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Participatory Variety Selection Genetic Variability and Heritability of Ten Exotic Commercial Sugarcane Varieties at Finchaa Sugar Factory Huru Gudro Zone Oromiya Regional State Ethiopia

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Abstract

Over the last two decades, Finchaa sugar Estate had been using only two to three old varieties; introduced some ten to 30 years ago owing to their limited involvement in variety introduction and selection among others. Aiming to alleviate the bottlenecked variety shortage of the Estate, ten new promising candidate varieties were promoted to a larger plot experiment (0.5 hectare) and managed as per the users over the 2014 - 2015 growing seasons and evaluated in participatory variety selection (PVS) in the valley of the Finchaa Sugar Estate. Data were collected for sprouting percentage, number of tiller and millable cane, internode length and cane height, cane yield, sugar percent cane, and sugar yield for plant cane crop (PC). In the PVS, the users, however, had diploid their own selection criterion including looking for; diseases free rough spiny leaf; more populated, lodging tolerant, thick and tall stalk; smut resistant; strong bud; more sweet and early maturing variety. The users identified stalk population as their first indirect selection criteria of cane yield, among others. Similarly, based on the researchers' data, the analysis of variance for characters confirmed the existence of variability, among studied genotypes for different characters including millable stalk population, which showed medium genotypic and phenotypic coefficients of variations (15.32 and 17.30). Moreover, heritability estimates indicated high heritability for millable cane (78.46) and cane yield (64.85). Therefore, the selection criterion sett by the users was found highly complementary to that of the researchers, and as such showed high heritability. This confirmed that phenotypic expression of such characters can be effectively utilized in selection criteria to bring heritable improvement among sugar yield of sugarcane varieties. Accordingly, based on the research data and users' selection criterion, candidate varieties SP70-1284, C132-81 and C86-56 on luvisol; and SP70-1284 and C90-501 on vertisol were recommended for commercial production. Furthermore, the role of the PVS was confirmed highly valuable in final variety selection to incorporate the need of the users to maximize the user satisfaction over that of merely ended technology provision. Therefore, this paper details the participatory sugarcane variety selection diploid in the valley of Finchaa Sugar Estate Western Ethiopia.

Keywords: *Participatory selection; Sugarcane; Finchaa Valley; Ethiopia*

Introduction

Sugarcane (*Saccharum* spp. hybrids) is an important agro industrial crop and knowledge of heritability of agronomic traits is important in breeding program worldwide. The genetic variability present in the sugarcane cultivars, cultivated by the producers, has hybrid origin, generally. The *Saccharum officinarum* has been contributing for genetic variability in sugarcane more than *S. spontaneum, S. sinense* and *S. barberi* [1]. In the genetic breeding program of sugarcane, the main goal is to obtain new cultivars with more productivity and best industrial characteristics (Bicudo, 1987). Nowadays the plant breeding has been based on a common genetic base obtained by the pioneer ones from the beginning of the century, through inter crosses and retro crosses of *S. officinarum* [1].

Sugarcane varieties in commercial cultivation are complex polyploid. The heterozygous and polyploidy natures of this crop have resulted in generation of greater genetic variability. The information on the nature and the magnitude of variability present in the genetic material is of prime importance for a breeder to initiate any effective selection program. Coefficients of variation along with heritability as well as genetic advance are very essential to improve any trait of sugarcane because this would help in knowing whether or not the desired objective can be achieved from the material [2].

Though variability is there and effort of sugar cane breeders exert paramount energy and resource on selection of genetic materials spending several times breeders goal could not be achieved unless the involvement of major stakeholders on selection process. Most breeding experiments suffer from the disadvantage that the major stakeholders are not involved in the selection and development of the varieties. This scenario leads to poor adoption and diffusion of the resulting technologies (Osiru., *et al*. 2010). Participatory varietal selection is premised on the basis that only a small percentage of varieties developed by breeders are eventually utilized because farmers are left out of the selection process Olaoye., *et al*. (2009). Farmer's Participatory Varietal Selection is a way to overcome the limitations of conventional breeding by offering farmers the possibility to choose, in their own environment, the varieties that better suit their needs and conditions (Ceccarelli and Grando, 2007).

Therefore, Participatory sugarcane variety selection technique were done at Fincha Sugar estate to compare and select better sugarcane varieties among ten exotic commercial sugarcane varieties.

