Madras Agric. J., 96 (7-12): 309-313, December 2009
https://doi.org/10.29321/MAJ.10.100494

Interrelationships of Sugarcane Yield and Quality Components and Their Utility in Family Selection

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Correlation coefficients among sixteen characters of sugarcane comprising of yield, quality and physiological aspects were studied from data collected on 1656 progenies obtained from 39 biparental crosses. The correlation was also studied in the progenies of individual families. The pattern of character association in the families showed that number of millable canes was positively associated with clump yield in all the families. Stalk height was the next important character associated with single stalk weight and clump yield in majority of the families. The correlation of single stalk weight and stalk diameter with yield was positive in majority of the families, and the correlation between these two characters was positively significant in all the families investigated. Number of millable canes and stalk diameter were negatively associated whereas number of millable canes and stalk height had a positive correlation only in five families. A balanced combination of these three characters seems to be essential while exercising selection for yield improvement in the population. The correlation coefficient between cane yield and sucrose per cent was not significant in majority of the families. The leaf area had highly significant positive association with clump yield and its component traits such as stalk diameter and single stalk weight when the population was considered as a whole. The results of the correlation between Hand Refractometer brix and sucrose per cent indicated that, Hand Refractometer brix at 240 days can be considered as an early indicator of juice quality during selection for sucrose per cent in the seedling population and thus aiding in the selection of early maturing high quality clones.

Key words: Sugarcane, correlation, cane yield, sucrose, family selection.

Sugarcane is an important agro industrial crop and is the major source of sugar. Cane sugar contributes around 60 per cent of the total sugar produced in the world, the rest being contributed by beet sugar and other sources. Though India is the highest producer of sugar in the world at present, the demand for sugar for internal consumption is growing due to increased *per capita* consumption and the increase in the population size. Improvement of sugarcane through genetic manipulation has been a directed, ongoing process since 1888, following the observation in 1858 that sugarcane produced viable seed (Stevenson, 1965).

Observations on growth or yield components of individual clones of sugarcane (*Saccharum* spp. hybrids) are frequently used to evaluate their yield potential. Visual selection rate in the early stages of a selection programme, frequently based on yield component measurements from individual progeny of the same family, is used to evaluate parents (Wu *et al*.,1980). However, the reliability of such evaluation depends on the correlation between yield components and actual yield. Hence a clear understanding of the association between yield and yield components is important in a crop improvement programme. The present investigation was undertaken to analyze interrelationships of cane yield and quality components and their utility in sugarcane family selection. An attempt was also made to assess the ratoon performance of progenies in the seedling ratoon crop after harvesting of the seedling crop at 360 days and correlated with other traits in the seedling crop.

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Materials and Methods

Experimental materials

This study was conducted at Sugarcane Breeding Institute (ICAR), Coimbatore, India (latitude; 11° North; longitude; 78°.8' East; altitude; 426.72 m MSL). The experimental materials consisted of 1656 progenies obtained from 39 biparental crosses involving 11 pollen parents and 34 pistil parents of sugarcane. Thirty six seedlings per replication per cross were planted in a randomized block design with 12 seedlings per row of 6m length along with the parents in two replications.

Biometrical observations studied

Out of the thirty six progenies from a family, twenty two seedlings were randomly selected per replication for recording biometrical observations and analysis. The biometrical observations such as tiller count (TLC) at 90 and 120 days, cane formed tillers (CFT) at 180 days, number of millable canes (NMC) at 300 and 360 days after planting, hand refractometer brix (HRB) at 240 and 300 days after planting, stalk diameter (STD) at 300 and 360 days after planting, leaf area (LAR) at 300 days after planting, and stalk height (SHT), single stalk weight (SSW), number of internodes (INN), internode length (INL), sucrose per cent (SUC) and stalk yield per clump (YLD) at 360 days after planting were recorded. Normal package of practices was adopted with respect to manuring, irrigation, earthing up *etc*. The seedlings were harvested at the age of 360 days and allowed for ratoon to assess the ratoonability of progenies. The number of sprouts (NOS) was recorded at 30 days from the date of ratooning of the seedlings and correlated with other traits of the seedling crop.

Character association

Correlation coefficient is a statistical measure, which is used to find out the degree and direction of relationship between two or more variables. In the present study correlation coefficients were worked out in the entire set of progenies irrespective of families to which they belong and in progenies of individual families.

Character relationship in the entire set of progenies was in terms of simple correlation coefficients obtained on the basis of mean of two observations from the two different replications. Genotypic and phenotypic level correlations were not considered here since the error variance and covariance appropriate to the families may not be available consequent on the randomization of the entire set of progenies. For similar reasons simple correlation coefficients were calculated in the progenies of individual families also.

