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# Studies on genetic variability in maize (*Zea mays* L.) under stress and non-stress environmental conditions

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## Abstract

Studies were carried out to estimate the extent of genetic variability in fifty six maize (Zea mays L.) genotypes (6 drought tolerant inbred lines, 7 other inbred lines, 42 crosses and a check) under non-stress and water stress at flowering. The genotypes were evaluated in 2012/2013 dry season across two locations, to obtain more information on their genetic and morphological diversity. The experimental design used was simple lattice design with two replications under each condition. Significant mean squares were obtained for the seven traits measured under non-stress and water stress in the combined analysis across locations. Differences observed in means of most traits studied were high. The highest mean value of 5877.80 kg/ha was produced the hybrid S3 x P2 for grain yield under non-stress across location while under water stress the hybrid S7 x P8 had maximum grain yield of 5877.80 kg/ha. The effect of drought stress on morphological traits was drastic and it significantly reduced the expression of most traits. Overall, plant height, ear height, number of ears per plant and grain yield were reduced by 15 %, 20 %, 28 % and 70 %, respectively, whereas, days to 50 % tasseling, days to 50 % silking and anthesis-silking interval increased by 5 %, 6 % and 33 %, respectively, under water stress. These findings will be useful in planning breeding programmes to develop improved maize varieties, synthetics and hybrids tolerant to drought for use by farmers and industries.

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Maize (*Zea mays* L.) is one of the three most important cereal crops in the world as well as in Nigeria. It is cultivated worldwide in an area of 159 million hectares with a production of 796.46 million metric tons (USDA, 2010). Maize production in Africa was estimated to be 41.6 million metric tons of which 27.7 million metric tons is produced in sub-Saharan Africa and Nigeria is the main producing country in tropical Africa (USAID, 2010). It is dual purpose crop being used as food for human and feed for livestock. It is also used as industrial raw material to manufacture different products. Its commercial products are corn oil, corn flakes, animal feeds, corn starch, tanning material for leather industry, custard, glucose, etc.

In Africa, maize is grown by small- and medium-scale farmers who cultivate 10 hectares or less (DeVries and Toenniessen, 2001) under extremely low-input systems where average yields are 1.3 tons/ha (Bänziger and Diallo, 2004). The low grain yields can be attributed to a number of constraints which include biotic stress such as diseases, pests and parasitic weeds and abiotic stresses such as low soil fertility and drought. Drought remains the most important devastating factor and it has different effects on maize depending on the growth stage at which it occurs. Soil moisture deficit in maize may cause drastic yield reduction, especially if it occurs during the reproductive phase (NeSmith and Ritchie, 1992; Basseti and Westgate, 1993). Therefore, breeding of drought tolerant maize varieties, will likely boost maize production beyond the present level. Progress in plant breeding depends on the extent of genetic variability present in the population. Therefore the first step in any breeding program is the study of the genetic variability present. This cannot easily directly be measured as the phenotypic expression reflects non-genetic as well as genetic influences. The genetic basis must be inferred from the phenotypic observations which are the results of interactions of genotype and environment.

In maize, most of the reports on genetic variability for grain yield and other traits under drought were carried out only on inbred lines with the belief that their hybrids will be drought tolerant. Saleem *et al.* (2011) reported significant differences for number of days taken to 50% tasseling, number of days taken to 50% silking, number of ears per plant and 100-grain weight among fifty maize inbred lines. They also reported decreased in days to tasseling and number of cobs while days to silking increased under drought conditions. Hussain *et al.* (2009) studied maize inbred lines under normal and drought conditions and reported significant differences among all lines for all characters studied. The objective of the present study was therefore to estimate genetic variability in some inbred lines and single cross hybrids of maize under non-stress and water stress at flowering. Such information will help to identify populations that could be used to develop drought-tolerant maize varieties, synthetics and hybrids.

## Materials and methods

*Experimental sites and genetic materials used*

Fifty six genotypes were used for this study. Six of these were drought tolerant inbred lines obtained from International Institute of Tropical Agriculture (IITA), Ibadan used as male parents. Seven inbred lines used as female parents were developed by the Institute for Agricultural Research (IAR), Samaru. Forty two genotypes resulted from crosses done and a commercial hybrid check (Oba 98) was included. The single cross hybrids were generated in the year 2012 rainy season using 7 x 6 North Carolina mating design II. The genotypes were evaluated at Samaru, (11$^{o}$11'N, 07$^{o}$38'E, 686m above sea level) in the northern Guinea Savanna and Kadawa, (11$^{o}$39'N, 08$^{o}$02'E, 496m above sea level), in the Sudan Savanna ecological zones of Nigeria under non-stress and water stress conditions in 2012/2013 dry season.

*Experimental design and procedure*

The experimental design used was 7 x 8 simple lattice design, replicated two times under each condition. Each entry was planted in a 3 m row plot spaced 0.75 m apart with 0.25 m spacing between plants within row. Two seeds were planted in a hill and thinned to one plant after emergence to obtain a population density of approximately 53,333 plants per hectare. All agronomic practices were kept uniform in both experiments except irrigation. Non-stress condition continued to receive irrigation water once every week until the end of physiological maturity. In water stress condition, stress was imposed by withdrawing irrigation water as from 5 weeks after planting to ensure drought stress at flowering stage. Because the average anthesis-silking interval was between 3-5 days at Samaru, an additional irrigation was applied at about 14 days after the end of male flowering to ensure that the small amounts of grains formed were filled adequately. No further irrigation water was applied at Kadawa because the average anthesis-silking interval is less than 3 days according to Banziger *et al.* (2000). The two conditions were separated from each other by 2.5m alley to prevent spill-over at the water stress sites during the period of imposed water stress and at the beginning and end of each replication; non experimental lines were planted to minimize the edge effects.

