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TRAIT RELATIONSHIPS IN SUGARCANE AT FINAL SELECTION STAGES
BY

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ABSTRACT

This study was conducted at Kom-Ombo Agricultural Research Station, Aswan Governorate to determine phenotypic and genotypic correlation coefficients among various traits in sugarcane (*Saccharum spp.*) and to analyze their interrelationships through path coefficient analysis. Other objectives were to determine broad-sense heritability and genetic advanced under selection for the traits studied (Stalk length, stalk diameter, stalk density, stalk weight, stalk number, cane yield, Brix, sucrose%, purity%, sugar recovery, and sugar yield). A total of 15 sugarcane genotypes that were selected during the final clonal selection stages and two check cultivars (PH 8013 and GT 54-9) were laid in a randomized complete block design during 2005/5006 (plant cane) and 2006 /2007 (first ratoon).

Results indicated that cane yield had a positive and significant correlation coefficients with stalk density, stalk weight and stalk number, however its correlation with stalk length and stalk diameter was positive but non significant in both plant cane and ratoon crop. Stalk weight had a positive correlation with stalk length, stalk diameter and stalk density. Stalk density had a negative and significant correlation with stalk length and stalk diameter in both crops. Brix and purity had a positive correlation with sugar recovery and with each other, however correlation between Brix and juice purity was increased in older crop from 0.196 to 0.785** at the phenotypic level and from 0.192 to 0.842** at the genotypic level. Correlation between cane yield and sugar recovery diminished in ratoon crop from 0.375** to -0.199 at the phenotypic level, and from 0.492 to -0.253 at the genotypic level. Sugar yield had a positive and significant correlation with cane yield and sugar recovery in both crops.

Path coefficient analysis indicated that stalk density was the primary direct determinant of stalk weight followed by stalk diameter and stalk length at the phenotypic and genotypic levels in both plant cane and ratoon crop. The direct effect of purity on sugar recovery was diminished in ratoon crop from 0.699 to 0.404 at the phenotypic level and from 0.793 to 0.390 at the genotypic level. The phenotypic and genotypic direct effects of Brix on sugar recovery were positive and about equal in magnitude in both plant cane and ratoon crop. Stalk weight had a large positive direct effect on cane yield followed by stalk number at the phenotypic and genotypic level in both crops. Cane yield was the primary direct determinant of sugar yield, while sugar recovery was secondary in determining sugar yield at the phenotypic and genotypic levels in both plant cane and ratoon crop.

Heritability estimates in each of plant cane and ratoon crop were relatively high for all studied traits. Maximum genetic advance (as percent of mean) in plant cane was observed For sugar yield (50.80 and 43.40) followed by stalk density (46.19 and 39.46), cane yield (43.81 and 37.43) and stalk weight (38.19 and 32.63) under 5 % and 10 % selection intensity, respectively . However in ratoon crop the highest values of genetic advance was observed for sugar yield (42.32 and 36.34), cane yield (38.82 and 33.33) and stalk weight (36.25 and 31.12) under 5 % and 10% selection intensity, respectively.

Stalk diameter and purity % had high heritability with low genetic advance in both crops under 5% and 10% selection intensities.

Additional index words: Phenotypic correlation, Genotypic correlation, Path coefficient, Genetic advance, *Saccharum spp.*

INTRODUCTION

Optimizing yield is the most important goal for most sugarcane breeders. Yield of sugarcane is a complex character that can be determined from several components reflecting positive or negative effects upon this trait. It is important to examine the relative contribution of each of these various components in order to give more attention to those having the greatest effect on yield. Therefore, information on heritability and the association of plant characters with cane and sugar yields is of great importance to the breeder in selecting a desirable genotype. Breeding decisions based only on correlation coefficients may not always be effective since they provide only one- dimensional information while neglecting important and complex interrelationship among plant traits (Kang, 1994). Path coefficient analysis is an excellent means that can be used by plant breeder to assist in identifying traits that are useful as selection criteria to improve crop yield (Kang *et al.*, 1989 and Milligan *et al.*, 1990a). Path coefficient analysis measures the direct influence of one variable on another. Each correlation coefficient between a predictor variable and the response variable is partitioned into the direct effect or path coefficient for the predictor variable and indirect effects, which involves the product of a correlation coefficient between two predictor variables with the appropriate path coefficient in the path diagram (Dewey and Lu, 1959).