Material and Methods

Study Areas

The experiment were conducted at Fincha sugarcane plantation of Ethiopia; Finchaa (9^0 30' to 10^0 00' N; 37^0 30' E); 1600 m.a.s.l elevation. Average min/max temperature ranges 15to 31 C°

Treatments and experimental design

Twelve sugarcane varieties introduced from Cuba and designated by C86-12, C90-501, C86-165, C132-81, C120-78, C1051-73, B78-505, B80-250, SP70-1284, NCO334, B52-298 and C86-56 were evaluated at Fincha sugarcane plantation. The trial was laid out in completely randomized block design with three replications in luvisoil. Each experimental plot composed of 6 rows of 5m length. The spacing was 1.45m for furrows, 1.5m between adjacent plots, 2m between replications, and 3 meters from the border crop. Equal number of two budded sett of each variety was planted.

Data collected and analysis

Data were collected from the four central rows of each plot for sprouting percentage, number of tiller and millable cane, internode length and cane height, cane yield, sugar percent cane, and sugar yield for plant cane crop (PC). All the data were subjected to statistical analysis using Mini Tab 11.12 computer software.

For the sake of convenience especially to estimate heritability and genetic advance, data were analyzed as per RCBD [3]. Mean comparisons among treatment means were conducted by the least significant difference (LSD) test at 5% levels of significance. The analysis of variance was used to derive variance components [3].

RCBD ANOVA was computed using the following model:

$Y_{ij} = \mu + r_j + g_i + \varepsilon_{ij}$

Where, Y_{ij} = the response of trait Y in the ith genotype and the jth replication

μ = the grand mean of trait Y

r_j = the effect of the jth replication

g_i = the effect of the ith genotype

ε_{ij} = experimental error effect

Estimation of phenotypic and genotypic variances

The phenotypic and genotypic variances of each trait were estimated from the RCBD analysis of variance. The expected mean squares under the assumption of random effects model was computed from linear combinations of the mean squares and the phenotypic and genotypic coefficient of variations were computed as per the methods suggested by Burton and Devane [4].

Genotypic variance ($\sigma^2 g$) =

$$\frac{Msg - Mse}{r}$$

Environmental variance ($\sigma^2 e$) = Mse

Where;

Msg and Mse are the mean sum of squares for the genotypes and error in the analysis of variance, respectively r is the number of replications.

The phenotypic variance was estimated as the sum of the genotypic and environmental variances.

Phenotypic variance ($\sigma^2 ph$) = $\sigma^2 g + \sigma^2 e$

Estimation of genotypic and phenotypic coefficient of variability

The genotypic and phenotypic coefficients of variability were calculated according to the formulae of Singh and Chaundary (1977).

Genotypic Coefficient of Variation (GCV) = (σg/grandmean) * 100

Phenotypic Coefficient of Variation (PCV) = (σph/grand mean) * 100

Source of variation	Df	Mean square	Expected mean square
Replication	r-1	Ms_r	$\sigma^2 e + g\sigma^2 r$
Genotypes	g-1	Ms_g	$\sigma^2 e + r\sigma^2 g$
Error	(r-1) (g-1)	Ms_e	$\sigma^2 e$

***Table 1:** ANOVA.*

Where, r: number of replications; Msr: mean square due to replications; g: number of genotypes; Msg: mean square due to genotypes; Mse: mean square of error; $\sigma^2 g$, $\sigma^2 r$ and $\sigma^2 e$ are variances due to genotype, replication and error

Participatory Variety Selection

Sugarcane Production Participatory Plant Breeding (PPB) is a complement to conventional breeding approaches that builds on almost three decades of practical experience in numerous breeding programs and countries all over the world (Asheby., *et al.* 2014).

Treatments and experimental design

Ten exotic sugarcane varieties introduced from Cuba designated by C120-78, C1051-73, B78-505, B80-250, SP70-1284, C86-12, C90-501, C86-165, C132-81 and C86-56 were planted in Luvi and Verti Soil types each varieties on single non-replicated half hectare /5,000m^2/ and total area of five hectares /50, 000m^2/ in each soil type.

Methodology Description

Nineteen Fincha Sugar Factory Agriculture Production staff was participated after brief description of the importance of Participatory Variety Selection (PVS) by four Ethiopian Sugar Corporation Research Division Researchers.

Participants put their own variety selection criterion based on their practical production experience and give rank for each varieties. Finally, by collecting each participant score summery data were analyzed then the result of PVS compared and contrast with the research result.

