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Stepwise Regression, Correlation and Path-coefficient Analysis for Sugar and Cane Yields in New Sugarcane Somaclones

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Abstract

The obtained results could be displayed the effeteness of stepwise regression analysis to determine the strongest trait/s to produce the high sugar, cane yields and sugar recovery in sugarcane. The model which has two independent traits of cane yield (CY) and sugar recovery (SR) resembled to be the fit model for sugar yield and gave R^2 = 1.000 in second and third ratoon crops as well as over both of them. Also, the model which has two independent traits of sugar yield (SY) and sugar recovery (SR) resembled to be the fit model for cane yield and gave R^2 = 1.000 in second and third ratoon crops as well as over both of them. The model included three traits of sucrose (SUC), brix (BR) and pol (PO) with R^2=1.000 in second ratoon or SUC and BR with R^2= 0.999 in third and over both ratoons crops, resembled to be the fit model for sugar recovery. High positive and significant estimates of correlation coefficients were recorded between cane yield and each of stalk height, stalk weight, stalk number/fed and sugar yield in all studied ratoon crops. High and positive significant estimates of correlation coefficients were recorded between sugar yield and each of stalk height, stalk weight and stalks number/fed over the two ratoon crops. It is remark result that the traits of brix, purity %, pol and sugar recovery were correlated each other in high significant and positive estimates in both ratoon crops, revealing the high quality traits as important components express high sugar in sugarcane. Path-coefficient analysis through the second, third and over both of ratoon crops revealed that the stalk weight, stalk number/fed and cane yield had the greatest direct and indirect influences on sugar yield. Moreover, the stalk number and stalk weight had the greatest direct and indirect influences on cane yield. The path coefficient analysis exhibited that sucrose contributed the greatest effects on sugar recovery even direct or indirect effects via pol, brix and purity over the both ratoon crops.

Keywords: *Sugarcane, Immature leaves, callus, somaclones, somaclonal variation.*

Introduction

Sugarcane (*Saccharum officinarum* L.) is one of the most important crops in the world (Dagar *et al.*, 2002). It is widely cultivated in the tropical to subtropical regions and annually provides around 60 to 70% of the world`s sugar (Shah *et al.,* 2009). Recently, around 50% of the sugar production produced from sugarcane in Egypt. The unique commercial variety GT-54 9 is using for more than forty years. Moreover, the traditional improvement and breeding programs take a long time, slow, difficult efforts and costs.

Tissue culture of sugarcane exhibited a wide range of genetic variation (Rajeswari *et al*., 2009), which termed as somaclonal variation (Larkin and Scowcroft, 1981). Somaclonal variation could prove to be a useful tool to overcome the difficulties in cane breeding (Bot *et al*., 2014). Also, it plays an important role in varietal improvement programs in sugarcane (Krishnamurthi & Tlaskal, 1974).

The obtained Subclones or somaclones via tissue culture of sugarcane were superior than their donor genotypes in many traits *i.e.* morphological traits, cane yield, weight of stalk, tillering, number of stalks, sucrose % and quality traits (Liu, 1983; Sreenivasan and Sreenivasan, 1984 a, b; Abo-Elwafa, 2011; Bot *et al.,* 2014 and Abo-Elwafa *et al*., 2015).

The study of relationship among various characters to detect and understood the effective characters for both cane and sugar yields. stepwise regression analysis indicated that the maximum R^2 value of 0.594 was recorded for brix value related to sugar recovery. The two variable model of cane yield and brix value yielded highest R^2 value of 0.699 with sugar recovery. Also, stepwise regression analysis showed the effects of individual character contributed the maximum variation (36.0%) to sucrose%, while two variables model (internode length and number of tillers/plant) accounted maximum variation of 40.1% (Ilyas and Khan, 2010). The stepwise regression and correlation coefficients studies indicated that brix value and sugar recovery were closely related each other (Nosheen & Ashraf, 2003).