The simple correlation was estimated as follows,

$$r_{xy} = \frac{\text{Cov}\,(x.y)}{\sqrt{\text{Var}\,x}\;\sqrt{\text{Var}\,y}}$$

Where,

r_{xy} = correlation coefficient between variables x and y

Cov ($x.y$) = covariance between x and y variable

Var x and Var y = variance of x and y respectively

The significance of correlation coefficient was tested by referring to table by Snedecor and Cochran (1967).

Results and Discussion

The correlation coefficients estimated in the entire set of progenies are presented in Table 1. Stalk yield and sucrose per cent are the two important characters that ultimately decide the sugar yield. Thus, it is extremely important to know how these characters are related between themselves as well as with other yield components. More over, it is also useful to know whether the type of association between two characters remain the same irrespective of families or it varies from family to family. The pattern of character association in terms of frequency of families showing positive or negative association for different traits showed that, positive association was noticed in all the families for NMC vs Clump yield and stalk diameter vs Single stalk weight. In majority of the families, positive

Table 1. Correlation coefficients for different yield and quality traits in sugarcane progenies

Character	TLC 120	CFT 180	NMC 300	HRB 240	NMC 360	HRB 300	STD 300	LAR	STD 360	SHT	INN	SSW	INL	SUC	YLD
TLC 90	0.689**	0.659**	0.612**	0.037	0.544**	0.004	-0.231**	-0.116**	-0.217**	0.114**	0.031	-0.144**	0.068*	-0.050	0.366**
TLC 120		0.763**	0.717**	-0.093**	0.694**	-0.136**	-0.204**	-0.083**	-0.187**	0.039	-0.019	-0.166**	0.050	-0.148**	0.491**
CFT 180			0.878**	-0.035	0.854**	-0.072*	-0.255**	-0.080*	-0.243**	0.157**	0.079*	-0.147**	0.069*	-0.079*	0.647**
NMC 300				-0.031	0.883**	-0.088*	-0.261**	-0.083**	-0.255**	0.169**	0.084**	-0.151**	0.074*	-0.092**	0.656**
HRB 240					-0.086**	0.690**	-0.032	-0.089**	-0.027	0.096**	0.109**	0.009	-0.005	0.516**	-0.078*
NMC 360						-0.126**	-0.243**	-0.056	-0.241**	0.129**	0.075*	-0.160**	0.047	-0.121**	0.750**
HRB 300							0.003	-0.062*	-0.008	0.143**	0.113**	0.081**	0.031	0.603**	-0.058
STD 300								0.254**	0.604**	-0.102**	0.085**	0.482**	-0.171**	0.021	0.091**
LAR									0.229**	-0.028	-0.020	0.219**	-0.009	-0.072*	0.086**
STD 360										-0.059	0.158**	0.597**	-0.199**	0.039	0.171**
SHT											0.436**	0.517**	0.519**	0.060	0.412**
INN												0.374**	-0.521**	0.000	0.284**
SSW													0.127**	0.065*	0.470**
INL														0.051	0.111**
SUC															-0.060

*/**Significant at 5% and 1% level of probability respectively

TLC - Tiller counts, CFT - Cane formed tillers, NMC - Number of millable canes , HRB- Hand Refractometer brix (%), LAR- Leaf area (cm^2) STD - Stalk diameter (cm), SHT - Stalk height (cm), INN - Number of internodes, SSW - Single stalk weight (kg), INL-Internode length (cm) SUC - Sucrose (%), YLD - Clump yield (kg) association was observed for stalk height vs clump yield, single stalk weight vs clump yield, stalk diameter vs clump yield and stalk height vs single stalk weight. Negative association like NMC vs stalk diameter, NMC vs single stalk weight and sucrose vs clump yield was registered in some families.

From the foregoing presentation, it becomes evident that only number of millable canes was positively related to clump yield in all the 39 families. A positive association between stalk number and stalk yield in an unselected population was reported by many authors. In three different crosses, James (1971) observed correlation coefficients of 0.59, 0.80 and 0.83 between stalk number and stalk yield. Mariotti (1971) found a very high positive correlation of 0.81 in an unselected population of 500 clones obtained from five different crosses. Mariotti (1977) was of the opinion that stalk number was the most conspicuous stalk yield component. Skinner (1982) found that stalk number was by far the main component of yield in sugarcane. Tai and Miller (1989), Pillai and Ethirajan (1993), ZuHu *et al.* (1995), Singh *et al*. (1995), Bissessur *et al.* (2001) and Tyagi (2007) also observed positive correlation of stalk yield with stalk number.

