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Estimation of genetic parameters of sugarcane *(Sacharrum officinarum* L.*)* varieties grown at Arjo-Dedessa sugar Projest, Western Ethiopia

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Abstract

In Ethiopian, sugarcane is grown as Agro-industrial crop since 1962. Now the country is under the expansion of its old sugar states and establishing of new projects but the numbers of improved varieties are so limited. Testing of the commercial varieties at new project's environment and select the best performing ones, is a major task of the research and development center. To make realistic selection of best performing varieties, it is mandatory to know traits having high values of heritability. Hence, this work was initiated with the aim of estimating genetic parameters of twelve sugarcane varieties planted in randomized complete block design. The treatments were replicated in threes; agronomic data of plant cane and first ratoon were collected and analyzed by SAS software. The tested varieties were significantly different for all traits at 5% level of significance and genotypic and phenotypic variance, GCV and PCV, heritability in broad sense (h^2) and genetic advance as percent of mean were calculated for all traits taken. Low genotypic variances were obtained as compared to the corresponding phenotypic variances for the traits taken. High GCV and heritability coupled with high genetic advance as percent mean were obtained for sugar yield per hectare per month. Hence, selection based on sugar yield per hectare per month is an appropriate trait for variety improvement program.

Keywords: Variety, broad sense heritability (h^2), genetic advance as percent of mean

1. Introduction

Sugarcane is a perennial, monocotyledonous crop plant which is cultivated in the tropical and sub-tropical regions of the world primarily for its ability to store high concentrations of sucrose or sugar in the inter-nodes of the stem (Negi et al., 2017). In Ethiopian, it is grown as Agro-industrial crop since 1962. Now, the country is expanding its old sugar estates and establishing new projects at different regions to satisfy its domestic sugar demand and earn foreign currency. But the numbers of improved varieties are so limited as compared to the size of the area of cultivation and environmental diversity owned by both old estates and the new projects. Not only scarcity of varieties but also their yielding potentials are decreasing from time to time.

Variety improvement is a key to solve the problems of the sugar industries with respect to diversifying the gene pool of improved varieties for increasing both the cane and sugar yield, tolerant to different environmental tresses like salinity and acidity of soils, water shortage etc. Hence, research and development center of the sugar Corporation of country is importing different varieties in the form of fuzz and sett and collecting local landraces from different regions of country. Beside to this, testing and selecting the best performing commercial varieties of the old sugar estates for environments of the new projects is another major task of the center.

Sugarcane is a highly heterozygous and complex polyploidy in its nature. So, this has resulted in generation of genetic variability and opportunity for improvement and selection. But the information on the nature and magnitude of the genetic variability is the prime prerequisite for a breeder to initiate any effective selection program (Swamy Gowda1 et al, 2016). Environmental factors (biotic and abiotic) are the determining factors for the heritability of traits of sugarcane varieties. Thus, for successful selection programme, it is important to know which traits give the highest estimates of heritability and which are the most repeatable over a number of seasons (O'reilly et al, 1999). In general, estimates of genotypic and phenotypic variance for various quantitative characters and their heritability are necessary for realizing effective selection of performing varieties. Therefore this work was initiated with the objective of estimating the genetic parameters of commercial varieties of the old sugar estates grown at Arjo-deddesa suagr project.

2. Materials and Methods

2.1. Description of the Study Site

Arjo-Dedessa sugar factory is located at Western Ethiopia of Oromiya Regional State in Eastern Wollega, Eilu Ababora and Jimma Zones at the Dedessa rift valley at a distance of 540 kilo meters from the capital city of the country (Addis Ababa) through the route of Addis Ababa to Jimma -Beddelie-Nekemet road. The altitude of the area is 1,350 meters above sea level while its annual rainfall is 1,400 millimeter. During the trial period, the metrology station was not established at the site; hence the meteorological data was taken from the feasibility report. The project area is categorized under warm sub-humid tropical climatic zone with the unimodal rainfall lasting from May to October. The mean temperature of the area is 22.51^{0}C with annual average maximum and minimum temperatures of 25.4^{0}C and 20.5^{0}C respectively. The average relative humidity of the area is 75.51% ranging from average maximum to average minimum of 88.6% and 56.6% respectively.

