International Journal for Research in
Applied Sciences and Biotechnology

ISSN: 2349-8889
Volume-8, Issue-5 (September 2021)

www.ijrasb.com

https://doi.org/10.31033/ijrasb.8.5.13

Evaluating Adaptability and Genetic Variability of Improved Maize Varieties

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ABSTRACT

Maize is one of the most important cereals broadly adapted worldwide. Though, a number of improved maize varieties have been released, each micro-environment has not been touched that is why the study carried out. The experiment was conducted using seven maize varieties in RCB design with three replications. The analysis of variance signifies the presence of significant difference ($p \leq 0.05$) among the seven maize varieties evaluated. High value of genetic (GCV) and phenotypic coefficient of variation (PCV) for grain yield (25.1 and 37.8%) were estimated and this infers less influence of environment. Additionally, moderately high heritability (44.2%) and high genetic advance in percent mean (34.4%) were estimated for grain yield which indicate the trait governed by additive gene action and could be improved via selection based on phenotypic performance. However, traits (male and female flower) with high heritability and moderate genetic advance in percent mean inherited mostly by non-additive gene action and heterosis breeding could be useful. Regarding agronomic performance, Hora maize variety provided highest grain yield (5.0 t/ha) followed by Kuleni (4.1 t/ha), Melkasa 2 (4.0 t/ha) and check (4.0 t/ha). Hora, Melkasa 2, Melkasa 4 and check flowered earlier as compared to the other and could be used as parent for generating early flowering varieties. In summary, Hora maize variety was better performing both statistically and in eyes of farmers and need seed multiplication and distribution to farming community. Moreover, the variability observed among the maize varieties could be utilizing in future breeding activities.

Keywords- Maize, Variability, Heritability, Genetic advance

I. INTRODUCTION

Maize is one of the most important cereals broadly adapted worldwide (Riedelsheimer *et al*., 2012). In Ethiopia maize is produced for food, especially, in major maize producing regions mainly for low-income groups, it is also used as staple food. Maize is consumed as "Injera," Porridge, Bread and "Nefro." It is also consumed roasted or boiled as vegetables at green stage. In addition to the above, it is used to prepare "Tella" and "Arekie." The leaf and stalk are used for animal feed and dried stalk & cob are used for fuel. It is also used as industrial raw material for oil & glucose production (MoARD, 2014).

In Ethiopia, it is grown in the lowlands, the mid-altitudes and the highland regions. It is an important field crop in terms of area coverage, production and utilization for food and feed purposes. However, maize varieties mostly grown in the highlands at an altitude ranging from 1,700 to 2,400 masl of Ethiopia are local cultivars with poor agronomic practices (Yosef *et al*.,2005). In Ethiopia, its total annual production and productivity exceeds all other cereals (23.24% of 13.7 million tons), and second after tef (*Eragrostis* tef) in area coverage (Wende *et al*., 2007). It is the most extensively cultivated food crops and main source of calorie in western, southern and eastern part of Ethiopian (Dagne *et al*., 2008). With the introduction of the hybrid seeds and the high yielding open pollinated varieties, and the increasing local demand, the importance of the crop may increase even further (Wende *et al*., 2007).

Maize is currently grown across 13 agro-ecological zones, which together cover about 90 percent of the country. Moreover, it is an increasingly popular crop in Ethiopia: The area covered by improved maize varieties grew from five percent of total area under maize cultivation in 1997 to 20 percent in 2014 (CSA, 2014/15). Maize cultivation is also a largely smallholder phenomenon in Ethiopia. The small-scale farmers that comprise some 80 percent of Ethiopia’s population are both the primary producers and consumers of maize in Ethiopia. In support of the growing popularity of maize, a number of research centers and institutions have emerged in Ethiopia over the last several years (Dawit and Spielman, 2006).

