

ASSESSMENT OF RELATIONSHIP BETWEEN CANE YIELD AND COMPONENT TRAITS IN SUGARCANE ACCESSIONS



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ABSTRACT

A study was undertaken to assess the relationship between seven designated traits (tiller count, plant height, stalk girth, stalk length, millable stalk, brix value and cane yield) in forty sugarcane varieties. The experiment was planted in a randomized complete block design with four replications at two locations in Nigeria. The trial was established in 2013 (plant crop) and terminated in 2017 (third ratoon crop). Regression, correlation and path coefficient analyses were carried out to assess the relationship among component traits and cane yield. The study revealed highly significant contribution (15%) of millable stalk to yield. Cane yield showed a strong positive correlation with tiller count plant height, stalk girth, stalk length and millable stalks. The brix value was negatively correlated with cane yield and all correlation coefficient were highly significant. Path coefficient analysis revealed the direct positive effect of millable stalks, plant height and tiller count on the response variable (cane yield). Stalk length had a low and negative direct effect on cane yield. A second path analysis to discover second order variables for cane yield revealed brix value and stalk girth as having direct positive effect on cane yield. In view of the significant direct effect of the first order predictors, all component traits should be taken into cognizance during selection for high cane yield.

KEYWORDS: plant crop, sugarcane ratoon, regression, phenotypic correlation, path analysis, cane yield, component traits

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is a cash crop of great importance, mainly grown in the tropics and sub-tropics. In Nigeria, it is a cash crop used for manufacturing white sugar; it is also a multipurpose crop which can be used to generate electricity, biofuel, ethanol, organic matter for crop nutrition, chip board and paper production (Khan *et al.*, 2013). The cumulative domestic production of sugarcane in Nigeria has been in the range of 10,000 – 55,000 tonnes annually, which can only meet about 5% of national demand.

This shows that the country is far from meeting consumption demand for sugarcane, especially when potential with respect to human and material resources in Nigeria is considered. Although Nigeria projected to attain 70% self-sufficient production of sugar in 2020, thereby making effort to revive all the sugar sector in the country (Ahmed and Alsharief, 2009). Adequate production of sugarcane is required to meet achieve this vision. The need for more improved varieties of sugarcane with high yielding traits of cane and brix is of utmost importance in achieving this goal.

Table 1a: Trend in consumption and production of sugar in Nigeria, 1999 - 2012

Year	Quantity in tonnes	Consumption Growth in %	Quantity in Tonnes	Production Growth (%)
1999	781,782		10,000	
2000	771,890	-1.27	36,000	260.00
2001	930,201	20.51	10,000	-72.22
2002	1,009,165	8.49	-	
2003	988,441	-2.05	-	
2004	865,000	-12.49	-	
2005	1,301,494	50.46	-	
2006	1,176,698	-9.59	50,000	
2007	1,258,966	6.99	55,000	10.00
2008	1,396,668	10.94	38,000	-30.91
2009	1,220,080	-12.64	39,000	2.63
2010	985,675	-19.21	30,000	-23.08
2011	1,139,410	15.60	35,000	16.67
2012	1,108,980	-2.67	10,843	-69.02
Average	1,066,749	4.08	31,384	-23.70

Source: National Sugar Development Council, Abuja.

A foremost objective in breeding sugarcane is an increase in the yield of sugar. Sugar yields are determined by two complex traits reported as important characters for the development of superior genotypes; the yield of cane and the percentage of sucrose in juice (Terzi *et al.*, 2009). Yield in sugarcane and other quality traits of agronomic importance are subject to environmental influences because they are quantitatively inherited. They are predisposed to the influence of some other traits that have direct or indirect contribution to yield (Chaudary and Joshi, 2005). In order to increase productivity, varietal improvement which discriminates in favour of promising genotypes and improve those genotypes should be done. New varieties can also be developed by selecting clones derived from true seeds obtained from hybrids of a cross of superior parents (Mehareb *et al.*, 2017).

Sugarcane breeding is a complex task due to the crop's high ploidy level and heterozygous nature (Tiawari *et al.*, 2011). However, in spite of its genetic complexity, obtaining new genotypes

from the segregating F_1 progenies is relatively easy since subsequent advancement of superior genotypes from one generation to the other is by vegetative propagation coupled with testing for good yield and adaptation over several cropping seasons within target environments representative of different regions (Guilly *et al.*, 2017). Furthermore, it is also a practice on farms to substitute varieties regularly with new clones in order to maintain high yields over the years (Ali *et al.*, 2017). The efficacy of selection in plant breeding relies mainly upon the direction and the degree of the association between yield and its components and also the relative importance of each of the factor which contributes to yield (Ahmad and Saleem, 2003). The desire of every farmer is high yield which is a product of association among various growth and yield parameters. The available information about this association assists in putting in place a breeding plan to improve the yield (Adesoji *et al.*, 2015).