Moreover, cane yield should positive and high significant correlation with single cane yield, stalk length and millable cane number and ratoon yield (Chaudhary & Joshi, 2005, Singh *et al.* 2005, Tyagi & Lal, 2007 and Abo-Elwafa *et al*., 2015). Cane yield positively correlated with number of shoots, number of millable cane, stalk diameter, stalk length and stalk weight. Otherwise, cane yield was negatively correlated with brix (Kumar & Kumar, 2014). Correlation coefficients of morphological traits with sugar recovery showed negative and non-significant correlation with number of tillers, stalk height and cane yield. Brix value showed positive correlation with sugar recovery (Nosheen & Ashraf, 2003). Non-significant but positive and weak correlation between weight of millable stalks and brix (0.05) as well as number of millable stalks and stalk height (0.285) were found by Tyagi & Lal (2007). The cane yield was positively and significantly correlated with sugar yield, single stalk weight, number of tillers and stalk length (Swamy Gowda *et al*., 2016; Tena *et al.* 2016; Pandya & Patel, 2017 and Agrawal & Kumar, 2018).

Path coefficient analysis revealed that the sugar/plot and cane sugar% along with dry matter and number of internodes were the major contributors to cane yield/plot whereas sugar yield was largely depended on both can yield and sucrose (Thippeswamy *et al*., 2003). High direct effects of millable canes per clump and single cane weight were observed for cane yield. Number of millable canes per clump and single cane weight emerged as the most important traits influencing cane yield (Kadian *et al*., 2006 & Tyagi and Lal

(2007). The effect of cane yield and sugar recovery on sugar yield was positive at the phenotypic and genotypic levels. The direct effect of stalk weight on cane yield was similar the that of number of millable cane on cane yield. Brix had negative effect on sugar recovery while sucrose had positive direct effect on sugar recovery (El-Taib, 2009). Moreover, the stepwise regression revealed that sweetness and purity presented in unique model with R^2 equal to unity (=1) and were superior to determine and selection for sugar yield in sugarcane (Abo-Elwfa *et al*., 2015; Pandya & Patel, 2017; Agrawal & Kumar, 2018; and Anbanandan *et al*., 2020).

The current study was aimed to determine the relationships of sugar and can yields as well as their relatives in new somaclones of sugarcane derived from callus of immature leaves of the donor GT-54 9 variety, through stepwise regression, correlation and path-coefficient analyses.

Materials and Methods

The current study was carried out at the Experimental Farm of Agronomy Department, Faculty of Agricultural, Assiut University, Egypt during two successive years *i.e.* 2018/19 (second ratoon crop) and 2019/20 (third ratoon crop).

I- Genetic materials:

Eleven somaclones (*i.e.* 1~ 11) and their donor GT-54 9; the commercial variety in Egypt. These somaclones were derived from the callus of immature leaves of the donor variety GT-54 9 at the Tissue Culture Laboratory of Agronomy Department, Faculty of Agricultural, Assiut University.

II- Field procedures:

The eleven somaclones and their donor GT-54 9 were sown on March 5th, 2018 in randomized complete block design (RCBD) of three replications. The plot size was 42 m^2 which consisted of 10 rows, 5.25 m long and 80 cm apart. A total of 132 buds were determined in the two middle rows to calculate cane yield. The millable stalks of one randomized stool/plot were harvested for different analyses. Each sample should be at least 25 Kg from each plot was taken at random, stripped, cleaned and squeezed by an electric pillot mill and used for quality traits. Also, the samples of 2 liters/plot were undertaken to measure quality traits. The following traits were measured in each plot:

- Stalk height (SH), cm; - Stalk dimeter (SD), cm; - Stalk weight (SW), kg; - Stalk number/fed (SNF); - Cane yield (CY), ton/fed. - Sugar yield (SY), ton/fed. - Brix (BR). - Sucrose% (SUC), kg; - Purity% (PU); - Pol% (PO); and - Sugar recovery (SR).

III- Statistical analysis

1- Stepwise regression analyses

The Ver. 10 of SPSS-PC program of Nie *et al.* (1975) was used to estimate stepwise multiple regression across second, third and over both ratoons crops for dependent factors of sugar yield, cane yield and sugar recovery using all studied traits as independent factors in each case. Also, coefficient of determination (R^2) was calculated for all models derived from stepwise analysis.