The importance and complex nature of agricultural research demands coordinated effort among biological scientists, extension agents and farmers in order to ensure that appropriate technology is developed and promoted (Rao *et al*., 2004). Participatory variety selection has shown success in identifying a greater number of preferred varieties by farmers in shorter time and accelerating their dissemination (Weltzien *et al*., 2003). Therefore, adding information on farmers' perspectives of plant and grain trait preferences to these criteria will be helpful to the variety selection process. Research costs can be reduced and adoption rates increased if the farmers are allowed to participate in variety testing and selection (Yadaw *et al*., 2006).

In Ethiopia, a number of improved maize varieties have been released to different agro-ecology in collaboration of farmers. However, each micro-environment has not been touched by research process in developing improved crop varieties. Thus, it seems indispensable to undertake a quick adaptation trial at different location of the country where the released varieties not tested. Therefore, with objectives of evaluate and identify well adapted and high yielding improved OPV maize varieties in collaboration with farmers the adaptation trial was carried out at Abote district, North Shewa.

II. MATERIAL AND METHODS

2.1 Site description

The field trial was conducted during 2011/2012 cropping season at Abote district which located in north shewa at distance of 137.6 km from the capital city of Ethiopia on the way to Fiche. The Abote district represents the mid altitude. The Woreda (district) was selected purposefully, because of its potential for maize production (personal communication with Abote district Bureau of agriculture, North Shewa).

Participatory evaluation methodology was used to aware the farming communities and extension workers with the improved maize varieties for facilitating their wider dissemination of the selected varieties. The selection of the farmer's field was done in collaboration with development agents. Accordingly, five farmers from each FTC were involved to select the varieties. Farmers were evaluated the varieties at the harvesting time by their own criteria they set. The criteria's they used to evaluate the varieties were recorded and score given on a scale from 1(very good) to 5 (very poor) for the criteria they set.

2.2 Experimental materials

Six maize varieties taken from three different research centers were evaluated at North shewa, Abote district on two sites for two consecutive seasons (2019 and 2020). One local check maize variety was included.

Table 1: List of open pollinated maize varieties evaluated at Abote district, North Shewa

S. N.	Varieties	Source	Altitude
1	Hora	AARC	1800-2400
2	Kuleni	BNMRC	1700-2200
3	Gibe 2	BNMRC	1000-1700
4	Gibe 3	BNMRC	1000-1700
5	Melkasa 2	MARC	Low moisture
6	Melkasa 4	MARC	Low moisture
7	Check	Farmer	

AARC = Ambo Agricultural Research Center, BNMRC = Bako National Maize Research Center, MARC = Melkassa Agricultural Research Center

2.3 Experimental Design and procedure

The experiment was laid out following the RCBD design with three replications. The spacing between plants and between rows is 25 and 75 cm, respectively. Two seeds were planted per hill and later thinned at the four-leaf stage. Each variety was planted on four rows with length of 4m. All cultural practice and recommended fertilizer rate NPS was handled by Development Agent at Abote district and highland maize researchers of Holeta Agricultural Research Center.

2.4 Data collected

Days to anthesise (DA): The number of days from planting to the date when 50% of the plants in a plot have tassels shedding pollen was recorded.

Days to silking (DS): The number of days from planting date to the date on which 50% of plants in the plot emerged 2-3cm long silk was recorded.

Ear aspect (EA): It was recorded on general appearance of all ears in the plot using 1-5 rating scale. Factors considered include ear size, grain filling, disease and insect damage, and uniformity and color. Grain yield (GY): Yield of total ears unshelled per plot measured in kg/plot and converted to ton per. Conversion made using moisture adjustment of 12.5% which measured in digital moisture tester and fresh ear weight as follow:

$$\mathbf{GY} = \frac{\textbf{fresh ear weight (kg/plot) x (100} - \textbf{MC) x shelling\% x 10}}{\textbf{(100} - \textbf{12.5) x area harvested}}$$

Fresh ear weight = unshelled ear weight using balanced weight in kg, MC= moisture content

Plant height (PH): Average height of five randomly selected plants measured in centimetres (cm) from ground level to the point where the tassel starts branching three weeks after flowering is completed.

