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ESTIMATING THE RELATIONSHIP BETWEEN SUGAR YIELD AND ITS COMPONENTS USING VARIOUS STATISTICAL METHODS IN SUGAR CANE

Hussein M. Al-Sayed[1], Hayam S. Fateh[2], W. M. Fares[2], Ahmed S. Attaya[3*]

1. Inst. Sugar Crops Res., Agri. Res. Cent., Giza, Egypt
2. Lab. Design and Stat. Analysis Res., Field Crop Res. Inst., Agri. Res. Cent., Giza, Egypt
3. Dept. Plant Prod., Fac. Environ. Agri. Sc., Suez Canal Univ., Egypt

ABSTRACT

Five statistical procedures were used to study the relationship between the sugar yield and its components using the data collected over the two successive seasons of (2012/2013 and 2013/2014) at Mallawy Research Station, Menia Governorate. The five methods of analysis namely, simple correlation coefficient, path analysis, full model regression, stepwise multiple linear regression and factor analysis that have different mathematical concepts. Highly significant and positive correlation coefficients were detected between sugar yield and each of number of internodes/stalk, number of millable stalks/m^2, total soluble solids % and sucrose %. The results of path analysis revealed that the number of millable stalks/m^2 was the most important character with the highest direct and indirect effects on sugar yield followed by sucrose % and stalk weight. The same three traits were also responsible for the most sugar yield variability using full model regression and stepwise multiple linear regression with goodness of fit. Factor analysis grouped the studied eight traits as sugar yield components into three main factors accounting for 85.3% of the total variability in the dependence structure. Factor I was responsible for 34.89% of the total variation and included stalk weight, stalk thickness and number of millable stalks/m^2. Factor II contained total soluble solids % and sucrose and contributed at 28.17% of the total variation. Stalk height, number of internodes/stalk and reducing sugar % were the components of the last factor and explained 22.25 % of the total variation. Based on the previous results, it could be concluded that the high sugar yield of sugarcane crop would be obtained by selecting breeding materials that have heavy weight of stalk, large number of millable stalks/m^2 and high percent of sucrose.

Key words: Sugar cane, genotypes, sugar yield, statistical analysis methods.

INTRODUCTION

Sugarcane is an essential constituent of the human diet as sweetener. In Egypt, sugarcane represents one of the main field crops. It is still considered the major source of sugar supply in ARE. Therefore, it is necessary to increase its sugar yield to meet the infinite needs of an ever-increasing population. Sugar yield is a complex quantitative character that is the final expression and contributions of its components. Hence, determining the most important affecting characters to the total variability of sugar yield is a vital target to successfully achieve a breeding program. Great efforts have been made to develop proper models that can explain and predict the relationship between the sugar yield and its components thus the interrelationships among them. Choosing the appropriate model is a special challenge faced the statisticians. Applying integrated analysis

* **Corresponding Author:** +201021289944
E-mail: ahmd.attaya@gmail.com

contained many statistical models may be other choice.

Different statistical techniques have been used in modeling yield variability, including simple correlation, multiple regression analysis in full model and stepwise procedures, path analysis and factor analysis. **(Kang, 1994)** revealed that breeding decisions based only on correlation coefficients may not always be effective since they provide only one-dimensional information neglecting important and complex interrelationships among plant traits. Moreover, Path coefficient analysis separates the direct effect from the indirect effects through other related traits by partitioning the simple correlation coefficients **(Dewey and Lu, 1959).** In addition, Factor analysis is a type of multivariate analysis that can be used to reduce a large number of correlated variables to small number of independent main factors.

