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Combining abilities among Quality Protein Maize (QPM) inbred lines for yield and other agronomic traits

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ABSTRACT

Quality Protein Maize (QPM) is bred for its high protein content compared to conventional varieties. To study the genetic effect of grain yield and other agronomic traits, field experiments were conducted at the Teaching and Research Farm, Ekiti State University, Ado-Ekiti and Saint Michael's Catholic Grammar School Farm, Efon-Alaaye, Ekiti State during 2011 cropping season in a complete diallel analysis using eight QPM inbred lines as parents with the objective to determine SCA and GCA among some selected Quality Protein Maize varieties. The mean values were significant with respect to grain yield with an average of 3.64 tha^{-1} for parents, 5.58 tha^{-1} for hybrids and 5.25 tha^{-1} for reciprocals, the hybrids had significantly higher grain yield than the parents. The GCA effects were significant for plant aspect, plant height, ear height, stalk lodge, ear drooping, ear rot, ear aspect and weight of 100seeds.However, the SCA was significant for all the traits. P1 (ACR,94TZECOM5-Y), P2 (OBATANPA/TZLCOM.1), P3 (POP66-SRQPM) and P4 (POP15-SR) are good combiners with P8 (POP66-SR). The crosses between P1 (ACR,94TZECOS5-Y), P2 (OBATASNPA/TZLCOMP.1), P4 (POP15-SR) and P8 (POP66-SR) have the potentials for superior hybrids formation.

Introduction

Maize (*Zea mays* L*)* is a widely grown crop in most part of the world; this is due to its adaptability and productivity. It is one of the most important food grains in the world most especially in the developing countries. In Nigeria, maize is an important crop as it provides food for and helps to sustain the rapidly increasing population. Apart from providing the staple diet for the population, maize is also important crop in industrial and livestock production in the country. Although maize is mainly considered as a carbohydrate source, the improvement in the protein content has now made it an important source of protein. Quality Protein Maize (QPM) varieties have considerably high level of essential amino acid such as lysine and tryptophan. It is also an important protein source because of its considerably total protein yield (Prasanna *et al.,* 2001*),* so there is a great demand for QPM due to its much better nutritional value in human consumption as well as feed in livestock industry. The discovery of the recessive opaque-2 mutant gene increases the proportion of the better-balanced proteins in the endosperm of maize kernel.

To establish a sound basis for any breeding programme, aimed at achieving higher yield, breeders must have information on the nature of combining ability of parents, their behaviour and performance of hybrid combination. Such knowledge of combining ability is essential for selection of suitable parents for hybridization and identification of promising hybrids for the development of improved varieties. The International Maize and Wheat Improvement Centre (CIMMYT) maize programme has made extensive use of the opeque gene in developing QPM germplasm in the past three decades. The opaque gene enhances the quality of endosperm protein, but is associated with many undesirable traits, such as slow drying, low grain yield, opaque endosperm phenotype, and greater vulnerability to ear rot, stem lodging, leaf spot and storage pests (Prasanna *et al*., 2001; Vasal., 2001). Using innovative breeding methodologies, CIMMYT scientists overcame the problems associated with opeque maize and developed source QPM germplasm with normal-looking kernel phenotype as well as grain yield comparable to normal endosperm materials, with protein quality an added bonus (Vasal *et al*., 2001). Diallel crosses have been widely used in plant breeding to investigate combining abilities of the potential lines in order to identify superior parents for use in hybrid development programmes. In this study, diallel cross of eight QPM inbred lines was used to estimate general combining ability (GCA) and specific combining ability (SCA) effects for grain yield potentials with the view to identifying their reciprocal effects.The objective of this study is todetermine the specific combining ability (SCA) and general combining ability (GCA) among some selected Quality Protein Maize (QPM) varieties,assess the paternal, maternal and reciprocal effects in crosses and determine heterosis pattern in the crosses.

Materials And Methods

The experimental materials used for this study comprised of 8 parent inbred lines of maize viz: ACR.94TZE COMP5-Y, OBATANPA / T2L COMP. 1, POP66-SRQPM, POP 15-SR/ACR.94, OBATANPA/IWDC2, POP66/T2UTSR-W,T2L COMP 1/2.DIPLO.SUNF2 andPOP66-SR/DMR-LSR-U. They were obtained from the Maize Improvement Programme (MIP) of International Institute of Tropical Agriculture (IITA), Ibadan. The lines were planted out such that each inbred line to be crossed are planted contiguously to allow for crossing in all possible ways. Each were planted in a row plots of 5m length, planting spacing adopted was 75cm x 25cm with each plant hill^{-1}.