Ear height (EH): Average ear height of five randomly selected plants measured from the ground to the upper most ear-bearing node three weeks after flowering is completed.

Husks cover (HC): record the number of ears in each plot that have any portion of the ear exposed and convert this figure into a percentage of poor husk cover by dividing it by the total number of ears harvested.

Number of ear/plot (NE): total number of ears per plots was recorded.

2.5 *Data Analysis*

The analysis of variance and estimation of phenotypic and genotypic variance were carried out using SAS version (SAS, 2010). Mean separation was done using least significance difference (LSD) at 5% level of significant.

Genetic parameters estimation: genetic parameters, mainly genotypic variance (σ^2g), phenotypic variance (σ^2p), phenotypic coefficient of variation (PCV), and genotypic coefficient of variation (GCV) were estimated based on the formula used by Karasu *et al*., (2009), Tiwari *et al*., (2019) and Burton and Devane (1953).

Genotypic Variance Component (δ^2_g) = $\frac{Msg-Msgl-Msgy+Msgly}{rly}$

Genotype by location Variance Component (δ^2_{gl}) = $\frac{Msgl-Msgly}{ry}$

Genotype by season variance component (δ^2_{gy}) = $\frac{Msgy-Msgly}{rl}$

Genotype by location by season variance component (δ^2_{gly}) = $\frac{Msgly-Mse}{r}$

Environmental variance or error variance (δ^2_e) = Mse

Phenotypic variance (δ^2_p) = $\delta^2_g + \frac{\delta^2_{gl}}{l} + \frac{\delta^2_{gy}}{y} + \delta^2_{gly} + \frac{\delta^2_{eg}}{rly}$

Genotypic coefficient of variation (GCV) = $\sqrt{\delta^2_g}$/mean * 100

Phenotypic coefficient of variation (PCV) = $\sqrt{\delta^2_p}$/mean * 100

GCV and PCV values 0-10%, 10-20%, 20% and above categorized as low, moderate and high respectively (Deshmukh *et al*., 2013).

Broad sense heritability (H^2), as percentage, was derived for each character using variance components as explained by DeLacy *et al*., (1996).

$H^2 = \delta^2_g/\delta^2_p$ The heritability estimate was categorized as described by Singh (2015) as very high (> 80%); values between (60 - 79%) are moderately high; values between (40 - 59%) are medium and low (<40%).

Estimation of Expected Genetic Advance from Selection: The genetic advance at selection intensity (k) at 5 % (2.06) was derived by using the following formula (Johnson *et al*., 1955): $GA = k * H^2 b * \delta_p$=k*H^2b*δ_p, expected genetic advance percentage of mean (GAM %) =GA/X × 100

The genetic advance as percent over mean was categorized as suggested by Johnson *et al*. (1955).< 10% = Low, 10-20% = Moderate, > 20 % = High

III. RESULT AND DISCUSSION

3.1 Analysis of Variance

The combined analysis of variance indicated that only the genotype (G) main effect was significant (*p<0.05*) for all traits studied (Table 2). Similarly, Dilnesaw *et al*. (2018) and Salami *et al*. (2016) reported significant difference among tested genotypes for days to flowering, plant height and grain yield. The significant differences observed among the genotypes for all the traits signify the existence of inherent genetic variability among the genotypes and simple selection could be possible based on those characters. Ndukauba *et al*., (2015) pointed that genetic variation in any given crop population is essential to successfully select and manage yield improvement programs. The Y x L interaction was also significant for all traits studied (*p≤ 0.05*). The G x Y interaction was only significant for number of ears per plot. On the other hand, the interaction between genotype and location (G x L) was not affected all the characters. This indicated that environment was unable to mask the existed difference among the genotypes. The triple interaction (G x L x Y) was found significant for grain yield, anthesis days, silking days, plant height and husk cover (Table 2).