The study of casual relationship between sugar yield and its related characters using the two former techniques was applied by many investigators, such as **(Ahmed *et al.,* 2010)** who found a positive correlation between cane yield and each of number of millable stalks/ m^2, stalk height, number of internodes/stalk and single stalk weight. Also, they noticed a negative association of cane yield with stalk diameter, juice pol and purity %. **(Tyagi and Lai, 2007)** reported that the weight of millable stalks was the most important character with the highest direct effect on sugarcane yield followed by stalk height, number of millable stalks and stalk thickness.On the other hand, (**El-Shafi and Ismail**, **2006)** used full model regression and stepwise multiple linear regression techniques to study the relationship between sugar yield and its components in sugarcane. They reported that cane yield, sugar recovery % and stalk diameter were the main variables that significantly explaining sugar yield with relative contribution (R^2) of 63.41, 36.11 and 0.13%, respectively. Thus, (**El-Geddawi *et al.*, 1992)** used factor analysis to determine the dependence structure of cane yield through some morphological and chemical traits. They pointed out that factor analysis divided the studied traits into four groups or factors accounted for 76.88% of the total variability in the dependence structure. The first factor contained the chemical characters that were most contributing in sugar yield. These traits were richness %, sucrose %, brix % and purity %.

The present study was carried out to assist the relationship between sugar yield and its components in sugarcane using five statistical procedures namely: simple correlation, path analysis, full model regression, stepwise multiple linear regression and factor analysis. The results may be helpful to plan appropriate selection strategies for improving sugarcane crop.

MATERIALS AND METHODS

A field experiment was conducted at Mallawy Research Station, Menia Governorate in two successive seasons of 2012/2013 and 2013/2014 to evaluate some statistical approaches that used for estimating the relative contribution of sugar yield factors in sugarcane. The present study included nine treatments which were the combination between three sugar cane varieties viz Phi 8013, G.99103 and G.54-9 and three growth promoters i.e Stimulate, Agrispon and check treatment (Control). The treatments were arranged in a split plot design and replicated three times. The treatments of growth promoters were devoted to the main plots while the sub plots were randomly assigned to sugarcane varieties. The sub plot area was 35 m^2 including 5 rows, 7 m long and 100 cm between rows. Cultural practices were maintained at recommended levels to satisfy maximum cane yield and sugar yield.

At harvest, three guarded rows from each plot were harvested, topped and cleaned to estimate yield and its components:

1- Stalk weight (kg).

2- Stalk height (cm).

3- Stalk thickness (cm).

4- Number of internodes/stalk.

5- Number of millable stalk/m^2: determined by counting the number of mature stalk in each plot.

6- Cane yield (tons/fed): determined from the weight of the three middle guarded rows of each plot and measuring it as related to feddan.

7- Sugar yield (ton/fed) = cane yield (ton/ fed) x sugar recovery %.

8- Total soluble solids or Brix %: determined by using hand refractometer.

9- Sucrose %: determined by using Sacharemeter according to A.O.A.C. (1980).

10- Sugar recovery %: was calculated according the following equation:

Sugar recovery % = Richness % **x** Purity %.

Where:

Richness = (Sucrose in 100 grams juice x factor) / 100.

Factor = 100-[Fiber % + physical impurities % + percent water free sugar].

11- Reducing sugar %

Statistical analysis

1- Simple correlation: a matrix of simple correlation coefficients between sugar yield and each of its components were computed according to (**Steel and Torrie, 1980).**

2- Path analysis: The methodology proposed by **(Dewey and Lu, 1959)** was used to partition the simple correlation coefficients of the previous step into direct and indirect effects.

3- Multiple linear regression: Full model regression and coefficient of determination (R^2) were estimated according to (**Draper and smith, 1981)** using sugar yield as resultant variable and its related characters as explanatory variables.

4- Stepwise multiple linear regression: this model was used according to (**Draper and smith, 1966)** to determine the variables that accounted for the majority of the total sugar yield variability.

