Applied Tropical Agriculture
Volume 22, No. 2, 73-78, 2017.

Dry Season Evaluation of Extra-Early Maize Hybrids for Growth and Yield in a Rainforest Agro-Ecological Zone

Fayeun, L.S.*, Adeseun, D.E., Mogaji, B.O. and Eniola, O.A.

Department of Crop, Soil and Pest Management, Federal University of Technology, P.M.B. 704 Akure, Ondo State Nigeria
*Corresponding author: fayeunls@yahoo.com

ABSTRACT

A field experiment was carried out during the 2015/2016 dry season at the Teaching and Research Farm of the Federal University of Technology, Akure with the aim of evaluating growth and yield performance of ten extra-early maize hybrids with two local checks. The experiment was laid out in a randomised complete block design. Data collected on number of days to 50% tasseling, number of days to 50% silking, plant height (cm), ear height (cm), number of cobs, cob length (cm), cob girth (cm), field weight (g), 100-grain weight (g) and number of kernel rows were subjected to analysis of variance. The hybrids differed ($p \leq 0.05$) significantly in reproductive traits (number of days to 50% tasseling and silking) and field weight. Heritability estimates were moderate in number of days to tasseling (32.75%) and silking (35.95%), ear height (33.43%), field weight (35.98%) and number of kernel rows (27.66%) while other triats were low implying high environmental influence. Field weight had positive and significant correlation with 100-grain weight (0.497), plant height (0.636) and ear height (0.616) but had negative and significant correlations with reproductive traits. Plant and ear heights also had negative and significant correlation with reproductive traits. Hybrid 'TZDEEI 13 × TZEEI 79' had the highest yield while hybrids 'TZDEEI 7 × TZEEI 79' was the earliest in maturity. A cross between hybrid 'TZDEEI 13 × TZEEI 79' and hybrid 'TZDEEI 7 × TZEEI 79' will lead to development of a double cross hybrid which will combine high yield and extra-earliness traits.

Key words: Hybrid; Extra-early; Variation; Correlation

INTRODUCTION

Maize (*Zea mays*) is a very important cereal crop in the world. The uses of maize is not only restricted to human food but it is also important as animal feed and for industrial purposes. Its prospects over other food crops are overwhelming, it is proposed to be the highest produced crop in the world by 2025 and demand for it would be doubled by 2050 in the developing countries (CIMMYT and IITA, 2010). The crop is cultivated worldwide on more than 160 million hectares every year, annual production was estimated at 785 million tons (Umar *et al*., 2014).

In many areas of Sub-Saharan Africa (SSA), maize is the principal staple crop, covering a total of nearly 27 million ha (FAO, 2010). It accounts for 30% of the total area under cereal production in this region: 19% in West Africa, 61% in Central Africa, 29% in Eastern Africa and 65% in Southern Africa (FAO, 2010). In Southern Africa, maize is particularly important, accounting for over 30% of the total calories and protein consumed (FAO, 2010).

Maize has been in the diet of Nigerians for centuries and is also a versatile crop on which many agro-based industries depend as raw materials. In the past maize was mainly cultivated in the rainforest and derived savannah zones of Nigeria. Now it is rapidly replacing other cereals (sorghum and millet) in the Savannahs (Fakorede *et al*., 2003). This spreading of maize cultivation could be attributed to availability of improved varieties that are tolerant to biotic and abiotic stresses. In addition, its high yields per unit area, husk cover (for protection against bird's damage and rain) and good competition against weeds are responsible for its widespread cultivation (Onwueme and Singha, 1991). Despite an increased area of land for maize cultivation in Nigeria since the mid- 2000s, its production per hectare is still low (1.3 t/ha) compared to the 8.6t/ha in developed countries (FAOSTAT, 2013). Maize yield is low in Nigeria because of some limiting factors of maize production, which include both; biotic (e.g. pests and diseases) and abiotic (e.g. drought, flooding) factors. The irregular distribution of rains due to climatic variations within each particular region causes drought of variable intensities. It has been estimated that drought problems depending on year and intensity could reduce maize production by 14% to 28% (Santos *et al*., 1996).