Table 2: Combined analysis of variance for yield and yield related traits of OPV maize variety over two main cropping seasons (viz., 2019,2020)

Source variation	Df	GY (t/ha)	AD (days)	SD (days)	PH (cm)	EH (cm)	NE (number)	HC (%)	EA (1-5 scale)
Y	1	2.4	1719.0	1885.8	2520.8	57.2	24.1	213.9	2.7
L	1	153.3	3394.7	3497.2	5294.7	3878.0	12024.1*	27.0	1.0
R(Y*L)	8	1.0*	13.5**	11.9**	500.3	128.1	195.2	15.4	0.4
G	6	3.3**	73.5**	70.2**	7036.4**	2419.3**	635.1**	109.7**	1.1**
Y*L	1	24.3**	3575.0**	3733.3**	3380.7**	3594.0**	3.4*	99.3*	2.3**
Y*G	6	2.2	2.1	2.0	429.9	193.5	535.6*	15.5	0.2
L*G	6	0.2	3.4	3.8	84.2	201.3	57.2	49.4	0.4

Y*L*G	6	1.1*	9.5**	10.7**	607.0*	191.7	77.7	61.5**	0.3
MSe	48	0.4	2.0	2.8	257.5	132.8	112.3	15.5	0.2
CV		16.5	1.4	1.6	7.0	9.8	18.0	51.9	16.6

Y= Year, L= Location, G=Genotype, R= Replication, Df =degree freedom, GY= Grain Yield, AD= Anthesis Days, SD= Silking Days, PH= Plant Height, EH= Ear Height, NE= Number of Ear, HC= Husk Cover, EA= Ear Aspect, Mse = error mean square, CV= Coefficient of Variation

3.2 Genetic parameters estimation

Investigating the magnitude of variability in crop species is crucial for a successful future plant breeding program. The estimates of genotypic variation (δ^2_g), phenotypic variation (δ^2_p), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), broad sense heritability (H^2b), genetic advance (GA), and genetic advance as percentage of mean (GAM) for different characters have been presented in Table 3. Phenotypic component of variance for all the measured traits was further partitioned into genotypic variance (δ^2_g), genotype x environment variance (δ^2_{gl}), genotype x year variance (δ^2_{gy}), genotype x year x environment variance (δ^2_{gly}) and error variance (δ^2_e). But only genotypic variance was compared with total phenotypic variance to understand the magnitude of genotypic contribution to maize improvement.

The higher phenotypic and genotypic coefficient of variance was recorded for grain yield (37.8 and 25.1%), plant height, ear height, husk cover and ear aspect (Table 3). Dilnesaw *et al*., (2018) also reported high phenotypic coefficient of variation for grain yield. High GCV indicates the presence of exploitable genetic variability for the traits, which can facilitate selection (Yadav *et al*., 2009). Low genetic coefficient of variation was recorded for days to 50% male and female flower (AD and SD) and number of ears per plot. Similarly, Amsal *et al*.(1994); Sharma *et al*. (1995)and Dilnesaw *et al*.(2018) reported low PCV and GCV value for days to 50% male and female flowering, and plant height. For the traits like grain yield, 50%male and female flowering days, plant height, ear height and ear aspect phenotypic coefficient of variation exceed the genetic coefficient of variation with low amount which indicates low environmental influence on the expression of these trait. Low difference between PCV and GCV value for these traits indicate selection based on phenotypic performance would be effective to attain considerable genetic improvement. The husk cover showed higher PCV value over GCV which signifies that this trait was more influenced by growing environment thus selection is not effective on those traits.

Broad sense heritability ranged from 13.9% (number of ear) to 95.5% plant height was estimated (Table 3). The heritability estimates give an insight into the extent of genetic control to express a particular trait and phenotypic reliability in predicting its breeding value (Ndukauba *et al*., 2015). Ullah *et al*. (2012) stated broad-sense heritability only indicates whether or not there is sufficient genetic variation in a population, which implies whether or not a population will respond to selection pressure. Days to 50% male and female flowering (AD and SD), plant and ear height showed higher heritability, while husk cover and ear aspect showed moderately high heritability. Medium heritability was estimated for grain yield (44.2%). High, moderately high and medium heritability estimated signifies a good response to selection for particular traits, while low heritability indicates high environmental influence. As the effects of additive and non-additive gene are not separated the estimated heritability need to be linked with genetic advance or genetic advance in percent of mean.