To avoid the lack of fit of both Full model regression and Stepwise multiple linear regression as a result of multicollinearity phenomenon (the strong association among sugar yield components), the level of multicollinearity was estimated using a common measure namely: Variance Inflated Factor (VIF) as suggested by **(Hair *et al*., 1992)**. Large VIF values (above 10) reported high collinearity causing a rejected model **(Hair *et al*., 1992).**

5- Factor analysis: this statistical approach was applied according to (**Cattell, 1965)** to reduce a large number of correlated variables to a much smaller number of independent clusters of variables called factors. After the loading of the first factor was calculated, the process was repeated on the residuals matrix to find further factors. When the contribution of a factor to the total percentage of the trace was less than 10%, the process was stopped. After extraction, the matrix of factor loadings was submitted to a varimax orthogonal rotation, as applied by (**Kaiser, 1958).** The purpose of rotation was to rebuilding the larger loadings in each factor, suppress the minor loading coefficient and to improve the opportunity of achieving meaningful biological interpretation of each factor.

RESULTS AND DISCUSSION

1- Simple correlation matrix

Correlation coefficients between all pairs of studied characters are shown in Table (1). The results revealed that there was a highly significant positive correlation between sugar yield and each of sucrose % (0.722**), total soluble solids % (0.621**) number of internodes/stalk (0.436**), and number of millable stalks/m^2 (0.4**). Stalk height character had only significant positive association with sugar yield with r value of 0.332**. Accordingly, the breeder should exploit the previous characters to achieve high sugar yield of sugarcane. However, insignificant associations were observed between sugar yield and each of stalk height (0.088), stalk thickness (-0.037) and reducing sugar (0.106) indicating that these traits may be independent in their genetic expression under the present study.

On the other hand, the sugar yield components exhibited important trends of associations among themselves. Negative and highly significant correlation was found between stalk weight and each of stalk height (-0.467**) and number of millable stalks/m^2 (0.803**). The correlation between stalk height and each of number of internodes/stalk, number of millable stalks/m^2, total soluble solids % and sucrose % was found to be positive and highly significant with r value being 0.669**, 0.600**, 0.425** and 0.402**, respectively. In addition, highly significant and negative correlation coefficient was observed between stalk thickness and number of millable stalks/m^2 with value of -0.814**. Positive and highly significant correlation was also detected between total soluble solids % and sucrose % recording 0.895**. The sugar cane breeder must take in account the interrelationships among the sugar yield components when planning the breeding program. It is worthwhile to note that the large sample size (n=54) of data may be a reason of the significance of some small values of correlation coefficients. The present results are similar to those reported by **(Tyagi and Lai, 2007; Ahmed *et al.*, 2010; Iiyas and khan, 2010).**

Table (1): Matrix of simple correlation coefficients among sugar yield and its components in sugarcane over 2012/2013 and 2013/2014 seasons.

Characters	SW	SH	ST	NI	NMS	TSS %	S %	RS %	SY
Stalk weight (SW)	1	-0.467**	0.878**	-0.181	-0.803**	-0.056	-0.013	-0.036	0.088
Stalk height (SH)		1	-0.369**	0.669**	0.600**	0.425**	0.402**	0.258	0.332*
Stalk thickness (ST)			1	-0.105	-0.814**	-0.074	-0.021	-0.142	-0.037
No. internodes/stalk (NI)				1	0.413**	0.220	0.322*	0.311*	0.436**
No. millable stalks/m^2 (NMS)					1	0.269	0.250	0.182	0.400**
Total soluble solids (TSS %)						1	0.895**	-0.129	0.621**
Sucrose % (S %)							1	-0.250	0.722**
Reducing sugar % (RS %)								1	0.106
Sugar yield (SY)									1

*, ** means significant at 0.05 and 0.01 probability levels, respectively.

2- Path analysis

Information obtained from simple correlation coefficient can be enlarged by partitioning it into direct and indirect effects for a given set of casual interrelationships. The matrix of direct and joint effects for the studied characters is shown in Table (2). The maximum direct effects were obtained for number of millable stalks/m^2 (0.962), followed by sucrose % (0.739) and stalk weight (0.731). It is noted that the indirect effects of number of millable stalks/m^2 and sucrose % were less important compared to their direct effects. The high positive direct effects of the number of millable stalks/m^2 and sucrose % in addition to their highly significant coefficients of correlation is an evidence that the direct selection through the two traits would be effective for improving sugar yield of sugarcane.

