Advances in Crop Science and Technology

Ali et al., Adv Crop Sci Tech 2018, 6:3
DOI: 10.4172/2329-8863.1000371

Research Article Open Access

Evaluation of Various Sugarcane Genotypes for Association of Quality Characters with Cane Yield

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Rec date: May 18, 2018; **Acc date:** June 01, 2018; **Pub date:** June 09, 2018

Abstract

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 assessed during 2012-15 using RCB design with three replications. Data were collected on brix (%), polarized sugar (%), purity (%), sugar recovery (%) and cane yield (t ha^{-1}). Analysis of variance exhibited highly significant differences between crops for all parameters except brix (%). Among the genotypes highly significant differences were observed for brix (%), polarized sugar (%) and cane yield (t ha^{-1}). Crops × genotypes revealed highly significant differences for cane yield (t ha^{-1}). Genotypes MS-92-CP-99 (72.92 t ha^{-1}), MS-2000-Ho-360 (72.13 t ha^{-1}), MS-2003-HS-274 (72.04 t ha^{-1}) and MS-91-CP-523(71.58 t ha^{-1}) showed superiority regarding cane yield. Positive phenotypic and genotypic correlations were observed for all the traits with cane yield (t/ha) except purity %. 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. Brix % showed highly significant correlation with polarized sugar (%) at genotypic (1.00**) and phenotypic (0.95**) level. 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) level showing its importance in clonal selection program for evolving improved sugarcane genotypes. 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 with high cane yield and sugar recovery should be evaluated further.

Keywords: Sugarcane; Correlation; Path analysis and quality traits

Introduction

Sugarcane (*Saccharum officinarum* L.) is world's largest crop with respect to total production and one of the important cash crop of Pakistan [1]. In Pakistan during 2016-17 the area cultivated for sugarcane crop reached 1217 thousand hectares, 63607 thousand tones production with an average yield of 60428 kg/ha [2].

Cane yield and sugar recovery are two important characters [3]. Cane yield is influenced by several quality characters [4]. To increase cane and sugar yield through selection for yield attributing and quality characters, the knowledge of association of various characters is important [5]. 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 the different quality traits and cane yield is important. Complex characters can be studied better by knowing the direct and indirect effect of interrelated components through path analysis [6].

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

The study was conducted at the Sugar Crops Research Institute Mardan, Khyber Pakhtunkhwa, Pakistan, located at 34° North latitude and 72° East longitude, altitude 283-meter, total rainfall 696 mm (summer 488 mm, winter 208 mm), summer mean temperature 39.8°C, winter mean temperature 1.33°C with a mean relative humidity of 60.8% on sugarcane crop 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 6.7 m 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. The quality parameters were studied in the analytical laboratory of Sugar Crops Research Institute Mardan.

Brix refers to the total solids content present in the juice expressed in percentage. Brix includes sugars as well as non-sugars. It was taken by measuring the brix (total soluble solids) in the cane in laboratory using a 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 a Schmitz table for a particular temperature.

Polarized sugar (%) is the actual sugar present in the juice. Polari meter is used for its determining. Cane juice 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 polarized sugar % [7].

Purity is the percentage of sucrose present in the total solids content in the juice.

It is calculated by the following formula:

Purity %=POL %/Corrected Brix × 100

Sugar recovery %: Calculated by the following formula

00.7 × [Polarized sugar %-0.5 (Corrected brix-polarized sugar %)] [8].

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.

Cane yield=(x × 1000/plot size × 1000)

Where "x" is the yield in kg per plot [9].

Statistical analysis

Analysis of variance was carried out as suggested by Gomez and Gomez [10]. R statistical package was used for Correlations calculation. Path analysis was performed by using these correlations as described by Singh and Chaudhary [11]. Multicollinearity analysis was performed before determining path coefficient analysis for the characters under study. PROC REG in SAS Version 9.3 was used for determining multicollinearity analysis [12].

Results and Discussion

Anova and mean performance

Highly significant differences were noted for all traits except brix % pertaining to crops/years. 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).

Source	DF	Brix %	Polarized sugar %	Purity %	Recovery %	Cane yield (t ha^{-1})
Crops/Years	3	1.4835^{ns}	21.7278**	270.271**	28.0558**	7389.49**
Reps(Crops)	8	0.47488	1.0077	3.328	0.6093	115.44
Genotypes	15	3.62521**	3.2354**	5.605^{ns}	1.58*	193.15**
Crops × Genotypes	45	1.05222^{ns}	0.9099^{ns}	1.711^{ns}	0.7786^{ns}	134.38**
Error	120	1.45222	1.4893	5.876	0.9001	48.71
CV%		6.1	6.85	2.69	8.31	10.38

Table 1: Mean squares. ns=non significant.

The genotypic mean squares were of higher magnitudes suggesting genetic control on the traits. Highly significant differences for cropping year revels the importance of different years. The genotype × crop interaction suggests different performance for cane yield of the genotypes in different years. Usually the performance of the second crop is not very good therefore genotypes with good plant as well as ratoon crops are desirable. These findings are in good agreement with Tahir et al. [7] who described similar kind of crops, genotypes and genotypes × crops interaction. Significant genotype × environment interaction was also reported by Khalid et al. [9].

