Genetic Variability of Maize (Zea mays L.) Genotypes on Some Yield and Yield Components at Haramaya, Eastern Ethiopia

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A B S T R A C T

Genetic improvement in components of economic importance along with maintaining a sufficient amount of variability is always the desired objective in any maize (Zea mays L.) breeding program which will be handled under the conditions of Haramaya, Eastern Ethiopia. Therefore, an experiment was conducted using (27) and (3) check/control varieties to determine the genetic variability of maize genotypes at Haramaya. The study results revealed that significantly the tallest plant heights for (PH) were recorded from (3) (170 cm) and (18) (167.5 cm) genotypes whereas the shortest PH were recorded from (13) (117.5 cm) and (23) genotypes (120 cm). Good plant aspects (PA) were obtained from genotype 12, 22 and 26 (PA - 1.5) and poor PA were attained from genotype 1 (PA - 2.5). Besides, genetic and phenotypic variances were estimated for seven components. The highest genotypic coefficients variation (GCV) and phenotypic coefficients variation (PCV) were calculated from grain yield (GY – 23.39%). Comparatively the higher GY were attained from the genotypes of 3, 9 and 12. It can be concluded that almost all components of the PCV are greater than the GCV. Superior selected genotypes are recommended to the researchers/breeders to develop disease resistant and high yielder varieties to increase maize production by farmers under Haramaya and other similar agroecologies.

Keywords: Maize (Zea mays L.) Genotypes Genetic variability Yield and yield components Haramaya

Introduction

Maize (Zea mays L., 2n=2×=20), a member of the grass family Gramineae (Poaceae), is one of the oldest cultivated crops. It is predominately cross-pollinated by wind, but self-pollination is also possible (Sleper and Poehlman, 2006). Maize is the most important crop worldwide and basic trade product recurring ingredient for millions of people in Sub-Saharan Africa (Nzuve et al., 2013). Among all cereals, maize is second to teff (Eragrostis tef Zucc.) in area coverage but first in productivity and total production (CSA, 2018). Similarly, maize is the second important cereal crop in area coverage and first in productivity following sorghum in east Hararghe (CSA, 2018).

In Ethiopia, maize is mainly produced for local consumption like raw material for a local drink, enjera, boiled grain (nifro), green cobs, and bread making. Millions of people depend on maize as a staple food. Given its high demand for food grains and high yield per unit area, maize has been among the leading food grains selected to achieve food self-sufficiency in Ethiopia (Benti et al., 1993).

Among the various other characteristics, the GY in maize is the most important and complex quantitative character controlled by numerous gene (Varaprasad et al., 2016). Yield is a complex trait, is considerably influenced by different contributing yield components like the EH, the PH and 1000–grain weight (Rahman et al., 1995). The GY is directly and positively associated with ear weight and ear circumference (Maia et al., 1997). Improvements in yield can be achieved by selection for the GY, 1000 grain weight, the PH and EH (Prodhan and Rai, 1997). The
additive genetic variance component is the most important component of genetic variability for all components (Betran and Hallauer, 1996). All this information helps a plant breeder to ensure efficient cultivar selection and screening of available sources of maize germplasm (Varaprasad et al. 2016).

Maize is the global leading cereal in terms of annual production which is about 1040.21 million tons, followed by wheat (=Triticum spp.) with the production of 748.24 million tons and third in the area under cultivation among all cereal crops. In Ethiopia, maize ranks second after teff (Eragrostis teff) in area coverage and first in total maize's kernel formed a black line.

Zea mays ranks second after teff (Kebede et al., 2015). With sandy clay loam (Anteneh et al., 2020). Growing season average maximum and minimum temperature during the growing season (April to October) was 786.6 mm and monthly distribution of the area is bimodal. Total rainfall in growing season (2015) was 423.5 mm. Geographically, Raare is located at 9° 26' N latitude and 42° 03' E longitude at an altitude of 1980 m. a.s.l. The rain distribution of the area is bimodal. Total rainfall in growing season (April to October) was 786.6 mm and monthly average maximum and minimum temperature during growing seasons (April to October) was 24.5 and 13.4 °C (Belay and Adare, 2020).

The soil of the experimental site is a well–drained deep alluvial with a sub–soil stratified with sandy clay loam (Anteneh et al., 2015).

