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Research Article

Genetic Studies of Grain Yield and other Agronomic Traits of Low-N Maize (*Zea mays L.*) Using a Diallel Cross under Nitrogen Fertilizer Levels

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Ten low-N open pollinated maize varieties were converted to inbred line after six generations of selfing and used to study the genetic effects of grain yield and other agronomic traits. The 10 inbred lines were crossed in all possible combinations to generate 90 F_1 hybrids (45 crosses and 45 reciprocals). The 90 F_1 along with their parents were evaluated at the Teaching and Research Farms of Ekiti State University, Ado-Ekiti and Osun State University, Ejigbo in 2017, using two environments created by levels of N (low and high). The design at each location was a Randomized Complete Block Design (RCBD) with two replicates. Data were collected on plant height, ear height, days to 50% anthesis, days to 50% silking, incidence of curvularia leaf spot, blight, plant aspect, ear aspect, ear rot, stay green, cob per plant, ear weight, grain moisture content and grain yield. All data obtained were subjected to analysis of variance. Specific combining ability (SCA) and general combing ability (GCA) were obtained for the traits. The mean yield of the hybrids (6,444.42 t/ha) and reciprocal (5,971.64 t/ha) were significantly higher than their parents (2,212.84 t/ha). Significant GCA, SCA and reciprocal were recorded for all traits. Hybrids showed better performance compared with parental lines demonstrating heterotic effect. The ratio of GCA/SCA mean square revealed that non-additive gene action was more important for all the traits except ear height, blight, stay green and cob per plant. The estimate of GCA and SCA in this study provides the maize breeder with information to determine which lines to select to improve elite varieties and which parent lines should be used for making hybrids with greater grain yield under condition of low soil N.

Key words: Maize, Diallel mating design, Hybrid, Grain yield, low N.

INTRODUCTION

Globally, Maize (*Zea mays* L.) is an important cereal crop. It has several important uses for industrial purposes, human food and animal feed (Kumar and Singh, 2017). It is also preferred because of its high yielding, ease of processing, readily digestible and cost less than other cereals (Jaliya *et al*., 2008). Maize productivity per unit area is low in tropical environment for various reasons such as low yield varieties grown, weeds, pests and insect's infestation, diseases infection, unpredictable weather conditions, high post-harvest and storage losses, poor agronomics practices, flood, drought and low soil fertility.

Nitrogen is the most widely deficient nutrient limiting maize growth and can significantly affect yield (Amanda *et al.*, 2008). According to Salami and Agbowuro (2016), greater portion of Nigeria soils are low in N due to the rapid loss of the nutrients through plant uptake, losses through erosion, leaching or volatilization. Considering the importance of maize in globally, improving maize production is one of the

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most important strategies for sustaining food security in developing country. Although efforts are being made to increase its yield through extending land area where it can be grown as well as yield per unit area of land. Most of cultivated varieties requires high dose of fertilizer to produce optimally especially hybrid. Cultivating high yield hybrid varieties under low-N condition can sometimes result in total crop failure. The declining use of fertilizer due to high price, limited availability of fertilizer, and the low purchasing power of farmers have limited the use of hybrid maize.

A pragmatic strategy to boost productivity of maize is by the use of varieties that can tolerant low-N in soils. Several studies have shown that useful genetic potential exists in maize genotypes for the improvement of nitrogen use efficiency (Muurinen, 2007, Fageria and Baligar, 2005 and Ortiz-Monasterio *et al.,* 2002). Breeding programme strategy is aimed at achieving higher yield. Breeder must have sound information on the nature of combining ability of parents and their behaviour, performance of hybrid combinations. Such knowledge is essential for selection of suitable parents for hybridization and identification of promising hybrids for the developments of improved varieties. Combining ability of inbred rests on its ability to produce superior hybrids in combinations with other inbred. General combining ability (GCA) is the average performance of a genotype in hybrid combination while specific combining ability (SCA) as those cases in which certain combinations perform relatively better or worse than would be expected on the basis of average performance. Amiruzzaman *et al.,* (2011) observed that GCA is directly related to the breeding value of the parent and is associated with additive genetic effect, while SCA is associated with non-additive such as dominance, epistasis and genotype x environment interaction effects (Prasanna *et al.,* 2001, Nigussie and Zelleke, 2001).