Genotypic and phenotypic correlation coefficient analysis can serve as guide to breeders for selecting the best genotypes.

Association between characters provides the information on how strongly such traits are genetically associated with one another, thus correlation estimates among the yield components are the basis for selection of superior genotypes from the different breeding populations (Tena *et al.*, 2016). However, the complexity of the yield, its association with other component traits and the relationship of these traits with one another renders correlation coefficient unproductive as an index for selection (Shaileshkumar, 2006). The use of path coefficient analysis provides the effective measure of direct and indirect source of association and exposes the status of each component trait which contributes to the final product (Jakhar *et al.*, 2017). It will aid selection of parental materials for the purpose of making crosses, the breeder is also armed with the knowledge of how a component character influences other characters. The present study was therefore conducted with the aim to assess the relationship of certain morpho-physiological parameters with cane yield in order to establish an appropriate selection criterion for our sugarcane breeding program.

MATERIALS AND METHODS

Description of experimental materials and experimental sites

The genetic materials used for this study comprised 40 sugarcane varieties selected among over 300 clones presently maintained in the Unilorin Sugar Research Institute (USRI) germplasm collection. The materials which were selected based on superiority for morpho-physiological attributes are representative of six different sugarcane breeding stations within and outside Africa (Table 1). The sugarcane clones were planted in two agro-ecologies: Ikenne (Rainforest zone located on longitude 6° 52'N and latitude 3° 42'E) has an annual rainfall and temperature range of 1000-1200 mm and

22° C – 32.2° C, respectively) and Agenebode (southern Guinea savannah is located on longitude 7° 6'N and latitude 6° 42'E with annual rainfall of 1300-1500 mm and temperature range of 28°C - 34° C.) Rainfall distribution pattern over a five-year period (including the period of field trials) is multimodal on both sites, with the highest peak in September of every year at Agenebode and between July and September at Ikenne depending on the year. The dry months on both sites are between December of the preceding year and February of the following year.

Field experimentation

The trials were established at Ikenne between 30th May and 3rd June, 2013 and at Agenebode between 11th and 14th December, 2013. Each trial was laid out as a randomized complete block design with four replicates within a block and a block comprised twenty (20) varieties. Each plot was six (6) rows, 10 m long and 1.3 m between the rows. The cane setts used were three-eyed cane setts of 6-7 months which were also free from diseases and pests. Thirty (30) cane setts were laid horizontally end-to-end per in row. Weeds were controlled by pre-emergence application of Primextra Gold[®] [proprietary mixture of metolachlor (290 g/L) and (370 g/L)] at 2.5kg a.i./ha at planting followed by supplementary directed sprayed of glyphosate at 2.0kg a.i./ha when necessary. NPK fertilizer was applied at the rate of 150 kg N, 60 kg P and 90 kg K in equal halves (split dose) at planting and at 8 – 10 weeks after planting.

Data collection

Data were collected each year from the four inner rows (i.e. net plot) on various parameters including germination count at 21 days after planting (DAP) and 42 DAP respectively, rating for disease infection (especially smut) beginning from 3-4

months after planting (MAP), monthly tiller count, stalk length (tape measurement), stalk diameter (Vernier caliper) from 6MAP and brix content (hand refractometer) from 8 MAP. Ten stalks which were sampled for brix content every month till harvest were also used to collect data on stalk height and diameter respectively. Ten randomly selected stalks within the net plot were cut at the base and the average of individual weights, using weighing scale, was recorded as single stalk weight for each variety while the total number of cane stalks with diameter ≥ 1.5 cm was counted for each plot as millable cane population. Canes from the net plot were harvested and weighed to obtain cane weight/plot and was later converted to tons per hectare.

Data analyses

Individual and combined analyses of variance were performed using a mixed model in SAS version 9.3 (SAS Institute, 2009). Replication, crop cycle and environment were considered as random effects while genotypes were considered as fixed effects. Path analysis and estimates of phenotypic correlation across locations were done. Significant means were separated with the use of least significant difference (LSD) as outlined by Steel and Torrie (1980).