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At flowering, ear were covered with shoot bags before pollination prior to emergence of the silk to prevent contamination. Pollen grains of the desired parent plant were collected by covering their tassels at pollen shed with 'shower proof tassel bags' done a day prior to pollination. The pollen grains of the desire 'male' plants were carefully used to pollinate the silks of the predetermined 'female' plants. The reciprocals of the crosses were also made. The pollinated silks were covered immediately after pollination with tassel bags to guide against contamination and marked appropriately. Eight plants each from the parents were also self-pollinated for evaluation purposes.At the end, seeds of 28 crosses, 28 reciprocals and 8 parents (a total of 64 entries) were generated for evaluation. The respective F_1 seeds were harvested, shelled, sorted and placed in separate envelopes, appropriately labeled and kept for field evaluation. The genetic materials were evaluated during late season of 2011 using Randomized Complete Block Design with two replications two different locations.Each experimental unit consisted of a row plot of 5m long, planting distance was 75cm between rows and 50cm within rows with two plants per hill to give 53,333 plants ha^{-1}. Data were taken on plant aspect, plant height, ear height, leaf spot *(Culvularialunata),* stalk lodging, ear drooping percentage, ear rot, ear aspect, weight of 100 seeds, grain yield (t ha^{-1}). Data collected were subjected to diallel analysis using Graffing (1956) Method II (parents and crosses together). Both general combining abilities (GCA) and specific combining abilities (SCA) were computated using SAS Institute (1995) for the parent inbred lines and hybrids with respect to maize grain yield and other agronomic characters.

Results And Discussion

The diallel cross methods 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 programmes. It is worthy to note that breeding for hybrid vigour with quality protein maize inbred lines with relatively high grain yield could be a way out of the problems posed by poor performance of conventional maize genotypes (Vacaro *et al.*, 2002)

The mean and the standard deviation of the agronomic characters of the evaluated maize genotype are shown in Table 1. The hybrids and reciprocals have a close range in their mean values. The mean values for hybrids and reciprocals had better phenotypic value compared with the parents inbred lines. Results of plant aspect showed that hybrids had 2.23 and reciprocals 2.24 while the parents had 3.14 this exhibited better plant appearances by the hybrids and the reciprocals over the parents. Plant height indicated that hybrids recorded 164.81 and 157.50cm for reciprocals compared with 134.73cm obtained for the parents. The same trend was also observed for ear height its hybrids had 79.14cm and reciprocals 75.27cm while parents has 62.23cm, these showed that the parents are not as good as hybrids and the reciprocals, this is an expression of hybrid vigour. The mean values for leaf spot, stalk lodge ear drooping and ear rot likewise showed that the hybrids are better than the parents. Ear aspect was 2.46 for both hybrids and reciprocals while 3.25 was recorded for parents, weight of 100 seeds shown that hybrids has 26.58g and reciprocals 25.40g compared with parents having 22.12g. The expression of these traits was shown in the results of grain yield which was 5.29 and 5.15 tha^{-1} for hybrids and reciprocals respectively while parents has 3.64 tha^{-1}, the average mean value for parents, hybrids and reciprocals were 3.64 tha^{-1}, 5.58 tha^{-1} and 5.25 tha^{-1}, respectively. The significant values of hybrids and the reciprocals over the parental lines were consistently maintained. A better phenotypic appearance exhibited by the hybrids and the reciprocals over the parents for almost all the agronomic traits considered in this study showed an expression of hybrid vigour, such findings have also been reported by (Saad*et al.*, 2004, Nigussie and Zelleke, 2001)

Table 1. Mean for all the agronomic traits of the parents, hybrids and reciprocals of the maize genotypes across two environments

Agronomic traits	Parents	Hybrids	Reciprocals
Plant aspect*	3.14 ±0.43	2.23 ±0.32	2.24±0.37
Plant height (cm)	134.73 ±15.47	164.81±23.19	157.50±17.29
Ear height (cm)	62.23±11.92	79.14 ±18.19	75.27 ±15.07
Leaf spot*	3.05 ±0.39	2.12 ±0.39	2.14 ±0.39
Stem lodge (%)	39.77±13.83	33.79 ±18.38	30.29 ±13.23
Ear Drooping (%)	24.69 ±1.23	26.20±6.52	25.62±6.44
Ear rot (%)	55.37 ±21.49	34.14 ±13.04	32.96±13.72
Ear aspect*	3.25 ±0.48	2.46 ±0.45	2.46 ±0.45
Weight of 100seeds(g)	22.12±3.25	26.58 ±3.46	25.40 ±3.41
Grain yield tha^{-1}	3.64 ±0.98	5.29 ±0.98	5.15 ±1.17

