MS-2000-Ho-360	Houma, USA	19.36bcde	17.78abc	90.74	11.89ab	72.13ab
MS-2003-HS-274	HSMRF Sindh,	18.98cde	17.13bcd	90.10	11.35bc	72.04abc
MS-2003-HS-366	HSMRF Sindh	19.63abcde	17.65abc	89.86	11.65b	66.06defg
CP-77/400	Check cultivar	20.18ab	18.17a	89.51	11.87ab	67.95bcde
Mardan-93	Check cultivar	19.78abcd	17.78abc	89.85	11.75ab	68.84bcde
Mean	-	19.76	17.81	89.95	11.67	67.25
$LSD_{0.05}$	-	0.97	.98	NS	.76	5.6

Means followed by the same letters do not differ significantly

Table 3. Phenotypic (above diagonal) and genotypic (below diagonal) correlation of quality characters and cane yield.

	Brix%	Polarized sugar%	Purity%	Sugar recovery%	Cane Yield (tha^{-1})
Brix%	1	0.95^{**}	0.04	0.67^{**}	0.02
Polarized sugar%	1.00^{**}	1	0.30	0.79^{**}	0.06
Purity%	0.00	0.00	1	0.41	-0.02
Sugar recovery%	0.66^{**}	0.74^{**}	0.00	1	0.47
Cane Yield (tha^{-1})	0.00	0.06	0.00	0.70^{**}	1

** = highly significant correlation

Table 4. Multicollinearity results of sugarcane genotypes (after removal of polarized sugar %).

Parameter Estimates							
Variable	**DF**	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr>|t|**	**Tolerance**	**Variance Inflation**
Intercept	1	99.26	142.60	0.7	0.51	.	0
Brix %	1	-0.19	2.56	-0.08	0.94	0.23	4.24
Purity %	1	-1.34	1.55	-0.86	0.42	0.41	2.41
Sugar recovery %	1	4.87	4.44	1.1	0.31	0.18	5.51

Table 5. Phenotypic direct and indirect effects of quality characters on cane yield.

S. No	Characters	Indirect effect			Direct effect	Correlation with Cane yield
		1	2	3		
1	**Brix %**	-	$P_{(1,2)}$,-0.01	$P_{(1,3)}$,0.28	**P(-0.02)**	0.02
2	**Purity %**	$P_{(2,1)}$,0.00	-	$P_{(2,3)}$,0.17	**P(0.00)**	-0.02
3	**Sugar recovery %**	$P_{(3,1)}$,-0.01	$P_{(3,2)}$,-0.08	-	**P(1.94)**	0.47
	Residual	0.18				

Table 6. Genotypic direct and indirect effects of quality characters on cane yield.

S. No	Characters	Indirect effect			Direct effect	Correlation with Cane yield
		1	2	3		
1	**Brix %**	-	$P_{(1,2)}$,0.00	$P_{(1,3)}$,1.28	**P(1.16)**	0.00
2	**Purity %**	$P_{(2,1)}$,0.00	-	$P_{(2,3)}$,0.00	**P(-0.21)**	0.00
3	**Sugar recovery %**	$P_{(3,1)}$,-0.77	$P_{(3,2)}$,0.00	-	**P(0.42)**	0.70^{**}
	Residual	-0.18				

Conclusion: The study showed that some of the genotypes i.e. MS-92-CP-99, MS-2000-Ho-360, MS-2003-HS-274 and MS-91-CP-523 performed better and could be recommended for further study. Sugar recovery % showed positive and significant correlation and direct higher effect on cane yield. Hence sugar recovery % might be taken into consideration for selecting improved sugarcane genotypes with high cane yields.

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