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Combining Abilities in Single Cross Hybrid of Quality Protein Maize for Grain Yield and Its Components

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Abstract
A trial involving five females normal maize and three males of Quality protein maize (parents) were mated in a line x tester mating design in 2012. The resultant 15 F_1 crosses and 8 parents were evaluated in 2012/2013 using lattice II design replicated three times at Institute for Agricultural Research, A.B.U Samaru, Zaria. Seven agronomic traits of parents and F_1 were studied to determine their general and specific combining abilities (GCA, SCA), highly significant differences was observed among the genotypes for all traits except plant height, ear height and ear weight. Sammaz 32 and sammaz 15 were the best parents in terms of G C A for grain yield parameters and most traits, In terms of SCA, hybrids sammaz 17 x sammaz 11 (2471.11) and sammaz 32 x sammaz 15 (1923.7) were the best in terms of grain yield and most traits . The highest value was between plant height and Grain yield. It was suggested that a three way hybrid crosses could be employed to improve the desired character in the population.
Keywords: Combining ability, Quality Protein maize, Yield, Yield Components.

INTRODUCTION

Maize (*Zea mays* L.) is one of the oldest food grains. It belongs to the grass family Poaceae (Gramineae), tribe Maydeae and it is the only cultivated species of economic importance in the genus.(Mertz, 1964) It is believed by many investigators that maize originated in Mexico, where maize and teosinte have coexisted since ancient times and where both species have a wide biodiversity (Iltis, 1983; Wilkes, 1989). The findings of fossils pollen and archeological maize cobs from caves in this region strongly support that maize originated in Mexico. An understanding of the evolution of maize is important for promoting aggressive breeding programs and for transferring desirable traits to maize from wild relatives and diverse landraces in a continuous effort to evolve and improve the crop. Maize is the most widely grown crop of the temperate, sub-tropical, tropical and semi-arid region of the world (Hallauer, 2001). Maize is the third most important cereal crop in the world after wheat and rice (FAO, 1997). Although maize is primarily a provider of calories supplying almost 20% of the world's calories, it also provides about 15% of all food crop protein (National Research Council, 1988). It is a source of food for human consumption, feed for livestock and raw materials for agro-based industries. It is one of the most important cereal crops in sub-Saharan Africa (SSA) as well as a major component in the diet of the people of west and Central Africa (WCA) especially in the North Guinea Savannas (NGS) and Southern Guinea Savannas (SGS). The importance of maize in human diet, livestock feed and as raw material for some industries has increased rapidly in the last two or three decades of the 20^{th} century (Fakorede *et al.*, 2003).

Maize is mainly considered a calorie provider or carbohydrate source; it is also an important protein source because of its considerable total protein yield per hectare (Bjornson and vassal, 1992). Maize provides about 20% of the world's food calorie and 15% of all food crop protein (NRC, 1988). From nutritional perspective, protein of maize and that of other cereals is deficient in the essential amino acids, lysine and tryptophan (Bjarnason *et al.,* 1987). This nutritional deficiency is of concern particularly for people with high protein requirements, e.g. young children, pregnant or lactating women, the ill and poor in countries where maize is a staple food and often a significant source of protein.

Maize is probably the cheapest and the purest organic material of agriculture available for large-scale industrial use. The use of QPM has helped to reduce nutrition related diseases and deaths and significantly improve nutritional status of individuals who depend primarily on maize for sustenance (Ado, 1999).Several researchers have demonstrated the superior protein quality and protein digestibility of QPM over Normal maize (Bressani, 1995; Mertz *et al*., 1964) Maize grain protein quantity and quality have received relatively little attention from breeders, although both traits can be manipulated by breeding, and information on heritability has been accumulating for many years, particularly about protein quantity. This neglect is a consequence of focusing breeding objectives on attributes of immediate concern like yield, maturity and resistance to stresses.

The concepts of general and specific combining ability were introduced by Sprague and Tatum (1942). General combining ability (GCA) is the average performance of a line in hybrid combination and specific combining ability (SCA) is the deviation of crosses on the basis of average performance of the lines involved.

The four experimental methods and two models were proposed (Griffing, 1956) for the analysis of GCA and SCA in a diallel mating design. Variance for GCA is associated to additive genetic effects while that of SCA includes non-additive genetic effects, arising largely from dominance and epistatic deviations (Falconer and mackay, 1996). Combining ability has been investigated by several authors in maize (Beck *et al*., 1990; Glover *et al*., 2005).

The objectives of this study were to estimate the general and specific combining abilities of the parents and their hybrid crosses for grain yield and its components.