*Data collection and Analysis*

Data were collected on days to 50% tasseling, days to 50% silking, anthesis-silking interval, plant height (cm), ear height (cm), number of ears per plant and grain yield (kg/ha).

The data collected were subjected to analysis of variance for each location followed by combined analysis across the two locations. The analyses were done according to the standard procedures using the generalized linear model (SAS Institute, 2004). Means comparison were conducted using Duncan's New Multiple Range Test (DMRT) described by Duncans (1955).

## Results and discussion

*Analysis of variance*

Mean squares from analysis of variance for various traits under non-stress and water stress conditions were presented in Table 1.

**Table 1.** Combined analysis of variance for traits measured under non-stress and water stress conditions across locations.

| | | Days to 50% tasseling | | Days to 50% silking | | Anthesis-silking interval | | Plant height | |
|---|---|---|---|---|---|---|---|---|---|
| Source | df | Non-stress | Stress | Non-stress | Stress | Non-stress | Stress | Non-stress | Stress |
| Location | 1 | 1032.86** | 1481.14** | 3068.04** | 1455.54** | 111.45** | 48.29** | 117883.15** | 98171.33** |
| Block(Locxrep) | 28 | 7.66 | 13.07 | 7.87 | 13.37* | 0.68 | 2.14* | 219.29 | 326.73* |
| Rep (Loc) | 2 | 112.86** | 58.02** | 16.61** | 51.11** | 30.02** | 4.02** | 977.79** | 176.17 |
| Genotypes | 55 | 57.47** | 32.12** | 60.93** | 33.72** | 7.20** | 2.33* | 1046.09** | 1439.93** |
| Gen x Loc | 55 | 14.34* | 9.83* | 14.36* | 10.75* | 3.69 | 0.75 | 360.81* | 321.15* |
| Error | 82 | 3.49 | 4.04 | 4.16 | 6.81 | 1.27 | 0.49 | 183.08 | 118.23 |
| | | Ear height | | Number of ears per plant | | Grain yield | |
| Source | df | Non-stress | Stress | Non-stress | Stress | Non-stress | Stress |
| Location | 1 | 91516.14** | 38142.54** | 0.41** | 0.06 | 75446417.00** | 112074486.30** |
| Block(Loc x rep) | 28 | 291.69* | 108.44* | 0.07 | 0.03 | 2135427.20* | 2696699.60** |
| Rep (Loc) | 2 | 1138.37** | 65.30 | 0.11 | 0.09 | 2074285.80* | 1984.00 |
| Genotypes | 55 | 385.73* | 533.33** | 0.18* | 0.25* | 7825972.35** | 2408797.50* |
| Gen x Loc | 55 | 147.01* | 105.10* | 0.04 | 0.02 | 1727771.60* | 704673.87 |
| Error | 82 | 51.68 | 97.95 | 0.03 | 0.02 | 876451.52 | 554066.68 |

*and **-significant at 0.05 and 0.01 probability level, respectively; NS=non-stress; S=stress; df=degree of freedom; Rep=replication; Loc=location; Gen=genotype.

Significant (P<0.05-0.01) differences were obtained among genotypes for all the traits under non-stress and water stress conditions. Similar results were reported by Ashofteh *et al.* (2011) and Saleem *et al.* (2011).

The significant differences obtained for all the traits studied under non-stress and water stress conditions indicated the presence of appreciable variability among genotypes which is a pre-requisite for any crop improvement program.

Significant mean squares due to locations were found for all the traits under non-stress and water stress except number of ears per plant under water stress. The significant mean square values obtained for location for all the traits except number of ears per plant under water stress indicated that the conditions in the two locations were not similar in many ways and that is why the genotypes did not perform in the same way in the two locations. The genotype × location interaction mean squares were also significant for all the traits under non-stress and water stress conditions except anthesis-silking interval and number of ears per plant under both conditions and grain yield under severe stress. The significant effects of genotype × location interaction mean squares obtained in most traits also suggest that the environmental conditions in the two locations influenced the performance of the genotypes. This suggested the need to test genotypes over different locations across years to ascertain their stability for use as reliable genetic materials for crop improvement practices. To minimize error and consequently increase the precision and reliability of estimates Allard and Bradshaw (1964) suggested increasing the sample size and number of locations or years during the trials. However, the disadvantage of this suggestion would be increased costs and delayed release of results.

**Table 2.** Mean performances of parents, hybrids and check for traits measured under non-stress and water stress conditions across locations.