2.2. Description of the Treatments and Experimental Design

2.2.1. Methodology

B52-298, Nco-334, B41-227, Co449, Co678, Mex54-245, N53-216, N-14, Nco-376, D42-58, Co740, and Co-680 are commercial varieties at older sugar estates of the country. Equal number of three budded setts of each variety were planted .The experiment was laid out in completely randomized block design with three replications of the varieties (treatments). The dimension of each experimental plot was 6 furrows with of 5m length. Each furrow has a width of 1.45m and the distance between adjacent plots was also 1.5m. The space between blocks and border crop was 2m and 3m respectively. All agronomic managements were adopted uniformly throughout the growing season as per the practice of the plantation of the project.

2.2.1. Data Collection and Analysis

Data were collected from the four central rows of each plot throughout the growing period including number of milleble cane, number of internodes, cane height, single cane weight, cane yield, sucrose percent cane and sugar yield of plant cane and ratoon. All data collected for each characters were subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS) software version 9.2 (SAS, 2008). Finally genetic parameters were estimated with the following formulas.

2.2.2.1. Estimation of Genotypic and Phenotypic Variances

Genotypic and phenotypic variances were calculated by method suggested by Burton and Devane (1953),

$$\text{Genotypic variance } \left(\sigma_g^2\right) = \frac{\text{GMS} - \text{EMS}}{r},$$

Where GMS is genotypic mean square, EMS is error mean square, r is number of replication, and

$$\textbf{Phenotypic variance is } (\sigma^2 p) = \sigma^2 g + \sigma^2 e$$

2.2.2.2. Estimation of Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV)

Phenotypic and genotypic coefficients of variation were estimated according to Singh and Chaundary (1977).

$$GCV = \sqrt{\frac{\sigma^2 g}{\bar{x}}} \times 100$$

Where;
$\sigma^2 g$- genotypic variance and $\bar{X}$ =grand mean

$$PCV = \sqrt{\frac{\sigma^2 p}{\bar{x}}} \times 100$$

Where,

$\sigma^2 p$= phenotypic variance and $\bar{X}$ =grand mean

2.2.2.3. Estimation of Heritability

Heritability in broad sense (h^2) was estimated according to Falconer (1989):

$$h^2 \text{ (Broad sense heritability)} = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where
$\sigma^2 g$ =genotypic variance and $\sigma^2 ph$ = phenotypic variance

2.2.2.4. Estimation of Genetic Advance

Genetic advance (GA) was estimated accordance the methods suggested by Singh and Chaudhury (1985):

$$\text{Genetic advance (G.A)} = K.\ \sigma\ p.\ h^2$$

Where
h^2 =heritability in broad sense, K=selection differential value which is 2.06 at 5% selection intensity, and σp=phenotypic standard deviation

Genetic advance as percentage of mean was calculated;

$$\text{GA (as per cent of mean)} = \frac{GA}{\bar{x}} \times 100$$

Where

GA= genetic advance, $\bar{X}$ = grand mean of characters

3. Results and Discussion

The analysis of variance indicating that the varieties were highly significant for all the characters studied (Table 1).This indicates that considerable amount of genetic variability was exist among them and there would be high extent of investigation of the examined characters of these varieties for improvement. Similar results were found by Bora et al., (2014) and Negi et al., (2017).

As indicated in (Table 2) all of the characters taken exhibited low genotypic variances as compared to its counterpart phenotypic variances. This implies that there is high influence of environment on the expression of these characters and it contradicts with result reported by Patel and Patil, (2017). PCV and GCV values considered to be high (>20), intermediate (10-20) and low (0-10) according to Shivasuburamanian and Menon, (1973). Low GCV values were exhibited by stalk length (8.8), stalk diameter (9.9), brix (8.3) and purity (2.8), intermediate for number of internodes (10.6), single cane weight (millable cane (12.6), poll percent (10.2), sucrose percent (11.7) and cane yield ton per hectare per month (17.5) and high only for sugar yield ton per hectare per month (23.4). Low PCV was exhibited only by purity (6.0) where as intermediate PCV values were obtained for stalk length (14.4), stalk diameter (11.8), number of internodes (17.0), brix (14.2), poll percent (15.8) and sucrose percent (17.8). High PCV values were recorded for single cane weight (26.9), millable cane (26.1), cane yield ton per month (28.8) and sugar yield ton per hectare per month (30.2). Similar results were investigated by Swamy Gowda et al., (2016). Low PCV and GCV values for purity are in agreement with result reported by and Negi et al., (2017) and Patil and Patel, (2017). High PCV and GCV values obtained in this investigation for sugar yield are in agreement with the result obtained by Esaya et al., (2016). This showed that sugar yield tone per hectare per month is under the influence of genetic control hence it suggest that better improvement by selection based on this trait is reliable.