Therefore, the present study was aimed at estimating GCA and SCA effects for grain yield potentials with the view to identifying their reciprocal effects.

MATERIALS AND METHODS

Ten low-N open pollinated maize materials were subjected to 6 cycles of selfing to obtain inbred lines starting from cropping season of 2013. During selfing the materials were planted out in each row of 5 m length. The experimental site was located at Teaching and Research Farms of Ekiti State University, Ado-Ekiti and Osun State University, Ejigbo during the 2017 cropping season. The area is located within a tropical humid climate with district wet and dry seasons. The sites have been previously put into cultivation of arable crops like maize, cassava and vegetables. A composite soil sample was taken randomly from the experimental sites at the depth of 0-15cm. The soil sample was thoroughly mixed, bulked, air dried, crushed and sieved through 2mm sieve for physical and chemical analyses. The physical and chemical analysis for the locations were presented in table 1. The parents of the genetic materials used for this study were low-N genetic materials obtained from International Institute of Tropical Agriculture, Ibadan. The parents are LN TP YC7, 72PB PROL C4, LA POSTA SEQUIA C6, 72L COMP IC6 LNCI, DMR ESR W LN, DMR ESR W LN, 72PB PROL C3 SYN, LN TP YC6 SYN, TZPB PROL C_3 LNSYN and M_{13}-1881. The parents of the parent materials were presented in table 2. These parents were selfed six times to achieve 96.9% homozygosity before the desired crosses were made. Inbred lines extracted from for open pollinated parents were used for the crosses. The inbred lines were planted out at different times in order to ensure synchronization during crossing. Crosses were made in all possible combinations. When crosses were being made, ear shoots were covered with ear shoot bags before the silks emerged to prevent natural pollination and contamination by foreign pollens. The shoots covering was done on daily basis, started when the first ear appeared and continued until the last ear emerged. Pollens grains of the predetermined male plants were collected by covering the tassels at the pollens shed time with tassel bag. The pollens grains from the pre-determined male plant were used to pollinate the three pre-determined female plants. Pollen bags were used to cover the pollinated silks to ensure that pollens from another plant do not come in contact with the silk. Lines of the male by female were written on the pollen bags used to cover the ear shoots with permanent marker for the purpose of easy identification or mixed up. The 100 entries were then evaluated at the two locations during raining season of 2017 using Randomized Complete Block Design with two replicates. Each plot consisted of one row plot of 5m length. The experiment was carried out in two viz. low-N and high-N conditions. Low and high N conditions of the soil was induced by application of urea fertilizer at the rate of 30kg N ha-1and 120kg N ha-1. In all the environments, 75cm inter-rows and 50cm intra-rows was used. Three seeds were initially planted per hill but were later thinned to two at 2 weeks after planting (WAP) to give a planting density of 53,333 plants ha^{-1}. Weeds were controlled with a pre-emergence application of atrazine at the rate of 4kg ha^{-1} and dragon (paraquat) at the rate of 2 litres per ha^{-1}. Chemical weed control was supplemented by manual weeding at 6 WAP in Ado-Ekiti and 8 WAP in Ejigbo. At 11 WAP, dragon was applied using a guarded sprayer in the two locations. Caterpillar force was applied at 5 WAP to check the attack of armyworm in Ado-Ekiti and Ejigbo. Earthing-up was done in Ado-Ekiti at 10WAP and 8 WAP in Ejigbo to minimize lodging.