| | DYTS | | DYSK | | ASI | | PLHT | | EHT | | EPP | | GY | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Genotypes | NS | S | NS | S | NS | S | NS | S | NS | S | NS | S | NS | S |
| S1 | 62$^{a-f}$ | 67$^{ab}$ | 64$^{a-f}$ | 73$^{ab}$ | 3$^{c-f}$ | 5$^{abc}$ | 156.25$^{a-h}$ | 114.68$^{fg}$ | 87.08$^{a-f}$ | 64.50$^{c-g}$ | 1.00$^{b}$ | 0.86$^{ab}$ | 2277.80$^{e-h}$ | 1222.20$^{a-d}$ |
| S2 | 61$^{a-g}$ | 64$^{a-e}$ | 64$^{a-f}$ | 68$^{a-g}$ | 3$^{c-f}$ | 4$^{a-d}$ | 146.84$^{d-i}$ | 128.83$^{c-g}$ | 93.34$^{a-e}$ | 70.75$^{b-f}$ | 1.13$^{ab}$ | 0.91$^{ab}$ | 1888.90$^{fgh}$ | 1111.10$^{a-d}$ |
| S3 | 62$^{a-f}$ | 65$^{a-d}$ | 65$^{a-d}$ | 68$^{a-g}$ | 3$^{c-f}$ | 3$^{bcd}$ | 134.33$^{g-j}$ | 129.50$^{c-g}$ | 78.75$^{a-f}$ | 67.08$^{b-g}$ | 1.07$^{ab}$ | 0.64$^{ab}$ | 1777.80$^{gh}$ | 833.30$^{bcd}$ |
| S4 | 58$^{d-g}$ | 67$^{ab}$ | 62$^{b-g}$ | 71$^{a-d}$ | 4$^{abc}$ | 4$^{a-d}$ | 138.58$^{f-j}$ | 130.33$^{b-g}$ | 85.42$^{a-f}$ | 62.50$^{c-g}$ | 1.06$^{ab}$ | 0.88$^{ab}$ | 1833.30$^{fgh}$ | 1222.20$^{a-d}$ |
| S5 | 57$^{efg}$ | 63$^{a-f}$ | 60$^{efg}$ | 67$^{a-h}$ | 3$^{c-f}$ | 4$^{a-d}$ | 138.67$^{f-j}$ | 131.25$^{b-g}$ | 62.08$^{f}$ | 64.75$^{c-g}$ | 1.03$^{ab}$ | 0.81$^{ab}$ | 2000.00$^{fgh}$ | 777.80$^{bcd}$ |
| S6 | 63$^{a-d}$ | 67$^{ab}$ | 66$^{abc}$ | 74$^{a}$ | 4$^{abc}$ | 7$^{a}$ | 127.33$^{ij}$ | 114.75$^{fg}$ | 68.33$^{ef}$ | 52.34$^{fg}$ | 1.00$^{b}$ | 0.75$^{ab}$ | 2722.20$^{d-h}$ | 1555.60$^{a-d}$ |
| S7 | 58$^{d-g}$ | 65$^{a-d}$ | 61$^{c-g}$ | 71$^{a-d}$ | 3$^{c-f}$ | 6$^{ab}$ | 129.50$^{hij}$ | 115.33$^{efg}$ | 70.75$^{c-f}$ | 53.67$^{fg}$ | 1.00$^{b}$ | 0.62$^{ab}$ | 1555.60$^{h}$ | 1000.00$^{a-d}$ |
| P1 | 61$^{a-g}$ | 63$^{a-f}$ | 64$^{a-f}$ | 68$^{a-g}$ | 3$^{c-f}$ | 5$^{abc}$ | 162.33$^{a-g}$ | 125.83$^{d-g}$ | 88.75$^{a-f}$ | 66.50$^{b-g}$ | 1.03$^{ab}$ | 0.79$^{ab}$ | 2555.56$^{d-h}$ | 722.20$^{bcd}$ |
| P2 | 63$^{a-e}$ | 63$^{a-f}$ | 65$^{a-d}$ | 68$^{a-g}$ | 3$^{c-f}$ | 5$^{abc}$ | 151.59$^{b-i}$ | 146.58$^{b-f}$ | 79.17$^{a-f}$ | 84.42$^{abc}$ | 1.33$^{ab}$ | 0.64$^{ab}$ | 2000.00$^{fgh}$ | 777.80$^{bcd}$ |
| P3 | 59$^{c-g}$ | 64$^{a-e}$ | 61$^{c-g}$ | 68$^{a-g}$ | 2$^{def}$ | 4$^{a-d}$ | 161.42$^{a-g}$ | 136.08$^{b-g}$ | 81.67$^{a-f}$ | 64.67$^{c-g}$ | 1.34$^{ab}$ | 0.61$^{ab}$ | 1888.90$^{fgh}$ | 777.80$^{bcd}$ |
| P4 | 60$^{b-g}$ | 65$^{a-d}$ | 64$^{a-e}$ | 70$^{a-f}$ | 4$^{abc}$ | 5$^{abc}$ | 134.08$^{g-j}$ | 118.17$^{efg}$ | 88.75$^{a-f}$ | 55.83$^{efg}$ | 1.16$^{ab}$ | 0.89$^{ab}$ | 2888.89$^{fgh}$ | 666.70$^{bcd}$ |
| P7 | 61$^{a-g}$ | 66$^{abc}$ | 65$^{a-d}$ | 73$^{ab}$ | 4$^{abc}$ | 7$^{a}$ | 143.42$^{e-i}$ | 123.58$^{d-g}$ | 74.17$^{b-f}$ | 56.50$^{d-g}$ | 1.00$^{b}$ | 0.99$^{ab}$ | 1555.60$^{h}$ | 444.40$^{d}$ |