The genetic advance as percent mean varied from 9.1 % for number of ear and144.8 % for husk cover (Table 3). Traits such as grain yield, plant and height, husk cover and ear aspect showed high genetic advance in percent mean and high to medium heritability (Table 3). This indicates that these traits governed by additive gene action and therefore provides the most effective condition for selection. Although high broad sense heritability was recorded for days to 50% silking and anthesis, they were associated with moderate genetic advance as percent mean indicating these traits among tested genotypes governed by non-additive gene action and thus heterosis breeding or developing hybrid variety could be useful. Low heritability and genetic advance as percent mean estimate was obtained for number of ears which signifies high influence of environment than genotype. Panse (1957) reported that high heritability coupled with high genetic advance indicates the additive gene effects while high heritability coupled with low genetic advance indicates the non-additive gene effects for control of the particular character.

Table 3: Combined estimated values of genetic parameter for yield and yield related traits of maize

Traits	**δ^2_g**	**δ^2_{gl}**	**δ^2_{gy}**	**δ^2_{gly}**	**δ^2_e**	**δ^2_p**	**GC (%)**	**PCV (%)**	**H^2 (%)**	**GA**	**GAM (%)**
GY	1.0	0.0	2.0	0.9	0.4	2.3	25.1	37.8	44.2	1.4	34.4
AD	68.7	1.9	0.5	8.8	2.0	72.3	8.3	8.5	95.1	16.7	16.7

SD	65.3	2.1	0.2	9.8	2.8	69.1	7.9	8.1	94.5	16.2	15.8
PH	6573	-17.0	328.8	521.2	257.5	6880	35.1	35.9	95.5	163	70.7
EH	2041	169.4	161.6	147.5	132.8	22531	38.4	40.3	90.5	88.5	75.2
NE	48.8	44.2	522.7	40.2	112.3	351.7	11.8	31.8	13.9	5.4	9.1
HC	50.0	39.1	5.3	56.3	15.5	87.6	93.0	123.1	57.1	11.0	144.8
EA	0.6	0.3	0.1	0.3	0.2	0.9	26.4	32.2	67.1	1.3	44.5

3.3 Agronomic Performance of open pollinated maize varieties

Comparisons were made between maize varieties used in terms of some important agronomical traits in the study. Seven maize genotypes were significantly different based on the traits observed (Table3). According to the results obtained over years and locations, the mean values of maize varieties for grain yield, 50% anthesis days, 50% silking days, plant height, ear height, ear number/plot, husk cover and ear aspect ranged between3.3 to 5 t/ha, 96.7 to 103 days, 99.3 to 105.3 days, 198.9 to 271.3 cm, 95.5 to 139.2 cm, 51.4 to 70.9 no, 4.6 to 12.4% and 2.5 to 3.2 scale respectively.

Grain yield: Hora maize variety revealed highest grain yield (5.0 t/ha) followed by kuleni (4.1 t/ha) and Melkasa-2 (4.0 t/ha) with overall mean of 3.8 t/ha (Table 3). However, as compared to local check only Hora maize variety provided significantly highest performance which indicates the variety is well adapted to the area and the farmer could be use for higher grain yield. Several author including Bhusal *et al*. (2017) reported genetic variability on released maize varieties for grain yield and related traits.

Plant and Ear height: the significant differences for plant and ear height indicates the existence of genetic variability among maize varieties kept under study (Table 4). Melkasa-4 (198.9 cm, 95.5 cm) and Gibe-2 (209 cm, 109.3 cm) were shorter in plant and ear height, while the rest varieties showed medium and highest plant and ear height. In favor of present study, genotypic variations on plant and ear height were previously reported by (Ogunniyan and Olakojo, 2014; Prasai *et al*., 2015; Sharma *et al*., 1995).