MATERIALS AND METHODS

The present investigation was carried out at the Institute for Agricultural Research farms located at Samaru, Zaria Kaduna state. The plant materials for this study comprised five varieties of maize used as female parents viz: Sammaz 11, Sammaz 18, Sammaz 26, Sammaz 15 and Sammaz 16, three testers used as male parents (QPM) are Sammaz 17, Sammaz 32, and Sammaz 36. The entire eight genotypes were obtained from the Institute for Agricultural Research. (I.A.R).

Maize is a cross pollinated plant by nature. Both males and females were planted using a staggered planting pattern of one week interval in order to synchronize the flowering and subsequent pollination. Selected female parents were pollinated with the pollen from selected male parents to produce crosses and Pollination was controlled to ensure progenies of known parentage using the line x tester mating design (Comstock and Robinson, 1948), among three males and five females, resulting in 15 F_1 hybrids.

The 8 parents together with 15 F_1 hybrids (23 entries) were evaluated at IAR, Samaru irrigation fields at Samaru, Zaria. The summary of the experimental layout is as follows;

Experimental design: Lattice II Design, Number of replications: 3, Row length: 5 m, Number of rows per plot: 1 Spacing between rows: 75 cm, Spacing between plants within the row: 50 cm, Plot size: 0.5 m × 0.75 m

After thorough land preparation, sowing was done by hand dibbling of seeds with three seeds per hill and the plot was irrigated. The plants were thinned to 2 plants per hill two week after planting to maintain two seedlings per hole. Tassel bags and silk covers were used to control pollination during mating. Experimental unit was treated similar to all agronomic and cultural practices from sowing to harvesting.

The data collected were statistically analyzed using analysis of variance (ANOVA) appropriate for RCBD and combined analysis was done with SAS version 9.1. When significant differences were detected, the Least Significant Difference (LSD) test was used in comparing the means. The following parameters were estimated: General and specific combining abilities

RESULTS

Analysis of Variance for Agronomic Traits

The maize hybrids derived through crosses, along with their parents were evaluated regarding agronomic parameters under field conditions. The result revealed that the genotypes were highly significant ($P<0.01$) for Ears per plant, Ear weight, and significant for days to 50% tasseling, Days to 50% silking, Plant height, Grain yield, and non-significance for Ear height.

Mean sum of squares for seven quantitative traits of parents and hybrids are presented in Table 1: The mean sum of squares for parents were non-significant for all traits except for Ears per plant and Ear weight .Plant height, Ears per plant , and ear height showed highly significant mean of squares for hybrids. Non significance mean sum of squares for all characters were observed in females and males except for Ears per plant in males. The mean sum of squares of female versus male were highly significant for ears per plant, Days to 50% tasseling.

Table 1: Mean sum of squares for parents and hybrids in respect of seven quantitative characters

Source of variation	df	DYTS	DYSK	PLHT	EHT	EPP	EWT	GY
Rep	2	14.49	15.29	105.05	92.17	0.00	797733.30	1880177.80
Var	24	55.53*	85.65*	392.36	365.71	0.09**	1055978.00	5028187.70*
C vs (P, H)	1	413.92**	296.27	618.70	541.30	0.00	489626.10	381238.00
P vs H	1	40.49	173.91	153.94	108.13	0.14*	5463924.00**	26482327.00**
Checks (C)	1	37.50	37.50	468.17	294.67	0.11	15000.00	426666.67
Parent (P)	7	30.38	46.38	213.57	192.21	0.12**	1271845.00	4686560.90
Hybrid (H)	14	44.87	87.38	477.23**	314.17	0.09**	748000.00	4327167.60
Line	4	37.31	70.11	534.81	398.88	0.11*	735222.20	4083358.00
Testers	2	17.87	20.60	792.42	651.12	0.02	268666.70*	1992691.40
Line x Tester	8	55.39	112.71	369.64	221.17	0.10**	874222.20	5032691.40
Error	48	30.27	78.13	189.19	123.42	0.03	417594.40	2790795.10

PHLT= Plant height, EHT = Ear height, EPP= Ear per Plant, EWT=Ear weight, DYTS= Days to 50% Tasseling, DYSK= Days to 50% Silking, GY= Grain yield

Combining ability effects for agronomic traits.

The general combining ability effects of 5 female parents (lines) and three male parents (testers) for 7 different traits are given in Table 2.

Days to 50 per cent tasseling

Among 5 lines, 2 lines exhibited negative GCA effects, whereas remaining 3 lines had positive GCA effects. Sammaz 16 (-3.60), Sammaz 15 (-4.49) showed Significant GCA effects in negative direction, whereas Sammaz

18, 26, and 11 showed non-significant GCA effects in positive direction. All testers showed GCA in negative direction. Sammaz 17 was highly significant while Sammaz 36 also showed significant GCA.