| P8 | 65$^{a}$ | 68$^{a}$ | 68$^{a}$ | 72$^{abc}$ | 3$^{c-f}$ | 4$^{a-d}$ | 113.33$^{j}$ | 99.00$^{g}$ | 69.17$^{def}$ | 50.92$^{g}$ | 1.38$^{ab}$ | 1.04$^{ab}$ | 2055.60$^{fgh}$ | 611.10$^{cd}$ |
| S1 x P1 | 60$^{b-g}$ | 61$^{a-g}$ | 63$^{a-g}$ | 65$^{a-j}$ | 4$^{abc}$ | 4$^{a-d}$ | 184.59$^{a}$ | 139.17$^{b-g}$ | 88.75$^{a-f}$ | 62.75$^{c-g}$ | 1.03$^{ab}$ | 0.89$^{ab}$ | 3655.60$^{a-h}$ | 1222.20$^{a-d}$ |
| S1 x P2 | 59$^{c-g}$ | 60$^{b-g}$ | 63$^{a-g}$ | 63$^{c-j}$ | 3$^{c-f}$ | 3$^{bcd}$ | 164.08$^{a-f}$ | 156.25$^{ab}$ | 100.42$^{ab}$ | 74.67$^{b-f}$ | 1.18$^{ab}$ | 0.72$^{ab}$ | 4433.30$^{a-f}$ | 1055.60$^{a-d}$ |
| S1 x P3 | 63$^{a-e}$ | 65$^{a-d}$ | 68$^{a}$ | 69$^{a-e}$ | 5$^{a}$ | 4$^{a-d}$ | 162.25$^{a-g}$ | 145.09$^{b-f}$ | 76.92$^{a-f}$ | 69.09$^{b-g}$ | 1.03$^{ab}$ | 0.92$^{ab}$ | 4766.70$^{a-d}$ | 1444.40$^{a-d}$ |
| S1 x P4 | 59$^{c-g}$ | 60$^{b-g}$ | 62$^{b-g}$ | 64$^{b-j}$ | 3$^{c-f}$ | 4$^{a-d}$ | 174.25$^{a-d}$ | 125.67$^{d-g}$ | 91.25$^{a-e}$ | 61.17$^{c-g}$ | 1.23$^{ab}$ | 0.68$^{ab}$ | 3877.80$^{a-h}$ | 888.90$^{a-d}$ |
| S1 x P7 | 61$^{a-g}$ | 60$^{b-g}$ | 65$^{a-d}$ | 63$^{c-j}$ | 4$^{abc}$ | 3$^{bcd}$ | 171.00$^{a-e}$ | 132.50$^{b-g}$ | 86.25$^{a-f}$ | 64.92$^{c-g}$ | 1.07$^{ab}$ | 1.26$^{a}$ | 4100.00$^{a-h}$ | 1000.00$^{a-d}$ |
| S1 x P8 | 59$^{c-g}$ | 62$^{a-f}$ | 61$^{c-g}$ | 67$^{a-h}$ | 2$^{def}$ | 6$^{ab}$ | 168.25$^{-f}$ | 139.84$^{b-g}$ | 99.17$^{abc}$ | 68.33$^{b-g}$ | 1.11$^{ab}$ | 0.94$^{ab}$ | 3433.30$^{a-h}$ | 666.70$^{bcd}$ |
| S2 x P1 | 64$^{ab}$ | 61$^{a-g}$ | 67$^{ab}$ | 64$^{b-j}$ | 3$^{c-f}$ | 3$^{bcd}$ | 177.42$^{abc}$ | 149.00$^{b-f}$ | 80.84$^{a-f}$ | 70.25$^{b-f}$ | 1.22$^{ab}$ | 0.66$^{ab}$ | 4433.30$^{a-f}$ | 1444.40$^{a-d}$ |
| S2 x P2 | 61$^{a-g}$ | 65$^{a-d}$ | 64$^{a-f}$ | 68$^{a-g}$ | 3$^{c-f}$ | 3$^{bcd}$ | 166.17$^{a-f}$ | 144.34$^{b-f}$ | 102.08$^{ab}$ | 67.75$^{b-g}$ | 1.06$^{ab}$ | 0.90$^{ab}$ | 3544.40$^{a-h}$ | 1222.20$^{a-d}$ |
| S2 x P3 | 59$^{c-g}$ | 65$^{a-d}$ | 62$^{b-g}$ | 67$^{a-h}$ | 3$^{c-f}$ | 3$^{bcd}$ | 180.58$^{ab}$ | 142.58$^{b-f}$ | 90.42$^{a-e}$ | 73.83$^{b-f}$ | 1.05$^{ab}$ | 0.65$^{ab}$ | 3766.70$^{a-h}$ | 1222.20$^{a-d}$ |
| S2 x P4 | 61$^{a-e}$ | 60$^{b-g}$ | 64$^{a-f}$ | 64$^{b-j}$ | 3$^{c-f}$ | 3$^{bcd}$ | 180.67$^{ab}$ | 140.25$^{b-f}$ | 79.17$^{a-f}$ | 68.75$^{b-g}$ | 1.16$^{ab}$ | 0.99$^{ab}$ | 3544.40$^{a-h}$ | 1166.70$^{a-d}$ |
| S2 x P7 | 59$^{c-g}$ | 61$^{a-g}$ | 61$^{c-g}$ | 67$^{a-h}$ | 3$^{c-f}$ | 5$^{abc}$ | 164.09$^{a-f}$ | 132.92$^{b-g}$ | 97.92$^{abc}$ | 68.58$^{b-g}$ | 1.03$^{ab}$ | 0.81$^{ab}$ | 4433.30$^{a-f}$ | 1833.30$^{abc}$ |
| S2 x P8 | 58$^{d-g}$ | 63$^{a-f}$ | 61$^{c-g}$ | 66$^{a-i}$ | 3$^{c-f}$ | 4$^{a-d}$ | 179.83$^{abc}$ | 152.25$^{a-d}$ | 90.42$^{a-e}$ | 75.34$^{a-f}$ | 1.08$^{ab}$ | 0.94$^{ab}$ | 3322.20$^{b-h}$ | 1333.30$^{a-d}$ |