However, reasonable improvement has been achieved in recent time due to the development of improved maize varieties that are resistant to striga, pests, diseases and drought. Hybridisation is one of the many improvement methods used in maize. Due to hybrid vigour, hybrids are high yielding, early maturing and are more resistant to weeds, pests and diseases. This hybrid vigour (heterosis) occurs when two genetically unrelated parents are crossed. Considering the importance and rising demand of maize as a feed and staple food in Nigeria, year-round cultivation would help meet this demand. Dry season cultivation of maize is challenging because of the characteristics of the season; dry air, high soil and air temperature, low relative humidity and limiting soil moisture. Thus, planting of extra-early maize varieties that can withstand these stresses would be reasonable. Extra-early maize variety reaches physiological or harvest maturity in less than 90 days (Badu-Apraku *et al*., 2012) and they are preferred to other cereals such as sorghum and pearl millet because they are more responsive to fertilizer application and attain maturity faster (Badu-Apraku *et al*., 2013). Extra-early maize varieties also provide farmers in various agro-ecological zones with the flexibility to plant maize when the rains are delayed as well as when the rainfall distribution is normal (Badu-Apraku *et al*., 2012). Use of drought tolerant extra-early hybrid maize during dry season will help farmers to minimise length of irrigation and maximise yield. Hence, this work was initiated to evaluate growth and yield performance among some extra-early maize hybrids during dry season and determine relationship between yield and related traits.

METHODOLOGY

This study was carried out at the Teaching and Research Farm of the Federal University of Technology, Akure (FUTA). Akure a tropical rainforest zone of south western Nigeria, lies between longitude 5°06'E to 5°38'E and between latitude 7°07'N to 7°37'N in the South-western Nigeria (Ayeni, 2011). The study location is characterized by bimodal pattern of rainfall with an annual mean of about 1524 mm with a mean temperature of 27^{0}C. Ten extra-early maturing and drought tolerant maize hybrids were obtained from the International Institute for Tropical agriculture (IITA) Ibadan, Nigeria and two checks varieties obtained from the Department of Crop, Soil and Pest Management, FUTA were used for the experiment. The experiment was laid out in randomized complete block design with three blocks (replications). The land was ploughed and harrowed. The experimental area was 8.5 m × 16.5 m (140.25 m^2). The land used was divided into three blocks and each block had two row plot that were 2.5 m long and spaced 0.75 m apart. Each block measured 2.5 m × 16.5 m. Alley way of 0.5 m were created between the blocks. Planting was done on 15th January, 2016. Two seeds were planted per hill (later thinned to one per hill). The field was manually weeded at 3 and 7 weeks after planting (WAP). NPK 20:15:15 fertilizer was applied at 3 WAP and Urea was applied three weeks later. The field was irrigated during the first six weeks before the rains began to fall. Out of the twenty plants per plot, growth data were collected on ten of them while all cobs harvested per plot were used for field weight. The following quantitative data were collected on each variety for agronomic and yield characters using appropriate equipment: number of days to 50% tasseling, number of days to 50% silking, plant height (cm), ear height (cm), number of cobs, cob length (cm), cob girth (cm), field weight (g), 100-grain weight (g) and number of kernel rows. The data obtained for each character on the basis of sampled plants were averaged and the mean values obtained were subjected to two-way analysis of variance using Minitab Version 17 and significant means were separated using Tukey test.