Stalk height was the next important character associated with single stalk weight, and clump yield in majority of the families. Hogarth (1971) observed a very high correlation of 0.85 between stalk height and stalk yield in a set of crosses. Mariotti (1971) and Hooda *et al.* (1979) reported a highly significant correlation between stalk height and stalk yield. Pillai and Ethirajan (1993), ZuHu *et al.* (1995) and Bissessur *et al.* (2001) also reported significant correlation between these two characters.

Next to number of millable canes and stalk height, the two other characters related to clump yield appear to be single stalk weight and stalk diameter. The correlation of these two characters with yield was positive in majority of the families, and the correlation between these two characters was positively significant in all the families investigated. This was in agreement with the findings of Singh *et al.* (1981). Hooda *et al.* (1979), Pillai and Ethirajan (1993) and Singh *et al.* (1995) reported positive correlation of single stalk weight with stalk yield. The same trend was noticed when the progenies were considered as a whole irrespective of families (Table 1). Stalk diameter was highly correlated with clump yield in majority of the families and in the entire set of progenies as well. James (1971) observed correlations of 0.08, 0.23, and 0.31 in three different populations, the latter two correlations being significant. Mariotti (1977) on the other hand, reported that, the association was not significant in a population of five crosses.

The most prominent character association among the yield components was between NMC and stalk diameter. These two characters were predominantly negatively associated. In addition to the correlation coefficients being significant in seven families, several other families also showed a definite trend of negative association. Perhaps, with

Table 2. Correlation between H.R. brix (240 days) and sucrose percent (360 days) in individual families

S.No.	Families	Correlation
1	Co 8371 x 971862	0.393*
2	Co 85002 x 971862	0.224
3	Co 86010 x Co 775	0.256
4	Co 86249 x Co 775	0.145
5	Co 87002 x 986179	0.356*
6	Co 88028 x Co 775	0.391*
7	Co 98003 x 971862	0.290
8	Co 98006 x 987001	0.433**
9	CoC 671 x Co 94008	0.175
10	CoH 76 x 985094	0.472**
11	CoH 110 x 984843	0.421*
12	CoH 110 x 986179	0.261
13	CoJ 72 x Co 62198	0.430**
14	CoM 9220 x 984843	0.589**
15	CoM 9220 x 987001	0.441**
16	ISH 1 x Co 94008	0.337*
17	RS 93-2182 x Co93009	0.521**
18	87A298 x Co 1148	0.491**
19	970311 x 986179	0.384*
20	971235 x Co 1148	0.601**
21	971235 x Co 62198	0.406*
22	971236 x Co 62198	0.332*
23	973402 x Co 775	0.678**
24	9844195 x Co A 7602	0.281
25	984727 x 984843	0.405*
26	984819 x Co 1148	0.387*
27	985040 x Co 1148	0.765**
28	985735 x Co 62198	0.495*
29	985931 x Co 775	0.544**
30	986046 x Co 775	0.268
31	986095 x Co 62198	0.479**
32	986095 x Co 94008	0.498**
33	986140 x Co 1148	0.428*
34	9869110 x Co 1148	0.169
35	9869110 x Co 62198	0.468**
36	987032 x Co 93009	0.618**
37	987080 x Co 1148	0.506**
38	987124 x Co 775	0.471**
39	9871144 x Co 775	0.443**

*/**Significant at 5% and 1% level of probability respectively

a larger progeny size, many more families would have shown a significant negative association and this was obvious when all the progenies are considered. Since NMC, stalk height, and stalk diameter constitute the components of clump yield, the nature of association among these three characters play a crucial role in influencing clump yield. The NMC and stalk height showed a positive correlation only in five families. The implications are that, simultaneous improvement in NMC and stalk height or in stalk diameter and stalk height might be possible. But possibility of simultaneous improvement in all these three characters is rather difficult because of the predominant negative relationship prevailing between NMC and stalk diameter. Hence a judicious combination of expression of these characters is needed for yield improvement, the limit being set by stalk diameter.

A negative association between stalk number and stalk diameter is almost an universal finding. Smith and James (1969), James (1971), Mariotti (1971) and Singh *et al*. (1981) are a few reports to cite. Brown *et al*. (1969) reported a high negative correlation between stalk number and stalk cross sectional area, a direct function of stalk diameter. Singh *et al.* (1981) and Bissessur *et al.* (2001) also reported a negative association between these two characters. A positive association between stalk number and stalk height was observed by Mariotti (1971). A positive association between stalk height and stalk diameter has been reported by Mariotti (1971), Hooda *et al.* (1979) and Singh *et al*. (1981).