2- The phenotypic (r_{pij}) correlations

The phenotypic (r_{pij}) correlation across second, third and over both ratoons crop was calculated among the studied traits as outlined by Walker (1960) as:

$rp_{ij} = Cov.\ p_{ij}/\sigma_{pi} x \sigma_{pj}$

Where: Cov. pij: the phenotypic covariance between i and j traits. σ_{pi} and σ_{pj} are the phenotypic standard deviation of the traits i and j, respectively.

3- Path coefficient analysis

The phenotypic path coefficient analysis across second, third and over the both ratoons crop was solving the simultaneous equations as done by Dewey and Lu (1959). Sugar yield (SY), cane yield (CY) and sugar recovery (SR) were the main targeted characters in this analysis with the highest four correlated traits (chosen characters) to manipulate the matrix for each main targeted character. Direct and indirect effects of chosen characters on the target character were presented in Fig. 1.

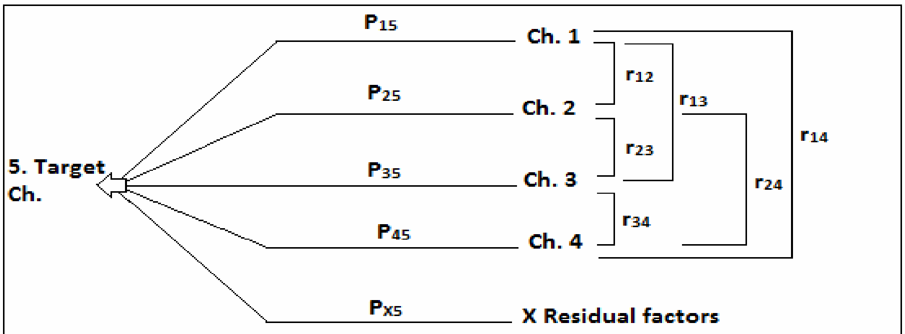

Fig. 1. Direct and indirect effects of chosen characters (Ch. 1 : Ch. 4) on targeted character (Ch. 5.).

Where,

$r_{15} = P_{15} + r_{12}P_{25} + r_{13} P_{35} + r_{14}P_{45}$

$r_{25} = r_{12}P_{15} + P_{25} + r_{23}P_{35} + r_{24}P_{45}$

$r_{35} = r_{13}P_{15} + r_{23}P_{25} + P_{35} + r_{34}P_{45}$

$r_{45} = r_{14}P_{15} + r_{24}P_{25} + r_{34}P_{35} + P_{45}$

$1 = P^2_{X5} + P^2_{15} + P^2_{25} + P^2_{35} + P^2_{45} + 2P_{15}r_{12}P_{25} + 2P_{15}r_{13}P_{35} + 2P_{15}r_{14}P_{45} + 2P_{25}r_{23}P_{35} + 2P_{25}r_{24}P_{45} + 2P_{35}r_{34}P_{45}$.

Results and Discussion

Stepwise regression analysis

Stepwise regression analysis was running three times for three dependent traits *i.e.* sugar yield (SY), cane yield (CY) and sugar recovery (SR) and all other studied traits were used as independent traits in each case through the two ratoon crops and over them as presented in Tables 1, 2, and 3.

A- Stepwise regression for sugar yield

In the second ratoon crop (2018/19), stepwise regression analysis for dependent trait of sugar yield (SY) revealed that two fitted models exerted from the second ratoon crop (2018/19) case, model 1 has only one independent trait of cane yield (CY) and gave R^2 = 0.982, and model 2 has two independent traits of cane yield (CY) and sugar recover (SR) resembled to be the fit model and gave R^2 = 1.000 (Table 1). In third ratoon crop (2019/20), three fitted models were exerted for dependent trait of sugar yield *i.e.* model 1 included one independent trait of cane yield with R^2 = 0.957, model 2 possessed two traits of cane yield (CY) and sugar recovery (SR) with R^2 = 1.000, and model 3 has three traits of cane yield (CY), sugar recovery (SR) and stalk height (SH) with R^2 =1.000. It be clear that the SH have nothing to add in R^2, consequently, the model 1 and 2 were identical in both ratoon crops concerning the independent traits and R^2 (Table 1). Over both ratoon crops, four fitted models exerted over both ratoon crops, the first two models were as produced in second and third ratoon crops, were model 1 has cane yield (CY) with R^2 = 0.974, model 2 has two traits of cane yield (CY) and sugar recovery (SR) with R^2 = 1.000, model 3 possessed three traits of cane yield (CY), sugar recovery (SR) and purity (PU) with R^2 =1.000 and model 4 included for traits of cane yield (CY), sugar recovery (SR), purity (PU) and brix (BR) with R^2 = 1.000 (Table 1). It be clear result that the model 3 and 4 have nothing to add in R^2, consequently, the model 1 and 2 were same as in both ratoon crops concerning the independent traits and R^2. The obtained results concluded that the contributions of cane yield and sugar recovery were powerful in sugar yield as outlined with R^2 = 1.000 in second, third ratoon crops and over them. Therefore, cane yield and sugar recovery should take strong place through the selection for sugar yield in sugarcane.