**Treatments and Experimental Design**

The experiment was comprised of (27) maize (Zea mays L.) genotypes and (3) standard checks provided from Ambo Agricultural Research Center. Treatments were laid out under alpha lattice design with (2) replications. The main plot size was 5.1 m × 2.25 m (11.475 m²) whereas the harvested net plot size was 5.1m × 1.5m (7.65 m²). Between and within row distances were 0.75 m and 0.25 m, respectively, and these experimental materials were used (Table 1).

Table 1. Experimental materials used in the study

| G | Stock ID  | G | Stock ID  |
|---|-----------|---|-----------|
| g1 | TH15104   | g17 | TH15244  |
| g2 | TH15162   | g18 | EBH161574 |
| g3 | TH15163   | g19 | TH15186  |
| g4 | TH15174   | g20 | TH15149  |
| g5 | TH15175   | g21 | TH15222  |
| g6 | TH15177   | g22 | EBH161576 |
| g7 | TH15180   | g23 | EBH161577 |
| g8 | TH15178   | g24 | EBH161578 |
| g9 | EBH161572 | g25 | EBH161579 |
| g10 | TH1551 | g26 | EBH1615780 |
| g11 | TH1550 | g27 | EBH161577 |
| g12 | TH15140 | g28 (AMH852Q) | Standard check |
| g13 | TH15143 | g29 (BHQFY545) | Standard check |
| g14 | TH15148 | g30 (AMH760Q) | Standard check |
| g15 | TH15149 | g31 | EBH161578 |
| g16 | TH15152 |

Source: Ambo Agricultural research center (2018), g=genotype

**Experimental Procedures**

The land was ploughed, disked and harrowed by a tractor. Field levelling was done manually before sowing. Then two seeds per hill were sown and then seeds covered with soil manually. Thinning to a single plant per each hill was done when seedlings produced three to four leaves to achieve the standard plant population. The full dose of 100k (NPS) and ½ 87 kg N fertilizers were applied at sowing while the remaining ½ N was applied 50 days after sowing as a side dressing. Besides, other cultural practices were uniformly applied throughout the cropping season as recommended.

**Data Collection and Measurements**

**Phenological parameters Days to 90% physiological maturity**

It was recorded as a number of days from planting to the period when 90% of the plants’ kernel formed a black layer at the point where it attached to the ear (CIMMYT, 1985).

**Yield and yield components**

**Plant height (PH – cm):** Ten randomly pre–tagged plants were taken from the net plot area and then their height was measured from the soil surface to the point where the tassel started to branch with a meter rod at physiological maturity (CIMMYT, 1985).

**Ear height (EH – cm):** was recorded from ten randomly pre–tagged plants from each net plot area and measured their ear height from the ground level to the node bearing the top useful ear with a meter rod at physiological maturity (CIMMYT, 1985).
The number of ears per plant (NEPPL): It was randomly taken from ten pre-tagged plants in the net plot at harvest (CIMMYT, 1985).

Plant aspect (PA): was scored using a 1–5 scale, where 1 indicates good (considering ear size, uniformity, disease infestation, husk cover, and so on) while 5 indicates poor genotype having undesirable ear components (CIMMYT, 1985).

Ear aspect (EA): was recorded at harvest using 1 to 5 scales where 1 refers very good looking ear while 5 refers to poor ear with undesirable components (CIMMYT, 1985).

Grain yield (GY – t ha⁻¹): Field weight of all the harvested ears was weighted and converted into the GY using shelling percent of 80 percent. It was then determined in tons per hectare after adjusting the moisture content of 12.5 percent (CIMMYT, 1985).

Data Collection

All collected data were subjected to analysis by using GenStat statistical software 17th (GenStat, 2014). For significant treatment effects, the mean separation was made using the least significant difference (Protected LSD) test at a 5% level of significance (Gomez and Gomez, 1984).