Effect of different selected traits on cane and sugar yields have been reported by many investigators. Kang *et al.* (1983b) found that plant height was less important than stalk diameter and stalk number as a component of cane yield at the phenotypic level, while at the genotypic level all three components were of equal importance. Sucrose % had a large direct effect on sugar recovery both at the phenotypic and genotypic level, while Brix showed a large positive indirect effect via sucrose. Cane yield and sugar recovery had about equal direct positive effect on sugar yield at the phenotypic level. Sugar recovery exerted a greater direct effect on sugar yield than did cane yield. Reddy and Reddy (1986) reported that in the first clonal generation, stalk number and stalk weight are considered to be the major component of equal importance influencing cane yield at the phenotypic and genotypic levels. Commercial cane sugar was largely dependent on cane yield rather than percentage sucrose. Kang *et al.* (1989) reported that cane yield would be increased by placing the greatest emphasis on stalk number, and next on stalk weight. Cane yield was the most important component of sugar yield followed by sugar concentration either in plant cane or ratoon crop. Milligan *et al.*, (1990a) found that stalk number was the primary determinant of cane yield and became more important in older crop. Stalk diameter was more important than stalk length in affecting stalk weight regardless of crop age. Brix and juice purity were highly correlated with sucrose content and with each other and were not affected by crop age. Cane yield was the most important determinant of sugar yield and became more important in older ratoon crops.

El- Hinnawy *et al.* (2001) found at the commercial level that the direct effect of stalk weight was more important determining of cane yield than stalk number in plant cane and/or ratoon crop. Stalk length was more important than stalk diameter in determining stalk weight and increased in influence in ratoon crop. The direct effect of sucrose on sugar recovery was high in plant cane or ratoon crop. Cane yield was the primary determinant of sugar yield in plant cane and / or ratoon crop. Masri (2004) reported that stalk number and stalk diameter are equally important and had considerable phenotypic and genotypic direct effects on cane yield than stalk length. Purity had higher direct effect on sugar recovery than Brix at phenotypic and genotypic levels. Cane yield and sugar recovery were of about equal importance in determining sugar yield at the phenotypic levels, whereas at the genetic level the direct effect of cane yield was slightly higher than sugar recovery. Mohamed (2007) found that sucrose had a large positive direct effect on sugar recovery, while Brix had a small negative direct effect on sugar recovery. The direct effect of cane yield on sugar yield was slightly higher than that of sugar recovery at the phenotypic level, while at the genotypic level the direct effect of sugar recovery on sugar yield was higher than that of cane yield. Singh and Singh (1999) evaluated 16 early maturing sugarcane genotypes. Results showed that heritability and genetic advance values were high for stalk weight, number of millable canes and cane yield in both plant and ratoon crops, whereas stalk length was high only in the ratoon crop. Masri (2004) found that broad-sense heritability estimates were high for stalk length, stalk diameter, stalk number, stalk weight, cane yield, sucrose %, purity %, sugar recovery% and sugar yield, in both plant and ratoon crops. High genetic advance accompanied by high heritability was observed for stalk weight, cane yield, sucrose%, purity%, sugar recovery and sugar yield, while low genetic advance with high heritability was observed for Brix in both plant and ratoon crops.

Chaudhary (2001) recorded high heritability estimates for millable cane number, stalk diameter and single cane weight. Maximum genetic gain as percent of mean was observed for single cane weight and millable cane number.

The main objectives of this study were to: (i) estimate phenotypic and genetic correlations and explore the nature of these correlations through path coefficient analysis, and (ii) determine broad sense heritability and genetic advance estimates for various important traits in sugarcane.

MATERIALS AND METHODS

A total of 15 sugarcane genotypes that were selected during the final stage of selection program and two check cultivars; PH 8013 and G T 54/9 were grown in 7m x 5 row plots with 1.0 m spacing between rows, thus plot size was $35m^2$ (1/120 fed.). The experimental design was a randomized compete block with three replications. Planting was done during March 2005 season at Kom-Ombo Agricultural Research Station, Aswan Governorate. Planting was achieved by placing fifteen 3-budded cane pieces in each row. Field was irrigated right after planting and all other agronomic practices were carried out as recommended. Plant cane was allowed to ratoon after harvest, which took place after 12 months from planting. Harvest of ratoon crop took place 12 month after cutting plant cane crop.

At harvest, the following traits were measured:

A- Cane yield and its contributing traits:

Sample of twenty stalks from each plot was removed to measure stalk length, stalk diameter, and stalk density.

1- Stalk length (cm) was measured from soil surface to the visible dewlap.
2- Stalk diameter (cm) was measured at midstalk with no reference to the bud groove.
3- Stalk density (gm cm^{-3}) was calculated as stalk weight per volume according to Milligan *et al.* (1990b), where volume = length . π . $radius^2$
4- Number of millable stalks/fed. was calculated on a plot basis
5- Stalk weight (kg) was calculated by dividing cane yield per plot by number of stalks per plot
6- Cane yield (ton/fed.) was calculated on a plot basis

B-Juice quality traits and sugar yield (ton/fed.):

Juice of twenty stalk sample from each plot was analyzed for determining the following traits:

1- Brix (percent soluble solids) determined with a hydrometer. 2-Sucrose percentage of clarified juice was determined by using automated sacharimeter according to A.O.A.C. (1980).
3- Purity [(Sucrose / Brix) x 100].
4- Sugar recovery% (rendment) was calculated according to the formula described by Yadav and Sharma, (1980) [Sucrose % - 0.4 (Brix – Sucrose %)] x 0.73
5- Sugar yield (ton/fed.) was estimated by multiplying net cane yield (ton / fed) by sugar recovery %.