B- Stepwise regression for cane yield

Stepwise regression analysis for dependent trait of cane yield (CY) revealed the same picture as in sugar yield, only sugar yield putted instead of sugar cane in all obtained models in second, third ratoon crops and over them. In the second ratoon crop (2018/19), stepwise regression analysis for dependent trait of cane yield (CY) revealed that two fitted models were obtained, model 1 gave only one independent trait of sugar yield (SY) with R^2 = 0.982, and model 2 possessed two independent traits of sugar yield (SY) and sugar recover (SR) resembled to be the fit model and presented R^2 = 1.000 (Table 2). In third ratoon crop (2019/20), three fitted models obtained for dependent trait of cane yield *i.e.* model 1 included one independent trait of sugar yield with R^2 = 0.957, model 2 possessed two traits of sugar yield (SY) and sugar recovery (SR) with R^2 = 1.000, and model 3 has three traits of sugar yield (SY), sugar recovery (SR) and stalk height (SH) with R^2 = 1.000. It be remark result that the SH have nothing to add in R^2, consequently, the model 1 and 2 were same in both ratoon crops concerning the independent traits and R^2 (Table 2). *Over the both ratoon crops,* also, four fitted models yielded over both ratoon crops, the first two models were as obtained in second and third ratoon crops, were model 1 has sugar yield (SY) with R^2 = 0.974, model 2 has two traits of sugar yield (SY) and sugar recovery (SR) with R^2 = 1.000, model 3 possessed three traits of sugar yield (SY), sugar recovery (SR) and purity (PU) with R^2 =1.000, and model 4 included for traits of sugar yield (SY), sugar recovery (SR), purity (PU) and brix (BR) with R^2 = 1.000 (Table 2). It be clear result that the model 3 and 4 have nothing to add in R^2, consequently, the model 1 and 2 were same as in both ratoon crops concerning the independent traits and R^2. The obtained results concluded that the contributions of sugar yield and sugar recovery were powerful in cane yield as outlined with R^2 = 1.000 in each of second, third ratoon crops and over them. Therefore, sugar yield and sugar recovery should take remarkable place through the selection program of cane yield in sugarcane.

C- Stepwise regression for sugar recovery

Stepwise regression analysis for dependent trait of sugar recovery (SR) revealed different picture comparing to sugar yield and cane yield. In the second ratoon crop (2018/19), stepwise regression analysis for dependent trait of sugar recovery (SR) revealed that four fitted models were obtained, model 1 gave only one independent trait of sucrose (SUC) with R^2 = 0.983, and model 2 possessed two independent traits of sucrose (SUC) and brix (BR) with R^2 = 0.999, model 3 included three traits of sucrose (SUC), brix (BR) and pol (PO) which resembled to be the fit model and presented R^2 = 1.000, and model 4 possessed four traits of sucrose (SUC), brix (BR), pol (PO) and stalk number/fed with R^2 =1.000 (Table 3). In third ratoon crop (2019/20), two fitted models obtained for dependent trait of sugar recovery *i.e.* model 1 included one independent trait of sucrose (SUC) with R^2 = 0.996, and model 2 possessed two traits of sucrose (SUC) and brix (BR) with R^2 = 0.998. This result for models 1 and 2 was the same in second ratoon (2018/19) (Table 3). Over the both ratoon crops, also, two fitted models (models 1 and 2) yielded over both ratoon crops and were as obtained in second and third ratoon crops, were model 1 has sucrose (SUC) with R^2 =0.996 and model 2 has two traits of sucrose (SUC) and brix (BR) with R^2 =0.999 (Table 3). It be clear result that sucrose and brix were the main effects on sugar recovery in both and over the two ratoon crops. The obtained results concluded that the contributions of sucrose and brix were powerful in sugar recovery as outlined with R^2 ~ 1.000 in each of second, third ratoon crops and over them. Therefore, sucrose and brix should take remarkable place through the selection and breeding programs of sugar recovery in sugarcane.