Genotypic and phenotypic coefficients of variation were computed using the procedure of Singh and Chaudhury (1985) as follows.

$$\text{Genotypic coefficients of variation (GCV)} = \frac{\sqrt{\sigma_g^2}}{\bar{x}} \text{ X } 100$$

$$\text{Phenotypic coefficients of variation (PCV)} = \frac{\sqrt{\sigma_p^2}}{\bar{x}} \text{ X } 100$$

GCV and PCV values were categorized as low, moderate and high Siva-Subramanian and Menon (1973)

0 – 10%: Low

10 – 20%: Moderate

21% and above: High

Broad sense heritability was estimated as the ratio of genetic variance to the phenotypic variance and expressed in percentage as recommended by Singh and Chaudhury (1985):

$$\text{Heritability (H)} = \frac{\sigma_g^2}{\sigma_g^2+\sigma_e^2} \, X \, 100$$

Where:

$$\sigma^2{}_g + \sigma^2 e = \sigma^2 p$$

Heritability percentage was categorized as low, moderate and high as by Elrod and Stanfield (2002) as follows,

0 – 20%: Low

20 – 50%: Moderate

50% and above: High

Genetic advance (GA) was computed according to the formula given by Johnson *et al*. (1955) as used by Fayeun *et al*. (2012).

$$GA = \frac{\sigma_g^2}{\sqrt{\sigma_p^2}} \text{ X K}$$

Where:

K = 2.06 (selection differential at 5%)

Where:

σ_g^2 = Genotypic variation

σ_p^2 = Phenotypic variation

$\bar{x}$ = Sample mean of the character

Correlation coefficients were calculated to determine the degree of association among the characters. This was done according to the formula given by Singh and Chaudhury (1985).

$$r_{xy} = \frac{cov_{xy}}{\sqrt{var_x var_y}}$$

Where:

r_{xy} = correlation coefficient between characters' x and y

$Cov_{(xy)}$ = covariance of character x and y

Var_x = variance of character x

Var_y = variance of character y

Test of significance of correlation was done by comparing the computed values against tabular 'r' values given by Fisher and Yates (1963).

RESULTS

The mean and the standard deviation of the characters in the hybrids are presented in Table 1. Number of days to 50% tasseling ranged from 31 days to 46 days with mean of 36.42 days while number of days to 50% silking ranged from 35 days to 47 days with mean of 41.19 days. The overall mean for plant height was 29.23 cm, the maximum plant height was 162.7 cm while the minimum was 70.5 cm. Considerable variation was observed among the hybrids for ear height with 26.88 cm, 75.0 cm and 56.72 cm as the minimum, maximum and mean values respectively. Number of cobs, cob length and cob girth varied from 4 to 28, 9.5 cm to 15.7 cm and 3.32 cm to 4.26 cm, respectively. Field weight had a very large variation, the lowest value obtained was 255 g while the highest was 1844 g with mean being 1153.9 g. 100-grain weight varied from 17 g to 30 g with mean of 24.19 g. However, number of kernel rows had low variation, with the range of 11.2 to 15.6.

Results presented in Table 2 showed that the hybrid check 'SUWAN-1SR-Y × ACR91-SUWAN1-SRC_1' had the highest number of days to 50% tasseling (41.33 days) and number days to silking (46.0 days). Hybrid 'TZDEEI 7 × TZEEI 79' was earliest flowering hybrid attaining number of days to 50% tasseling and number of days to silking in 32.67 days and 36.0 days, respectively. The hybrid check 'SUWAN-1SR-Y × ACR91-SUWAN1-SRC_1' produced plants with the tallest plant height (151.39 cm) and ear height (69.73 cm) while hybrid 'TZDEEI 7 × TZEEI 58' had the shortest plant height (95.95 cm) and ear height (38.54 cm). There was no variation in some characters such as number of cobs, cob length, and cob girth. Hybrids 'TZDEEI 13 × TZEEI 79' and 'TZDEEI 96 × TZEEI 13' had the highest field weight and 100 grain weight while the non-hybrid local check 'SUWAN-1SR-Y' had the lowest field weight (522.67 g).