Husk Cover (HC): the maximum mean of husk cover recorded for Hora and Melkasa-4 (12.4 and 11.1% respectively), while the minimum mean of husk cover recorded for Kuleni and Gibe-3 (4.6 and 4.8% respectively) (Table 4). The varieties with low husk cover problem could be used as parents in improving this trait under future breeding work. Though Hora variety performs better in grain yield, improvement of husk cover problem could be indispensable.

Table 4. Mean of yield and yield components of OPV maize varieties tested at Abote,

Entry	GY (t/h)	AD (days)	SD (days)	PH (cm)	EH (cm)	NE (number)	HC (%)	EA (1 - 5scale)
Check	4.0	96.7	99.3	248.7	130.3	59.9	7.2	3.2
Gibe-2	3.3	103.0	105.3	209.0	109.3	51.6	6.3	3.1
Gibe-3	3.9	100.9	103.4	230.0	118.6	56.8	4.8	2.7
Hora	5.0	98.4	101.1	234.6	119.3	66.0	12.4	2.7
Kuleni	4.1	101.9	104.9	271.3	139.2	51.4	4.6	2.5
Melk2	4.0	101.6	103.6	223.6	112.6	70.9	6.7	3.1
Melka4	3.5	97.3	99.8	198.9	95.5	56.1	11.1	3.2
Mean	4.0	100.0	102.5	230.9	117.8	59.0	7.6	2.9
LSD $_{(0.05)}$	0.5	1.2	1.4	13.2	9.5	8.7	3.3	0.4
F-test	**	**	**	**	**	**	**	**

3.4 Farmer perception

Farmer field visit was undertaken to collect their awareness and perception on seven maize varieties evaluated at the area. Five female, 10 male farmers and seven developmental agents were participated in evaluation of maize varieties at harvesting time. Accordingly, the farmers were identified that Hora and Kuleni maize varieties are best performing based on criteria’s such as grain filling, ear length, ear diameter, seed size, yield potential and disease tolerance (Fig 1). Particularly, they were requested seed of Hora variety to produce on their field.

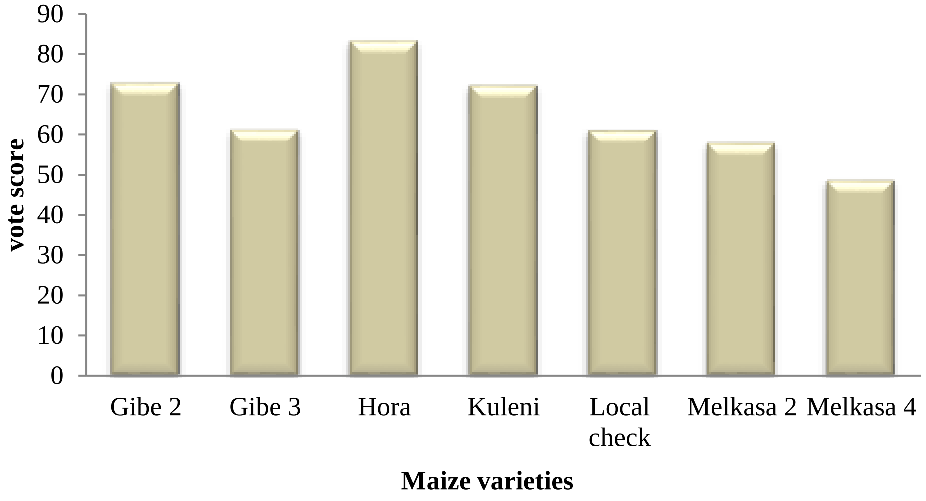

Figure 1: Farmers' preference vote score of improved maize varieties

IV. CONCLUSION

The analysis of variance showed that maize varieties significantly different ($p \leq 0.05$) for all recorded traits. The highest mean grain yield was obtained from Hora (5.0 t/ha) maize variety followed by kuleni (4.1 t/h), Melkasa-2 (4.0 t/ha) and check (4.0t/ha). Regarding flowering days, the check and Melkasa-4 varieties were flower earlier which could be used as parent in developing early maturing variety in the future breeding program. The result also conveys the high genetic coefficient of variation, high genetic advance in percent mean, medium heritability for grain yield. This indicate the possibility of direct selection and to some extent heterosis breeding also affordable as trait inherited by additive and non-additive gene action. Based on the experimental result and farmer perception Hora maize variety could be advised for production at the study area.