D- Expected and actual values comparison

The expected sugar yields for all fitted stepwise models were insignificant different relative to the actual sugar yield in the second, third and over the two successive ratoon crops as revealed by *t-test* which tend to be zero in most models (Table 4). Moreover, the correlation coefficients between expected and actual sugar yield were positive, very high and reached to the unity in most of cases. These results displayed the effeteness of stepwise regression analysis to determine the strongest trait/s to in contribution to high sugar yield in second and third ratoon crops of sugarcane.

Also, the expected cane yields for all fitted stepwise models were insignificant different relative to the actual cane yield in the second, third and over the two successive ratoon crops as revealed by *t-test* which was insignificant in all models (Table 5).

Moreover, the correlation coefficients between expected and actual cane yield were positive, very high and reached to the unity in most of cases. These results exhibited the effeteness of stepwise regression analysis to detect the strongest trait/s to in contribution to high cane yield in second and third ratoon crops of sugarcane.

Moreover, the expected sugar recovery for all fitted stepwise models were insignificant different relative to the actual sugar recovery in the second, third and over the two successive ratoon crops as revealed by *t-test* which tend to be zero in some models (Table 6). Moreover, the correlation coefficients between expected and actual sugar recovery were positive, very high and reached to the unity in most of cases. These obtained results presented the effeteness of stepwise regression analysis to determine the strongest trait/s in contribution to high sugar recovery in second and third ratoon crops of sugarcane.

Stepwise regression analysis showed the maximum variation (36.0%) to sucrose percentage as one variable model, while the two variable model using internodal length and number of tillers plant^{-1} that accounts for maximum variation of 40.1%. Variation for sucrose content on single factor basis was caused by tillers, therefore, this character was the most important to increase overall sucrose of *S. officinarum* L. However, second variable model exhibited that tillers and internodal length were important traits for increasing overall sucrose in sugarcane (Panhwar *et al.*, 2003 and Ilyas & Khan 2010). Moreover, Nosheen & Ashraf (2003) found that the stepwise regression analysis indicated that on single factor basis the maximum R^2 value of 0.594 was for brix value related to sugar recovery. The two variable model including the cane yield and brix value yielded highest R^2 value of 0.699 with sugar recovery. Stepwise multiple linear regressions proved to be more efficient than the full model regression to determine the predictive equation for yield (Nasri *et al.*, 2014). Moreover, Abo-Elwafa *et al.* (2015) found that the stepwise regression revealed that sweetness and purity presented in unique model with R^2 equal to unity (=1) and were superior to determine and selection for sugar yield in sugarcane.

Correlation coefficients

High positive and significant estimates of correlation coefficients were recorded between cane yield and each of stalk height, stalks number/fed and sugar yield in second, third ratoon crops and over both of them, which accounted 0.672, 0.606 and 0.707 with stalk height, 0.605, 0.836 and 0.763 with stalk number/fed and 0.991, 0.978 and 0.987 with sugar yield, respectively. Also, cane yield correlated high and positive significant values with stalk weight in second ratoon and over the both ratoon crops in values of 0.772 and 0.678, respectively (Table 7). Cane yield recorded negative weak values of correlation with each of brix, sucrose, purity, pol and sugar recovery. Moreover, high and positive significant estimates of correlation coefficients were recorded between sugar yield and each of stalk height in second (0.674), third (0.576) and over the two ratoon crops