Coefficients of variation, heritability and genetic advance of evaluated characters of the maize hybrids are presented in Table 3. Number of days to 50% tasseling (9.03%), number of days to 50% silking (5.93%), and number of kernel rows (7.72%) had low phenotypic coefficient of variation (PCV), plant height (16.17%), ear height (18.64%), and 100 grain weight (12.75%) had moderate PCV. Number of cobs (30.08%) and field weight (38.83%) had high PCV. Low genotypic coefficient of variation (GCV) (< 10%) were observed for number of days to 50% tasseling, number of days to 50% silking, plant height, 100-grain weight, number of kernel rows while moderate GCV were observed for ear height (10.78%) and number of cobs (12.71%). Field weight had the highest GCV of 23.29%. Number of days to 50% tasseling (32.75%), number of days to 50% silking (35.95%), ear height (33.43%), field weight (35.98%) and number of kernel rows (27.66%) recorded moderate heritability estimates while the other traits had low heritability s (> 20%). High genetic advance (332.05) accompanied moderate heritability estimate for field weight. Also, field weight had the highest genetic gain of 28.78% Correlation coefficients among the characters are presented in Table 4. Number of days to 50% tasseling had significant and positive correlation (0.581) with number of days to 50% silking and negative and significant correlation (-0.378) with 100-grain weight.

Table 1: Means, standard deviation and ranges of ten characters of the maize hybrids

Variable	Mean	Standard Deviation	Minimum	Maximum
Number of days to 50% tasseling	36.42	3.53	31	46
Number of day to 50% silking	41.19	3.8	35	47
Plant height(cm)	129.23	21	70.5	162.7
Ear height (cm)	56.72	10.77	26.88	75
Number of cobs	17.28	5.24	4	28
Cob length (cm)	13.31	1.55	9.5	15.7
Cob girth (cm)	3.79	0.29	3.32	4.26
Field weight (g)	1153.9	452.3	255	1844
100-grain weight (g)	24.19	3.21	17	30
Number of kernel rows	12.55	0.95	11.2	15.6

Table 2: Means of vegetative and reproductive traits in selected hybrids of maize

HYBRIDS	Number of kernel rows	100-grain weight (g)	Field weight (g)	Cob girth (cm)	Number of cobs	Cob length (cm)	Ear height (cm)	Plant height (cm)	Number of days to 50% silking	Number of day to 50% tasseling
TZEEI 29 × TZEEI 21	12.27ab	25.67ab	1345.67ab	3.81a	18.67a	13.5a	57.09ab	130.19ab	41.33ab	35.33abc
TZDEEI 96 × TZEEI 13	11.87ab	27.67a	1357.67ab	3.78a	17.33a	12.26a	60.57ab	137.6ab	39.33ab	36.0abc
TZEEYPOPSTRC5 × TZEEI 58	12.53ab	24.0ab	841.33ab	3.54a	15.33a	13.82a	47.81ab	120.2bc	43.33ab	36.33abc
TZDEEI 7 × TZEEI 79	12.93ab	23.67ab	1348.67ab	3.91a	16.33a	13.77a	57.95ab	127.5ab	36.0b	32.67c
TZDEEI 91 × TZEEI 14	12.8ab	24.67ab	1207.33ab	3.82a	19.67a	12.99a	57.87ab	124.23ab	42.33ab	38.0abc
TZDEEI 13 × TZEEI 79	12.07ab	25.33ab	1701.33a	3.74a	20.67a	12.18a	58.61ab	139.03ab	38.33ab	36.0abc
TZDEEI 12 ×T ZEEI 58	11.93ab	25.33ab	1293.33ab	3.88a	16.33a	12.97a	62.41ab	145.38a	40.33ab	36.33abc
TZDEEI 64 × TZEEI 54	11.67b	24.0ab	1259.33ab	3.70a	18.0a	14.82a	60.53ab	128.39ab	41.33ab	33.33bc
TZDEEI 7 × TZEEI 58	12.64ab	22.67ab	593.67b	3.68a	12.0a	13.65a	38.54b	95.95c	41.33ab	34.67abc
TZDEEI 78 × TZEEI 29	12.62ab	25.33ab	1231.67ab	3.77a	21.0a	12.07a	50.96ab	125.08ab	39.67ab	36.33abc
SUWAN-1SR-Y × ACR91SUWAN1SRC1	14.27a	22.67ab	1243.67ab	4.07a	21.67a	12.67a	69.73a	151.39a	46.0a	41.33a
SUWAN-1SR-Y	13.02ab	19.33b	522.67b	3.80a	10.33a	14.01a	58.5ab	125.53ab	45.0a	40.67ab