Days to 50 per cent silking

Out of 5 lines, three lines Sammaz 18 (-0.11), Sammaz 16(-4.11) and Sammaz 15 (-7.89) showed GCA effects in negative direction. With Sammaz 15 showing highly significant effects. Among the testers only Sammaz 36 showed significant GCA effect in negative direction with Sammaz 32 in the positive direction.

Table 2: General combining ability effects of parents in respect of seven quantitative characters

Parents	DYTS	DYSK	PLHT	EHT	EPP	EWT	GY
Lines							
Sammaz 18	3.29	-0.11	6.16	8.16	0.13*	291.11	106.67
Sammaz 26	1.51	8.00**	10.27*	11.27*	-0.07	46.67	195.56
Sammaz 16	-3.6*	-4.11	-5.51	-5.51	0.1	-386.67	-2167.4**
Sammaz 11	3.29	4.11	-3.96	-4.96	-0.13*	235.56	551.11
Sammaz 15	-4.49*	-7.89**	-6.96	-8.96*	-0.03	-186.67	1314.07*
S.E±	1.83	2.95	4.58	4.58	0.06	215.41	556.86
Testers							
Sammaz 17	-3.20**	0.47	0.82	0.82	0.12*	13.33	-1227.4**
Sammaz 36	-2.93*	-5.33*	6.82	7.82	-0.09*	126.67	361.48
Sammaz 32	-0.27	4.87*	-7.64*	-8.64*	-0.03	-140.00	865.93*
S.E±	1.42	2.28	3.55	3.55	0.05	166.85	431.34

PHLT= Plant height, EHT = Ear height, EPP= Ear per Plant, EWT=Ear weight, DYTS= Days to 50% Tasseling, DYSK= Days to 50% Silking,
GY= Grain yield

Plant height

The magnitude of GCA effects varied from -3.96 to 10.27.Only one line Sammaz 26 Showed significant GCA effects and that of three of the lines Sammaz 16, 11, and 15 were in negative direction. Testers did not have significant GCA effects in either direction except sammaz 32 in negative direction.

Ear height

Two parents showed significant GCA effects in the negative direction (Sammaz15 and Sammaz 32), while Sammaz 26 and Sammaz 36 showed significant GCA effect in the positive direction.

Ears per plant

Two lines, Sammaz 18 (0.13) and Sammaz 11 (-0.13), manifested significant GCA effects in both Positive and negative direction respectively. While two testers also showed significant GCA effects in both the directions.

Ear weight

Out of the 8 parents, only one line showed significant GCA effect in the positive direction. While none of the testers' shows significant effect in either direction.

Grain yield

Among the lines, 2 lines exhibited significant GCA effect in both negative and positive directions, Sammaz 16 (-2167.41) and Sammaz 15 (1314.07), respectively. While the testers also show significant GCA in both direction in Sammaz 17 and Sammaz 32. The magnitude of the GCA effect ranges from -2167.42 to 1314.07 among both the lines and the testers.

Specific combining ability effects

The specific combining ability effects of 10 single cross hybrids are given in Table3

Days to 50 per cent tasseling

Among 15 single cross hybrids two crosses showed significant sca effects in negative direction. Sammaz 17 x18 (-6.76) and Sammaz 36 x 16 (-7.07). The range of sca effects was found to be from -7.07 to 7.04.

Days to 50 per cent silking

The range of sca effects was from -10.89 to 5.58, only one cross Sammaz 36 x 16 revealed significant sca effects in the negative direction, among the crosses Sammaz 17 x 18, Sammaz 36 x 18, Sammaz 32 x 18, Sammaz 32 x 26, Sammaz 32 x 16 and Sammaz 32 x 15 all show sca effect in negative direction.

Plant height

The Single crosses hybrid such as Sammaz 36 x 11 (18.98) and Sammaz 36 x 15 (15.62) showed significant sca effect in the positive direction, while Sammaz 36 x 26 (-16.49) showed significant sca effect in the negative direction.