Estimation of Variance Components

Variance components were estimated to identify genetic variability among inbred lines, genotypic (σ²g), phenotypic (σ²p), and error variance (σ²e), were calculated from expected mean squares of analysis of variance by adopting the formula suggested by Hallauer and Miranda (1988).

\[ GV = \frac{(MSe - MSe) \times 100}{r} \]

Where:
- \( GV \) = Genotypic variance \( \sigma^2_g \)
- \( MSe \) = Mean square of genotype
- \( MSe \) = Mean square of error
- \( r \) = Number of replications

\[ PV = \sigma^2_e + \sigma^2_g \]

Where:
- \( PV \) = Phenotypic variance \( \sigma^2_p \)
- \( \sigma^2_e \) = Error variance
- \( \sigma^2_g \) = Genotypic variance

\[ PCV = \frac{\sqrt{\sigma^2_p} \times 100}{\bar{x}} \]

Where:
- \( PCV \) = Phenotypic coefficient analysis
- \( \sigma^2_p \) = Phenotype variance
- \( \bar{x} \) = Mean of the PCV

GCV Values were categorized as low, moderate, and high values as indicated by Sivasubramanian and Menon (1973) as follows: 0–10% = low, 10–20% = Moderate and >20% = high

\[ GCV = \frac{\sqrt{\sigma^2_g} \times 100}{\bar{x}} \]

Where:
- \( GCV \) = Genotypic coefficient analysis
- \( \sigma^2_g \) = Genotypic variance
- \( \bar{x} \) = Mean of the PCV

Results and Discussion

Phenological and Growth Parameters

Days to maturity (Days)

Analysis of variance showed that statistical variation was not observed among genotypes due to days to maturity though the numerical difference was depicted among genotypes (Table 2). Genotypes 1, 13, and 14 were comparatively took fewer days (174.5, 174.5, 174.0) to reach days to maturity as compared to other genotypes (Table 2). Similarly, Khan et al. (2017) found that genotype E–77 took the longest days (73.3) to reach 50% silking whereas genotype MTM–2 took the shortest days to reach 50% silking. These results were supported by Hassain et al. (2005) reported genetic variation among different maize genotypes for days to 50% silking. They viewed that the differences in maturity among genotypes was due to genetic basis and reflection of weather pattern i.e. temperature, available soil moisture, etc.

Plant and ear height (PH – cm and EH – cm)

The PH was significantly influenced by the main effect of genotypes; however, the EH was not influenced due to the main effect of genotypes (Table 2). According to our results, the tallest PH values were recorded from 3 and 18 genotypes (167.5 and 170 cm) whereas the shortest PH were taken from 13 and 23 genotypes (117.5 and 120 cm) (Table 2). The variation found in PH trait could be due to genetic variations within the genotypes. This result is in line with the finding of Umakanth et al. (2000) who reported that similar results on genetic differences for the PH in maize genotypes. Nizam–ud–din et al. (2010) also reported a highly significant effect of genotypes on the PH, but, Hassan et al. (2018) reported that the different PH values (158.9 -203.8 cm) were recorded from various genotypes, it is a genetically inherited trait.

Plant and Ear Aspects (The PA and EA)

Analysis of variance depicted that the PA was significantly affected by the main effect of genotypes but the EA was not influenced (Table 2). Therefore, good the PA (1.5) were recorded from 12, 22 and 26 genotypes but poor plant aspect (2.5) was recorded from genotype 1. Generally, genotypes like 12, 22 and 26 are good the PA as compared to standard checks (Table 2).

Yield Components and Yield of The Genotypes

Number of ears per plant (NEPPL)

There was no statistical disparity obtained among tested genotypes due to the main effect of genotypes. However, numerical variations of the NEPPL were observed in the genotypes. A relatively the higher NEPPL were recorded from genotypes 5, 12, 18, 20 and 30 (1.6,1.7,1.6,1.6 and 1.6 ) as compared to other genotypes including checks. The maximum NEPPL was recorded from genotype 12 (1.7) whereas the minimum NEPPL was obtained from the BHQPY 545 (0.9) (Table 2). This result was in line with Khan et al. (2017) who reported that different genotypes produced the different NEPPL values.