ACKNOWLEDGMENT

All authors contributed to the conception and design of the study. Moreover, the funding institute, Ethiopian Institute of Agricultural Research (EIAR), Holeta center.

REFERENCE

[1] Amsal T.D., Tanner G., Getenet G., 1994. Effect of genetic improvement of Morph-physiological character related to grain yield of bread wheat in Ethiopia. African Crop Sci J 2: 247-255.

[2] Bhusal, T., Lal, G.M., Marker, S. and Synrem, G.J., 2017. Genetic variability and traits association in maize (Zea mays L.) genotypes. *Annals of Plants and Soil Research*, *19*(1), pp.59-65.

[3] Burton, G.W. and Devane, D.E., 1953. Estimating heritability in tall fescue (Festuca arundinacea) from replicated clonal material 1. Agronomy journal, 45(10), pp.478-481.

[4] CSA (Central Statistical Agency of the Federal Democratic Republic of Ethiopia), 2014/15.Agricultural Sample Survey, 2014/15. Report on Area and production of major crops (Private Peasant Holdings, meher season). Statistical Bulletin 278. Vol. I, Addis Ababa, Ethiopia.

[5] Dawit, A. and Spielman, D.J., 2006, June. The Ethiopian seed system: Regulations, institutions and stakeholders. In *ESSP Policy Conference* (pp. 6-8).

[6] DeLacy, I.H., Basford, K.E., Cooper, M., Bull, J.K. and McLaren, C.G., 1996. Analysis of multi-environment trials–an historical perspective. *Plant adaptation and crop improvement*, *39124*.

[7] Deshmukh, S.N., Basu, M.S. and Reddy, P.S., 1986. Genetic variability, character association and path coefficients of quantitative traits in Virginia bunch varieties of groundnut. *Indian Journal of Agricultural Sciences*.

[8] Dilnesaw, Z., Hailu, T., Bedada, A., Abdissa, F. and Alemaw, G., 2018. Maize (Zea mays L.) Variety Adaptation Performance Evaluation at Tendahoo Sugar Factory Afar Regional State Ethiopia. *Irrigat Drainage Sys Eng*, *7*(201), p.2.

[9] Johnson, H.W., Robinson, H.F. and Comstock, R.E., 1955. Estimates of genetic and environmental variability in soybeans. *Agronomy journal*, *47*(7), pp.314-318.

[10] Karasu, A., Oz, M.E.H.M.E.T., Göksoy, A.T. and Turan, Z.M., 2009. Genotype by environment interactions, stability, and heritability of seed yield and certain agronomical traits in soybean [Glycine max (L.) Merr.]. *African Journal of Biotechnology*, *8*(4).

[11] Ministry of Agriculture and Rural Development, 2014. Animal and Plant Health Regulatory Directorate. Crop Variety Registry issue no.17; June,Addis Ababa, Ethiopia.

[12] Ndukauba, J., Nwofia, G.E., Okocha, P.I. and Ene-Obong, E.E., 2015. Variability in egusi-melon genotypes (Citrullus lanatus [Thumb] Matsum and Nakai) in derived savannah environment in South-Eastern Nigeria. *International Journal of Plant Research*, *5*(1), pp.19-26.

[13] Ogunniyan, D.J. and Olakojo, S.A., 2014. Genetic variation, heritability, genetic advance and agronomic character association of yellow elite inbred lines of maize (Zea mays L.). *Nigerian Journal of Genetics*, *28*(2), pp.24-28.

[14] Panse, V.G. and Sukhatme, P.V., 1957. Genetics of quantitative characters in relation to plant breeding. *Indian J. Genet*, *17*(2), pp.318-328.