Data were subjected to variance and covariance analysis assuming all genetic components as random. Broad-sense heritability, genetic advance, genetic and phenoltypic correlations were calculated for each crop from the variance and covariance components (Falconer, 1981). Direct and indirect path coefficients were calculated as initially proposed by Wright (1934) and latter described by Dewey and Lu (1959) and by Li (1975). The use of path analysis requires on additive cause and effect relation among the variables involved (Sidwell *et al.*, 1976).

RESULTS AND DISCUSSION

Phenotypic and genetic correlation coefficients (r_p and r_g respectively) among various traits were calculated in plant cane and ratoon crop in order to explore trait relationships, and investigate the effect of crop age on these relationships. Both of phenotypic and genetic correlation coefficient between the different pair of agronomic traits are shown in Table 1. In most cases, the sign of the phenoltypic correlation coefficient matched that of genetic correlation-coefficient. In those cases where the magnitude of the phenotypic and genetic correlation coefficients was nearly the same, the environmental variance and covariance had been reduced to zero or to a negligible level, i.e., the influence of environment on these relationships was minimal (knag *et al.*,1983 a). Correlations between certain stalk related traits (stalk length, stalk diameter, stalk density, stalk weight and stalk number), and cane yield were nearly the same in both plant cane and ratoon crop at the phenotypic and genetic levels except for correlation between stalk density and cane yield, which increased in older crop at the phenotypic level from r_p = 0.284* to r_p = 0.470** and at the genetic level from r_g = 0.369 to r_g = 0.638. All correlation coefficients between stalk related traits and cane yield were positive and significant except for stalk length and stalk diameter which were positive but non significant. Correlation between stalk length and stalk weight decreased in older crop at the phenotypic level from r_p = 0.300* to r_p = 0.143 and at the genetic level from r_g = 0.322 to r_g = 0.207, while correlation between stalk diameter and stalk weight increased in ratoon crop at both phenotypic (from r_p = 0.238 to r_p = 0.347*) and genetic levels (from r_g = 0.354 to r_g = 0.596). Positive and significant correlation was found between stalk density and stalk weight in each crop. However the value of correlation was increased in older crop at the phenotypic level (from r_p = 0.376** to r_p = 0.549**) and at the genetic level (from r_g = 0.409 to r_g = 0.675).

Correlation between stalk number and cane yield and stalk weight and cane yield agreed with the data of Milligan *et al.*, (1990a), EL-Hinnawy *et al.* (2001) and Mohamed (2007). Correlations between stalk diameter and stalk weight and stalk density and stalk weight were similar to those reported by Milligan *et al.* (1990a). Both phenotypic and genetic correlation indicated that emphasis should be placed on selection for stalk weight vs. stalk number to improve cane yield and selection for stalk density over stalk diameter and stalk length to improve stalk weight.

Phenotypic and genetic correlation coefficients between the different pair of biochemical traits are presented in Table 2. In all cases, the sign of phenotypic correlation coefficients matched that of genetic correlation coefficients as well as the magnitude of the phenotypic and genetic correlation coefficients was nearly the same. Positive and significant correlation was found between all biochemical traits studied (Brix, sucrose, juice purity and sugar recovery), and sugar yield. The values of correlation between sugar yield and each of sucrose, purity and sugar recovery were decreased in older crop at both phenotypic and genetic levels, while the correlation between Brix and sugar yield was nearly the same at both phenotypic (0.398** and 0.458** in plant cane and ratoon crop respectively) and genetic level (0.403 and 0.429 in plant cane and ratoon crop, respectively). Positive and significant correlation was observed between sugar recovery and each of Brix, sucrose and juice purity in both plant cane and ratoon crop.

Correlation between cane yield and sugar recovery and cane yield and sugar yield are shown in Table 3. The correlation between cane yield and sugar recovery decreased from r_p = 0.375** to r_p = -0.199 and from r_g = 0.492 to r_g = -0.253 in ratoon crop than in plant cane. Phenotypic and genetic correlation coefficients between cane yield and sugar yield were nearly the same in plant cane (r_p = 0.957**, r_g = 0.978) and ratoon crop (r_p = 0.780**, r_g = 0.775).

Table (1): Phenotypic and genetic correlation coefficients⁺ among different agronomic traits.

Traits	Crop	Stalk				Cane yield
		diameter	density	weight	number	
Stalk length	PC	0.204	-0.531**	0.300*	-0.251	0.181
		0.267	-0.623	0.322	-0.260	0.190
	FR	0.165	-0.315*	0.143	0.043	0.155
		-0.047	-0.113	0.207	0.039	0.199
Stalk diameter	PC		-0.594**	0.238	-0.110	0.150
			-0.395	0.354	-0.233	0.144
	FR		-0.527**	0.347*	-0.245	0.121
			-0.091	0.596	-0.428	0.184
Stalk density	PC			0.376**	-0.010	0.284*
				0.409	0.074	0.369
	FR			0.549**	-0.120	0.470**
				0.675	-0.061	0.638
Stalk weight	PC				-0.285*	0.726**
					-0.244	0.737
	FR				-0.358**	0.691**
					-0.323	0.690
Stalk number	PC					0.438**
						0.465
	FR					0.417**
						0.455

PC= plant cane, n = 51; FR= first ratoon, n = 51

*,** Significant at the 0.05 and 0.01 levels, respectively.