Result and Discussion

Variances

The analysis of variance for characters confirmed the existence of highly significant variability among studied genotypes for INL, PH, SD, cm, chm and scs at p 0.01 level and significant variability were also resulted for shm at p 0.05 significance level (Table 2). This indicates that there was significant amount of phenotypic variability and all the genotypes differed from each other with regard to the characters that opened a way to proceed for further improvement through simple selection [5]. Rewati R Chaudhary [6] reported similar results for characteristics such as Millable Cane number, Single stock weight, Can height and Sucrose %. These result point to that there are wider variations among the studied genotypes possibly characters lead to design better sugar cane improvement breeding programs.

Source	Df	NI	INL	PH	SD	cm	chm	scs	shm
Replication	2	1.69	1.13	465.7	8.817	27.8	1.99	0.02	0.05
Genotypes	11	2.87	3.59**	1163.2**	10.791**	1256.9**	14.34**	3.52**	0.12*
Error	22	1.97	0.74	322.4	2.032	105.4	2.93	0.54	0.05

***Table 2**: ANOVA of eight for twelve studied characters.*

*** Significant at 1% level; * Significant at 5% level*

Where: Df: degree of freedom; NI: number of Internodes; INL: Internodes' length(cm); PH: Plant height(cm); SD: Stalk diameter(cm); cm: millebel cane (000/ha); chm: cane yield /ha/month; scs: Sucrose % and shm: Sugar yield/ha/month

Genotypic and phenotypic coefficients of variation

After separating components of variance, genotypic and phenotypic variance were computed and results indicated that medium GCV and PCV were recorded for Millable cane (15.32 and 17.30), Cane Yield (13.22 and 17.59) and low GCV and Medium PCV were recorded for Sugar Yield (8.73 and 15.05) while; number of inter node (2.64), cane diameter (6.28) and sucrose % (8.19) resulted low GCV (Table 3). Results of current study are not similar to Feyissa., *et al*. [7], Balasundarum and Bhagyalakshmi [8]; Nair., *et al*. [9] high genotypic coefficient of variation for millable cane were reported; this report is against to Singh and Sangwan [10] reported before High genotypic and phenotypic coefficients of variation for a cane weight and millable cane number. As stated by Shivasubramanian and Menon [11] the PCV and GCV values are ranked as low, medium and high with 0 to 10%, 10 to 20% and > 20% respectively. The estimates for phenotypic coefficient of variation (PCV) were higher than for genotypic coefficient of variation (GCV) in all the traits, indicating greater influence of environment on genetic variation. High GCV and PCV indicated that selection may be effective based on these characters and their phenotypic expression would be good indication of the genotypic potential [12].

Parameters	NI	INL	PH	SD	cm	chm	scs	shm
σ^2_g	0.30	0.95	280.27	2.92	383.83	3.80	0.99	0.02
σ^2_{ph}	2.27	1.69	602.67	4.95	489.23	6.73	1.53	0.07
σ_{ph}	1.51	1.30	24.55	2.23	22.12	2.59	1.24	0.27
σ_g	0.55	0.98	16.74	1.71	19.59	1.95	1.00	0.16
GCV	2.64	8.23	6.83	6.28	15.32	13.22	8.19	8.73
PCV	7.25	10.97	10.01	8.18	17.30	17.59	10.17	15.05

h2b	13.26	56.28	46.50	58.96	78.46	56.49	64.85	33.65
Gmean	20.78	11.85	245.24	27.22	127.85	14.75	12.16	1.78

Table 3: *Estimation of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), Broad sense heritability (hb2) for twelve studied genotypes.*

Where: σ^2_g = genotypic variance, σ^2_{ph}= phenotypic variance, $\boldsymbol{\sigma}_{ph}$= phenotypic standard deviation, $\boldsymbol{\sigma}_g$= genotypic standard deviation, GCV=genotypic coefficient of variation, PCV= coefficient of variation and h^2b= broad sense heritability

Heritability

Phenotypic and Genotypic coefficient of variation alone is not a correct measure to know the heritable variation present and should be considered together with heritability estimates. Therefore, heritability of traits should also in composed in setting better plan breeding strategy, as indicated in table three High heritability were recorded for characters such as cane yield (64.85) and millable cane (78.46); moderate heritability for internodes length (56.28), plant height (46.50), stalk diameter (58.96) and sugar yield (33.65), while low heritability were recorded for number of internodes (13.26) (table 3). Heritability values are categorized as low (0 - 30%), moderate (30 - 60%) and high (60% and above) as stated by Robinson., *et al.* [13].