RESULTS

Means for cane yield and associated traits in each of the cropping cycles and planting sites are presented in Table 2. Cane yield was significantly higher at Agenebode compared to Ikenne in the plant and first ratoon crops while the reverse was the case in the second and ratoon crops. While Brix remained relatively stable regardless of the crop cycle and planting site. There was a steady reduction in cane yield in subsequent ratoon crops on both sites.

There was no definite trend on the other characters such as the length, diameter, millable population and single stalk weight either in the subsequent ratoon or at particular site except for stalk diameter which declined in subsequent ratoon crops at Agenebode.

The results of interrelatedness between cane yield and other traits are presented in Table 2 and 3. Stepwise multiple regression analyses for of cane yield showing the contribution of component traits in sugarcane (Table 2). Results show that millable stalk, plant height, stalk length and tiller count gave a total contribution of 18.83% to cane yield, with millable stalk showing the largest involvement having contributed about 15%. Results further showed that these contributions are highly significant for all the characters which is a suggestion that the above traits govern how yield of cane varies with respect to their percentage of contribution.

Table 4 shows the phenotypic correlation between cane yield and yield component of sugarcane varieties. Results show that tiller count ($r = 0.66^{**}$) plant height ($r = 0.65^{**}$), stalk girth ($r = 0.54^{**}$), millable stalks ($r = 0.69^{**}$) were positively correlated with cane yield while Brix value (-0.41^{**}) and the associations were highly significant.

Path coefficient analysis revealed the direct positive effect of millable stalks (0.14), plant height (0.37) and tiller count (0.35) on the response variable (cane yield). The direct result of millable stalk on yield in sugarcane was stated by Kang *et al* (1989) and Chaudry and Joshi, (2005). Stalk length had a low and negative direct effect (-0.09) on cane yield but had a positive indirect effect through tiller count, plant height and millable stalk.

Table 1b: List of the 40 sugarcane varieties evaluated in Ikenne and Agenebode (Southern Nigeria).

S/N	Variety	Point of collection	S/N	Variety	Point of Collection
1.	B0072	Barbados	21.	D8687	Demarara
2.	B74541	Barbados	22.	KN93067	Sudan
3.	B77602	Barbados	23.	KNH80412	Sudan
4.	B80689	Barbados	24.	M1176/77	Mauritius
5.	B85266	Barbados	25.	M1246/84	Mauritius
6.	B85877	Barbados	26.	M1334/84	Mauritius
7.	B93310	Barbados	27.	M1672/90	Mauritius
8.	B98653	Barbados	28.	M1861/89	Mauritius
9.	BR042008	Barbados	29.	M1954/91	Mauritius
10.	RB82/5211	Brazil	30.	M2238/89	Mauritius
11.	BR971007	Barbados	31.	M2256/88	Mauritius
12.	BR98006	Barbados	32.	M2593/92	Mauritius
13.	BT871646	Barbados	33.	M703/89	Mauritius
14.	Co6806	Coimbatore	34.	RB72/454	Brazil
15.	Co8605	Coimbatore	35.	RB86/3129	Brazil
16.	Co88025	Coimbatore	36.	RB94/2991	Brazil
17.	Co91017	Coimbatore	37.	SP71-6180	Brazil
18.	Co94102	Coimbatore	38.	SP81-3250	Brazil
19.	Co9906	Coimbatore	39.	B47419+	Barbados
20.	CoC671	Coimbatore	40.	Co997+	Coimbatore

+: Check entry

Table 2: Means for cane yield and related traits in different crop cycles in two planting sites in southern, Nigeria

Crop cycle(CC)	Stalk characteristics				°Brix	Cane yield (t/ha)	%Reduction relative to plant crop
	Length (cm)	Diameter (cm)	Millable population (number/plot)	Single stalk weight (kg)			
Agenebode (southern Guinea savannah Zone)							
Plant crop	197.30	2.52	164	2.41	21.73	76.83	
First Ratoon	390.90	2.43	152	1.13	22.95	62.63	18.48
Second Ratoon	207.30	2.33	164	1.17	21.10	43.06	43.95
Third Ratoon	177.29	1.06	153	1.18	18.37	39.10	49.11
Ikenne (Rain forest Zone)							
Plant crop	162.30	2.36	141	2.61	20.09	69.45	
First Ratoon	158.00	0.78	109	1.23	18.43	52.38	24.58
Second Ratoon	253.20	1.08	110	1.08	22.00	51.64	25.64
Third Ratoon	253.00	2.29	195	2.14	21.18	45.02	35.18
LSD _{0.05} (PS)	19.14	0.06	9.27	0.34	0.53	7.25	
LSD _{0.05} (CC)	10.98	0.18	33.40	0.06	1.30	14.30	
LSD _{0.05} (PS x CC)	24.59	0.18	43.54	0.55	1.36	18.57	