\+ Upper and lower values represent phenotypic and genetic correlation coefficients in each crop, respectively.

Several researchers reported phenoltypic and genetic correlations among sugar cane traits. However, Milligan (1988) showed that the genetic variance and covariance of traits changed with selection. Thus accurate variance-covariance estimates should be selection- stage specific. Therefore, our results of trait relationships may be similar or different, higher or lower than reported from other studies. Kang *et al.* (1983 a), Milligan *et al.* (1990a), Masri (2004), Chaudhary and Joshi (2005) and Mohamed (2007) concluded differences of correlation among studies because of differences in the degree of prior selection in the population, and differences in the environmental conditions among the studies.

Table (2): Phenotypic and genetic correlation coefficients+ among sugar yield and different juice quality traits.

Traits	Crop	Sucrose	Juice purity	Sugar recovery	Sugar yield
Brix	PC	0.832**	0.196	0.728**	0.398**
		0.746	0.192	0.628	0.403
	FR	0.982**	0.785**	0.967**	0.458**
		0.987	0.842	0.977	0.429
Sucrose	PC		0.706**	0.986**	0.600**
			0.796	0.987	0.648
	FR		0.887**	0.998**	0.455**
			0.916	0.999	0.429
Juice purity	PC			0.815**	0.560**
				0.884	0.598
	FR			0.914**	0.344*
				0.936	0.336
Sugar recovery	PC				0.622**
					0.660
	FR				0.451**
					0.426

Table (3): Phenotypic and genetic correlation coefficients+ of sugar yield with sugar recovery and cane yield.

Traits	Crop	Cane yield	Sugar yield
Sugar recovery	PC	0.375**	0.622**
		0.492	0.660
	FR	-0.199	0.451**
		-0.253	0.426
Cane yield	PC		0.957**
			0.978
	FR		0.780**
			0.775

PC= plant cane, n = 51; FR= first ratoon, n = 51

*,** Significant at the 0.05 and 0.01 levels, respectively

+ Upper and lower values represent phenotypic and genetic correlation coefficients in each crop, respectively.

Path coefficient analysis were carried out in accordance with the causal relationships shown in path diagram (Fig. 1) dividing inter-phenotypic and genotypic correlation coefficient into direct and indirect causal effects. Indirect effects are due to correlation between the cause of interest and other effects affecting the dependent trait. Coefficients are interpreted on a relative scale and have little intrinsic meaning.

