Bangladesh J. Sugarcane, **35** : 28-36 June, 2014

Genetic Variability, Correlation and Path Analysis of Some Yield Components of Sugarcane Genotypes

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ABSTRACT

Genetic variability, correlation coefficient, direct and indirect effects among cane yield and its component traits were estimated for 10 sugarcane genotypes grown under three environments in two consecutive years. The genotypes were developed from the crosses of North Carolina Design-I at Bangladesh Sugarcrop Research Institute. The mean squares for genotypes were highly significant for all the characters measured. Maximum phenotypic variation was recorded for cane stalk height (431.01) followed by leaf length (54.04). Phenotypic and genotypic coefficient of variation was highest for cane stalk height and germination percentage with value of 164.33 and 13.55, respectively. The error coefficient of variation was lower than phenotypic but higher than genotypic coefficient of variation for all the traits. The studied characters showed low heritability (h^2_b) ranged from 1.11 to 18.48 and most of them were positively correlated at genotypic level. The high direct effect of number of millable canes per clump, leaf breadth both at phenotypic and genotypic level and germination percentage at phenotypic, cane stalk girth at genotypic level suggested that these traits are good yield enhancing indices.

Key words: Correlation coefficient, direct and indirect effects, phenotype, sugarcane

INTRODUCTION

Yield in a crop is one of the most important and complex trait, improvement of yield remains the top priority in most breeding programme Cox *et al.* (1994). The sugarcane varieties trend to decrease its yield after a few years in a particular area. This necessitates a continuous flow of new varieties from the breeders to maintain productive genotypes in the field. For a successful sugarcane breeding programme it is important to know which traits give the highest estimates of heritability and which are the most repeatable over a number of seasons. Various traits are accounted for variations in cane and sugar yields. Many of these character components are quantitatively inherited and interrelated with each other. Stevenson (1965) pointed out that there may not be specific genes controlling the complex characters, but sum total effect of its component might be influencing the two most important characters, namely, cane yield and sucrose in sugarcane. Knowledge of interrelationship among the various characters is considered to

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be important in devising proper selection strategies in sugarcane breeding (De Sousa and Scott, 2005). In the context of yield enhancement, in order to have a good choice of character for selection of desirable genotypes under planned breeding programme. The association of component characters with yield and their exact contribution through direct and indirect effects are very important. Barber (1916) made the first systematic effort in correlating some of the morphological characters with juice quality in sugarcane. Correlation coefficient analysis has been extensively used by plant breeders to obtain precise information on interrelationship among plant traits to better assess outcome of selecting one or more trait (Furtado *et al.*, 2002). It is a handy technique which provides information that selection for one character results in progress for other positively correlated characters. Path coefficient analysis has been widely used in crop breeding to determine the nature of relationships between grain yield and its contributing components, and to identify those components with significant effect on yield for potential use as selection criteria (Samonte *et al.*, 1998). Keeping these views in mind the present study was aimed with the following objectives:

1. Determine the relationship between cane yield and related characters
2. Find out the direct and indirect effects of morphological traits on cane yield

MATERIALS AND METHODS

Fifteen sugarcane varieties/ genotypes including five males (Isd 40, Isd 35, I 101-66, Co 642 and I 17-01) and 10 females (Isd 31, Isd 29, Isd 25, I 4-71, I 157-94, I 216-92, I 34-95, I 324-86, Co 1148 and CPI 85-80) were mated as North Carolina Design I (NCD I) of Comstock and Robinson (1952). Following this NCD I each male mated with two different females and produces 10 progeny families. Each family consists of randomly selected five F_1. The mean values of selected F_1 of a family was considered as a genotype's value and calling them genotype1 (G_1) to genotype10 (G_{10}) for 10 families. These ten F_1 genotypes were subjected in this study as materials.

Experimental site and Design

The whole crossing work was done at Breeding Division of Bangladesh Sugarcrop Research Institute (BSRI), Ishurdi, Pabna, Bangladesh in the cropping year of 2006 -2007 following North Carolina Design I (NCD I) under a higher study programme. This crossing design produces 10 progeny families. Each family consists of randomly selected five F_1's. The mean values of selected F_1 of a family was considered as a genotypic value and calling them genotype 1 (G_1) to genotype 10 (G_{10}) for 10 families. The field trials of these genotypes (G_1 - G_{10}) were conducted under three different locations in two consecutive years 2008-2009 and 2009-2010 following RCB Design with three replications. The locations were 1. BSRI, Ishurdi, Pabna, 2. Horian, Rajshahi and 3. Regional Sugarcrop Research Station, Thakurgoan districts of Bangladesh. These locations are geographically situated at 24°, 24.37° and 26.03°N latitude, 89.25°, 88.6° and 88.47° E longitude and 30, 24.37 and 37 m above sea level, respectively. The plot size of the experiment was 4 m x 4 m having a 1 m row-to-row distance. Fertilizers were applied according to the fertilizers recommended guides of Bangladesh Agricultural Research Council (BARC), 2005.