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

Mean of the parents, crosses and the reciprocals for grain yield (t ha^{-1}) of the two environments

The mean of the parents, crosses and the reciprocals for grain yield are shown in Table 2, P1 x P8 appeared as the best combiners for grain yield with 7.556 t ha^{-1}. The grain yield for the parental lines ranged from 3.000 t ha^{-1} for P5 to 3.999 t ha^{-1} for P1 and P8, the grain yield for the hybrids ranged from 4.440 t ha^{-1} for P6 x P7 to 7.556 t ha^{-1} for P1 x P8, and from 4.446 t ha^{-1} for P6 x P5 to 7.040 t ha^{-1} for P4 x P1 for the reciprocals.

Pearson correlation coefficients among the agronomic traits of the maize genotypes

The relationships among the studied traits as revealed by Pearson correlation coefficients are shown in Table 3. The correlation coefficients showed that plant height, ear height and weight of 100 seeds showed positive and highly significant correlation effect with grain yield (0.33**, 0.38**, and 0.59** respectively). Also, plant aspect, ear rot and ear aspect exhibited negative and significant correlation effects with grain yield (-0.45**, -0.35* and -0.52* respectively).Worth mentioning again is that of plant aspect which had a negative and significant correlation with plant height (-0.46**), ear height (-0.32**), but this same trait had positive and significant correlation with ear rot (0.34*), ear aspect (0.41**) and weight of 100 seeds (0.44**). Moreover, plant height exhibited positive but significant effect with ear height, stalk lodge and weight of 100 seeds (0.19*, 0.32** and 0.16* respectively) while negative but significant correlation were observed with leaf spot (-0.42**) and ear aspect (-0.45**). The correlation between ear height and other traits showed positive and significant effect with stalk lodge weight of 100 seeds at 0.46** and 0.52** respectively, while negative but significant for leaf spot, ear drooping, ear rot and ear aspect at -0.41**, -0.41**-0.16* and -0.51** respectively.

The effect of positive and significant means, as the value of a trait is increasing the value of another trait is increasing while the negative but significant effect means, as the value of a trait is increasing the value of another trait is decreasing.

Mean square values attributed to general combining abilities (GCA), specific combining abilities (SCA) and other sources of variation among inbred lines.

Table 2. Mean of the parents (underlined), crosses (upper diagonal) and the reciprocals (lower diagonal) for grain yield (t ha^{-1}) of the two environments

Parents		P1	P2	P3	P4	P5	P6	P7	P8
ACR, 94TZECO5-Y	(P1)	<u>3.999</u>	5.280	4.667	5.200	4.851	5.171	5.240	7.556
OBAT/TZLCOMP.1	(P2)	5.680	<u>3.200</u>	5.080	5.067	5.240	4.880	5.217	5.480
POP66-SRQPM	(P3)	5.556	4.533	<u>3.800</u>	4.626	4.800	5.400	5.248	5.800
POP15-SR	(P4)	7.040	6.720	5.133	<u>3.600</u>	5.520	5.920	5.840	5.800
OBATANPA/TWDC2	(P5)	4.493	5.520	6.040	4.747	<u>3.000</u>	6.720	5.760	5.387
TZUTSRQPM	(P6)	4.680	5.480	5.800	5.600	4.446	<u>3.800</u>	4.440	5.160
TZLCO1/2.DIP.SF2	(P7)	5.240	5.800	4.960	5.120	4.800	5.447	<u>3.720</u>	5.013
POP66-SR	(P8)	4.533	4.760	4.600	4.760	5.387	5.240	5.000	<u>3.999</u>

Table 3. Pearson correlation coefficients among the traits studied

Traits		1	2	3	4	5	6	7	8	9	10
Plant asp	(1)	-	-0.46**	-0.32**	0.12	-0.04	-0.01	0.34*	0.41**	0.44**	-0.45**
Plant ht	(2)	-	-	0.19*	-0.42**	0.32**	0.07	0.04	-0.45**	0.16*	0.33**
Ear ht.	(3)	-	-	-	-0.41**	0.46**	-0.41**	-0.16*	-0.51**	0.52**	0.38**
Leaf spt	(4)	-	-	-	-	-0.01	-0.02	0.35**	0.41**	-0.07	-0.09
Stalk	(5)	-	-	-	-	-	-0.01	0.15*	0.16*	-0.05	-0.10
Droop.	(6)	-	-	-	-	-	-	0.07	-0.04	0.61**	0.04
Ear rot	(7)	-	-	-	-	-	-	-	0.45**	-0.16*	-0.35*
Ear asp.	(8)	-	-	-	-	-	-	-	-	- 0.14*	-0.52*
Wt100s	(9)	-	-	-	-	-	-	-	-	-	0.59**
Grain Yield	(10)	-	-	-	-	-	-	-	-	-	-

*, ** Significant at <0.05 and < 0.01 level of probability, respectively.