In contrast, although significant positive coefficients of correlation were recorded between sugar yield and each of stalk height, number of internodes/stalk and total soluble solids %, their direct effects were negligible. This result may be attributed to that path analysis discarded the indirect effects from the simple correlation coefficient. The components of indirect effect were more important than the part of direct effect considering the traits of stalk height, stalk thickness and number of internodes/stalk. The highest values of their indirect effects on sugar yield were those especially via number of stalks/m^2 recording 0.577, -0.783 and 0.397, respectively. Considering the trait of total soluble solids %, the important part of its joint effects was that via sucrose% listing 0.661. Trivial components of joint effect were observed for the rest traits.

In fact, the efficiency of path analysis is clear in the present study. For example, the association between stalk weight and sugar yield was not significantly different from zero (0.088) considering only simple correlation coefficient. When the indirect effects are separated from simple correlation coefficient by path analysis, however, the direct effect revealed strong relationship (0.731) between the two traits.

The coefficient of determination and relative importance using path analysis for sugar yield and its related characters are shown in Table (3).

Table (2): Path coefficients (direct and joint effects) of sugar yield and its related characters in sugarcane.

Character	SW	SH	ST	NI	NMS	TSS%	S%	RS%	r_{xy}
SW	**<u>0.731</u>**	0.082	0.062	-0.008	-0.772	0.009	-0.01	-0.006	0.088
SH	-0.341	**<u>-0.175</u>**	-0.026	0.029	0.577	-0.071	0.297	0.042	0.332*
ST	0.642	0.065	**<u>0.07</u>**	-0.005	-0.783	0.012	-0.016	-0.023	-0.037
NI	-0.132	-0.117	-0.007	**<u>0.044</u>**	0.397	-0.037	0.238	0.05	0.436**
NMS	-0.587	-0.105	-0.057	0.018	**<u>0.962</u>**	-0.045	0.185	0.029	0.4**
TSS%	-0.041	-0.074	-0.005	0.01	0.259	**<u>-0.168</u>**	0.661	-0.021	0.621**
S%	-0.01	-0.07	-0.001	0.014	0.24	-0.15	**<u>0.739</u>**	-0.04	0.722**
RS%	-0.026	-0.045	-0.01	0.014	0.175	0.022	-0.185	**<u>0.162</u>**	0.106

Residual effect = 0.382

SW= stalk weight, SH= stalk height, ST= stalk thickness, number of internodes/stalk, NMS= number of millable stalks/ m^2, TSS %= total soluble solids %, S%= sucrose % and RS %= reducing sugar %.

The direct effects occupied the diagonal cells (bold and underline).

Table (3): The coefficient of determination (CD) and relative importance (RI %) of sugar yield components in sugarcane.

Characters		Sugar yield	
		CD	RI %
Direct effects			
Stalk weight (SW)		0.534	**<u>10.766</u>**
Stalk height (SH)		0.030	0.605
Stalk thickness (ST)		0.005	0.101
No. internodes/stalk (NI)		0.002	0.040
No. millable stalks/m^2 (NMS)		0.925	**<u>18.649</u>**
Total soluble solids (TSS %)		0.028	0.565
Sucrose (S %)		0.546	**<u>11.008</u>**
Reducing sugar (RS %)		0.026	0.524
Indirect effects			
SW via	**SH**	0.119	2.399
	ST	0.09	1.815
	NI	-0.0116	0.234
	NMS	-1.129	**<u>22.762</u>**
	TSS %	0.014	0.282
	S %	-0.014	0.282
	RS %	-0.0085	0.171
SH via	**ST**	0.009	0.181
	NI	-0.0103	0.208
	NMS	-0.202	**<u>4.073</u>**
	TSS %	0.025	0.504
	S %	-0.104	2.097
	RS %	-0.015	0.302
ST via	**NI**	-0.0006	0.012
	NMS	-0.11	2.218
	TSS %	0.002	0.040
	S %	-0.002	0.040
	RS %	-0.003	0.060
NI via	**NMS**	0.035	0.706
	TSS %	-0.003	0.060
	S %	0.021	0.423
	RS %	0.004	0.081
NMS via	**TSS %**	-0.087	1.754
	S %	0.355	**<u>7.157</u>**
	RS %	0.057	1.149
TSS % via	**S %**	-0.221	**<u>4.456</u>**
	RS %	0.007	0.141
S % via	**RS %**	-0.059	1.190
Total (direct + indirect)		**0.854**	**97.06**
Residuals		**0.146**	**2.94**
Total		**1.000**	**100**