Similar to present study high heritability estimates results were reported in Rewati R Chaudhary [6] for millable cane number (88%) and cane weight (84%), Nair., *et al.* [9] and Singh., *et al.* [12] reported similar results for mentioned characters. This indicates that simple selection for these traits would be effective method of sugar cane variety selection since these traits are highly heritable from parents to progenies. Selections might be considerably difficult or virtually impractical for a character with low heritability (less than 0.4) due to the masking effect of environment on genotypic effects [14-25].

Mean Comparison

Mean Comparison for yield and yield related parameters were done for Cane Yield (ton ha-1 month-1), Sucrose % Cane and Sugar Yield (ton ha^{-1} $month^{-1}$). The lowest average cane yield (ton $ha^{-1}month^{-1}$) was recorded on luvisol and vertisol at Finchaa (11.32 and 9.02). Significantly the highest cane yield was recorded by C86-12, C 132-81, SP70-1284, C86-56 and the check NCO334 on luvisol, and C86-165 and the check NCO334 on vertisol (Table 4).

Varieties	Cane Yield (ton ha^{-1} $month^{-1}$)		Sucrose %Cane		Sugar Yield (ton ha^{-1} $month^{-1}$)	
	Light Soil	Heavy soil	Light Soil	Heavy soil	Light Soil	Heavy soil
C86-12	12.29 ab	8.64 b-e	13.61 b-c	13.68 a	1.65 a	1.10 cd
C90-501	10.05 c	8.45 c-e	13.33 cd	13.60 a	1.33 eg	1.12 b-d
C86-165	11.77 b	10.13 a	13.46 c	13.39 ab	1.56 ab	1.31 a
C132-81	12.73 a	8.85 b-d	12.39 e	12.94 b	1.55 a-c	1.10 b-d
C120-78	9.64 c	8.63 b-e	13.58 bc	13.45 ab	1.31 fg	1.17 b-d
C1051-73	10.16 c	8.03 e	14.04 a	13.93 a	1.40 d-f	1.12 b-d
B78-505	9.71 c	8.13 de	12.99 d	13.35 ab	1.24 g	1.06 d
B80-250	8.82 d	8.68 b-e	13.96 ab	13.64 a	1.22 g	1.19 bc
SP70-1284	12.22 ab	9.32 b	13.36 cd	13.58 a	1.66 a	1.22 ab
C86-56	12.22 ab	9.26 bc	11.96 f	11.85 c	1.43 c-e	1.06 d
B52298	12.47 ab	10.17 a	12.26 ef	12.88 b	1.51 b-d	1.22 ab

Significance	**	**	**	**	**	**
LSD (5%)	0.813	0.716	0.380	0.564	0.113	0.122
CV%	5.07	14.07	18.86	7.44	13.73	15.93

Table 4: *Response of Ten xotic varieties for Cane Yield (ton ha^{-1} month^{-1}), Sucrose %Cane and Sugar Yield (ton ha^{-1}month^{-1}) in Luvisol and Vertisol at Finchaa.*

All of the candidates resulted in equal or significantly better sucrose % cane over the checks. In sugar yield, the average result of Finchaa, on luvisol indicated that six candidates, namely C86-12, C86-165, C132-81, C1051-73, SP70-1284 and C86-56; and on vertisol C86-12, C90-501 C86-165, C132-81, B80-250 and SP70-1284 performed statistically equal to the best check in sugar yield. Generally, in sugar yield per month, the highest record was obtained by SP70-1284 gave 1.66 t/ha/m while that of the check B52298 was 1.51 t/ha/m (9.93% over the check B52298).

Participatory Variety Selection

Plant breeding is the art and science of changing the traits of plants in order to produce desired characteristics. Plant breeding can be accomplished through many different techniques ranging from simply selecting plants with desirable characteristics for propagation, to more complex molecular techniques. Plant breeding has been practiced for thousands of years, since near the beginning of human civilization. It is now practiced worldwide by individuals such as gardeners and farmers, or by professional plant breeders employed by organizations such as government institutions, universities, crop-specific industry associations or research centers. International development agencies believe that breeding new crops is important for ensuring food security by developing new varieties that are higher-yielding, resistant to pests and diseases, drought-resistant or regionally adapted to different environments and growing conditions.