| S3 x P1 | 61$^{a-g}$ | 61$^{a-g}$ | 64$^{a-f}$ | 66$^{a-i}$ | 3$^{c-f}$ | 5$^{abc}$ | 179.33$^{abc}$ | 145.09$^{b-f}$ | 83.50$^{a-f}$ | 76.75$^{a-f}$ | 1.17$^{ab}$ | 0.70$^{ab}$ | 4988.90$^{abc}$ | 1333.30$^{a-d}$ |
| S3 x P2 | 58$^{d-g}$ | 59$^{c-g}$ | 60$^{efg}$ | 62$^{d-j}$ | 3$^{c-f}$ | 3$^{bcd}$ | 171.34$^{a-e}$ | 140.33$^{b-f}$ | 78.33$^{a-f}$ | 63.33$^{c-g}$ | 1.31$^{ab}$ | 0.96$^{ab}$ | 5877.80$^{a}$ | 888.90$^{a-d}$ |
| S3 x P3 | 63$^{a-d}$ | 63$^{a-f}$ | 67$^{ab}$ | 66$^{a-i}$ | 4$^{abc}$ | 4$^{a-d}$ | 174.25$^{a-d}$ | 140.83$^{b-f}$ | 81.25$^{a-f}$ | 58.08$^{d-g}$ | 1.20$^{ab}$ | 0.47$^{b}$ | 3322.20$^{b-h}$ | 1666.70$^{a-d}$ |
| S3 x P4 | 56$^{g}$ | 64$^{a-e}$ | 60$^{efg}$ | 68$^{a-g}$ | 4$^{abc}$ | 4$^{a-d}$ | 150.00$^{c-i}$ | 147.75$^{b-f}$ | 78.33$^{a-f}$ | 80.08$^{a-d}$ | 1.05$^{ab}$ | 0.71$^{ab}$ | 5433.30$^{ab}$ | 777.80$^{bcd}$ |
| S3 x P7 | 57$^{efg}$ | 59$^{c-g}$ | 60$^{efg}$ | 62$^{d-j}$ | 3$^{c-f}$ | 3$^{bcd}$ | 167.75$^{a-f}$ | 145.67$^{b-f}$ | 82.09$^{a-f}$ | 79.00$^{a-e}$ | 1.06$^{ab}$ | 0.67$^{ab}$ | 4211.10$^{a-g}$ | 888.90$^{a-d}$ |
| S3 x P8 | 62$^{a-f}$ | 59$^{c-g}$ | 62$^{b-g}$ | 63$^{c-j}$ | 0$^{f}$ | 4$^{a-d}$ | 178.59$^{abc}$ | 141.00$^{b-f}$ | 91.25$^{a-e}$ | 67.59$^{b-g}$ | 1.00$^{b}$ | 1.04$^{ab}$ | 5100.00$^{abc}$ | 1222.20$^{a-d}$ |
| S4 x P1 | 58$^{d-g}$ | 61$^{a-g}$ | 61$^{c-g}$ | 66$^{a-i}$ | 3$^{c-f}$ | 5$^{abc}$ | 156.00$^{a-h}$ | 151.09$^{a-e}$ | 95.42$^{a-e}$ | 86.75$^{a}$ | 1.13$^{ab}$ | 0.76$^{ab}$ | 3988.90$^{a-h}$ | 1333.30$^{a-d}$ |
| S4 x P2 | 58$^{d-g}$ | 58$^{d-g}$ | 61$^{c-g}$ | 61$^{e-j}$ | 3$^{c-f}$ | 3$^{bcd}$ | 166.61$^{a-f}$ | 136.00$^{b-g}$ | 90.00$^{a-e}$ | 71.50$^{b-f}$ | 1.10$^{ab}$ | 0.79$^{ab}$ | 3877.80$^{a-h}$ | 444.40$^{d}$ |
| S4 x P3 | 63$^{a-d}$ | 65$^{a-d}$ | 64$^{a-f}$ | 68$^{a-g}$ | 1$^{ef}$ | 3$^{bcd}$ | 158.50$^{a-h}$ | 134.17$^{b-g}$ | 95.00$^{a-e}$ | 71.83$^{b-f}$ | 1.04$^{ab}$ | 0.80$^{ab}$ | 4100.00$^{a-h}$ | 1888.90$^{ab}$ |
| S4 x P4 | 57$^{efg}$ | 62$^{a-f}$ | 59$^{fg}$ | 66$^{a-i}$ | 2$^{def}$ | 4$^{a-d}$ | 172.00$^{a-e}$ | 140.50$^{b-f}$ | 94.58$^{a-e}$ | 68.59$^{b-g}$ | 1.08$^{ab}$ | 0.69$^{ab}$ | 4433.30$^{a-f}$ | 777.80$^{bcd}$ |
| S4 x P7 | 59$^{c-g}$ | 64$^{a-e}$ | 61$^{c-g}$ | 67$^{a-h}$ | 2$^{def}$ | 3$^{bcd}$ | 162.75$^{a-g}$ | 144.08$^{b-f}$ | 103.33$^{a}$ | 72.84$^{b-f}$ | 1.13$^{ab}$ | 0.97$^{ab}$ | 4322.20$^{a-g}$ | 1333.30$^{a-d}$ |
| S4 x P8 | 59$^{c-g}$ | 62$^{a-f}$ | 61$^{c-g}$ | 65$^{a-j}$ | 2$^{def}$ | 3$^{bcd}$ | 169.42$^{a-e}$ | 149.75$^{a-f}$ | 100.42$^{ab}$ | 75.67$^{a-f}$ | 1.00$^{b}$ | 0.82$^{ab}$ | 3433.30$^{a-h}$ | 888.90$^{a-d}$ |
| S5 x P1 | 57$^{efg}$ | 61$^{a-g}$ | 60$^{efg}$ | 64$^{b-j}$ | 3$^{c-f}$ | 3$^{bcd}$ | 173.75$^{a-e}$ | 129.09$^{c-g}$ | 92.08$^{a-e}$ | 62.00$^{c-g}$ | 1.00$^{b}$ | 0.55$^{ab}$ | 3766.70$^{a-h}$ | 1666.70$^{a-d}$ |