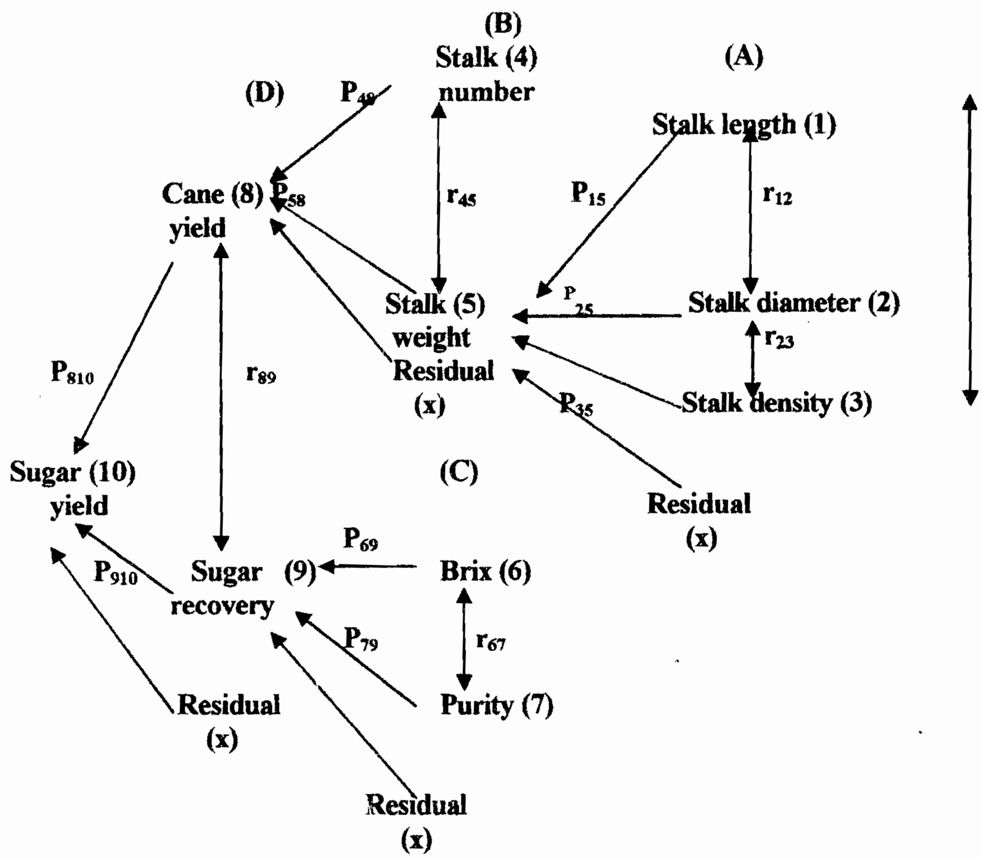

Fig. (1): Path diagram, showing interrelationships of: (A) stalk length, stalk diameter and stalk density with stalk weight, (B) stalk number and stalk weight with cane yield, (C) Brix and purity with sugar recovery, and (D) cane yield and sugar recovery with sugar yield. (P and r, indicate direct path coefficient and correlation coefficient, respectively).

The most important direct determinant of stalk weight was stalk density followed by stalk diameter and stalk length at phenotypic and genotypic levels in both crops (table 4). The direct effect of stalk length was diminished in older crop at the phenotypic level from 0.829 to 0.352 and at the genotypic level from 0.923 to 0.326. Crop age effect was negligible on the direct effect of stalk diameter at both phenotypic level (from 0.856 to 0.881) and genotypic level (from 0.588 to 0.682). The phenotypic direct effects of stalk density were nearly similar in both crops (1.324 and 1.124 in plant cane and ratoon crop, respectively), while the genotypic direct effect was affected by crop age, since it decreased from 1.216 in plant cane to 0.774 in ratoon crop. In plant cane the large positive phenotypic and genotypic direct effects of stalk density on stalk weight was counter balanced by a negative phenotypic and genotypic indirect effects of stalk length via stalk density and stalk diameter via stalk density,while in ratoon crop the same findings was observed only at the phenotypic level. The negative indirect effect of stalk density via stalk length or stalk diameter and that of stalk diameter or stalk length via stalk density indicated need for a suitable compromise level for simultaneous selection for stalk length or stalk diameter and stalk density.

Path coefficient analysis for cane yield (Table 5) indicated that stalk weight was the primary direct determinant of cane yield followed by stalk number at both phenotypic and genotypic levels in plant cane and ratoon crop. In plant cane the direct effect of stalk weight was 0.926 and 0.904 at the phenotypic and genotypic levels, respectively. The corresponding values in ratoon crop were 0.964 and 0.934, however, the same trend was observed with respect to the direct effect of stalk number on cane yield. The phenotypic and genotypic direct effects of stalk weight and stalk number on cane yield in both crops were about equal in magnitude, indicating that the direct effect in question was little affected by nonadditve genetic or environmental effects. Accordingly, the direct effects of stalk weight and stalk number on cane yield were mainly of additive genetic nature in accordance with one provided by Sidwell *et al.* (1976).The direct effects of stalk weight and stalk number on cane yield were similar to the findings of El-Hinnawy *et al.* (2001) and Chaudhary and Joshi (2005). Indirect effects for both components were similar to each other, secondary in magnitude to direct effects and initially negative. The negative indirect effects suggest that stalk weight will decline when selecting for stalk number to improve cane yield.

Table (4): Phenotypic and genotypic path coefficient (P) analysis of stalk weight and its components.

Pathway	Plant cane		First ratoon	
	Phenotypic	Genotypic	Phenotypic	Genotypic
Stalk weight vs. stalk length				
Direct effect, $P_{1,5}$	0.829	0.923	0.352	0.326
Indirect effect via				
stalk diameter, $r_{1,2} P_{2,5}$	0.174	0.157	0.145	-0.032
stalk density, $r_{1,3} P_{3,5}$	-0.703	-0.758	-0.354	-0.087
Correlation $r_{1,5}$	0.300	0.322	0.143	0.207
Stalk weight vs. stalk diameter				
Direct effect, $P_{2,5}$	0.856	0.588	0.881	0.682
Indirect effect via				
stalk length, $r_{1,2} P_{1,5}$	0.169	0.246	0.058	-0.015
stalk density, $r_{2,3} P_{3,5}$	-0.787	-0.480	-0.592	-0.071
Correlation $r_{2,5}$	0.238	0.354	0.347	0.596
Stalk weight vs. stalk density				
Direct effect, $P_{3,5}$	1.324	1.216	1.124	0.774
Indirect effect via				
stalk length, $r_{1,3} P_{1,5}$	-0.440	-0.575	-0.111	-0.037
stalk diameter, $r_{2,3} P_{2,5}$	-0.508	-0.232	-0.464	-0.062
Correlation $r_{3,5}$	0.376	0.409	0.549	0.675
Residual (Px_5)	0.224	0.00	0.163	0.061
$1 - P^2 x_5$	0.950	1.00	0.973	0.996