Table 3: Coefficient of variation, heritability and genetic advance of evaluated characters of the maize hybrids

Characters	Genotypic coefficient of variation (GCV) (%)	Phenotypic coefficients of variation (PCV) (%)	Heritability (%)	Genetic advance	Expected genetic gain
Number of days to 50% tasseling	5.17	9.03	32.75	2.22	6.09
Number of days to 50% silking	5.35	8.93	35.95	2.72	6.61
Plant height (cm)	6.8	16.17	17.69	7.62	5.89
Ear height (cm)	10.78	18.64	33.43	7.28	12.83
Number of cobs	12.71	30.08	17.84	1.91	11.06
Field weight (g)	23.29	38.83	35.98	332.05	28.78
100-grain weight (g)	5.31	12.75	17.38	1.1	4.56
Number of kernel rows	4.06	7.72	27.66	0.55	4.4

Table 4: Correlation coefficients among evaluated characters of the hybrids

	Number of days to 50% silking	Plant height (cm)	Ear height (cm)	Number of cobs	Field weight (g)	100 grain weight (g)	Number of kernel rows
Number of days 50% tasseling	0.581**	0.153	0.158	0.04	-0.313	-0.376*	0.233
Number of days 50% silking		-0.315	-0.245	-0.004	-0.676**	-0.479**	0.09
Plant height (cm)			0.864**	0.309	0.636**	0.286	0.073
Ear height (cm)				0.389*	0.616**	0.25	0.17
Number of cobs					0.541**	0.371*	0.15
Field weight (g)						0.497**	0.091
100-grain weight (g)							-0.137

Field weight (-0.676) and 100-grain weight (-0.479) were observed to have negative and significant correlation with number of days to 50% silking. Plant height was positively and significantly correlated with ear height (0.864) and field weight (0.636). Ear height had strong and positive correlation with field weight (0.616) and number of cobs (0.389). Field weight had positive and significant correlation with 100-grain weight (0.497).

DISCUSSION

The result from this experiment revealed significant ($p<0.01$) differences among the hybrids for the traits evaluated in this study. This variation may be attributed to the different genetic background of the genotypes (Fayeun *et al*., 2012). Different researchers have reported significant variation in different maize hybrids (Ihsan *et al*., 2005; Izge and Dugje, 2011). All the hybrids had higher field weight over the non-hybrid check variety (SUWAN-1SR). This superiority of the hybrids may be attributed to heterosis (hybrid vigour). Similar superiority in the yield of hybrids over open pollinated varieties was reported by Kim *et al*. (1993) and Ajibade and Ogunbodede (2000).

The poor yield of the shortest hybrid 'TZDEEI 7 × TZEEI 58' might be attributed to the inability to intercept enough solar radiation for synthesis of photo-assimilate. This is contrary to the findings of Izge and Dugje (2011) who reported that short hybrids had higher yield than the tall ones. One supposed reason for this difference might be the different agro-ecologies in which the experiments were carried out. Izge and Dugje, 2011 carried out their experiment in Sahel savannah, an agro-ecology with higher insolation than the location in which this study was carried out. The earliest hybrid in flowering 'TZDEEI 7 × TZEEI 79' with high field weight (1153.9g) can be recommended for the rain forest agro-ecology based on early maturing and high yielding attributes. Two types of hybrid (double crossed and three-way cross) could be derived from hybrid 'TZDEEI 7 × TZEEI 79' (the earliest in flowering) and hybrid 'TZDEEI 13 × TZEEI 79' (highest field weight). The double cross hybrid can be developed by simply crossing the two single hybrids [('TZDEEI 7 × TZEEI 79') x ('TZDEEI 13 × TZEEI 79')] while the three-way cross hybrid could be in this form [('TZDEEI 13 × TZEEI 7') × 'TZDEEI 79'] since inbred 'TZEEI 79' is common to the two single cross hybrids. The two new hybrids will combine high yield and extra-earliness traits. Both double-cross and three-way cross hybrids are advantageous because they are more genetically broad-based (Acquaah, 2007).