(0.667); stalk weight in second (0.802) and over the two ratoon crops (0.688); and stalk number/fed in third ratoon (0.820) and over the two ratoon crops (0.740). Also, the high and significant values of correlation coefficients were recorded between stalk weight and stalk height in second ratoon (0.901) and over the two season ratoon crops (0.818). In more details estimates correlation for technological traits, brix possessed high positive and significant values with sucrose in second (0.929), third (0.971) and over both ratoon crops (0.984); purity in third (0.884) and over both ratoon crops (0.894); pol in second (0.913), third (0.960) and over both ratoon crops (0.985); and sugar recovery in second (0.875), third (0.959) and over both ratoon crops (0.972). Moreover, sucrose exhibited high positive and significant values with purity in second (0.676), third (0.0.943) and over both ratoon crops (0.942); pol in second (0.991), third (0.987) and over both ratoon crops (0.994); and sugar recovery in second (0.992), third (0.992) and over both ratoon crops (0.998). Also, purity exerted high positive and significant values with pol in second (0.684), third (0.994) and over both ratoon crops (0.935); and sugar recovery in second (0.763), third (0.948) and over both ratoon crops (0.954). In addition to, the pol has high positive and significant values with sugar recovery in second (0.988), third (0.983) and over both ratoon crops (0.990).

It is remark result that the traits of brix, purity %, pol and sugar recovery were correlated each other in high significant and positive estimates in range from 0.676 to 0.991 in second, from 0.884 to 0.998 in third and from 0.894 to 0.998 over the both ratoon crops (Table 7), revealing the high quality traits as important components express high sugar in sugar cane.

The cane yield was considered as the most important trait of sugarcane and positively and significantly correlated with number of millable canes, stalk length, stalk diameter, and stalk weight (Chaudhary & Joshi, 2005, Kumar & Kumar, 2014), but negatively correlated with brix (Kumar & Kumar, 2014). Weight of millable canes revealed positive and significant correlation with number of millable canes (Tyagi & Lal, 2007). Moreover, all quality parameters like juice brix, sucrose % in juice and commercial cane sugar percent had highly positive and significant genotypic correlation with Pol % in cane. Also number of millable cane, single cane weight and cane height showed significant positive correlation with ratoon yield and sugar ton/ hectare, but there was weak negative correlation between number of millable cane and single cane weight (Singh, *et al.* 2005, Brasileriro *et al.* 2013, Abo-Elwafa *et al.* 2015, Pandya & Patal 2017, Ahmed *et al.* 2019, Agrowal & kumar, 2018 and Anbanandan *et al.* 2020).

Swamy Gowda *et al*., (2016) found that the cane yield was positively and significantly correlated with sugar yield, single stalk weight, number of tillers and stalk length. Also, positive significant correlation coefficients of number of millable cane and stalk diameter were recorded with cane yield. Cane yield was negatively and significantly correlated with brix and pol. Otherwise, sugar yield showed positive and significant correlation with single stalk weight, cane length, pol and purity.

The previous findings of correlation estimates should take place in sugar cane breeding and selection program, especially when using the somaclonal variation (genetic variation) exerted through the tissue culture in sugarcane to over new somaclones which characterized with superior traits such as yields of cane and sugar and other technological traits. The short time to get these somaclons is additive positive issue comparing to the traditional breeding program of sugarcane.

Path coefficient analysis

The path coefficient analysis through second, third and over the both ratoons crops was done as Dewey and Lu (1959). Sugar yield (SY), cane yield (CY) and sugar recovery (SR) were the main targeted characters in this analysis. The targeted trait and its highest four correlated traits (chosen characters) were used to manipulate the matrix for each main targeted character. Direct and indirect effects of chosen characters were calculated on each target character.