**Table 2. Continue.**

| | DYTS | | DYSK | | ASI | | PLHT | | EHT | | EPP | | GY | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Genotypes | NS | S | NS | S | NS | S | NS | S | NS | S | NS | S | NS | S |
| S5 x P2 | $57^{efg}$ | $62^{a-f}$ | $60^{efg}$ | $64^{b-j}$ | $2^{def}$ | $3^{bcd}$ | $176.17^{a-d}$ | $148.71^{b-f}$ | $68.80^{ef}$ | $71.50^{b-f}$ | $1.18^{ab}$ | $0.83^{ab}$ | $3655.60^{a-h}$ | $1333.30^{a-d}$ |
| S5 x P3 | $58^{d-g}$ | $58^{d-g}$ | $60^{efg}$ | $61^{e-j}$ | $2^{def}$ | $3^{bcd}$ | $159.17^{a-g}$ | $146.92^{b-f}$ | $82.08^{a-f}$ | $63.42^{c-g}$ | $1.16^{ab}$ | $0.60^{ab}$ | $3988.90^{a-h}$ | $1222.20^{a-d}$ |
| S5 x P4 | $58^{d-g}$ | $60^{b-g}$ | $61^{c-g}$ | $63^{c-j}$ | $3^{c-f}$ | $2^{cd}$ | $170.59^{a-e}$ | $137.92^{b-g}$ | $95.00^{a-e}$ | $61.42^{c-g}$ | $1.24^{ab}$ | $0.67^{ab}$ | $4211.10^{a-g}$ | $1333.30^{a-d}$ |
| S5 x P7 | $57^{efg}$ | $60^{b-g}$ | $59^{fg}$ | $62^{d-j}$ | $2^{def}$ | $2^{cd}$ | $173.00^{a-e}$ | $152.67^{a-d}$ | $82.09^{a-f}$ | $76.00^{a-f}$ | $1.35^{ab}$ | $0.64^{ab}$ | $3877.80^{a-h}$ | $555.60^{d}$ |
| S5 x P8 | $60^{b-g}$ | $59^{c-g}$ | $62^{b-g}$ | $63^{c-j}$ | $2^{def}$ | $4^{a-d}$ | $161.92^{a-g}$ | $128.92^{c-g}$ | $94.17^{a-e}$ | $67.59^{b-g}$ | $1.08^{ab}$ | $0.70^{ab}$ | $5100.00^{abc}$ | $1333.30^{a-d}$ |
| S6 x P1 | $58^{d-g}$ | $59^{c-g}$ | $60^{efg}$ | $64^{b-j}$ | $2^{def}$ | $5^{abc}$ | $156.08^{a-h}$ | $152.17^{a-d}$ | $79.17^{a-f}$ | $85.17^{ab}$ | $1.41^{a}$ | $0.66^{ab}$ | $3766.70^{a-h}$ | $888.90^{a-d}$ |
| S6 x P2 | $58^{d-g}$ | $62^{a-f}$ | $60^{efg}$ | $64^{b-j}$ | $2^{def}$ | $2^{cd}$ | $171.67^{a-e}$ | $147.92^{b-f}$ | $86.67^{a-f}$ | $69.92^{b-g}$ | $1.36^{ab}$ | $0.82^{ab}$ | $4988.90^{abc}$ | $888.90^{a-d}$ |
| S6 x P3 | $57^{c-g}$ | $64^{a-e}$ | $60^{efg}$ | $67^{a-h}$ | $3^{c-f}$ | $3^{bcd}$ | $165.67^{a-f}$ | $136.42^{b-g}$ | $80.00^{a-f}$ | $78.08^{a-f}$ | $1.24^{ab}$ | $0.87^{ab}$ | $5433.30^{ab}$ | $1444.40^{a-d}$ |
| S6 x P4 | $60^{b-g}$ | $59^{c-g}$ | $63^{a-g}$ | $62^{d-j}$ | $3^{c-f}$ | $3^{bcd}$ | $164.84^{a-f}$ | $149.75^{a-f}$ | $89.17^{a-f}$ | $76.33^{a-f}$ | $1.15^{ab}$ | $0.96^{ab}$ | $3766.70^{a-h}$ | $1277.80^{a-d}$ |
| S6 x P7 | $59^{c-g}$ | $62^{a-f}$ | $63^{a-g}$ | $65^{a-j}$ | $3^{c-f}$ | $3^{bcd}$ | $174.67^{a-d}$ | $159.42^{a}$ | $97.50^{a-d}$ | $71.50^{b-f}$ | $1.08^{ab}$ | $0.83^{ab}$ | $5211.10^{abc}$ | $1166.70^{a-d}$ |
| S6 x P8 | $62^{a-f}$ | $65^{a-d}$ | $64^{a-f}$ | $68^{a-g}$ | $2^{def}$ | $3^{bcd}$ | $161.83^{a-g}$ | $140.92^{b-f}$ | $77.50^{a-f}$ | $74.00^{b-f}$ | $1.00^{b}$ | $0.79^{ab}$ | $4655.60^{a-e}$ | $833.30^{bcd}$ |
| S7 x P1 | $57^{efg}$ | $58^{d-g}$ | $60^{efg}$ | $62^{d-j}$ | $3^{c-f}$ | $5^{abc}$ | $185.00^{a}$ | $154.08^{abc}$ | $89.58^{a-f}$ | $84.75^{abc}$ | $1.07^{ab}$ | $1.13^{ab}$ | $3655.60^{a-h}$ | $666.70^{bcd}$ |
| S7 x P2 | $57^{efg}$ | $60^{b-g}$ | $59^{fg}$ | $63^{c-j}$ | $3^{c-f}$ | $3^{bcd}$ | $161.09^{a-g}$ | $143.50^{b-f}$ | $90.42^{a-e}$ | $74.92^{b-f}$ | $1.08^{ab}$ | $1.06^{ab}$ | $4322.20^{a-g}$ | $1500.00^{a-d}$ |
| S7 x P3 | $59^{c-g}$ | $59^{c-g}$ | $62^{b-g}$ | $63^{c-j}$ | $3^{c-f}$ | $4^{a-d}$ | $169.67^{a-e}$ | $142.58^{b-f}$ | $92.08^{a-e}$ | $71.67^{b-f}$ | $1.13^{ab}$ | $0.76^{ab}$ | $4100.00^{a-h}$ | $1111.10^{a-d}$ |
| S7 x P4 | $57^{efg}$ | $58^{d-g}$ | $60^{efg}$ | $63^{c-j}$ | $3^{c-f}$ | $5^{abc}$ | $163.83^{a-f}$ | $140.75^{b-f}$ | $85.00^{a-f}$ | $72.17^{b-f}$ | $1.14^{ab}$ | $0.82^{ab}$ | $4100.00^{a-h}$ | $1111.10^{a-d}$ |
| S7 x P7 | $56^{g}$ | $62^{a-f}$ | $59^{fg}$ | $66^{a-i}$ | $3^{c-f}$ | $3^{bcd}$ | $170.33^{a-e}$ | $137.67^{b-g}$ | $97.92^{abc}$ | $67.25^{b-g}$ | $1.05^{ab}$ | $0.94^{ab}$ | $4988.90^{abc}$ | $1888.90^{ab}$ |
| S7 x P8 | $57^{efg}$ | $59^{c-g}$ | $61^{c-g}$ | $62^{d-j}$ | $3^{c-f}$ | $3^{bcd}$ | $183.67^{a}$ | $139.58^{b-g}$ | $93.33^{a-e}$ | $69.34^{b-g}$ | $1.17^{ab}$ | $1.00^{ab}$ | $4655.60^{a-e}$ | $2111.10^{a}$ |
| Check | $62^{a-f}$ | $64^{a-e}$ | $65^{a-d}$ | $66^{a-i}$ | $3^{c-f}$ | $2^{cd}$ | $166.08^{a-f}$ | $152.75^{abc}$ | $81.67^{a-f}$ | $76.42^{a-f}$ | $1.19^{ab}$ | $0.62^{ab}$ | $5000.00^{abc}$ | $1111.10^{a-d}$ |
| MEAN | 59 | 62 | 62 | 66 | 3 | 4 | 162.97 | 138.78 | 86.41 | 69.38 | 1.13 | 0.81 | 3761.51 | 1126.98 |
| CV (%) | 5.35 | 6.24 | 5.22 | 6.28 | 30.66 | 48.22 | 10.55 | 11.48 | 18.11 | 16.4 | 19.67 | 44.51 | 37.3 | 60.74 |
| % increase/ decrease | | 5 | | 6 | | 33 | | -15 | | -20 | | -28 | | -70 |