Data collection and analysis

Data were collected following nine agronomical characters such as germination percentage (G%), number of tillers/clump (NT/C), number of millable canes/clump (NMC/C), cane stalk height (CSH), cane stalk girth (CSG), leaf length (LL), leaf breadth (LB), field brix percentage (Brix%) and cane yield per clump (CY/C). Data of G% and NT/C were collected 60 and 150 days after plantation, respectively and rest of the data were collected at the time of harvesting of cane. Data for all the variables measured were subjected to Analysis of Variance (ANOVA), to estimate the level of variability among the sugarcane genotypes following the biometrical techniques of analysis as developed by Mather (1949) based on the mathematical models of Fisher (1932). Genotypic correlation coefficients (r_g) and phenotypic correlation coefficients (r_p) were performed following Singh and Choudhury (1985). Path coefficients analysis was estimated according to the method suggested by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Genetic variability

The mean squares and estimated genetic parameters of the studied sugarcane genotypes over two growing seasons under three locations are presented in Table 1. It is clear that the mean squares for the genotypes were highly significant for all the characters measured. The phenotypic variance ($?^2_p$) was partitioned into genotypic variance ($?^2_g$) and environmental variance ($?^2_e$) components. Phenotypic variation was greater than those of genotypic variance for all the characters. The highest phenotypic variation was observed for CSH with a value of 431.01 and the lowest 0.04 by CSG. The magnitude of environmental variance ($?^2_e$) for all the yield contributing characters were however higher than the genotypic variance ($?^2_g$) Table 1. This result is in accordance with the report of Podder (1993), Devagiri *et al.* (1997) in sugarcane and Hossain (2004) in soyabean. The highest environmental variance ($?^2_e$) with value of 276.69 was found for CSH followed by LL and G%, while the lowest value of 0.02 for CSG. The highest PCV and GCV were recorded for CSH and G% with the value of 164.33 and 13.55, respectively. Whereas, lowest for CSG with the value of 1.77 and 0.13. This result is in conformity with Mian and Awal (1979) in sugarcane. The environmental coefficient of variation (ECV) was lower than PCV but higher than GCV for all the traits. The lowest genotypic value of the characters NMC/C, CSG, LB and CY/C indicating difficulties in improving these traits through selection as these are under polygenic control.

In this study all the characters showed greater phenotypic coefficient of variability than genotypic. Similar result is reported by Samad (1991), Hossain *et al.* (2000) and Khan (2009). The difference between PCV and GCV was greater in magnitude for G%, NT/C, NMC/C, CSH, Brix% and CY/C indicated that environment had considerable effect on these characters. These results are in conformity with the findings of Podder (1993) and Chubbey and Richharia (1993). The low variability recorded in the present study for LB and CSG indicating difficulties in improving of these traits through selection, it should be based on genetic differences. The low variability in cane length, cane thickness, brix percent and sucrose percent of sugarcane was reported by Singh *et al.* (2002); Venkatachalam *et al.*(2002); Lourdusamy and Selvan (2009) and Anbanandan and Saravanan (2010). Broad sense heritability (h^2_b) was low for all the characters assessed and ranged from 1.11 to 18.48 (Table 1). The low GCV and broad sense heritability coupled with low genetic gain were observed for all of the characters under study indicating predominance of non-additive gene under polygenic control and difficulty in selection. These results are in conformity with Mukopadhya *et al.* (1986) and Geeta and Prabhakaran (1987).