Table 3: Specific combining ability effects of single cross hybrids in respect of seven characters

Crosses	DYTS	DYSK	PLHT	EHT	EPP	EWT	GY
Sammaz 17x 18	-6.76*	-5.02	4.18	24.18**	0.16	8.89	-728.89
Sammaz 17x 26	1.04	3.78	-5.49	-20.49**	0.04	62.22	320.00
Sammaz 17x 16	-0.29	1.24	1.31	7.31	-0.2*	-71.11	408.89
Sammaz 17 x 11	2.69	1.87	-2.27	-4.27	0.26*	886.67*	2471.11*
Sammaz 17 x 15	2.49	3.67	7.40	17.4*	0.01	6.67	-835.56
Sammaz 36 x 18	-5.18	-5.53	-5.13	-15.13	-0.27*	-893.33*	-1935.6*
Sammaz 36 x 26	1.80	5.31	-16.49	-17.49*	0.02	-80.00	189.63
Sammaz 36 x 16	-7.07*	-10.89*	-2.49	-2.49	0.04	-60.00	-183.70
Sammaz 36 x 11	4.27	5.58	18.98*	14.98	-0.07	140.00	-5.93
Sammaz 36 x 15	0.91	1.42	15.62*	16.62	-0.29**	-302.22	-1795.6*
Sammaz 32 x 18	-1.96	-0.78	-7.38	-9.38	0.00	-82.22	586.67
Sammaz 32 x 26	7.04*	-0.64	-8.24	-8.24	0.29**	384.44	408.89
Sammaz 32 x 16	-4.64	-3.58	-5.04	-7.04	0.05	-513.33	-936.3
Sammaz 32 x 11	4.49	4.22	7.96	7.96	-0.1	73.33	112.59
Sammaz 32 x 15	1.16	-0.64	-2.91	-3.91	0.05	440	1923.7*
S.E±	3.18	5.1	7.94	7.94	0.1	373.09	964.5

PHLT= Plant height, EHT = Ear height, EPP= Ear per Plant, EWT=Ear weight, DYTS= Days to 50% Tasseling, DYSK= Days to 50% Silking,
GY= Grain yield

Ear height

Five crosses showed significant sca effects. Among which, three crosses expressed sca effects in positive direction and two in negative direction. The range for the sca effects was found to be from (-20.49) Sammaz 17 x 26 to (24.18) Sammaz 17 x 18.

Ear weight

The range of sca effects was from -893.33 (Sammaz 36 x 18) to 886.67 (Sammaz 17 x 11) for
Ear weight. The crosses Sammaz 17 x 11 showed significant sca effect in positive direction, while Sammaz 36 x 18 showed significant sca effect in the negative direction.

Grain yield

Four crosses manifested significant sca effects, of which Sammaz 17 x 11 (2471.11) and Sammaz 32 x 15 (1923.70) expressed in the positive direction and Sammaz 36 x 18 (-1935.56) and Sammaz 36 x 15 (-1795.56) expressed in the negative direction.

DISCUSSION AND CONCLUSION

Combining ability refers to the ability of a parent to transmit desirable traits or performance through series of specific crosses to its progeny. It serves as a useful tool to plant breeders since breeding methodologies depend upon the nature of gene action that controls a particular character within a population. Combining ability analysis is of special importance in cross pollinated crops like maize as it helps to know the genetic architecture of various traits and enables the breeder to design effective breeding plan. The GCA effects revealed that Sammaz 15 was the best general combiner for grain yield traits and other desirable agronomic traits like days to 50% tasselling and days to 50% silking and plant height which influence the grain yield. The taller the plant, the better the yield. Sammaz 15 shows the same earliness in flowering and silking, tall plant with good yield. These parents can be selected due to their ability to combine well for these traits to produce good yield. Similar results were observed by Roy *et al.* (1998) who reported positive GCA values for these traits.

Specific combining ability (SCA) effects revealed that Sammaz 32 x Sammaz 18 followed by Sammaz 32 x Sammaz 15 had the best sca for days to 50% tasselling, 50% silking, with an advantage of shorter plant height and good grain yield. It was observed either that one or both of parents were good combiners (Sammaz 32, Sammaz 18 and Sammaz 15) for desirable agronomic traits including grain yield. The above crosses involved high x high and low x high combining parents. This was supported by Xing Ming *et al.* (2002), who reported the involvement of good parents in high yielding crosses.

In case of the protein quality traits, Sammaz 17, Sammaz 11 and Sammaz 36 were good general combiners for percent protein. While Sammaz 36 x Sammaz 11 and Sammaz 32 x Sammaz 18 were the superior combiners for protein percentage.

The results generally showed that GCA effects of the parents were not reflected in their SCA effect for all the traits as reported by Ivy and Howlader (2000). Moreover, Amiruzzaman *et al*. (2011) also pointed out that the SCA is a result of the interaction of GCA effects of the parents and that it can improve or deteriorate the hybrid expression compared to the expected effect based on GCA only.

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