DYTS=Days to 50% tasseling; DYSK=Days to 50% silking; ASI=Anthesis-silking interval; PLHT=Plant height; EHT=Ear height; EPP=Number of ears per plant; GY=Grain yield; NS=Non-stress; S=Stress

Means with same letters in a column are not significant difference according to Duncan Multiple Range Test (DMRT) at 5% level of probability.

*Mean performance*

Mean performances of parents, hybrids and check for traits measured under non-stress and water stress conditions across locations are presented in Table 2. The result showed significant differences among the genotypes for yield and other traits studied. Days to 50 % tasseling varied from 56 days to 65 days under non-stress condition and 58 to 68 days under water stress condition. Under non-stress condition, the inbred line P8 took maximum number of days to 50% tasseling (65) while the hybrids S3 x P4 and S7 x P7 took minimum number of days to 50% tasseling (56). Under water stress condition, the inbred line P8 took maximum number of days to 50% tasseling (68) while the hybrids S5 x P3, S7 x P4, S4 x P2 and S7 x P1 depicted minimum number of days to 50% tasseling (58). The number of days taken to 50 tasseling increased under water stress condition by 5 %. This result contradicts the report of Saleem *et al.* (2011) who reported reduction in number of days taken to 50% tasseling.

Days to 50% silking varied from 59 to 68 days under non-stress condition and 61 to 74 days under water stress condition. Under non-stress condition, the inbred line P8 and the hybrid S1 x P3 took maximum mean number of days to 50% silking (68) while the minimum mean number of days to 50% silking (59) was taken by the hybrids S5 x P7, S4 x P4, S7 x P2 and S7 x P7.

The inbred line S6 took maximum number of days to 50% silking (74) while the hybrids S5 x P3 and S4 x P2 took minimum mean number of days to 50% tasseling (61) under water stress condition. The number of days taken to 50% silking increased under water stress condition by 6 %. Increase in days taken to silking under drought was also reported by Saleem *et al.* (2011).