Table 1. Estimates of mean squares, variance components and heritability of ten sugarcane genotypes average over two cropping seasons at three different locations

Traits	Mean	MS	σ^2_p	σ^2_g	σ^2_e	PCV	GCV	ECV	h^2_b
G%	33.36	118.77**	24.45	4.52	10.99	73.29	13.55	32.97	18.48
NT/C	5.36	13.61**	0.83	0.009	0.50	15.57	0.17	9.33	1.11
NMC/C	3.61	4.86**	0.48	-0.01	0.29	13.49	-0.34	8.22	-2.54
CSH	262.27	5000.25*	431.01	24.10	276.69	164.33	9.19	105.49	5.59
CSG	2.61	0.56**	0.04	0.003	0.02	1.77	0.13	1.04	7.68
LL	124.29	407.39**	54.04	-8.56	28.28	43.47	-6.89	22.75	-15.85
LB	3.34	0.57**	2.58	-0.01	0.05	2.58	-0.01	1.64	-0.56
Brix%	18.49	17.74**	1.13	0.06	0.56	6.15	0.36	3.05	5.96
CY/C	2.70	4.76**	0.21	0.01	0.11	7.99	0.45	4.10	5.70

MS = mean squares, σ^2p = Phenotypic variance, σ^2g = Genotypic variance
σ^2e = Environmental variance
PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation
ECV = Environmental coefficient of variation and h^2b = Heritability in broad sense

Correlation

The association between any two characters is dependent upon their inheritance. If they are inherited together, the relationship between them may be observed. Genes governing two or more characters, that is, location of genes on the same chromosome pair is the cause for association between characters at phenotypic and genotypic levels. In the present research nine characters were studied and obtained 36 pairs of correlation coefficients combinations in each case of phenotypic and genotypic level. The phenotypic and genotypic correlation coefficients among the various characters are presented in Table 2. The results from the table revealed that cane yield per clump (CY/C) positively correlated with G% (0.89 and 0.10), NT/C (0.17 and 0.12), NMC/C (0.67 and 0.08), CSH (0.15 and 0.09) and CSG (0.06 and 0.34) both at phenotypic and genotypic level, respectively. It suggests that when G%, NMC/C and CSH is increased cane yield will be increased. Similar result was reported by Kundu and Gupta (1997) and Kadian *et al.* (2006). Conversely, CY/C was negatively correlated with LL at phenotypic level and LB and Brix% at both the levels. The results from the Table 2 revealed that most of the characters showed positively higher correlation at genotypic level than phenotype.

Highly significant correlation was observed between Brix% and LL and LB at phenotypic levels indicating Brix% will be increased with an increased leaf length (LL) and leaf breadth (LB). Long and wide leaf can absorb more sunlight which increases the photosynthetic rate of the plant to produce more energy that stored in stem as sucrose. This result is in agreement with Tyagi and singh (2000). Where they observed that increased sucrose % is related with an increased number of green leaves and top weight, however they found significant and positive association between pol% cane and sucrose% and top weight. Kumar and Kumar (2014) also reported similar result in sugarcane.

Table 2. Phenotypic and genotypic correlation coefficients between yield and yield contributing characters of randomly selected ten sugarcane genotypes

Traits	NT/C	NMC/C	CSH	CSG	LL	LB	Brix%	CY/C	
G%	0.25	-0.18	-0.14	0.34	-0.89**	0.22	-0.13	0.89**	r_p
	0.70	0.91**	0.59	0.36	0.39	0.69	1.58*	0.10	r_g
NT/C		0.24	0.33	-0.12	-0.66*	-0.93**	0.11	0.17	r_p
		1.60**	0.06	1.03**	0.50	0.94**	1.26**	0.12	r_g
NMC/C			0.22	0.10	0.55	-0.14	-0.29	0.67*	r_p
			0.18	-0.86*	1.17	-1.03	-0.67*	0.08*	r_g
CSH				-0.27	0.41	0.46	-0.02	0.15	r_p
				0.88*	-1.19	-0.66*	1.26*	0.09**	r_g
CSG					-1.69*	-0.41	0.15	0.06	r_p
					0.06	0.88**	0.70**	0.34	r_g
LL						0.86	1.12**	-0.09	r_p
						1.01**	-1.15	0.68**	r_g
LB							0.46**	-0.04*	r_p
							-0.90	-0.63	r_g
Brix%								-0.21**	r_p
								-1.05	r_g

Here, r>1.0, may be due to subtraction effects arising from sampling error
* and ** indicates significant at 5% and 1% level, respectively

Path analysis

Path coefficient analysis among all characters related to CY/C derived from F_1 crosses was estimated separately at phenotypic and genotypic levels. The direct, indirect and total effects of eight characters on average CY/C over two seasons are presented in Table 3.