Bold and underline cells indicate the highest values of direct and indirect effects.

The results revealed that the greatest parts of sugar yield variability were explained by the direct effects of number of millable stalks/m^2 (18.65), sucrose% (11.01) and stalk weight (10.77). The great contribution of these traits on sugar yield plus the easy of visually selecting them supported their importance as selection criteria in sugarcane breeding program. According to the relative importance of joint effects components, it appeared that the highest values were recorded for the indirect effect of stalk weight on sugar yield through its association with number of millable stalks/m^2 (22.76) followed by the joint effect of number of millable stalks/m^2 via sucrose (7.16) followed by total soluble solids via sucrose (4.46) and stalk height through number of millable stalks/m^2 (4.07). Trivial values of relative importance were obtained by the other direct and indirect effects. Totally, the studied characters accounted for 97.06 % of sugar yield variation. The current results were in parallel line with those obtained by (**Hooda *et al*., 1990; Kang *et al*., 1983; Kang *et al*., 1989; Kang *et al*., 1991; Choudhary and Singh, 1994; Tyagi and Lai, 2007).**

Although the path analysis provides a clear picture of the patter of association, but it can not construct a prediction equation for sugar yield using its components. Considering this point of view, the multiple linear regression analysis may usefully play this role.

3- Multiple linear regression analysis

Data in Table (4) shows the regression coefficients and their significance for some agronomic and chemical traits in predicting sugar yield (SY) using full model regression. The prediction equation was formulated as follows:

SY = -13.75 + 3.44 (SW) - 0.004 (SH) + 0.154 (ST) + 0.032 (NI) + 0.477 (NMS) - 0.187 (TSS %) + 0.777 (S %) + 1.93 (RS %)

In addition to the highly significance of the used model ($P < 0.01$), it successfully accounted for 85.3% of the total variation of sugar yield expressed as R^2. The residuals content (14.7%) may be attributed to unknown variation (random errors), human errors during measuring the studied traits and/or some other traits that were not in account under the present investigation. Furthermore, the obtained results reported that the stalk weight, number of millable stalks/m^2, sucrose % and reducing sugar % significantly contributed towards sugar yield while the other four traits did not.

On the other hand, the values of Variance Inflation Factor (VIF) for all studied characters were less than 10 indicating trivial influence of multicollinearity problem. The present results ensured the goodness of fit for the proposed model of regression.

4- Stepwise linear regression analysis

This method was used to determine the more effective traits that mostly explained the variation of sugar yield. Table (5) shows the partial regression coefficients as well as their significance for the accepted limiting three variables that significantly contributing to variation of sugar yield. These variables were stalk weight, number of millable stalks/m^2 and sucrose %. According to the results, 82.7% (expressed as R^2) of the total variation in sugar yield could be attributed to these aforementioned three traits. The other five traits were not included in the model due to their very low relative contribution ($R^2 = 2.6$).

The prediction equation for sugar yield formula was as follows:

SY =-13.65 + 4.213 (SW) + 0.5 (NMS) + 0.51 (S %)

Table (4): Multiple linear regression model to explain sugar yield variation using some its related characters.