1842
Table 2. Mean values of the DM, PH and EH, NEPPL, PA and EA as well as the grain yield.

| Genotypes | DM (cm) | PH (cm) | EH (cm) | NEPPL | PA | EA | GY(t ha⁻¹) |
|-----------|---------|---------|---------|-------|----|----|------------|
| 13        | 174.5   | 117.5   | 50      | 1.50  | 2.25  | 2.5 | 6.2       |
| 23        | 176.0   | 120.0   | 55      | 1.07  | 2.0   | 2.5 | 3.5       |
| 1         | 174.5   | 125.0   | 52      | 0.92  | 2.5   | 2.5 | 4.7       |
| 16        | 175.5   | 127.5   | 70      | 1.21  | 2.0   | 2.0 | 6.3       |
| 2         | 175.0   | 130.0   | 50      | 1.21  | 2.25  | 2.5 | 4.1       |
| 25        | 177.0   | 130.0   | 57.5    | 1.33  | 2.25  | 2.5 | 4.9       |
| 24        | 176.0   | 132.5   | 60      | 1.56  | 2.0   | 2.5 | 4.8       |
| 8         | 175.0   | 135.0   | 60      | 1.13  | 2.0   | 2.5 | 5.5       |
| 6         | 175.0   | 137.5   | 50      | 1.42  | 2.25  | 2.5 | 6.4       |
| 21        | 175.5   | 137.5   | 60      | 1.4   | 2.25  | 2.5 | 4.6       |
| 4         | 175.0   | 140.0   | 55      | 1.4   | 2.0   | 2.0 | 8.9       |
| 7         | 176.0   | 140.0   | 62.5    | 1.15  | 2.0   | 2.5 | 6.7       |
| 9         | 176.0   | 140.0   | 62.5    | 1.54  | 2.0   | 2.5 | 9.9       |
| 10        | 177.0   | 140.0   | 65      | 1.52  | 2.0   | 2.5 | 6.8       |
| 27        | 176.0   | 142.5   | 52.5    | 1.50  | 2.0   | 2.5 | 5.7       |
| 20        | 175.0   | 147.5   | 62.5    | 1.60  | 2.0   | 2.5 | 5.4       |
| 5         | 174.0   | 150.0   | 70      | 1.26  | 1.75  | 2.25 | 5.5       |
| 14        | 175.5   | 152.5   | 60      | 1.51  | 2.0   | 2.0 | 5.9       |
| 11        | 176.0   | 155.0   | 65      | 1.18  | 2.0   | 2.5 | 5.7       |
| 12        | 177.5   | 155.0   | 75      | 1.70  | 1.5   | 2.0 | 8.9       |
| 22        | 175.0   | 155.0   | 75      | 1.35  | 1.5   | 2.5 | 6.3       |
| 28        | 176.0   | 157.5   | 77.5    | 1.18  | 2.0   | 2.25 | 5.2       |
| 19        | 175.0   | 160.0   | 67.5    | 1.23  | 1.75  | 2.25 | 5.6       |
| 30        | 176.0   | 160.0   | 65      | 1.60  | 1.75  | 2.5 | 7.5       |
| 17        | 175.5   | 162.5   | 65      | 1.52  | 1.75  | 2.25 | 8.8       |
| 26        | 176.5   | 162.5   | 72.5    | 1.24  | 1.5   | 2.0 | 6.1       |
| 15        | 176.5   | 165.0   | 75      | 1.56  | 1.75  | 2.5 | 8.7       |
| 18        | 176.0   | 167.5   | 75      | 1.60  | 1.75  | 2.0 | 8.2       |
| 3         | 175.5   | 170.0   | 70      | 1.49  | 1.75  | 2.25 | 9.3       |

LSD (0.05) NS 27.3 NS NS 0.22 NS 1.99
CV (%) 0.6 9.2 15.5 16.7 11.4 12.8 15.1

Means in the column followed with the same letter(s) are not significantly different from each other at 5% level of significance. DM= Days to Maturity, PH= Plant Height, EH= Ear Height, NEPPL= Number of ears per plant, PA= Plant Aspect, EA= Ear Aspect, LSD (0.05) = Least Significance Difference at 5% probability level; CV = Coefficient of Variation; NS = Non-significant

Grain yield (GY – t ha⁻¹)

Analysis of variance showed that the GY was highly (P<0.01) significantly influenced by the main effect of genotypes. Therefore, the highest GY were obtained from genotype 3 (9.3 t ha⁻¹) and 9 (9.9 t ha⁻¹) whereas the lowest GY (3.5 t ha⁻¹) was obtained from genotype 23. Most of the genotypes gave higher GY as compared to the standard check (Table 2). The possible reason for the observed differences could be variation in their genetic makeup. This result is harmonized with Waqar et al. (2007) who reported that different maize genotypes gave different GY due to variation in their genetic yield potential. The results are in agreement with the findings of Drinic and Vancetovic (1994), who obtained similar results and further confirmed by Zhang et al. (2000). Similarly, Arwailayah et al. (2019) reported that there was highly significant genetic variability in the maize genotypes for GY.