The estimation of heritable variation with the help of genetic coefficient of variation alone may be misleading (Negi et al., 2017). Therefore genotypic coefficient of variation is not a correct measure to

Table 1 .Analysis of variance for 11 characters of 12 sugarcane varieties

Parameters	Block Df=2	Variety Df=11	Year Df=1	Variety x Year Df=11	EMS	CV (%)	R^2	Mean
Stalk Length(SL)	0.129 ns	0.229**	14.97**	0.119*	0.048	11.17	0.896	1.96
Stalk Diameter (SD)	19.59**	38.90**	446.00**	3.15ns	2.32	6.17	0.899	24.69
Number of Internodes(NI)	34.63 ns	52.62**	910.22**	44.04**	11.10	13.37	0.80	24.92
Single Cane Weight(SW)	0.084 ns	0.136**	5.89**	0.027ns	0.04	22.029	0.81	0.91
Millable Cane in 1000/ha(MC)	4250.01*	2506.74**	30151.50 **	788.09ns	730.24	22.81	0.69	118.24
Brix (%) (BX)	6.13 ns	18.00**	1303.90**	5.78ns	4.397	11.52	0.89	18.20
Puol % (PoL)	11.28 ns	20.94**	846.66**	6.64ns	3.98	12.08	0.86	16.52
Purity(PU)	61.53 ns	62.02*	351.13**	38.45ns	23.40	5.31	0.59	91.01
Sugar Percent cane(SP) %	9.08*	13.16**	307.93**	4.49ns	2.37	13.45	0.82	11.46
Cane yield ton/ha /moth(CY)	0.11 ns	8.75**	60.22**	1.64ns	1.93	22.78	0.70	6.09
Sugar yield ton/ha/moth(SY)	0.019 ns	0.205**	1.74**	0.09*	0.024	20.67	0.82	0.74

*** Significant at 1% level, * Significant at 5% level and ns- refers for non-significant, SL =Stalk length (m), Diameter (mm), NI = Number of Internodes, SW=Single cane weight (kg), MC=Number of Millable cane per ha in 1000s, CY =Cane yield in tone per ha per month, BX=Brix in %, PoL=Pol %, PU=Purity in %, SP=Sugar yield % cane, SY=Sugar yield tone per ha per month*

Table 3. Genotypic Variance, Phenotypic Variance, Genotypic Coefficient of variation (GCV), Phenotypic Coefficient of variation (PCV), Heritability (h^2), Estimation of Genetic Advance (GA) and Estimation of Genetic Advance as percent of mean result of eleven traits of sugarcane varieties

	Quantitative Traits										
Sources of Variation	**SL**	**SD**	**NI**	**SW**	**MC**	**BX**	**PoL**	**PU**	**SP**	**CY**	**SY**
$\sigma^2 g$	0.03	6.01	6.92	0.02	221.08	2.27	2.83	6.44	1.8	1.14	0.03
$\sigma^2 ph$	0.08	8.42	18.02	0.06	951.32	6.66	6.81	29.84	4.17	3.07	0.05
σg	0.17	2.45	2.63	0.14	14.87	1.51	1.68	2.54	1.34	1.07	0.2
σph	0.28	2.90	4.24	0.24	30.84	2.58	2.61	5.46	2.04	1.75	0.2
GCV	8.8	9.9	10.6	15.5	12.6	8.3	10.2	2.8	11.7	17.5	23.4
PCV	14.4	11.8	17.0	26.9	26.1	14.2	15.8	6.0	17.8	28.8	30.2
$h^2 b$	37.5	71.4	38.4	33.3	23.2	34.1	41.6	21.6	43.2	37.1	60.01
Genetic Advance	0.22	4.27	3.36	0.17	14.77	1.81	13.52	2.43	1.82	1.34	0.28
Genetic advance as % of mean	11.22	17.29	13.48	18.68	12.49	9.95	81.84	2.67	15.88	22.00	37.84