Characters \ Reg. Parameters	Regression coefficient (b)	Standard Error (SE)	Probability level (P-value)	Variance Inflation Factor (VIF)
Stalk weight (SW)	3.44**	0.68	000	6.41
Stalk height (SH)	-0.004	0.002	0.09	3.06
Stalk thickness (ST)	0.154	0.318	0.63	6.45
No. internodes/stalk (NI)	0.032	0.068	0.64	2.61
No. millable stalks/m^2 (NMS)	0.477**	0.066	000	5.4
Total soluble solids (TSS %)	-0.187	0.161	0.25	6.4
Sucrose (S %)	0.777**	0.163	000	7.3
Reducing sugar (RS %)	1.93*	0.90	0.037	1.7
Intercept	-13.75			
Model sig.	000			
R^2	85.3			
Adjusted R^2	82.7			

Table (5): Regression parameters of the accepted variables according to stepwise multiple linear regressions.

Characters \ Reg. Parameters	Regression coefficient (b)	Standard Error (SE)	Probability level (P-value)	Variance Inflation Factor (VIF)
Stalk weight (SW)	4.213 **	0.49	000	3.15
Number of millable stalks/m^2(NMS)	0.5 **	0.05	000	3.36
Sucrose (%)	0.51 **	0.07	000	1.19
Intercept	-13.65			
Model sig.	000			
R^2	82.7			
Adjusted R^2	81.7			
R^2 of eliminated traits	2.6			

On the other hand, the validity of the proposed model was established where the values of Variance Inflation Factor (VIF) for the accepted variables were less than 10 indicating no effect of multicollinearity. As mentioned before, the stalk weight, number of millable stalks/m^2 and sucrose % were the most important variables according to stepwise analysis. Therefore, these three traits have to be ranked the first in any breeding program for improving sugar yield in sugarcane. The current results of full model regression and stepwise multiple linear regression were in harmony with those obtained by (**El-Shafai and Ismail, 2006; Iiyas and Khan, 2010).**

5- Factor analysis

The factor analysis technique divided the eight sugar yield components into three independent groups or factors which explained 85.31 % of the total variability in the dependence structure. The factors were constructed by applying the principal component approach to establish the dependent relationship between sugar yield attributes in sugarcane. Factor loadings that greater than 0.5 were considered important. A summary of the composition of variables of the three extracted factors with loading are given in Table (6).

Factor I included three variables which accounted for 34.89% of the total variability. The three variables were stalk weight, stalk thickness and, number of millable stalks/m^2. The sign of the loading values indicates the direction of the relationship between the factor and its related characters. So, the negative sign of the number of millable stalks/m^2 indicate the negative correlation coefficients with each of the other two variables in factor I (Table 1). The three variables had high communality with factor I. Therefore, this factor may be called cane yield factor.

Factor II was made up of total soluble % and sucrose %. Because factor II concerned with sugar content, it was called sugar factor. It accounted for 28.17 % of the total variability in the dependence structure. In factor II, both variables had a high loading in the factor.

Factor III was responsible for 22.25% of the total variability in the dependence structure. It included three characters namely: stalk height, number of internodes/stalk and reducing sugar %. It contains the variables usually regarded as a growth factor. These results were in agreement with **(El-Geddawi *et al*., 1992)**. Use of factor analysis by plant breeders has the potential of increasing the comprehension of the casual relationship of variables and can help to determine the nature and sequence of traits to be selected in a breeding program.

Finally, it can be recommended from the previous results that, the important traits overall statistical procedures of analysis were number of millable stalks/m^2, stalk weight and sucrose %. These characters will enable the breeders or agronomists to realize high income of sugar yield in sugarcane.

Table (6): Summary of factor loadings for the eight characters of sugarcane.