A- Sugar yield (SY)

Path-coefficient analysis was used to determine the direct and indirect effects of the cane yield, stalk number/fed, stalk weight and stalk height on sugar yield in second, third and over the both ratoon crops as presented in Table 8. In second, third and over the both ratoon crops, stalk weight, stalk number/fed and cane yield had the greatest influence on sugar yield as indicated by correlation as well as path coefficient analyses. The path coefficient analysis revealed that the stalk weight, stalk number/fed and cane yield contributed the main and most direct effects of .7845, 0.2782 and 0.7386; 0.4763, .4145 and 0.6720; and 0.1690, 0.5066 and 0.1090 in second, third and over the both ratoon crops, respectively. The indirect effects of stalk weight on sugar yield were 0.6056, 0.1480 and 0.5008 via cane yield and 0.7068, 0.1552 and 0.6042 via plant height in second, third and over the both ratoons crops, respectively. Other contributions were very small and be neglected values. Also, the residual factors effect was very small and accounted 0.093, 0.204 and 0.122 in second, third and over the both ratoon crops, respectively.

To sum, stalk weight, stalk number/fed and cane yield of sugarcane could be generally a function of sugar yield. Consequently, it was concluded that the stalk weight, stalk number/fed and cane yield were important for selection of high sugar yield in sugarcane.

El-Taib (2009) reported that the direct effect of cane yield and sugar recovery on sugar yield was positive at the phenotypic and genotypic levels. Also, path coefficient analysis revealed that the sugar yield was one of the most traits contributed by cane yield and the selection on base of sugar yield would be worthwhile for ameliorating over pol and cane yield (Swamy Gowda *et al.* 2016). Ahmed *et al.* (2019) reported that commercial cane sugar yield will be more rewarding for obtaining the high yielding sugarcane clones. Moreover, Anbanandan *et al.* (2020) found that cane yield had moderate direct effect on sugar yield.

B- Cane yield (CY)

The relative importance of the cane yield components was compared through path-coefficient analysis. Path-coefficient analysis was applied to detect the direct and indirect effects of the sugar yield, stalk number/fed, stalk weight and stalk height on cane yield in second, third and over the both ratoon crops as presented in Table 9. In second, third and over the both ratoon crops, stalk number/fed and stalk weight had the highest influence on cane yield as indicated by estimates of correlation and path coefficient analyses. The path coefficient analysis exhibited that stalk number/fed and stalk weight contributed the greatest and most direct effects of 0.5942, 0.7933 and 0.7144; and 0.6864, 0.5133 and 0.6481 in second, third and over the both ratoon crops, respectively. The indirect effects of stalk weight on cane yield were 0.5505, 0.2674 and 0.4459 via sugar yield and 0.6185, 0.2864 and 0.5302 via stalk height in second, third and over the both ratoon crops, respectively. Also, the indirect effect of stalk number/fed on cane yield was 0.0.3328, 0.6505 and 0.5286 via sugar yield in the same ratoons respect. It be noted that the other contributions were very small and be neglected values. Simultaneous, the residual factors effect was neglected estimates of 0.060, 0.072 and 0.071 in second, third and over the both ratoon crops, respectively.

In the end, stalk number/fed and stalk weight of sugarcane could be generally a function of cane yield. Consequently, it was concluded that these traits are important for selection of high cane yield through sugarcane improvement program and breeding.

Path coefficient analysis revealed that sugar yield and number of millable canes were major direct contributors for cane yield (Swamy Gowda *et al.,* 2016). Moreover, Ahmed *et al*., (2019) reported the path coefficient analysis revealed that the number of millable canes, single cane weight, cane height, plant height and commercial cane sugar yield contributed indirectly to cane yield through brix yield. Moreover, path coefficient analysis revealed that number of millable cane and single cane weight had the highest direct effect on cane yield than other traits (Kumar and Kumar, 2014 and Agrawal and Kumar, 2018). Single cane weight had the highest positive direct effect on cane yield followed by millable cane number as revealed by Chaudhary and Joshi, 2005 and Pandya and Patel, 2017. Path analysis revealed the highest positive direct effect of millable cane number (0.812) on cane yield followed by single cane weight (0.682) (Tena *et al*., 2016).