In this study the influence of the environment was very high as it was reflected in the low to moderate heritability estimates of the traits and low genetic advance for most of the traits except field weight. The moderate heritability estimates recorded for number of days to 50% tasselling and silking, ear height, field weight and number of kernel rows might be due to the fact that the traits depend on other variables which are under environmental influence (Fayeun *et al*., 2016). This reason for this might be because of the period (dry season) the experiment was carried out which was characterized by a lot of environmental variability. More variable conditions usually reduce heritability estimates, whereas uniform conditions increase it (Falconer, 1980). Therefore, this might imply that relying only on off season evaluation for selection might be misleading.

The strong and positive correlations between plant height and field weight and negative association between plant height and earliness (number of days to tasseling and silking) implies that early maturing hybrids that were short were low yielding while tall hybrids were late and were high yielding. This finding was in agreement with what have been reported by Burak and Magoja (1991) and Singha and Prodhan (2000) that yield in maize is positively associated with plant height. Therefore, in crop improvement of extra-early maize for the rain forest agro-ecology selection of tall plants could lead to yield increase.

CONCLUSION

In conclusion variation existed among the hybrids for field weight and reproductive traits studied. Environmental influence was high in the expression of the observed traits as shown by low heritability estimates. Plant and ear height respectively had positive and significant correlation with field weight. It was observed that earliness was not associated with tallness and high yielding. Hybrid 'TZDEEI 13 × TZEEI 79' that had the highest yield can be recommended for rain forest agro-ecology. Hybrid 'TZDEEI 7 × TZEEI 79' that was the earliest in flowering and hybrid 'TZDEEI 13 × TZEEI 79' that had highest field weight can be crossed to develop double crossed hybrid or three-way cross [('TZDEEI 7 × TZEEI 79') × 'TZDEEI 13'] that will combine high yield and extra-earliness traits.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria for the provision of planting materials.

REFERENCES

Acquaah, G. 2007. Principles of plant genetics and breeding. Blackwell publishing LTD. USA. pp 569

Ajibade, S.R. and Ogunbodede, B.A. (2000). AMMI analysis of maize yield trials in south-western Nigeria. *Nigerian Journal of Genetics* 15: 22–28.

Ayeni A (2011). Malaria Morbidity in Akure, Southwest, Nigeria: A Temporal Observation in a Climate Change Scenario. *Trends in Applied Science Research*. 6: 488-494.

Badu-Apraku, B., Akinwale, R. O., Franco, J. and Oyekunle, M. (2012). Assessment of reliability of secondary traits in selecting for improved grain yield in drought and lownitrogen environments. *Crop Science* 52, 2050–2062.

Badu-Apraku, B., Oyekunle, M., Akinwale, R. O. and Aderounmu, M. (2013). Combining ability and genetic diversity of extra-early white maize inbreds under stress and nonstress environments. *Crop Science* 53, 9–26.

Burak, R. and Magoja, J.L. (1991). Yield and yield components of full-sib and half-sib families derived from perennial teosinte introgression population. *Maize Genetics Corp., Newsletter*. 7: 431-76.

CIMMYT, IITA. (2010). Maize-Global alliance for improving food security and livelihoods of the resource-poor in the developing world. Draft proposal submitted by CIMMYT and IITA to the CGIAR Comortium Board. E I Batan, Mexico, 91pp.

Dowswell, C.R., Paliwal, R.L. and Cantrell, R.P. (1996). Maize in the Third World. Oxford: Westview Press.

Elrod, S. and Stanfield, W. 2002. Genetics. 4th Ed. Tata McGraw Hill Co., New Delhi.