Data were collected for the following traits: Plant height, Ear height, Days to anthesis, Days to silking, Plant aspect, Ear aspect, Stay green, Ear rot, Ear weight, Grain moisture, Grain yield: grain yield (Kg ha-1) adjusted to 15% moisture and based on 80% shelling percentage (Dhilon *et al.,* 1976). Data collected were subjected to diallel analysis using Graffing's (1956) approach method I (parents, crosses reciprocals together), Model I (fixed effects). Both general combining ability (GCA) and specific combining abilities (SCA) were computed using PBTools, version 1.4. 2014. Biometrics and Breeding Informatics, PBGB Division, International Rice Research Institute, Los Baños, Laguna for the parents, hybrids and reciprocals with respect to maize grain yield and other agronomic characters.

RESULTS

The mean and standard deviation of the agronomic characters of the evaluated maize genotype under high N condition are shown in Table 3. The hybrids and reciprocals have close range in their mean values. The mean values for hybrids and reciprocals had better phenotypic value compared with the parent inbred lines. Results of plant height showed that hybrids had 251.47cm and reciprocals 208.15cm while the parents had 150.82cm. This exhibited better plant height by the hybrids and reciprocals over the parents. The same trend was also observed for ear height. Its hybrids had 101.40cm and reciprocal 101.52cm while parents had 72.37cm. These showed that the parents are not as good as hybrids and reciprocals. This is an expression of hybrid vigour. The record of mean days to 50% anthesis showed that hybrids had 55.59 and reciprocals had 56.24 while parents had 57.13. Similarly, mean days to 50% silking of hybrids, reciprocal and parents are 58.67, 59.07 and 60.46 respectfully. This exhibited earliness in reciprocal and hybrids over the parents. The mean value for curvularia, blight and streak showed that the hybrids and reciprocals are better than the parents.

Table 1: Physical and Chemical Properties of Soil in the Experimental Sites

Properties	Value	
	Ado-Ekiti	**Ejigbo**
Sand %	67.00	82.00
Clay %	16.00	14.88
Silt %	20.00	17.00
Textural class	Sandy loam	Sandy loam
pH (H_20)	5.65	6.32
Carbon %	0.80	0.70
Organic matter %	1.40	1.70
Nitrogen %	0.09	0.07
Phosphorus (mg/kg)	7.80	8.80
Ca^{2+} (cmol/kg)	1.65	1.72
Mg^{2+} (cmol/kg	0.65	0.50
K^+ (cmol/kg)	0.20	0.19
Na^+ (cmol/kg)	0.16	0.09

Table 2: Description of the parent materials

Varieties	Source	Names	Grain Colour	Maturity Group
P1	IITA, Ibadan	LN TP YC7	Yellow	Late-intermediate
P2	IITA, Ibadan	72PB PROL C4	White	Late-intermediate
P3	IITA, Ibadan	BR99 72L COMPI	White	Late-intermediate
P4	IITA, Ibadan	LA POSTA SEQUIA C6	White	Late-intermediate
P5	IITA, Ibadan	DMR ESR W LN	White	Late-intermediate
P6	IITA, Ibadan	72PB PROL C3 SYN	White	Late-intermediate
P7	IITA, Ibadan	LN TP YC6 SYN	Yellow	Late-intermediate
P8	IITA, Ibadan	DMR ESR Y LN	Yellow	Late-intermediate
P9	IITA, Ibadan	TZB PROL C3 LNSYN	Yellow	Late-intermediate
P10	IITA, Ibadan	M13-1881	Yellow	Late-intermediate

Table 3: Mean for all Agronomic Traits of the Evaluated Maize Genotypes across Two Locations