C- Sugar recovery (SR)

The real importance of the sugar recovery components was determined through path-coefficient analysis. Path-coefficient analysis was carryout to detect the direct and indirect effects of the sucrose, pol, brix and purity on sugar recovery in second, third and over the both ratoon crops as presented in Table 10. In second, third and over the both ratoon crops, sucrose possessed the highest effect on sugar recovery as exerted by estimates of correlation and path coefficient analyses. The path coefficient analysis exhibited that sucrose contributed the greatest and most direct effects of 1.1053, 1.2083 and 1.2275 in second, third and over the both ratoon crops and indirect effects via pol of 1.0954, 1.1926 and 1.2202; via brix of 1.0268, 1.1732 and 1.2079; and via purity of 0.7472, 1.1394 and 1.1563 in second, third and over the both ratoon crops, respectively. It be concluded that the other contributions were very small and be neglected values. Simultaneous, the residual factors effect was neglected values as 0.000, 0.045 and 0.026 in second, third and over the both ratoon crops, respectively.

It is clear remark that the sucrose could be generally a function of sugar recovery. Consequently, it was concluded that the sucrose is important for selection of high sugar recovery in sugarcane improvement programs.

El-Taib (2009) reported that the brix had negative effect on sugar recovery while sucrose had positive direct effect on sugar recovery. Also, Ahmed *et al.,* (2019) found that the path coefficient analysis revealed that sucrose showed highest positive direct effects on cane sugar yield. Otherwise, Nosheen and Ashraf, (2003) noted that the brix has maximum R^2 (0.594) related to sugar recovery. Moreover, Anbanandan *et al.* (2020) found that sucrose had indirect effect (0.92) on sugar yield.

The present study suggests that the obtained somaclones through *in vitro* cultures can be exploited to develop and improve the agronomical and technological traits in short time comparing to conventional breeding programs in sugarcane.

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الانحدار المتدرج والارتباط ومعامل المرور لمحصولي السكر والقصب في سلالات جسمية جديدة من قصب السكر

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الملخص

من النتائج التي تم الحصول عليها من تحليل الانحدار التدريجي لتحديد أقوى صفة / صفات في محصولي السكر والقصب والسكر النظري في قصب السكر. أظهر الموديل الذي يحتوي على صفتين مستقلتين هما محصول قصب السكر والسكر النظري هو المناسب لمحصول السكر وأعطى $R^2 = 1.000$ في محصول الخلفة الثانية والثالثة. أيضًا، فإن الموديل الذي يحتوي على صفتين مستقلتين هما محصول السكر والسكر النظري هو الموديل المناسب لمحصول قصب السكر وأعطى $R^2 = 1.000$ في محصول الخلفة الثانية والثالثة. كما أن الموديل المحتوى على ثلاث صفات هي السكروز، والبركس والبول مع $R^2 = 1.000$ في محصول الخلفة الثانية أو السكروز والبركس مع $R^2 = 0.999$ في محصول الخلفة الثالثة ومتوسط الخلفتين هو الموديل المناسب لأعلى سكر نظري.

تم تسجيل تقديرات موجبة وذات معنوية عالية لمعاملات الارتباط بين محصول القصب وكل من ارتفاع الساق ووزن الساق وعدد الساق/ فدان ومحصول السكر في الخلفة الثانية والثالثة. كما تم تسجيل تقديرات معنوية عالية وموجبة لمعاملات الارتباط بين محصول السكر وكل من ارتفاع الساق ووزن الساق وعدد الساق/ فدان محصول الخلفتين. ومن الملاحظ أن صفات البركس، نسبة النقاوة، البول واستخلاص السكر كانت مرتبطة ببعضها البعض في تقديرات عالية معنوية وإيجابية في كلا الخلفتين، مما يكشف عن أن أنها صفات مهمة للجودة ويعبر عنها في عن نسبة عالية من السكر في قصب السكر. أظهر تحليل معامل المرور من خلال محصول الخلفة الثانية والثالثة أن وزن الساق وعدد السيقان/فدان ومحصول القصب لهم أكبر التأثيرات المباشرة وغير المباشرة على محصول السكر. علاوة على ذلك، كان عدد السيقان/فدان ووزن الساق لهما أكبر التأثيرات المباشرة وغير المباشرة على محصول قصب السكر. كما أظهر تحليل معامل المرور أن السكروز ساهم بأكبر التأثيرات على استخلاص السكر سواء التأثيرات المباشرة أو غير المباشرة عن طريق البول والبركس والنقاوة على محصولي الخلفتين.