Path coefficient analysis for sugar recovery (Table 6) reveled that the direct effect of purity on sugar recovery in plant cane was positive and slightly greater than that of Brix on sugar recovery at both phenotypic (0.699) and genotypic (0.793) levels. While in ratoon crop Brix was the primary direct determinate of sugar recovery at both phenol-typic (0.651) and genotypic (0.649) levels. However the direct effect of purity on sugar recovery diminished in older crop from 0.699 to 0.404 at the phenotypic level and from 0.793 to 0.390 at the genotypic level . Indirect effect of Brix via purity was positive and increased in older crop from 0.137 to 0.316 at the phenotypic level and from 0.152 to 0.328 at the genotypic level. The same trend was observed for the indirect effect of purity via Brix since it increased in older crop from 0.116 to 0.510 at the phenotypic level and from 0.091 to 0.546 at the genotypic level. Indirect effects of purity via Brix in ratoon crop were nearly as important as direct effects in affecting sugar recovery. The strong positive correlation between Brix and Purity especially in ratoon crop (Table 2) suggested that either could be used to predict sugar recovery accordingly to Milligan *et al.* (1990a). In both the phenotypic and genotypic models all of the variation in sugar recovery was explained. The almost equal magnitude of direct effects of Brix and purity (%) on recoverable sucrose at both the phenotypic and genotypic levels indicated that these effects were under genetic control with little or no environmental effects. From a practical standpoint, increasing the level of purity (sucrose %) and Brix would naturally be expected to increase sugar recovery.

Table (5): Phenotypic and genotypic path coefficient (P) analysis of cane yield and its components.

Pathway	Plant cane		First ratoon	
	Phenotypic	Genotypic	Phenotypic	Genotypic
Cane yield vs. stalk number				
Direct effect, $P_{4,8}$	0.702	0.686	0.762	0.757
Indirect effect via				
stalk weight, $r_{4,5}$ $P_{5,8}$	-0.264	-0.221	-0.345	-0.302
Correlation $r_{4,8}$	0.438	0.465	0.417	0.455
Cane yield vs. stalk weight				
Direct effect, $P_{5,8}$	0.926	0.904	0.964	0.934
Indirect effect via				
stalk number, $r_{4,5}$ $P_{4,8}$	-0.200	-0.167	-0.273	-0.244
Correlation $r_{5,8}$	0.726	0.737	0.691	0.690
Residual (Px_8)	0.142	0.121	0.127	0.104
1 - P^2 x_8	0.980	0.985	0.984	0.989

Table (6): Phenotypic and genotypic path coefficient (P) analysis of sugar recovery and its components.

Pathway	Plant cane		First ratoon	
	Phenotypic	Genotypic	Phenotypic	Genotypic
Sugar recovery vs. Brix				
Direct effect, $P_{6,9}$	0.591	0.476	0.651	0.649
Indirect effect via				
purity, $r_{6,7}$ $P_{7,9}$	0.137	0.152	0.316	0.328
Correlation $r_{6,9}$	0.728	0.628	0.967	0.977
Sugar recovery vs. purity				
Direct effect, $P_{7,9}$	0.699	0.793	0.404	0.390
Indirect effect via				
Brix, $r_{6,7}$ $P_{6,9}$	0.116	0.091	0.510	0.546
Correlation $r_{7,9}$	0.815	0.884	0.914	0.936
Residual (Px_9)	0.00	0.00	0.032	0.032
1 - P^2 x_9	1.00	1.00	0.999	0.999

Path coefficient analysis for sugar yield (Table 7) revealed that cane yield was the primary direct determinant of sugar yield at both phenotypic and genotypic levels in plant cane and ratoon crop, while sugar recovery was secondary in determining sugar yield. In plant cane the direct effect of cane yield was 0.842 and 0.862 at the phenotypic and genotypic levels, respectively. The corresponding values in ratoon crop were 0.906 and

0.943. However the direct effect of sugar recovery on sugar yield increased in older crop from 0.306 to 0.631 at the phenotypic level and from 0.236 to 0.664 at the genotypic level. In plant cane indirect effects via sugar recovery were positive and small, while indirect effects via cane yield were positive and higher than the direct effect of sugar recovery at the genotypic level, indicated that both of cane yield and sugar recovery could be improved simultaneously by selection. In ratoon crop indirect effects among these relationships were negative and usually unimportant.

A limitation in this study is that sugar yield was obtained as a product of cane yield and sugar recovery. This method of calculating sugar yield may cause an artificial correlation between cane yield and sugar yield and between sugar recovery and sugar yield. Kang *et al.* (1983 a) concluded that an artificial correlation tended to inflate the relative importance of cane yield and sugar recovery may not be far from reality because cane yield and sugar recovery were determined independently. The results obtained are in agreement with Milligan *et al.* (1990a), El-Hinnawy *et al.* (2004). However, Kang *et al.* (1983 b), Masri (2004) and Mohamed (2007) reported that cane yield and sugar recovery were of the same importance in determining sugar yield. Kang *et al.* (1989) stated that "it would appear that for sugar yield" path coefficient obtained for one population may not be applicable to a different population

Table (7): Phenotypic and genotypic path coefficient (P) analysis of sugar yield and its components.