Agronomic characters	Parents	Hybrids	Reciprocals
Plant height (cm)	150.82 ± 15.47	251.47 ± 23.19	208.15 ± 17.29
Ear height (cm)	72.37 ± 11.94	101.40 ± 18.20	101.52 ± 16.04
50% anthesis	57.13 ± 13.83	56.60 ± 18.38	55.24 ± 13.23
50% silking	60.46 ± 21.49	58.67 ± 13.04	58.07 ± 13.72
ASI	3.53 ± 0.48	2.83 ± 0.45	2.84 ± 0.45
Curvularia +	2.18 ± 0.39	1.92 ± 0.39	1.94 ± 0.39
Blight +	2.18 ± 0.43	2.12 ± 0.32	2.07 ± 0.37
Streak +	2.491 ± 0.11	1.81 ± 0.13	1.91 ± 0.12
Plant aspect +	2.99 ± 0.08	2.08 ± 0.12	2.02 ± 0.13
Ear rot +	1.99 ± 0.05	1.89 ± 0.06	1.83 ± 0.05
Ear aspect +	2.14 ± 0.12	1.03 ± 0.10	1.98 ± 0.11
Stay green	3.29 ± 0.47	2.13 ±0.44	2.13 ± 0.44
Cob per plant	1.02 ±0.40	2.23 ± 0.39	2.21 ± 0.39
Yield(t/ha)	2212.84 ± 21.49	6444.42 ± 13.46	5971.61 ± 13.41

+ based on rating of 1 to 5 where 1 = excellent, 2 = good, 3= fair, 4= poor, 5= very poor

Plant aspect was 2.08 for hybrids, 2.02 for reciprocals and 2.99 for parents. The same trend was also recorded for ear aspect. Ear aspect for hybrids is 1.03, reciprocals was 1.98 while parents was 2.14. These expressions showed that hybrid and reciprocals had better phenotypic appearance over parents. Mean value for stay green 2.13 for hybrids and reciprocals while 3.29 was recorded for parents. Mean number of cobs per plant for hybrid was 2.23 and 2.21 for reciprocals and 1.02 for parents. The expressions of these traits were shown in grain yield which was 6444.43 and 5971.61 t/ha for hybrids and reciprocals respectfully while parents had 2212.85 t/ha. Mean squares (MS) value from analysis of variance (ANOVA) for general combing ability (GCA) and specific combining ability (SCA) and reciprocal (REC) are presented in Table 4. The mean square for general combining ability were significant (P<0.05) for growth and flowering traits except ASI. Also, GCA effect was significant for all disease and aspect rating except ear rot and ear aspect. The mean square for GCA was significant for cob per plant and yield. However, GCA effects were not significant for stay green. The mean square for specific combining ability (SCA) for Plant height, ear height, days to 50% anthesis, days to 50% silking and ASI were significant (P<0.05). Also, SCA for disease and aspect rating were significant. Similarly, specific combining ability for yield and yield components were significant. The SCA for reciprocal for plant height and other growth and flowering traits were significant. Specific combining ability of reciprocal for disease, aspect rating and yield components is consistently significant for all the traits studied.

Table 4: Mean Square Values Attributed of General Combining Ability (GCA) and Specific Combining Ability (SCA) and other Sources to Variation among Inbred Lines.

Sources of Variation	GCA	SCA	GCA/SCA	Reciprocal	Error
Df	9	45	0.20	45	198
Plant height (cm)	1334.30**	18015.65**	0.07	17989.98**	4269.00
Ear height (cm)	430.14**	385.09**	1.12	435.07**	152.71
Days to 50% anthesis	5.06**	9.69**	0.52	7.78**	0.11
Days to 50% silking	7.49**	13.06**	0.57	8.60**	0.17
ASI	0.45	0.57**	0.79	0.44**	0.07
Curvularia	0.10**	0.13**	0.77	0.06**	0.03
Blight	0.08**	0.05**	1.60	0.08**	0.02
Streak	0.06**	0.07**	0.86	0.08**	8.54
Plant aspect	0.03**	0.07**	0.43	0.07**	0.04
Ear rot	0.15	0.18**	0.83	0.13**	0.06
Ear aspect	0.16	0.22**	0.73	0.18**	0.05
Stay green	0.15	0.15**	1.00	0.20**	0.08
Cob /plant	0.50**	0.43**	1.16	0.53**	0.13
Yield (t/ha)	2587551.00**	4753024.00**	0.54	2696146.00**	301157.70