PS= Planting Site

PS= Planting Site

DISCUSSION

Yield improvement is given topmost priority in most breeding programs (Cox *et al.*, 1996) however, direct selection for yield sought by breeders have been complicated by the complex nature of its inheritance and also because of the negative correlation between cane yield and other traits of importance like percent brix. To increase yield, selection for component traits that have a high heritability and a positive correlation with yield is usually done in breeding programmes (Sabesan *et al.*, 2009; Ullah *et al.*, 2011, Ogunbayo *et al.*, 2014).

The use of regression and correlation coefficient analyses reveals the genetic relationship that exists with yield and other yield related traits, it also shows their association with the various environment. The significant contribution of millable stalk, plant height, stalk length and tiller count imply that the yield of cane is dependent on these contributing characters especially on millable stalk. This therefore shows that an increase or improvement in millable stalk will be significant on the cane yield of sugarcane. The above corroborates the findings of Hussein *et al.* (2012) who reported millable stalk as one of the contributory traits to the yield of sugarcane.

Correlation coefficient between cane yield and its component traits may be due to genetic association among the characters which is of utmost importance to a breeder. The strong correlation between component traits and cane yield suggests that the traits could be improved simultaneously. This is in line with the findings of Khan *et al.*, (2012) who reported positive and significant association between the yield of cane, its girth, the weight per stool, yield of sugar, number of tiller and percent purity among twelve sugarcane clones. Ali *et al.*, (2017) also stated that positive correlations was

observed between all measured traits among sugarcane genotypes. Percent brix however had a negative and significant correlation with cane yield suggesting a converse relationship between traits and this implies that both traits cannot be improved simultaneously. The negative correlation observed between these traits is in agreement with the findings of Tahir *et al.*, (2014), Sanghera *et al.*, (2015), Shikanda *et al.*, (2017) also reported that among sugarcane, the association between cane yield and percent brix is negative in nature. Therefore, the higher the yield of cane, the lesser the percent brix content. Path coefficient analysis allows the decomposition of the correlations into the components of direct and their indirect effects through other component characters by partitioning correlation which helps breeders to identify the traits that can be used as a criterion for selection in a breeding programme (Vinesh *et al.*, 2018). Therefore, it is more effective when selection is carried out for correlated characters that have a direct influence on yield, necessitating the use of path coefficient analysis which is an excellent tool for assessing direct and indirect effect of the component traits on complex traits (Kang *et al.*, 1989). In other words, correlation did not explain the true relationship between these characters and indirect effects through some other traits seem to be the cause of the correlation. Khan *et al.*, (2013) stated that the association of yield with its components could result from a direct effect or an indirect effect through some other components traits. Tena *et al.* (2016) also reported similar results. The influence of number of stalks, its diameter, length and single cane weight on cane yield have been reported by Shanmuganathan *et al.* (2015) and Sanghera *et al.* (2017). From the results of this study, it can be concluded that correlation studies revealed that cane yield of sugarcane had positive and

significant associations with all the other component traits studied except brix value which was also significant but negatively correlated. Characters like millable stalks, tiller count, plant height and stalk length made the greatest direct contribution to cane yield of sugarcane.

These yield-contributing components were also involved in the contribution of other characters to cane yield. Therefore, these characters should be considered as important selection criteria for the improvement of these varieties for higher yield.

Table 3: Summary of Stepwise multiple regression of cane yield on other agronomic traits of Sugarcane

Characters	Partial R	% Contribution to Yield	F-value
Millable stalk	0.1501	15.01	225.64**
Plant height	0.0177	1.77	27.17**
Stalk length	0.0107	1.07	16.62**
Tiller count	0.0098	0.98	15.40**

** Significantly different at 0.01 level of probability

Table 4: Phenotypic correlation coefficients for yield and component traits in sugarcane varieties

	Tiller count	Plant height (cm)	Stalk girth (cm)	Stalk length (cm)	Millable Stalks	Brix value	Cane Yield
Tiller count							
Plant height, cm	0.62**						
Stalk girth (cm)	0.16	0.35*					
Stalk length (cm)	0.34*	0.43**	-0.04				
Millable Stalks	0.86**	0.78**	0.17	0.34*			
Brix value	-0.22	-0.25	-0.13	-0.02	-0.22		
Cane Yield	0.66**	0.65**	0.54**	0.23	0.69**	-0.41**	

Table 5: Direct and indirect effects of first order predictor variables on cane yield of sugarcane.