The development of agricultural science, with phenomenon like the Green Revolution arising, have left millions of farmers in developing countries, most of whom operate small farms under unstable and difficult growing conditions, in a precarious situation. The adoption of new plant varieties by this group has been hampered by the constraints of poverty and the international policies promoting an industrialized model of agriculture. Their response has been the creation of a novel and promising set of research methods collectively known as participatory plant breeding. Participatory means that farmers are more involved in the breeding process and breeding goals are defined by farmers instead of international seed companies with their large-scale breeding programs.

Setting Selection criterion

PVS participants set selection criterion as indicated in table (1). These selection criterions are very important for future breeding strategy focus. As indicated from result table 5, the users identified stalk population as their first selection criteria, among others.

Similarly, based on the researchers' data, the analysis of variance for characters confirmed the existence of variability, among studied genotypes for different characters including millable stalk population, which showed medium genotypic and phenotypic coefficients of variations (15.32 and 17.30). Moreover, heritability estimates indicated high heritability for millable cane (78.46) and cane yield (64.85).

Therefore, the selection criterion sett by the users was found highly complementary to that of the researchers, and as such showed high heritability. This confirmed that phenotypic expression of such characters can be effectively utilized in selection criteria to bring heritable improvement among sugar yield of sugarcane varieties. Furthermore, the role of the PVS was confirmed highly valuable in final variety selection to incorporate the need of the users to maximize the user satisfaction over that of merely ended technology provision.

After setting up selection criterion and ranking were done on candidate varieties SP70-1284, C132-81 and C86-56 on luvisol; and SP70-1284 and C90-501 on vertisol. Generally, the PVS result were similar with the data analysis result we found in the experiment as indicated in table (6).

No	Criterion	Reason for setting criteria	First ranking given for
1	Stalk Population Density	Higher cane yield	Higher density
2	Stalk thickness	Higher cane yield	Higher thickness
3	Stalk Height	Higher cane yield	Higher stalk height
4	Stalk stand nature	Non-Lugging varieties for easy cultivation and harvest operation machinery mobilization	Not Lugged stalk
5	Smut tolerance	Higher cane yield	Non-susceptibility
6	Foliar disease resistance	Higher biomass	Disease free
7	Spiny leaf	To protect from human and animal attack	Rough spiny leaf
8	Sugar	Higher Sugar yield	Higher Sweetness
9	Bud strength	Soft buds eye easily removed during seed cane preparation and transportation	Higher bud strength
10	Maturity period	Maturity related with management costs	Early maturing

Table 5: *Variety selection criterion of the Users', (Agricultural Staff representative of Finchaa).*

No.	Entries	Cane Yield Qt/ha/m light soil	Sugar Yield Qt/ha/month	Sugar Yield Advantage over the Check Qt/ha/Month	Sugar Yield Advantage Over Standard Check Qt/Year
1	C86-12	122.9	16.5	1.4	16.8
2	C86-165	117.8	15.6	0.5	6
3	C132-81	127.3	15.5	0.4	4.8
4	SP70-1284	122.2	16.6	1.5	18
5	B52298*	124.7	15.1	0	0

Table 6: *Varieties Selected in the experiment in Cane yield, Sugar Yield and Yield advantage.*

Conclusion and Recommendation

This result point to that there are wider variations among the studied genotypes possibly characters lead to design better sugarcane improvement breeding programs. Based on the researchers' data, the analysis of variance for characters confirmed the existence of variability, among studied genotypes for different characters including millable stalk population, which showed medium genotypic and phenotypic coefficients of variations (15.32 and 17.30). Moreover, heritability estimates indicated high heritability for millable cane (78.46) and cane yield (64.85).

The users also identified stalk population as their first indirect selection criteria of higher cane yield, among others. Therefore, the selection criterion sett by the users was found highly complementary to that of the researchers, and as such showed high heritability. Furthermore, the role of the participatory variety selection was confirmed highly valuable in final variety selection to incorporate the need of the users to maximize the user satisfaction over that of merely ended technology provision.

Accordingly, based on the research data and user's selection criterion, candidate varieties SP70-1284, C132-81 and C86-56 on luvisol; and SP70-1284 and C90-501 on vertisol were recommended for commercial production.

Additionally, candidate C86-12 and C86-165, based on research based sugar yield advantage for luvisol, and candidate B80-250 based on users' selection on vertisol were recommended for provisional release on conditions they sustain competitive sugar yield against the check.

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