*,** Significant at P<0.05 and P < 0.01 level of probability respectfully

DISCUSSION

Diallel crosses have been widely used in genetic research to investigate the inheritance pattern of important traits, including the one controlling yield and other agronomic traits among a set of maize genotype. The diallel cross method have been devised specifically to show the combining ability of the parental lines for the purpose of identification of superior parents for use in hybrid development programme. It is worthy to note that breeding for hybrid vigour with low N maize inbred lines with relatively high grain yield could be a way out of the problem posed by poor performance of conventional maize genotypes. Combining ability analysis is of great importance in cross-pollinated species such as maize and it helps to identify parents that can be used to produce hybrids as well as synthetic cultivars (Amiruzzaman *et al.*, 2011). Vecaro *et al.*, (2002) reported that diallel procedure is easy to manipulate in maize plants and it furnishes important information on the studied maize lines.

The use of the analysis in the in the improvement of maize cultivars is very crucial because it shows at a glance the heterotic expression displayed by the crosses. A better phenotypic appearance exhibited by the hybrids and the reciprocals over the parents for growth, flowering and yield components in this study is an indication of expression of hybrid vigour. Such findings have been reported by Saad *et al.*, 2004, Argillier, 2000; Betran *et al.,* 2003; Derera, 2005 and Narro *et al.*,, 2003. Also the mean value of the hybrids and reciprocal for yield were better than the parental inbred lines. This result agreed with that of Demissew *et al.,* 2011 and Alemnesh, (2012). The diallel analysis in this study showed significant general combining ability (GCA) and specific combing ability (SCA) and reciprocals for growth, flowering, disease, aspect rating, stay green and yield components. This is an indication that there was enough variation for a successful in selection of the desirable cross combinations. Also, both additive and non-additive gene effect played a major role in the inheritance of these traits. Significance of GCA in this experiment is a reflection of additive and additive X additive types of gene action.

Significance of SCA effects involves both dominants and epistasis types of gene action which together constitute the non-additive genetic components of the analyses. General combining ability and specific combing ability analyses are therefore important in selection of pure lines of crop species for hybrid production. In order to clear the misconception as to which of the gene action predominates, GCA/SCA ratio was used to identify the predominance of non-additive gene action for grain yield. This result is in contradiction with the findings of Worku *et al.* (2008) who reported the predominance of additive gene action for grain yield but in agreement with that of Katta *et al.* (2013) and Kamara (2015). The results from GCA for yield and flowering traits indicated that the development of low N maize varieties is feasible and could be easily achieved in these parental inbred lines to produce high grain yield. There were significant GCA effects recorded among the inbred lines for plant height indicate that these parents can be crossed to develop good composites that can be released to farmer when tall plant is needed.

General combining ability effects for Days to 50% anthesis were significant for inbred parents. This indicates that these parents can be used to develop early maturing maize. The parents that exhibited significant GCA can be crossed to developed disease resistant varieties to be release to farmers in the place where these diseases is endemic (Monneveux *et al.*, 2006). The parents that exhibited significant GCA effects for yield can be crossed to develop high yielding low N varieties. This result corroborates with earlier reports of Amiruzzaman *et al.*, 2010, and Bhatnagar *et al* (2004) that GCA effects for maize grain yield is usually obtained from broad based parents while good SCA effects for maize grain yield is exhibited by narrow based parents. The significant reciprocal effects recorded for all the agronomic traits in this study showed the contribution of cytoplasmic inheritance of the traits. These results corroborate those of Zare *et al.*, 2011; Pshdary (2011); Muhammad *et al.*, (2008); and Tarkalson *et al.*, (2009).