Estimation of Genetic Variability Parameters

Phenotypic and genotypic variance (PCV and GCV)

Genetic and phenotypic variances were estimated for seven components. The GCV for different components was ranged from 0.24% for days to maturity to 23.39% for the NEPPL (Table 3). As the number of ears is determined by multiple minor genes whose effects are sensitive to environmental and experimental variations. In fact, a high coefficient of variation is expected. The trend in the PCV is not consistent with the GCV. However, the PCV for various components ranged from 0.6% for the days to maturity to 28.4% for the GY. Therefore, the lowest GCV (0.24) and PCV (0.6) were found from days to maturity (Table 3).

According to Deshmukh et al (1986), the highest GCV (23.39%) and PCV (28.4%) were taken from the GY. The PCV and GCV values greater than 20% is considered as high, whereas values less than 10% regarded as to be low and values 10% and 20% to be medium (Deshmukh et al. 1986). Based on this scale, the components like the NEPPL (23.5%) and the GY (28.4%) showed the high PCV. This result was in line with Hussain et al. (2005) who reported that high the PCV (42.0) was recorded from the GY. However, the PH (11.9%), the EH (17.1%), the PA (16.4%) and the EA (14.3%) showed medium PCV while only days to maturity showed low PCV. On the other hand, high GCV value was obtained from the GY (23.39%) where components like days to maturity (0.24%), the PH (7.63%), the EH (7.11%), the PA (8.72%) and the EA
(4.46%) were grouped under low GCV. Jilo et al. (2018) reported that the high GCV and PCV were found from the FY, anthesis and silking interval, ear diameter, the EH and the PA suggesting that these components are under the influence of genetic control. The remaining components such as the number of kernel rows per ears (10.36), leaf length (8.56), days to 50% anthesis (5.21), days to 50% silking (4.83) and days to maturity (2.67) showed a low PCV. Similarly, Kumar et al. (2014) and Nzve et al. (2014) also reported the highest GCV and PCV for the PH, the EH, 1000 grain weight and the kernel number per row. The result showed that almost all components of the PCV are greater than the GCV. This indicated that all components were affected by environmental factors. Similar results were reported by Arunkumar et al. (2013) and Chavan et al. (2010).

Table 3. Genotypic (σ²g) and phenotypic (σ²p) variations, gcv (%) pvc (%) and broad sense heritability (h²-%) in the genotypes

| Traits                  | σ²g  | σ²p  | GVC (%) | PVC (%) | H² (%) |
|-------------------------|------|------|---------|---------|--------|
| Days to maturity        | 0.19 | 1.1  | 0.24    | 0.6     | 16.5   |
| Plant height            | 123.88 | 301.5 | 7.63    | 11.9    | 41.1   |
| Ear height              | 20.46 | 116.7 | 7.11    | 17.1    | 17.5   |
| Plant aspect            | 0.03 | 0.1  | 8.72    | 16.4    | 40.1   |
| Ear aspect              | 0.01 | 0.1  | 4.46    | 14.3    | 9.5    |
| Number of ears per plant| 0.02 | 0.1  | 10.28   | 23.5    | 23.9   |
| Grain yield             | 2.34 | 3.3  | 23.39   | 28.4    | 71.2   |

Conclusion

In Ethiopia, the maize plant is mainly produced for local consumption, and grown under a wide range of environmental conditions. In this study, totally (30) maize genotypes were used. Some genotypes were not influenced due to genotype effect whereas other components were significantly affected. Therefore, among tested genotypes, the tallest PH was obtained from genotype 3 (=170 cm) and the good PA were obtained from genotypes 12, 22 and 26 with checks. Likewise, comparatively the higher GY values were taken from the genotypes 3, 9 and 12 (=Values?). The PH (11.9%), the EH (17.1%), the PA (16.4%) and the EA (14.3%) showed medium PCV while only days to maturity showed the low PCV. The high GCV value was obtained from the FY (23.39%) where components like days to maturity (0.24%), the PH (7.63%), the EH (7.11%), the PA (8.72%) and the EA (4.46%) were grouped under the low GCV. In the light of these findings, it can be concluded that almost all components of the PCV are greater than the GCV and different genotypes have various genetic yield potential and other components. Therefore, the superior selected genotypes are recommended to breeders to develop new maize varieties to maximize maize production under Haramaya and other similar agro-ecologies.

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