Traits	Tiller count	Plant height (cm)	Stalk length (cm)	Millable Stalks
Tiller count	0.35	0.23	-0.03	0.12
Plant height (cm)	0.21	0.37	-0.04	0.11
Stalk length (cm)	0.12	0.16	-0.09	0.05
Millable Stalks	0.30	0.29	-0.03	0.14

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REFERENCES

- Adesoji, A.G., Abubakar, I.U. and Labe, D.A. 2015. Character Association and Path Coefficient Analysis of Maize (*Zea mays* L.) Grown under Incorporated Legumes and Nitrogen. *Journal of Agronomy*, 14 : 158 - 163 . [doi: 10.3923/ja.2015.158.163](https://doi.org/10.3923/ja.2015.158.163)
- Ahmed, S.A. and Alsharief, H. (2009). *Master plan for the Nigerian sugar sector*. A Kelele Nigeria Limited Document. Pp. 89
- Ahmad, A. and Saleem, M. 2003. Path coefficient analysis in *Zea mays* (L.). *International Journal of Agricultural Biology*, 5: 245-248.
- Ali, A., Khan, S.A., Farid, A., Khan, A., Khan, S.M. and Ali, N. 2017. Assessment of sugarcane genotypes for cane yield. *Sarhad Journal of Agriculture*, 33(4): 668-673. <http://dx.doi.org/10.17582/journal.sja/2017/33.4.668.673>
- Ali, A., Khan, S.A., Tahir, M., Farid, A., Khan, A. 2018. Evaluation of Various Sugarcane Genotypes for Association of Quality Characters with Cane Yield. *Advance Crop Science Technology* 6: 371. [doi:10.4172/2329-8863.1000371](https://doi.org/10.4172/2329-8863.1000371)
- Chaudhary, R.R. and Joshi, B.K. 2005. Correlation and Path Coefficient Analyses in Sugarcane. *Nepal Agricultural Research Journal*, 6: 24-27
- Darvasi, A. and Pisanté-Shalomm, A. 2002. Complexities in the Genetic Dissection of Quantitative Trait Loci. *Trends in Genetics*, 18:489-491. [http://dx.doi.org/10.1016/S0168-9525\(02\)002767-1](http://dx.doi.org/10.1016/S0168-9525(02)002767-1)
- Guilly, S., Thomas D., Audrey T., Laurent B., Jean-Yves H. 2017. Analysis of multienvironment trials (MET) in the sugarcane breeding program of Reunion Island. *Euphytica* 213:213 DOI 10.1007/s10681-017-1994-1
- Hogarth, O.M. 1971. Quantitative Inheritance Studies in Sugarcane: Correlations and Predicted Responses to Selection. *Australian Journal of Agricultural Research*, 22:103-109. <http://dx.doi.org/10.1071/AR9710103>
- Hussein, M. A., Hayam, S. F., Fares, W.M., Ahmed, S. A. 2012. Multivariate Analysis of Sugar Yield Factors in Sugar Cane. Multivariate Analysis of Sugar Yield Factors in Sugar Cane. *American-Eurasian Journal of Sustainable Agriculture*, 6(1): 44-50, 2012 ISSN 1995-0748
- Jakhar, D.S., Singh, R. and Kumar, A. 2017. Studies on Path Coefficient Analysis in Maize (*Zea mays* L.) for Grain Yield and Its Attributes. *International Journal of Current Microbiology and Applied Sciences* , 6 : 2851 - 2856 . <https://doi.org/10.20546/ijcmas.2017.604.327>
- Jamoza, J.E. 2011. Genetic and phenotypic relationship among some yield components in sugarcane pp. 1-2, 10-20, 79-81, 95-97.
- Kang, M.S., Sosa, O. and Miller, J.D. 1989. Path analyses for per cent fiber and cane and sugar yield in sugarcane. *Crop Science*, 29 (6): 1481-1483. <http://dx.doi.org/10.2135/cropsci.1989.0011183X002900060032x>
- Khan, I.A., Bibi, S., Yasmin, S., Khatrri, A., Seema, N. and Abro, S.A. 2012.