Pathway	Plant cane		First ratoon	
	Phenotypic	Genotypic	Phenotypic	Genotypic
Sugar yield vs. cane yield				
Direct effect, $P_{8,10}$	0.842	0.862	0.906	0.943
Indirect effect via				
sugar recovery, $r_{8,9} P_{9,10}$	0.115	0.116	-0.126	-0.168
Correlation $r_{8,10}$	0.957	0.978	0.780	0.775
Sugar yield vs. sugar recovery				
Direct effect, $P_{9,10}$	0.306	0.236	0.631	0.664
Indirect effect via				
cane yield, $r_{8,9} P_{8,10}$	0.316	0.424	-0.180	-0.238
Correlation $r_{9,10}$	0.622	0.660	0.451	0.426
Residual (Px_{10})	0.063	0.032	0.089	0.00
$1 - P^2 x_{10}$	0.996	0.999	0.992	1.00

Means, broad-sense heritability (H values in percent) and expected genetic advance under two selection intensities (5% and 10%) are shown for all studied traits in Table 8. It can be argued that with a crop like sugarcane in which a single superior genotype once identified can be multiplied clonally. Therefore, estimates of broad-sense heritability are more relevant to the breeder than those of narrow sense heritability. Results indicated that heritability estimates in each of plant cane and ratoon crop were relatively high for all studied traits .This might be due to high genetic variance. Genotype X environment interaction could not be estimated and this component is confounded with genotypic variance .Thus high values of heritability suggested the possibility of improvement of those traits through selection. High heritability estimates for stalk length, stalk diameter, stalk number, Brix, sucrose, Purity, sucrose content, cane yield, and sugar yield were similar to the findings of knag *et al.*(1983 b) and Masri (2004).

Heritability estimates along with expected genetic is more useful than heritability value alone in predicting the resultant effect for selecting the best genotypes (Chaudhary, 2001). Maximum genetic advance (as percent of mean) in plant cane was observed For sugar yield (50.80 and 43.40) followed by stalk density (46.19 and 39.46), cane yield (43.81 and 37.43) and stalk weight (38.19 and 32.63) under 5 % and 10 % selection intensity, respectively . However in ratoon crop the highest values of genetic advance was observed for sugar yield (42.32 and 36.34), cane yield (38.82 and 33.33) and stalk weight (36.25 and 31.12) under 5 % and 10% selection intensity, respectively .

High genetic advance (as percent of mean) for stalk weight, cane yield and sugar yield was also reported by Masri (2004). Stalk diameter and purity % had high heritability with low genetic advance in both crops under two selection intensities, suggesting a little scope in the improvement of these traits (Pandey, 1989).

The results suggest that selection for increased sugar yield should emphasize cane yield with particular emphasis on stalk weight. The results simply that stalk density is more important in determining stalk weight followed by stalk diameter and stalk length. Crop age affected the strength of some sugar cane yield component relationships and must be considered in developing selection strategies as suggested by Milligan *et al* (1990).

Table (8): Means, broad sense heritability (H), and expected genetic advance (Gs) under 5% and 10% selection intensities.

	Mean		H%		Gs % of mean			
					PC		FR	
	PC	FR	PC	FR	5%	10%	5%	10%
Stalk length (cm)	257.00	288.33	97.40	88.78	33.58	28.69	12.31	10.57
Stalk diameter (cm)	2.68	2.48	74.15	70.93	12.62	10.78	9.93	8.52
Stalk density (g cm^3)	0.92	0.88	83.98	70.67	46.19	39.46	26.03	22.35
Stalk weight (kg)	1.27	1.21	96.11	95.36	38.19	32.63	36.25	31.12
Stalk number /fed. x 10^3	42.04	54.13	97.25	96.74	34.73	29.67	29.04	24.93
Cane yield (ton/fed.)	52.67	64.66	98.26	97.89	43.81	37.43	38.82	33.33
Brix	22.55	21.33	74.52	96.99	6.53	5.58	15.70	13.48
Sucrose %	19.14	18.39	84.37	97.25	11.13	9.51	20.76	17.83
Purity %	84.83	86.04	95.90	94.74	8.16	6.97	6.25	5.37
Sugar recovery %	12.97	12.57	87.96	97.17	14.65	12.51	23.38	20.07
sugar yield (ton/fed.)	6.88	8.10	97.87	96.69	50.80	43.40	42.32	36.34

PC = plant cane, FR = first ratoon

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العلاقات بين الصفات فى قصب السكر فى نهاية مراحل الانتخاب

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اجريت هذه الدراسه بمحطة بحوث كوم امبو بمحافظة اسوان بغرض تقدير معاملات الارتباط الظاهرية والوراثيه بين مجموعه من الصفات فى قصب السكر مع استخدام معامل المرور لتحليل العلاقات بين هذه الصفات على المستوى الظاهرى والوراثى وكذلك لتقدير كفاءة التوريث فى المعنى العام وتقدير التقدم فى ظل الانتخاب كنسبه مئويه من المتوسط العام لكل صفه.