The nature of association between single stalk weight and NMC was significant but in negative direction in several families. However, both the traits had a significant positive association with clump yield. These results indicate the difficulty in simultaneous improvement of these two characters. Selection of either of them would adversely affect the clump yield. In these circumstances, a suitable compromise has to be made in order to have maximum number of canes coupled with moderate single cane weight. Tai and Miller (1989) and Singh *et al*. (1995) reported negative association of NMC with single stalk weight.

Association between sucrose per cent and clump yield provides the most important information from the point of view of sugarcane improvement. In an unselected population, it has been frequently suggested that yield and sucrose content are independently inherited based on the absence of significant correlation between these two characters. Bissessur *et al.* (2001) and Mariotti (1971) reported that stalk yield and sucrose content varied independently. Mariotti (1977) has advocated alternate or joint selection for yield and quality (sucrose per cent), since these two characters was found to be independent. In the present investigation also, correlation coefficient between clump yield and sucrose per cent was not significant in almost all the families giving apparently a possibility of simultaneous selection for these two characters. In the high yielding families, *viz*., 985040 x Co1148, Co 98003 x 971862, CoH 110 x 986179, 987080 x Co1148, and 971144 x Co775, the association between these two characters was not related while in the family 985040 x Co 1148 and in others, it was negative but not significant. The same trend was observed when the population is considered as a whole. This indicates that a compromise between yield and quality is necessary during selection, if we are to maximize the ultimate sugar yield.

Stalk height and single stalk weight, the component traits of clump yield showed a significant association with sucrose per cent in some families. In the family RS 93-2182 x Co 93009 there was a high significant positive correlation of sucrose per cent with stalk height and single stalk weight, while its association with clump yield was not related. The physiological trait leaf area had highly significant positive association with clump yield and its component traits such as stalk diameter and single stalk weight and negative association with H.R brix. Singh *et al*. (1981) and Singh *et al*. (1995) also reported the positive significant association of LAR with stalk diameter and negative association with H.R brix. It reveals that, the leaf area should be given due consideration during selection for improvement of cane yield.

The association of H.R brix (300 days) with stalk height, number of internodes and single stalk weight is positive and significant. Sharma and Singh (1998) also reported a significant association of H.R brix with stalk height, number of internodes and internodal length. In an attempt to obtain information on the early indicator of juice quality, a correlation was made between H.R brix at 240 days and sucrose per cent at 360 days in all the families (Table 2). The results indicated that, H.R brix at 240 days can be considered as a reliable early indicator of juice quality in the seedling population and thus aids in the selection of early maturing high quality clones. Kang *et al*. (1983) reported that, brix can be used as a good indicator of sucrose content. Hogarth (1977) also reported that, selection for sugar by measuring brix should be effective because brix has a high degree of genetic determination and is not greatly affected by environment. The correlation of number of sprouts in seedling ratoon with other characters in seedling crop (Table 3) showed that, it was strongly associated with cane population traits and yield components indicating that, selection of progenies for cane population traits and yield components in the seedling crop would provide additional information on the ratoonability of the progenies.

From the present studies it can be concluded that, correlation of single stalk weight and stalk

Table 3. Correlation between number of sprouts in seedling ratoon and other traits in seedling crop

S. No.	Character (Seedling crop)	NOS Ratoon crop)
1.	TLC 90	0.363**
2.	TLC 120	0.504**
3.	CFT180	0.572**
4.	NMC300	0.617**
5.	HRB 240	-0.064*
6.	NMC360	0.631**
7.	HRB 300	-0.098**
8.	STD 300	-0.164**
9.	LAR	-0.073*
10.	STD 360	-0.130**
11.	SHT	0.134**
12.	INN	0.158**
13.	SSW	-0.055
14.	INL	-0.033
15.	SUC	-0.184**
16.	YLD	0.501**

*/** Significant at 5% and 1% level of probability respectively
NOS - Number of sprouts

diameter with yield was positive and significant in majority of the families. The NMC and stalk diameter were negatively associated whereas NMC and stalk height had a positive correlation only in five families. A balanced combination of these three characters seems to be essential while exercising selection for yield improvement in the population. The correlation coefficient between cane yield and sucrose percent was not significant in majority of the families. The results of the correlation between H.R brix and sucrose per cent indicated that H.R brix at 240 days can be considered as an early indicator of juice quality during selection for sucrose per cent in the seedling population and thus aiding in the selection of early maturing high quality clones.

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Received: June 25, 2009; Revised: October 28, 2009; Accepted: November 20, 2009