Germination percentage (G%)

The direct effect at phenotypic level of this character was positive (0.63) and exhibited highly significant positive association with CY/C. In this level the contribution of other characters indirectly on cane yield through G% appeared to be positive value in respect of NT (0.09), CSH (0.04), CSG (0.02), LL (0.11) and LB (0.13). The contribution had negative indirect effects via NMC (-0.16) and Brix% (-0.008). In case of genotypic level the direct effect of G% (0.17) and other characters those are indirectly involved on yield character via G% except NT/C (-0.80) and Brix% (-2.55) were positive. In this level the total effects of G% was positive (0.89 and 0.10) at phenotypic and genotypic levels, respectively. The total effect of G% at phenotypic level was higher than others but at genotypic level it was lower than LL and CSG.

Number of tillers per clump (NT/C)

The NT/C expressed a considerably positive direct effect on cane yield (0.37) at phenotypic level but it was negative (-1.12) at genotypic level. This character had positive correlation with CY/C at phenotypic and genotypic levels. The indirect effect of NT/C was positive through NMC/C (0.22) and LL (0.08) and negative via CSH (-0.10), CSG

(-0.007), LB (-0.55) and Brix% (-0.007) at phenotypic level. The association recorded positive indirect effects via NMC/C (1.56), CSH (0.16), CSG (0.42), LL (0.17), LB (0.80) and negative via Brix% (-2.04) at genotypic level.

Number of millable canes per clump (NMC/C)

This character appeared to influence sugarcane yield directly as positive value of 0.89 and 0.97 at phenotypic and genotypic level, respectively. NMC/C character recorded significant positive correlation with CY/C at both the levels. The contribution of other characters indirectly on cane yield through NMC/C to be positive value in respect of CSH (0.22 and 0.18) and LL (0.55 and 1.17) and negative via LB (-0.14 and -1.03) and Brix% (-0.29 and -0.67) at phenotypic and genotypic level, respectively. Therefore this trait appears to be most important in influencing cane yield and selection should be oriented towards higher number of millable cane.

Cane Stalk Height (CSH)

The direct influence of cane stalk height towards cane yield (CY/C) was positive (2.55) at genotypic level but at phenotypic level it was negative (-0.29). The CSH recorded positive correlation with CY/C at both the levels; in case of genotypic level it was highly significant. The contribution of other characters indirectly on CY/C through this character showed positive value in respect of NT (0.12), NMC/C (0.20), LB (0.27) and Brix% (0.001) at phenotypic level and G% (0.10), NMC/C (0.18) and CSG (0.36) at genotypic. The contribution showed negative indirect effects via G% (-0.09) and LL (-0.05) at phenotypic level and NT (-0.07), LL (-0.41), LB (-0.57) and Brix% (-2.04) at genotypic level.

Cane Stalk Girth (CSG)

It was observed that this character appeared to influence cane yield (CY/C) directly as positive value 0.06 and 0.41 at phenotypic and genotypic level, respectively. CSG recorded non significant positive correlation with CY/C at both the levels. The contribution of other characters indirectly on CY/C through CSG as positive in respect of G% (0.21), NMC/C (0.08) and CSH (0.08) at phenotypic and G% (0.06), CSH (2.26), CSG(0.41), LL (0.02) and LB (0.75) at genotypic level. The association exhibited negative indirect effects via NT (-0.04), LL (-0.08), LB (-0.24) and Brix % (-0.01) at phenotypic and NT (-1.16), NMC/C (-0.84) and Brix% (-1.15) at genotypic level.

Leaf length (LL)

The direct effect of LL on cane yield (CY/C) was positive (0.34) at genotypic level and negative (-0.12) at phenotypic level. LL character recorded highly significant positive correlation with cane yield at genotypic level but it was negatively non-significant at phenotypic level. The indirect contribution to CY/C through LL was positive in respect of CSG (0.04) and LB (0.51) at phenotypic level, in case of genotypic levels G% (0.07), NMC/C (1.15), CSG (0.02), LB (0.86) and Brix% (1.85) were positive. The association exhibited negative indirect effects via G% (-0.56), NT/C (-0.25), (NMC/C (-0.59), CSH (-0.12), LL (-0.12) and Brix % (-0.07) at phenotypic level, while CSH (-3.06) at genotypic level.

Leaf breadth (LB)

The direct contribution of leaf breadth (LB) on cane yield (CY/C) was positive 0.59 and 0.85 at phenotypic and genotypic level, respectively, although LB showed negative association with cane yield. The contribution of other characters indirectly on LB appeared to be positive value in respect of G% (0.14) at phenotypic, and G%, CSG, LL and Brix% at genotypic level. The association exhibited negative indirect effects via NT/C, NMC/C, and CSH at both the levels, otherwise, CSG, LL and Brix% at phenotypic level.