Table 4. Mean square values attributed to general combining ability (GCA), specific combining ability (SCA) and other Sources of variation among inbred lines

Variation Due to	Degree of Fredm	Plt asp.	Plt Ht.	Ear ht	Leaf spt.	Stalk Logd	Drop.	Ear rot	Ear asp.	Wt100s	GYld (tha^{-1})
GCA	7	814.17**	2.69**	5.55**	894.3	4.421**	24.02**	5.06**	5422.57*	110.46**	0.00096
SCA	28	174.31	0.58	0.12	191.53	0.09	0.51	0.11	116.15	1.73	0.00015
REC	28	46.14	0.02	0.03	50.70	0.03	0.14	0.03	30.75	0.63	0.00054
MAT	7	41.51	0.02	0.023	45.61	0.02	0.12	0.03	27.66	0.56	0.00049
NMAT	21	47.69	0.02	0.03	2.39	0.03	0.14	0.03	31.77	0.65	0.00056
GCAXENV	7	152.82	0.05	0.10	167.9	0.08	0.45	0.09	10.82	2.07	0.00018
SCAXENV	28	78.01	0.03	0.05	85.70	0.04	0.23	0.05	51.98	0.63	0.00055
RECXENV	28	47.31	0.02	0.03	1.98	0.03	0.14	0.03	31.53	0.64	0.00056
MATXENV	7	82.37	0.27	0.069	0.49	0.05	0.24	0.05	54.88	1.12	0.00097
NMATXENV	21	35.63	0.012	0.02	39.15	0.02	0.11	0.02	23.74	0.48	0.00042
ERROR	126	0.117	353.05	171.69	0.107	215.35	39.65	188.17	0.176	8.62	99739.2

*, ** Significant at < 0.05 and < 0.01 levels of probability, respectively

Table 5. Estimates of general combining ability (GCA) effects for the parental inbred lines for different traits

Parents	Plant asp.	Plant Height	Ear height	Leaf spot	Stalk Lodge	Dro-oping	Ear rot	Ear aspect	Wt100sG	Yild(t ha^{-1})
ACR, 94TZE5-Y (P1)	0.88**	-22.98**	-15.70*	0.88**	5.87	0.67	0.38	0.38	-3.51*	-0.900
OBAT/TZLCOMP.1 (P2)	0.98**	-17.81	-7.78	0.55**	16.10*	-3.47**	1.03**	1.03**	-0.10	-1.792**
POP66-SRQPM (P3)	0.78**	-22.18**	-12.34	0.90**	3.06	-3.08**	0.92**	0.92**	-3.52*	-1.128
POP15-SR (P4)	0.34*	-19.21*	-15.93*	0.53**	4.39	-0.03	0.57	0.57	-2.32**	-1.488**
OBAT/IWDC2 (P5)	1.10**	-33.51**	-15.25*	0.67**	3.45	-0.97	0.64**	0.64**	-4.82**	-1.886**
TZUTSRQPM (P6)	0.95**	-21.19*	-13.84	1.14**	9.31	-0.50	0.61**	0.61**	-5.69**	-1.398**
TZ1/2.DIP.SF2 (P7)	0.59**	-20.58*	-12.03	0.76*	4.54	-0.81	0.55	0.55	-3.79*	-1.287**
POP66-SR (P8)	0.12	-11.67**	-2.17	0.06	0.86	-0.31	0.13	0.13	-2.13	-1.359**

*, ** Significant at < 0.05 and < 0.01 levels of probability, respectively

Table 6. Specific combining ability (SCA) effects for grain yield (t ha^{-1}) for the hybrids (upper diagonal) and the reciprocals (lower diagonal)