Fakorede, M.A.B., Badu-Apraku, B., Kamara, A.Y., Menkir, A., Ajala, S.O. (2003). Maize Revolution in West and Central Africa. In *Proceedings of a Regional Maize Workshop,* edited by B. Badu-Apraku, M.A.B Fakorede, M. Ouedraogo, R.J. Carsky, and A. Menkir. May 14–18, 2001. Ibadan: WECAMAN IITA. pp. 3-5.

FAO, (2010). Rome: Food and Agricultural Organization of the United Nations (FAO). FAO statistical database.

FAOSTAT, 2013. Statistical Databases on Global Food Production and Trade. Food and Agriculture Organization, Rome.

Falconer DS. 1981. Introduction to quantitative genetics. 2th ed. Longman, London, UK.

Fayeun, L.S., Odiyi, A.C. Makinde, S.C.O. and Aiyelari, O.P. (2012). Genetic Variability and Correlation Studies in the Fluted Pumpkin (*Telfairia occidentalis* Hook. F.). *Journal of Plant Breeding and Crop Science*. 4(10). 156-160.

Fayeun, L.S, Hammed, L. A., Oduwaye, O. A., Madike, J. U. and Ushie, U. E (2016). Estimates of Genetic Variability for Seedling Traits in Fluted Pumpkin (*Telfairia occidentalis* Hook. F). *Plant Breeding and Biotechnology*. 4(2):. 262-270

Fisher, G. and Yates, M. (1963): Statistical tables for biological, *Agricultural and Medical Research*, 6: 62-63.

Ihsan, H., Khalil, I.H., Rehman, H. and M.Iqbal. (2005). Genotypic Variability for morphological traits among exotic maize hybrids. Sarhad *Journal of Agriculture*. 21(4): 599-602.

International Institute for Tropical Agriculture (IITA). (2006). Annual Report for 2005, Ibadan, Nigeria: International Institute for Tropical Agriculture.

Izge, A.U. and Dugje, I.Y. (2011). Performance of Drought Tolerance Three-way and Top-cross Maize Hybrids in Sudan Savanna of North Eastern Nigeria. *Journal of Plant Breeding and Crop Science*. 3(11): 669-675.

Johnson, H.E., H.F. Robinson and R.E. Comstock. (1955). Estimates of genetic and Environmental viability of soybean. *Agronomy Journal* 47:314-318.

Kim, S.K., Fajemisin, J.M., Fakorede, M.A.B. and Iken, J.E. (1993). Maize improvement in Nigeria – Hybrid performance in the savannah zone. In: Fakorede, M.A.B., Alofe, C.O. and Kim, S.K. (eds). Maize Improvement, production and utilization in Nigeria. Maize Association of Nigeria. pp. 15–39.

Onwueme, I.C. and Singha, T.D. (1991). Field Crop Production in Tropical Africa. CTA, Ede, the Netherlands 480p.

Santos, M.X., Lopes, M.A., Coelho, A.M., Guimarães, P.E.O., Parentoni, S.N., Gama, E.E.G. and França, G.E. (2006). Drought and Low N Status Limiting Maize Production in Brazil. Developing Drought- and Low N Tolerant Maize Proceedings of a Symposium. March 25-29, 1996, CIMMYT, El Batán, Mexico.

Singh, R.K. and Chaudhary, B.D. (1985). Biometrical Methods in Quantitative Analysis. Kaljuni Publishers. New Delhi. 318pp.

Singha, N. and Prodhan, S.H. (2000). Character association in green maize. *Environmental. Ecology*. 18: 962-925

Siva-Subramanian, S. and Menon, M. (1973). Heterosis and inbreeding depression in rice. *Madras Agricultural Journal*, 60: 1139.

Umar U.U, Ado S. G., Aba D. A., and Bugaje S. M. (2014). Estimates of Combining Ability and Gene Action in Maize (*Zea mays* L.) Under Water Stress and Non-stress Conditions. *Journal of Biology, Agriculture and Healthcare* pp 247-254 www.iiste.org.

*****