- Correlation studies of agronomic traits for higher sugar yield in sugarcane. *S.M. Pakistan Journal of Botany*, 44:969.
- Khan, I.A., Nighat, S., Raza, S., Yasmine, S. and Sajida, B. 2013. Environmental interaction of sugarcane genotypes and yield stability analysis of sugarcane. Nuclear Institute of Agriculture, Tando Jam, Pakistan. *Pakistan Journal of Botany*, 45(5):1617-1622.
- Mehareb, E.M., Kun, Y., Jun, Z., Aboelenen, F.F., Wei, Q., Fenggang, Z., Jiayong, L., Hongming, X., Li, Y., Peifang, Z., Yong, Z., and Caiwen, W. 2017. Evaluation of seventy-six sugarcane families at early selection stages. *Journal of Plant Breeding and Crop Science*, 9(9): 151-159.
- Ogunbayo S.A., M. Si, D. K. Ojo, K. A. Sanni, M. G. Akinwale, B. Toulou, A. Shittu, E. O. Idehen, A. R. Popoola, I. O. Daniel and G. B. Gregori 2014. Genetic variation and heritability of yield and related traits in promising rice genotypes (*Oryza sativa* L.). *Journal of Plant Breeding and crop science* Vol. 6(11), pp. 153-159, November 2014 DOI: 10.5897/JPBCS2014.0457
- Ramburan, S., Dlamini, N. and Labuschagne, M. 2018. Genotype x environment interactions and optimum resource allocation for sugarcane yield trials in Swaziland. *Journal of Crop Improvement*. 1-12. 10.1080/15427528.2018.1445680.
- Risch, N.J. 2000. Searching for Genetic Determinants in the New Millennium. *Nature*, 405, 847-856. <http://dx.doi.org/10.1038/35015718>
- Sanghera, G.S., Singh, H., Singh, R.P., Tyagi, V. and Thind, K.S. 2017. Interrelationship Patterns among Cane Yield Attributes and Physiological Traits in Sugarcane under Normal and Water Stress Conditions. *Journal of Experimental Agriculture International*, 17(4): 1-11.
- Shaileshkumar C. M. 2006. Variability, correlation, path analysis, genetic divergence and stability analysis in Sugarcane (*Saccharum* spp.). A PhD thesis submitted to Navsari Agricultural University Navsari. 238p
- Shanmuganathan, M., Annadurai, K., Nageswari, R. and Asokhan, M. 2015. Evaluation of sugarcane clones for quantitative yield and quality characters in aicrp trials for early season. *Electronic Journal of Plant Breeding*, 6(1): 292-297
- Steel, R.G.D. and Torrie, J.W. 1960. *Principles and procedures of statistics with special reference to the biological science*. McGraw Hill Book Company, INC. New York.
- Tahir, M., Khalil, I.H., McCord, P.H., Glaz, B. 2014. Character association and selection indices in sugarcane. *American Journal of Experimental Agriculture* 4: 336.
- Tena, E., Mekbib, F. and Ayana, A. 2016. Correlation and Path Coefficient Analyses in Sugarcane Genotypes of Ethiopia. *American Journal of Plant Sciences*, 7:1490-1497. <http://dx.doi.org/10.4236/ajps.2016.710141>
- Terzi, F.S.P., Rocha, F.R., Vencio, R.Z.N., Felix, J.M., Branco, D.S. and Waclawovsky, A.J. 2009. Sugarcane Gene Associated with Sucrose Content. *Genomics*, 10: 1471-2164.
- Tiawari, D.K., Pandey, P., Singh, R.K., Singh, S.P. and Singh, S.B. 2011. Genotype x Environment Interaction and

Stability Analysis in Elite Clones of Sugarcane (*Saccharum officinarum* L.). *International Journal of Plant Breeding and Genetics*, 5: 93-98.

Ullah, M.Z., Bashar, M.K., Bhuiyan, M.S., Khalequzzaman, M., Hasan, M.J. 2011. Interrelationship and cause-effect analysis among morpho- physiological traits in biroin rice of Bangladeshi. *International Journal of Plant Breeding and Genetics*. 5:246-254. <http://dx.doi.org/10.3923/ijpbg.2011.246.254>

Vinesh, B., Prasad, L.C. and Ravindra, P. 2018. Character Association and Partitioning of Correlations of Yield and Its Attributing Traits in Late Sown Barley (*Hordeum vulgare* L.). *International. Journal of Current Microbiology and Applied Sciences*. 7(7): 2020- 2026. doi:<https://doi.org/10.20546/ijcmas.2018.707.238>