Parents	P1	P2	P3	P4	P5	P6	P7	P8
ACR,94TZECOM5-Y (P1)	____	0.534*	0.305	0.206*	-0.220	-0.124	0.227**	1.145**
OBAT/TZLCOMP.1 (P2)	-0.000	____	0.043*	0.027	0.441*	0.085*	0.510**	1.124**
POP66-SRQPM (P3)	-0.630*	-0.000	____	-0.206	0.436	0.460*	0.059*	0.598**
POP15-SR (P4)	0.000	0.000	-0.253*	____	0.147*	0.617	0.866*	1.206**
OBATAN/IWDC2 (P5)	0.179	-0.140	-0.620	0.387*	____	0.541*	0.334	-0.258
TZUTSRQPM (P6)	0.246	-0.300	-0.200	0.160*	1.137**	____	-0.309	-0.387*
TZLCO1/2.DIP.SF2 (P7)	0.060*	-0.291	0.144	0.360	0.480*	-0.353	____	-0.378*
POP66-SR (P8)	0.360**	0.360*	0.600	0.520	0.265	-0.040	0.007	____

*, ** Significant at < 0.05 and < 0.01levels of probability, respectively

The mean square (MS) values for analysis of variance (ANOVA) for general combining ability (GCA), specific combining ability (SCA), reciprocal (REC), maternal (MAT) effects, non-maternal (NMAT) effects and the effects due to other sources of variation are presented in Table 4. The mean square values for general combining ability (GCA) were significant ($P < 0.05$) for most studied traits, like plant aspect 8138.17**, plant height 2.69**, ear height 5.55**, stalk lodge 4.42**, drooping 24.02**, ear rot 5.06**, ear aspect 5422.57* and weight of 100seeds 110.46**.

The specific combining ability (SCA) effects, the reciprocals (REC), maternal (MAT), non-maternal (NMAT), GCA x environment (GCA x Env) and non-maternal x environment (NMAT x Env) were not significant also, there was no significant paternal or maternal effect exhibited for results. This however indicates any of the parents can be used as male or female without any significant effect on the agronomic traits.

General combining ability (GCA) effects for the parental inbred lines for different traits

The analyses of variance (ANOVA) for general combining ability (GCA) effect of the parental lines for different characters are presented in Table 5.The general combining ability (GCA) effects for the traits varied significantly for almost all the traits. The general combining ability (GCA) recorded significant effects in plant aspect for all the parental lines except for P8. Also, plant height showed significant effects except for P2, significant GCA effects for ear height were observed only in P1, P4 and P5. The GCA effects for ear rot and ear aspect were significant for P2, P3, P5 and P6. Significant but negative GCA effects for weight of 100 seeds while there was no significant effect for P1, P3, P4, P5, P6 and P7 while P2 and P8. Negative but significant effects for grain yield were recorded in P2, P4, P5 P6 and P7.

Table 6 showed the SCA effects for grain yield, for the hybrids, significant values were obtained in P1xP4, P1xP7, P1xP8, P2xP5, P2xP8, P3xP6, P3xP8, P4xP7, P4xP8, P5xP6, P6xP8 and P7xP8. Also, the reciprocals showed SCA significant effects in crosses like P5xP4, P6xP1, P6xP4, P6xP5, P7xP5, P8xP1 and P8xP2.

Crosses P1 x P8, P2 x P8 and P4 x P8 were outstanding with excellent SCA effects for grain yield. It is worth mentioning that, the best crosses which showed high SCA effect for a trait were not always involving two parents with desirable GCA for that particular trait. This means that 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 (Al-Naggar*et al.*, 1990).

In conclusion, the study revealed that significant differences were recorded on the mean values with respect to grain yield with an average of 3.64 tha^{-1} for parents, 5.58 tha^{-1} for hybrids and 5.25 tha^{-1} for reciprocals, the hybrids had significantly higher grain yield than the parents, significant GCA and SCA were recorded for grain yield and other agronomic traits. Additive and dominance gene effects therefore played major roles in the inheritance of grain yield and other agronomic traits of maizegeno types. The general combining ability effects were significant for plant aspect, plant height, ear height, stalk lodge, ear drooping, ear rot, ear aspect and weight of 100 seeds, the specific combining ability were significant for all the traits. P1 (ACR,94TZECOM5-Y), P2 (OBATANPA/TZLCOM.1), P3 (POP66- SRQPM) and P4 (POP15-SR) are good combiners with P8 (POP66-SR),there were no significant maternal, paternal and reciprocal effects, which indicate any of the parents can be used as male or female without any significant effect on the agronomic traits. The hybrids (crosses and reciprocals) show better performance compared with parental lines demonstrating positive heterotic pattern.

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