SL =Stalk length (m), DM=diameter (mm), NI = Number of Internodes, SW=Single cane weight (kg), MC=Number of Millable stalk per ha in 1000s, CY=Cane yield in tone per ha per month, BX=Brix in %, PoL=Pol %, PU=Purity in %, SP=Sugar yield % cane, SY=Sugar yield tone per ha per month.

know the heritable variation present and should be considered together with heritability estimates (Swamy Gowda et al., 2016). Heritability values are categorized as low (0–30 %), moderate (30–60 %), and high (60 % and above) (Singh et al, 1994). Low heritability values were obtained in this study for millable cane (23.2%) and purity (21.6%) which are similar with results reported by Ranjan and Kumar, (2017); but high heritability was obtained by Alam et al., (2017) for number of millable cane. This may be due to environmental and genetic difference of the varieties used in the study. Selections might be virtually impractical for these traits, due to the masking effect of environment on genotypic effects. Moderate heritability values were recorded for stalk length, number of internodes, single cane weight, brix%, poll%, sugar percent cane and cane yield ton per hectare per month as indicated in table 2, whereas high heritability was exhibited by stalk diameter (71.4) and sugar yield ton per hectare per month (60.01). This is in agreement with result reported by Ranjan and Kumar, (2010). So, selection breeding for improvement of these varieties based these traits may be reliable.

But heritability alone provides no indication of the amount of genetic improvement that would result from selection of individual genotype. Thus, information of heritability should be coupled with genetic advance. Genetic advance (GA) is referred as the improvement of characters in genotypic value for the new population compared with the base population. Genetic advance as per cent mean is categorized as low (0-10), moderate (10-20) and high (>20) as given by Johnson *et al.*, (1955). As indicated in table 2, high values of genetic advance as percent of mean were obtained for poll% (81.84), cane yield ton per hectare per month (22.0) and sugar yield per hectare per month (37.84). The high heritability coupled with high genetic advance was obtained only for sugar yield ton per hectare per month. Thus, sugar yield ton per hectare per month is under the control of additive genetic effects and it confirms that selection based on the phenotypic performance of this trait is best for variety improvement program. Similar results were reported by Esayas et al., (2016), Ranjan and Kumar, (2017) and Negi et al. (2017).

Sugar yield per hectare per month is less influenced by environment and it is highly heritable trait as compared to others. As presented in table 3, stalk length and diameter, number of internodes, single cane weight, brix, poll, sugar percent cane and cane yield per hectare per month were highly and positively correlated with sugar yield per hectare per month at 1% level of significance. Whereas purity has non-significant negative correlation with cane yield per hectare per month at 5% level of significance. Similar result was obtained by Esayas et al., 2016 for single cane weight, stalk diameter, poll% and sucrose percent cane where it contrasts for purity.

Table 3. Correlation coefficients of eleven traits

Pearson Correlation Coefficients

	SL	**SD**	**NI**	**SW**	**BX**	**PoL**	**PU**	**SP**	**MC**	**CY**	**SY**
SL	1	0.61**	0.77**	0.849**	0.781**	0.741**	-0.23*	0.69**	0.542**	0.64**	0.71**
SD		1	0.47**	0.75**	0.65**	0.63**	-0.10ns	0.60**	0.31**	0.53**	0.56**
NI			1	0.66**	0.59**	0.56**	-0.14ns	0.51**	0.38**	0.52**	0.58**
SW				1	0.761**	0.71**	-0.27*	0.64**	0.35**	0.67**	0.64**
BX					1	0.98**	-0.14ns	0.93**	0.57**	0.64**	0.60**
Poll						1	0.043ns	0.99**	0.55**	0.6**	0.60**
PU							1	0.20ns	-0.06ns	-0.01ns	0.04ns
SP								1	0.52**	0.62**	0.58**
MC									1	0.66**	0.58**
CY										1	0.82**
SY											1

Correlation coefficients where'' - significant at 5% '**'significant at 1% and 'ns'-non-significant and '-'negative correlation*

4. Conclusion and Recommendations

From this experiment, sugar yield ton per hectare per month is the trait which exhibited high value of GCV, broad sense heritability (h^2) and genetic advance as percent of mean as compared to the rest studied traits. Hence, selection of the best performing varieties based on sugar yield ton per hectare per month would be appropriate for selection breeding.

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