The highest cane yield (74.92 t ha^{-1}) was given by genotype MS-92-CP-99 followed by MS-2000-Ho-360 (72.13 t ha^{-1}), MS-2003-HS-274 (72.04 t ha^{-1}) and MS-91-CP-523 (71.58 t ha^{-1}). The cane yield is the result of a number of independent traits which include cane height, cane diameter, internode length and number of nodes [1]. Regarding qualitative traits of the genotypes MS-92-CP-99 performed good as compared to other genotypes. The highest sugar recovery (12.44%) was given by genotype MS-92-CP-99 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%). 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%). The highest brix (20.41%) was given by 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%). According to Khan et al. it is very difficult to achieve high cane yields and sugar recovery, in the same genotype [1]. It has been observed over the years that improvement in one trait results in impact on many others [13]. Most of the genotypes in the study performed better and the genotypes with high cane yield as well as quality traits are selected for further testing (Table 2).

Genotypes	Brix %	Polarized Sugar %	Purity %	Sugar Recovery %	Cane Yield (t/ha)
MS-2000-Ho-535	20.17^{ab}	18.22^{a}	90.17	11.66^{b}	63.38^{efg}
MS-99-Ho-6	19.64^{abcd}	17.98^{ab}	91.34	11.89^{ab}	64.57^{efg}

MS-2000-Ho-115	20.37^{a}	18.10^{ab}	88.83	11.26^{bc}	65.03^{efg}
MS-2000-Ho-357	19.68^{abcd}	17.89^{ab}	90.91	11.52^{bc}	61.15^{f}g
S-98-SSG-363	19.94^{abc}	18.18^{a}	89.88	11.85^{ab}	66.00^{defg}
S-98-SSG-612	20.24^{ab}	18.26^{a}	90.18	11.88^{ab}	66.43^{cdef}
MS-91-CP-248	20.30^{ab}	18.12^{a}	89.98	11.81^{ab}	67.60^{bcde}
MS-91-CP-249	18.67^{e}	16.58^{d}	88.74	10.88^{c}	60.49^{g}
S-92-US-72	19.82^{abc}	17.88^{ab}	90.18	11.84^{ab}	67.83^{bcde}
MS-91-CP-523	18.84^{de}	16.88^{cd}	89.49	11.22^{bc}	71.58^{abcd}
MS-92-CP-99	20.41^{a}	18.38^{a}	89.49	12.44^{a}	74.92^{a}
MS-2000-Ho-360	19.36^{bcde}	17.78^{abc}	90.74	11.89^{ab}	72.13^{ab}
MS-2003-HS-274	18.98^{cde}	17.13^{bcd}	90.1	11.35^{bc}	72.04^{abc}
MS-2003-HS-366	19.63^{abcde}	17.65^{abc}	89.86	11.65^{b}	66.06^{defg}
CP-77/400	20.18^{ab}	18.17^{a}	89.51	11.87^{ab}	67.95^{bcde}
Mardan-93	19.78^{abcd}	17.78^{abc}	89.85	11.75^{ab}	68.84^{bcde}
Mean	19.76	17.81	89.95	11.67	67.25
$LSD_{0.05}$	0.97	0.98	NS	0.76	5.6

Table 2: Mean data. a,b,c,d,e,f,g=Values of independent traits.

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) at phenotypic level. 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).

	Brix %	**Polarized sugar %**	**Purity %**	**Sugar recovery %**	**Cane Yield (t ha^{-1})**
Brix %	1	0.95**	0.04	0.67**	0.02
Polarized sugar %	1.00**	1	0.3	0.79**	0.06
Purity %	0	0	1	0.41	-0.02
Sugar recovery %	0.66**	0.74**	0	1	0.47
Cane Yield (t ha^{-1})	0	0.06	0	0.70**	1

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

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. reported negative phenotypic and genotypic correlation of brix with cane yield [5].

Smiullah et al. reported positive association of yield with brix [14]. Likewise, Tyagi et al. reported significant phenotypic and genotypic correlations of number of canes per plot and cane yield with sucrose % [15]. They suggested that these characters could be selected for improving cane yield (Table 4).

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t-Value	Pr>|t|	Tolerance	Variance Inflation
Intercept	1	99.26689	142.6066	0.7	0.5124	.	0
Brix %	1	-0.1939	2.5694	-0.08	0.9423	0.23539	4.2482
Purity %	1	-1.34407	1.55911	-0.86	0.4218	0.41341	2.41888
Sugar Recovery %	1	4.87264	4.44483	1.1	0.315	0.18141	5.51239

Table 4: Test of multicollinearity (after exclusion of polarized sugar %).

Path analysis

Before path coefficient analysis multicollinearity was carried out and the character with VIF value higher than 10 was removed i.e., Polarized sugar %.

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).

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

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).

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
2	Purity %	$P_{(2,1)}$, (0.00)		$P_{(2,3)}$, 0.00	P (-0.21)	0
3	Sugar recovery %	$P_{(3,1)}$, -0.77	$P_{(3,2)}$, 0.00		P (0.42)	0.70**
	Residual	-0.18				

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

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 [3]. 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 [16,17]. Negative direct effects of brix on cane yield were noted by Tena et al. [18] while they observed positive direct effects of POL%. On the other hand, Singh and Khan described a negative relationship of cane yield with sucrose content and suggested a combine selection approach for these traits to obtain more cane and sugar yield [19,20].

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 can be selected for further study. Recovery was found out to have positive and significant correlation and direct higher effect on cane yield. Therefore, recovery should be taken into consideration for selecting improved sugarcane genotypes with high cane yields.

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