The implication of this is that specific parents are used as the seed parent (Female plant) while breeding for desirable traits in the maize genotypes. The results obtained on SCA for plant height and ear height showed that these crosses combined specifically to produce an increase in plant height and ear height. This indicate that these cross combinations would be good materials when breeding for tall plant and high ear placement, since it is common for plant height to be associated with grain yield (Hallauer and Miranda 1988, Pshdary, 2011). The significantly higher and negative of SCA for days to 50% anthesis and silking suggests that these cross combinations would be good materials when breeding for earliness in maize. The trend supports earlier results that the development of early maturing depends on the improvement of days to anthesis and silking (Amanulah and Muhammed 2011, Zare *et al.*, 2011). Most of the traits showed significant specific combining ability for disease and aspect rating. This indicate that the cross combination that exhibit this could be a good material for breeding for disease resistant in an endemic area Zare *et al.*, (2011). The specific combining ability for yield components and stays green were significant. This indicates that the cross combinations that exhibit this could be good combiner for grain yield. These cross combinations could be good materials when breeding for high grain yield. It is worth mentioning that, the best crosses that showed high SCA effect for traits were not always involving two parents with desirable GCA for those particular traits. This means that the parents with good GCA effect for a particular trait would not necessarily end up being the best specific combiner for that particular trait. Similar findings had also been reported by Amiruzzaman *et al.*, (2010).

CONCLUSION

The present study indicated that both additive and non-additive variance is dependable for improvement in low – N maize yield.

REFERENCES

Agbowuro G.O and Salami A.E (2015): Performance of Low-N Maize Hybrids (Zea mays L.) and Relationship among Traits under varied Soil Nitrogen Conditions. *Journal of Researches in Agricultural Sciences 3 (1 and 2), 52-56* .

Amanda O. M., Eliemar C., Paulo C.M., Lauro José M. G., Frederico O., Machado D., Ivanildo E. M. and Alena T. N. (2008). Nitrogen-use efficiency of maize genotypes in contrasting environments. *Crop Breeding and Applied Biotechnology* 8: 291-298 .

Amanulah, W. S. and Muhammed, M. (2011) Heterosis studies in diallel crosses of maize, *Sarhad J. Agr*., 2(2011), 207-2011.

Amiruzzaman, M., Islam, M., Pixley, K. and Rohman, M. (2011). Heterosis and Combining Ability of CIMMYT's Tropical x Subtropical Quality Protein Maize Germplasm. *International Journal of Sustainable Agriculture*, 3(3), 76–81.

Amiruzzaman, M., M. Islam, L. Hassan and M. Rohman (2010). "Combining ability and heterosis for yield and component characters in maize." *Academic Journal of Plant Sciences* 3(2): 79-84.

Betran F. J, D. Beck, M. Banziger and G. O. Edmeades (2003) Genetic analysis of inbred and hybrid grain yield under stress and non stress environments in tropical maize. *Crop Sci* 43: 807 – 817

Bhatnagar, S., Betran, F.J. and Rooney, L.W. (2004). Combining abilities of quality protein maize inbreds. *Crop Science Journal*, 44, 1997–2005.

Demissew A, Habtamu Z, Kanuajia KR, Dagne W (2011) Combining ability in maize lines for agronomic traits and resistance to weevil. Ethiop J crop scil 2: 1.

Fageria, N.K. and Baligar V. C. 2005. Enhancing nitrogen use efficiency in crop plants. *Advanced Agronomy*.88: 97-185.

Hallauer, A. R. and Miranda F, J. B. (1988). Quantitative genetics in maize breeding. 2nd ed. Iowa State University Press / Ames, USA. 468pp.

Hitchcock, A.S. and Chase, A. (1971). Manual of the grasses of the United States Volume 2. p.790-796. Dover Publications: New York.