Anthesis-silking interval varied from 0 to 5 days under non-stress condition and 2 to 7 days under water stress condition. The hybrid S1 x P3 recorded maximum mean of anthesis-silking interval (5 days) while the minimum mean of anthesis-silking interval (0 day) was recorded by the hybrids S3 x P8 under non-stress condition. The inbred lines S6 and P7 recorded the maximum mean of anthesis-silking interval (7 days) while the minimum mean of anthesis-silking interval (2 days) were observed for the hybrids S5 x P7, S6 x P2, S5 x P4 and check under water stress condition. Anthesis-silking interval increased under water stress condition by 33 %.

Bolanos and Edmeades (1993) reported that a stress period of water shortages causes delay in anthesis, silking and anthesis-silking interval in maize.

Plant height varied from 113.33 cm to 185.00 cm under non-stress condition and 99.00 cm to 159.42 cm under water stress condition.

The hybrid S7 x P1 was the tallest (185.00 cm) under non-stress condition while the inbred line P8 was the shortest (113.33 cm). Under water stress condition, the tallest hybrid was S6 x P7 (159.42 cm) while the inbred line (P8) was the shortest (99.00 cm). Plant height reduced under water stress condition by 15 %. Reduction in plant height may be due to reduction in internodes and number of nodes. Similar result was reported by Maleki *et al.* (2014) who reported that drought stress reduced plant height by stunting internodes and reduced number of nodes.

Ear height varied from 62.08 cm to 103.33 cm under non-stress condition and 50.92 cm to 86.75 cm under water stress condition. The hybrid S4 x P7 recorded the tallest ear height (103.33 cm) while the inbred line S5 had the shortest ear height (62.08 cm) under non-stress condition. Under water stress condition, the hybrid S4 x P7 recorded the tallest ear height (86.75 cm) while the shortest was recorded by P8 (50.92 cm). Ear height was reduced under water stress condition by 20 %. Reduction in ear height may also be due to reduction in internodes and number of nodes.

Number of ears per plant varied from 1.00 to 1.41 under non-stress condition and 0.47 to 1.26 under water stress condition. The inbred lines S1, S6, S7, P7 and the hybrids S6 x P8, S5 x P1, S3 x P8 and S4 x P8 recorded the lowest number of ears per plant (1.00) under non-stress condition while the hybrid S6 x P1 recorded the highest number of ears per plant (1.41). Under water stress condition, the hybrid S1 x P7 recorded the highest number of ears per plant (1.26) while the lowest was recorded by S3 x P3 (0.47). On overall bases number of ears per plant decreased under water stress condition by 28 %. Reduction in number of ears per plant under drought was also reported by Saleem *et al.* (2011). Drought at flowering causes severe barrenness and destabilizes the grain yield. Ability of a genotype to produce an ear under such adverse conditions is an important characteristic of drought tolerance in maize (Banziger *et al.,* 2000).
Grain yield varied from 1555.60 kg/ha to 5877.80 kg/ha under non-stress condition and 444.40 kg/ha to 2111.10 kg/ha under water stress condition. The hybrid S3 x P2 recorded the highest grain yield (5877.80 kg/ha) under non-stress condition while the inbred lines S7 and P7 recorded the lowest grain yield (1555.60 kg/ha). Under water stress condition, the hybrid S7 x P8 recorded the highest grain yield (2111.10 kg/ha) while the inbred line S6 and the hybrid S4 x P2 recorded the lowest grain yield (444.40 kg/ha). The wide variability observed for yield as a quantitatively inherited character among the genotypes means there is ample opportunity for selection among the genotypes for improvement of this important economic character. The differences in performance among the genotypes are an indication of variability which could be heritable and can be exploited in the overall process of selection in breeding programs for drought tolerance. The trial mean grain yield of 1126.98 kg/ha under severe stress condition across the two locations reported in this study was 70 % lower than the trial mean of 3761.51 kg/ha under non-stress condition across the two locations. Banziger *et al.* (2000) reported yield reduction ranges of 80-85 % under drought stress at flowering which was slightly higher than the result obtained in the current study. However, Betran *et al.* (2003) reported yield reductions of 50% under severe drought stress in one site and reductions of 48% in another site during the same season which were lower than that obtained in this study.

*Population variability*

Coefficients of variation (CVs) are used to measure variability in genetic populations, to determine the best plot size in uniformity trials, to measure stability of phenotypes, or measure variation in individual or population attributes. In general, larger CVs were obtained for most of the traits under water stress compared to non-stress (Table 2). Badu-Apraku *et al.* (2005) reported similar result under drought stress and suggested that CVs are usually higher under stressed conditions. The CVs for anthesis-silking interval, numbers of ears per plant and grain yield were high probably because the data were derived from other traits or based on proportions.

This confirmed the reports of Ajala *et al.* (2009) who reported that the CVs of traits derived from other traits are usually higher than the ones measured directly. Days to 50 % tasseling, days to 50 % silking, plant height and ear height showed low magnitude of CVs under both non-stress and stressed conditions. Acquaah (2007) reported that a CV of 10 % or less is generally desirable in biological experiments.

## Conclusion

The success of any breeding program depends upon the genetic variation in the materials at hand. The greater the genetic variability, the higher would be the heritability and hence the better the chances of success to be achieved through selection. There was considerable variability present in the materials used. As such these results will be useful for choosing populations to be used in developing new improved maize populations under drought conditions. The study suggested that, the hybrids S7 x P8 followed by S7 x P7, S4 x P3 and S2 x P7 having broader genetic makeup and high yield under drought conditions might be exploited in breeding programs for the development of drought tolerant maize varieties, synthetics and hybrids.

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