Variables	loading	Communality	Eigen values	% of variance	Suggested factor name
Factor I					
Stalk weight	0.96	0.925	2.971	34.89	**Cane yield factor**
Stalk thickness	0.956	0.917			
No. millable stacks/m^2	-0.87	0.893			
Factor II					
Total soluble solids %	0.927	0.867	2.253	28.17	**Sugar factor**
Sucrose %	0.967	0.939			
Factor III					
Stalk height	0.655	0.796	1.78	22.25	**Growth factor**
No. internodes/stalk	0.813	0.765			
Reducing sugar %	0.766	0.722			
Cumulative variance				**85.31**	

- Bold and underline cells indicate to the highest values of factor loadings and variables communality.
- Extraction method: principal component analysis.
- Rotation method: varimax with Keiser normalization.

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تقدير العلاقة بين محصول السكر ومكوناته باستخدام طرق إحصائية متعددة في قصب السكر

حسين محمد السيد[١] – هيام سيد فاتح[٢] – وليد محمد فارس[٢] – أحمد سعد عطايا[٣]

١- معهد المحاصيل السكرية - مركز البحوث الزراعية - جيزة - مصر

٢- معمل بحوث التصميم والتحليل الاحصائي – معهد المحاصيل الحقلية - مركز البحوث الزراعية - جيزة - مصر

٣- قسم الإنتاج النباتي - كلية العلوم الزراعية البيئية بالعريش - جامعة قناة السويس - شمال سيناء - مصر

استخدمت خمسة طرق للتحليل الاحصائي وهي (معامل الارتباط البسيط – تحليل المسار – نموذج الانحدار الكامل المتعدد – الانحدار الخطي التدريجي – تحليل العوامل) والتي لها مفاهيم رياضية مختلفة لدراسة العلاقة بين محصول السكر ومكوناته باستخدام البيانات المجمعة خلال موسمين زراعيين (٢٠١٢/٢٠١٣ و ٢٠١٣/٢٠١٤) بمحطة بحوث ملوي بمحافظة المنيا. تم تسجيل اعلى معنوية وارتباط ايجابي بين محصول السكر وكلاً من صفات عدد السلاميات او العقل/العود و عدد العيدان القابلة للعصر/م٢ و نسبة المواد الصلبة الكلية و نسبة السكروز. كشفت نتائج تحليل المسار ان صفة عدد العيدان القابلة للعصر/م٢ كأهم صفة وبأعلى تأثيرات مباشرة وغير مباشرة على محصول السكر تليها صفتي نسبة السكروز ووزن العيدان. كذلك فان مثل هذه الصفات الثلاثة كانت الأكثر تأثيراً والمسؤولة عن اختلافات محصول السكر باستخدام تحليل نموذج الانحدار الكامل والانحدار الخطي التدريجي. تحليل العوامل قام بتجميع الصفات الثمانية المدروسة كمكونات محصول السكر الى ثلاثة عوامل رئيسية تمثل ٨٥,٣% من التباين الكلي في بنية او تركيب التبعية. العامل الأول كان المسئول عن حوالي ٣٤,٨٩% من التباين الكلي وشمل صفات وزن العيدان وسمك العيدان وعدد العيدان القابلة للعصر/م٢. احتوى العامل الثاني على صفات نسبة المواد الصلبة الكلية ونسبة السكر وساهم بنسبة ٢٨,١٧% من التباين الكلي. صفات ارتفاع العيدان وعدد السلاميات او العقل/العود وانخفاض نسبة السكروز كانت مكونات العامل الثالث والأخير والتي سجلت ٢٢,٢٥% من التباين الكلي. وبناء على النتائج السابقة، يمكن التلخيص بان محصول السكر العالي لقصب السكر يمكن الحصول عليه عن طريق اختيار مواد التربية التي لديها صفات الوزن الثقيل للعيدان، العدد الكبير من العيدان القابلة للعصر/م٢، النسبة العالية للسكروز.

المحكمــــون:

١- أ.د. رمضان ثابت عبد ربه أستاذ المحاصيل- كلية الزراعة- جامعة عين شمس.

٢- أ.د. إبراهيم حنفي الجداوي أستاذ المحاصيل- معهد بحوث المحاصيل السكرية- مركز البحوث الزراعية.