تم اختيار ١٥ تركيب وراثي فى المراحل النهائية للانتخاب بجانب الصنفان التجاريان PH8013 ، GT 54/9 . تم تقييم هذه التراكيب الوراثية فى مرحلة الغرس (موسم ٢٠٠٥/ ٢٠٠٦) وفى مرحلة الخلفة الاولى (موسم ٢٠٠٦/ ٢٠٠٧) فى تصميم القطاعات كاملة العشوائية. تم دراسة صفات طول الساق، سمك الساق، كثافة الساق، متوسط وزن الساق، عدد العيدان للفدان، نسبة المواد الصلبة الذائبة (البركس)، نسبة السكروز، نسبة النقاوة، ناتج السكر ، محصول العيدان للفدان، محصول السكر للفدان.

أظهرت النتائج وجود ارتباط موجب ومعنوى بين محصول العيدان وكل من كثافة الساق و متوسط وزن الساق و عدد العيدان فى كل من محصولى الغرس والخلفة.كذلك كان الارتباط موجب بين متوسط وزن الساق وكل من كثافة الساق و سمك الساق و طول الساق. كان الارتباط سالب ومعنوى بين كثافة الساق وكل من سمك الساق وطول الساق فى كل من محصولى الغرس والخلفة. تأثر الارتباط بين البركس والنقاوة بالعمر المحصولى حيث زادت قيمة الارتباط الظاهرى من ٠,١٩٦ الى ٠,٧٨٥ ، كما زاد

الارتباط الوراثى من ٠,١٩٢ الى ٠,٨٤٢ وتأثر الارتباط بين محصول العيــدان ونـــاتج الســكر بـــالعمر المحصولى حيث انخفض الارتباط الظاهرى من ٠,٣٧٥ الى -٠,١٩٩ كما انخفض الارتباط الوراثى مـــن ٠,٤٩٢ الى -٠,٢٥٣ . كان الارتباط موجب ومعنوى بين محصول السكر وكل من محصول العيدان وناتج السكر على مستوى محصولى الغرس والخلفة.

أظهرت نتائج تحليل معامل المرور أن التأثير المباشر لكثافة الساق على متوسط وزن العود كـــان أكبر من التأثيرات المباشرة لكل من سمك الساق وطول الساق على المستوى الظاهرى والوراثى فى كل من محصولى الغرس والخلفة. أثر العمر المحصولى على التأثير المباشر للنقاوة على ناتج السكر حيث انخفض التأثير المباشر الظاهرى من ٠,٦٩٩ الى ٠,٤٠٤ كما انخفض التأثير المباشر الـــوراثى مـــن ٠,٧٩٣ الـــى ٠,٣٩٠ .كان التأثير المباشر للبركس على ناتج السكر موجب ومتكافيء على المستوى الظاهرى والـــوراثى فى كل من محصولى الغرس والخلفة. كان لمتوسط وزن الساق التأثير المباشـــر الأكبـــر علـــى محصـــول العيدان مقارنة بعدد العيدان على المستويين الظاهرى والوراثى فى كل من محصولى الغرس والخلفة، كذلك أظهرت النتائج أن محصول العيدان هو المحدد المباشر والأكثر أهمية بالنسبة لمحصول السكر مقارنة بناتج السكر على المستويين الظاهرى والوراثى فى كل من محصولى الغرس والخلفة.

أظهرت النتائج أن تقديرات كفاءة التوريث فى المعنى العام كانت عالية نسبيا لجميع الصفات تحت الدراسة سواء فى محصول الغرس أو الخلفة. سجلت أعلى القيم للتقدم المتوقع فـــى ظـــل الانتخـــاب فـــى محصول الغرس لصفات محصـــول الســـكر (٥٠,٨٠ و ٤٣,٤٠) ، كثافـــة الســـاق (٤٦,١٩ و ٣٩,٤٦) ، محصول العيدان (٤٣,٨١ و ٣٧,٤٣) ، ومتوسط وزن الســـاق (٣٨,١٩ و ٣٢,٦٣) تحـــت ٥% ، ١٠% كثافة انتخابية على التوالى، بينما فى محصول الخلفة فقد سجلت أعلى القـــيم لصـــفات محصـــول الســـكر (٤٢,٣٢ و ٣٦,٣٤) ، محصول العيدان (٣٨,٨٢ و ٣٣,٣٣)، متوســـط وزن الســـاق (٣٦,٢٥ و ٣١,١٢) تحت ٥% ، ١٠% كثافة انتخابية على التوالى. كفاءة التوريث العالية لصفتى سمك الساق والنقـــاوة كانـــت مصحوبة بقيم منخفضة للتقدم فى ظل الانتخاب تحت ٥% ، ١٠% كثافة انتخابية.