[15] Prasai, H.K., Kushwaha, U.K.S., Joshi, B.P. and Shrestha, J., 2015. Performance evaluation of early maize genotypes in far western hills of Nepal. *Journal of Maize Research and Development*, *1*(1), pp.106-111.

[16] Rao, N.H., Katyal, J.C. and Reddy, M.N., 2004. Embedding the sustainability perspective into agricultural research: implications for research management. *Outlook on Agriculture*, *33*(3), pp.167-176.

[17] Riedelsheimer, C., Czedik-Eysenberg, A., Grieder, C., Lisec, J., Technow, F., Sulpice, R., Altmann, T., Stitt, M., Willmitzer, L. and Melchinger, A.E., 2012. Genomic and metabolic prediction of complex heterotic traits in hybrid maize. *Nature genetics*, *44*(2), pp.217-220.

[18] Salami, H.A., Sika, K.C., Padonou, W., Aly, D., Yallou, C., Adjanohoun, A., Kotchoni, S. and Baba-Moussa, L., 2016. Genetic diversity of maize accessions (Zea mays L.) cultivated from Benin using microsatellites markers.

[19] SAS Institute Inc. 2010. SAS Guide for personal computers version 9.3 Edition. SAS Institute Carry NC, USA.

[20] Sharma, D.J., Yadav, R.K. and Sharma, R.K., 1995. Genetic variability and association of some yield components in winter x spring nursery of wheat. *Adv. Pl. Sci., India*, *8*, pp.95-99.

[21] Singh, B.D., 2015. *Plant breeding: principles and methods*. Kalyani publishers.New Delhi-Ludhiana, India 506 p.

[22] Tiwari, D.N., Tripathi, S.R., Tripathi, M.P., Khatri, N. and Bastola, B.R., 2019. Genetic variability and correlation coefficients of major traits in early maturing rice under rainfed lowland environments of Nepal. *Advances in Agriculture*, *2019*.

[23] Ullah, M.Z., Hasan, M.J., Chowdhury, A.Z.M.K.A., Saki, A.I. and Rahman, A.H.M.A., 2012. Genetic variability and correlation in exotic cucumber (Cucumis sativus L.) varieties. *Bangladesh Journal of Plant Breeding and Genetics*, *25*(1), pp.17-23.

[24] Wegary, D., Zelleke, H., Abakemal, D., Hussien, T. and Singh, H., 2008. Combining ability of maize inbred lines for grain yield and reaction to grey leaf spot disease. *East African Journal of Sciences*, *2*(2), pp.135-145.

[25] Weltzien, E., Smith, M.E., Meitzner, L.S. and Sperling, L., 2003. Technical and institutional issues in participatory plant breeding-from the perspective of formal plant breeding: A global analysis of issues, results, and current experience.

[26] Wende, A., Mosisa, W., Birhanu, T., Legesse, W. and Twumasi, A., 2007. Performances of CIMMYT maize germplasm under low-nitrogen soil conditions in the mid-altitude sub humid agro-ecology of Ethiopia. In *8th African Crop Science Society Conference, El-Minia, Egypt, 27-31 October 2007* (pp. 15-18). African Crop Science Society.

[27] Yadav, Y.C., Kumar, S., Bisen, B. and Dixit, S.K., 2009. Genetic variability, heritability and genetic advance for some traits in cucumber. *Indian Journal of Horticulture*, *66*(4), pp.488-491.

[28] Yadaw, R.B., Khatiwada, S.P., Chandhary, B., Adhikari, N.P., Baniya, B., Mudwari, A. and Tripathi, B.P., 2006. Participatory varietal selection (PVS) of rice varieties for rain fed conditions. Rice Fact Sheet. *International Rice Research Institute (IRRI)*.

[29] Yosef, B., Botha, A.M. and Myburg, A.A., 2005. A comparative study of molecular and morphological methods of describing genetic relationships in traditional Ethiopian highland maize. *African Journal of Biotechnology*, *4*(7), pp.586-595.