Table 3. Path-coefficient analysis showing direct and indirect effects of yield components on yield of sugarcane genotypes at phenotypic and genotypic levels

Characters	G%	NT/C	NMC/C	CSH	CSG	LL	LB	Brix%	Total effect	
G%	**0.63**	0.09	-0.16	0.04	0.02	0.11	0.13	-0.008	0.89	P
	0.17	-0.80	0.89	1.51	0.14	0.13	0.59	-2.55	0.10	G
NT/C	0.16	**0.37**	0.22	-0.10	-0.007	0.08	-0.55	-0.007	0.17	P
	0.12	**-1.12**	1.56	0.16	0.42	0.17	0.80	-2.04	0.10	G
NMC/C	-0.11	0.09	**0.89**	-0.06	0.006	-0.07	-0.08	0.01	0.67	P
	0.16	-1.80	**0.97**	0.48	-0.35	0.41	-0.88	1.09	0.08	G
CSH	-0.09	0.12	0.20	**-0.29**	-0.01	-0.05	0.27	0.001	0.15	P
	0.10	-0.07	0.18	**2.55**	0.36	-0.41	-0.57	-2.04	0.09	G
CSG	0.21	-0.04	0.08	0.08	**0.06**	-0.08	-0.24	-0.01	0.06	P
	0.06	-1.16	-0.84	2.26	**0.41**	0.02	0.75	-1.15	0.34	G
LL	-0.56	-0.25	-0.59	-0.12	0.04	**-0.12**	0.51	-0.07	-1.18	P
	0.07	-0.56	1.15	-3.06	0.02	**0.34**	0.86	1.85	0.68	G
LB	0.14	-0.35	-0.12	-0.13	-0.02	-0.24	**0.59**	-0.03	-0.17	P
	0.12	-1.06	-1.01	-1.70	0.36	0.86	**0.85**	1.45	-0.12	G
Brix%	-0.08	0.04	-0.26	0.006	0.009	-0.14	0.27	**-0.06**	-0.21	P
	0.28	-1.42	-0.66	3.24	0.29	-0.40	-0.76	**-1.61**	-1.05	G

Phenotypic Residual effect= 0.44 and Genotypic Residual effect= 0.87

Field brix percentage (Brix%)

It was observed that this character has no direct effect on cane yield as it shows negative value (-0.06 and -1.61) both at phenotypic and genotypic levels. At phenotypic level Brix% recorded significant negative correlation with cane yield, whereas, it was negatively non significant at genotypic level. The contribution of other characters indirectly on cane yield through Brix% showed positive value in respect of NT/C (0.04), CSH (0.006), CSG (0.009) and LB (0.27) at phenotypic level and G% (0.28), CSH (3.24) and CSG (0.29) at genotypic level. The association exhibited negative indirect effects via G% (-0.08), NMC/C (-0.26) and LL (-0.14) at phenotypic and NT/C (-1.42), NMC/C (-0.66), LL (0.40) and LB (-0.76) at genotypic level.

In the present study, the path coefficient analysis was performed for cane yield as a dependent variable. The high direct effect of NMC/C, LB both at phenotypic and genotypic level and G% at phenotypic, CSG at genotypic level suggested that these traits are good yield enhancing indices. However, the indirect effect of LB on cane yield was negative at both phenotypic and genotypic levels. According to Izge *et al.* (2006) higher indirect values could most likely be neutralized in most cases by negative indirect effects via other characters and this can lead to their low and non-significant genotypic correlations with total yield. Leaf length (LL) was found negative direct effect on cane yield at phenotypic level. This negative direct effect was counter balanced through characters like G%, NT/C, NMC/C, CSH, CSG and Brix% was found negative direct effect on cane yield both at phenotypic and genotypic levels. The positive indirect effect of brix was found through NT/C, CSH, CSG and LB at phenotypic level and G%, CSH and CSG at genotypic level.

Thus, on the basis of correlation and path coefficient analysis it can be concluded that number of millable canes and cane stalk height are most important characters for cane yield. Correlation and path analysis revealed that while selecting the clones from F_1 and subsequent clonal generation, the characters viz., germination percentage, number of millable canes, cane height, leaf length and brix% must be taken into consideration for ameliorating overall sucrose and cane yield.

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