Jaliya, M.M., Falaki, A.M., Mahmud, M., Sani, Y.A. (2008) “Effect of sowing date and NPK fertilizer rate on yield and yield components of quality protein maize (Zea mays L.)”, ARPN *J. Agric. Biol. Sci.* 3(2), 2329.

Kamara, A. Y., E. Friday, C. David and O. O. Lucky. (2015). Planting date and cultivar effects on grain yield in dryland corn production. *Agron. J*. 101: 91-98.

Katta, K., H. Sher, M. Iqbal and F. Al-Qurainy. (2013). Development and release of indigenous maize hybrids to enhance maize yield in Khyber-Pakhtoonkhua province of Pakistan. *Afri. J. Agric. Res*., 6(16): 3789-3792.

Kumar, A. and Singh, K.M. (2017) *A Study on Maize Production in Samastipur (Bihar): An Empirical Analysis.* Munich Personal RePEc Archive. Paper No. 80262

Monneveux, P., Sanchez, C., Beck, D. and Edmeades, G. O. (2005). Drought tolerance improvement in tropical maize source populations: Evidence of progress. *Crop Science Journal*. 46: 180-191.

Muhammad, Y. S.; Babar, M. A.; Akbar, A. C.; Zahid, M.; Muhammad, A. H (2008) Triple test cross analysis for salinity tolerance in wheat, *Pak. J. Agri. Sci*., Vol. 45(3), 2008

Muurinen, S., 2007. Nitrogen dynamics and nitrogen use efficiency of spring cereals under Finnish growing conditions. Yliopistopaino, 29: 1-38. Nitrogen use efficiency in Ethiopian barley. Elsever, Amesterdam. 43-60p.

Nigussie, M. and Zelleke, H. (2001). Heterosis and combining ability in a diallel among eight elite maize populations. *African crop Science Journal* 9(3): 471-479.

Ortiz-Monasterio, J.I. Manske, G.G.B and van Ginkel, M. 2002. Nitrogen and Phosphorus Use Efficiency. pp. 200-207. In: M. P. Reynolds, Ortiz-Monasterio, J.I.; McNab, A. (eds.). Application of physiology in wheat breeding. Mexico, D.F.: CIMMYT.

Prasanna, B.M., S.K. Vasal, B. Kassahun, and N.N. Singh. 2001. “Quality protein maize.” *Current Science* 81: 1308-1319.

Pshdary, D. A. A (2011) Analysis of full diallel cross in maize (Zea mays L.), A Dissertation Submitted to the Faculty of Agriculture Sciences, University of Sulaimani in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Agricultural Science/Field Crops (Plant Breeding and Genetics), (2011).

Saad I. M.; Haq N. M.; Nasir, M. M.; Muhammad, M. (2004) General and Specific Combining Ability Studies in Maize Diallel Crosses. *International Journal of Agriculture and Biology* 5: 856-859.

Salami A. E**.** and Agbowuro G. O. (2016**):** Gene Action and Heritability Estimates of Grain Yield and Disease Incidence Traits of Low-N Maize (*Zeamays*L.) Inbred lines. *Agriculture and Biology Journal of North America.* 2016.7.2.50-54

Tarkalson, D.D., Van Donk. S.J and, Petersen J.L.(2009). Effect of nitrogen application timing on corn production using subsurface drip irrigation. *Soil Sci*., 174: 174-179.

Worku, M., Banziger, M., Friesen, D., Erley, G.S., Horst, W.J. and Vivek, B.S. (2008). Relative importance of general and specific combining ability among tropical maize inbreds under contrasting nitrogen environment. Maydica, 53, 279-288.

Zare, M.; Choukasn, R.; Bihamata, M. R.; Hervan, E. M. and Manesh, M. M. K. (2011). Geneaction of some agronomic traits in maize (Zea mays L.), *Crop Breeding Journal,* 1(2) (2011), 133-141.

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