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COMPLETE DIALLEL TO ESTIMATE COMBINING ABILITY VARIANCE COMPONENTS OF MAIZE (*Zea mays* L.)

Ibrahim, A. K.

Department of Agronomy, Bayero University, Kano, Nigeria, PMB 3011, Kano, Nigeria.

Corresponding Author's Email: aikurawa.agr@buk.edu.ng

ABSTRACT

A full-diallel cross comprising eight varieties belonging to four different maturity groups was developed and studied for some selected characters to determine the nature of gene action of parents and hybrids. Eighty-one genotypes comprising of crosses, reciprocals, selfs, parents and nine checks were evaluated at Kadawa under irrigation using two different planting dates (environments). The results for environments one, two and combined across environments, revealed that the magnitudes of General Combining Ability (GCA) components were much higher than that of Specific Combining Ability (SCA) for days to 50% tasselling, days to 50% silk, number of leaves per plant and number of kernels per row indicating the predominance of additive gene action controlling the traits, where SCA is small relative to GCA, performance of single cross progeny can be predicted on the basis of the GCA of the parents. Those traits having higher SCA components to that of GCA were controlled by the non-additive type of gene action, revealed that these traits were purely under dominance effect of gene and that, selection for these traits should be performed using recurrent selection method. High variance components due to reciprocals for plant height, ear height and grain yield for both environments and combined indicating the importance of maternal effects for these characters.

Keywords: GCA, SCA, Diallel, Reciprocal, Additive effects, Variance.

INTRODUCTION

Maize has become a major food item in Nigeria and it is consumed in many forms. It is consumed as green maize when the ear is boiled or roasted. When dry, the grain may be processed into different forms of products such as pap (*ogi*) and starch, it is also an industrial crop in Nigeria (Oluwaranti, Fakorede, & Badu-Apraku, 2008). It is an important food crop in Sub-Saharan Africa, providing 50% of the calories in diets in Southern Africa, 30% in Eastern Africa and 15% in West and Central Africa (Vivek, Crossa, & Alvarado, 2009). Overall, 21% of the total world maize production is consumed as food, with consumption and utilization varying greatly around the world (Morris, 1998). One of the appropriate means to detect performance of offspring is diallel mating system, a method in which the parents and progeny performance can be statistically separated into components relating to General Combining Ability (GCA) [the 'expected' value of any particular cross, according to (Allard & Bradshaw, 1964), is the sum of the GCA's of its two parental lines] and Specific Combining Ability (SCA) [deviation from this expected value is called SCA]. Diallel approaches are used to investigate the inheritance of important traits among a set of genotypes and gene effects (Malik, Malik, Minhas, & Munir, 2004), additionally it is useful for obtaining the genetic information about the traits of interest through fixed and random selection sets of parental lines in short time (Griffing, 1956), investigate combining abilities of the parental lines in order to identify superior parents for use in hybrid development programmes, additionally are used to determinate the inheritance of a trait among a set of genotypes and to identify superior parents for hybrid development (Weikai Yan & Manjit Kang, 2003). Griffing's diallel approach (1956) is been used for estimating combining ability. GCA values describe the overall usefulness of the parental form in terms of the concerned trait, whereas SCA specifies the importance of the joint action of the genes of parental forms (Baker, 1978). Generally, the amount of enhancement expected to come from GCA and SCA will be proportional to their variances (Griffing, 1956). The mean square ratio for GCA and SCA is employed to determine the prevailing gene actions (additive or non-additive) of a quantitative trait. As Baker, (1978) reported that, the closer the ratio is to unity, the greater the performance of the progeny selected based on GCA values. The GCA/SCA ratio with a value greater than one indicates additive genetic effect, whereas, GCA/SCA ratio with a value lower than one indicates a dominant genetic effect. The predominance of GCA is conducive for the improvement of selection efficiency in segregating populations (Boćanski, Srećkov, & Nastasić, 2009). Specific combining ability is the cumulative performance of any two accessions in their specific hybrid combination. Variance due to general combining ability (GCA) is an indicator for the extent of additive gene action whereas; variance due to specific combing ability (SCA) shows the extent of non-additive gene action. Additive and non-additive types of gene actions were very important for genetic expression of yield and related traits. The majority of yield-related traits are controlled by additive genes.

Selection of appropriate breeding program for maximum genetic improvement is based on relative values of general and specific combining ability (Griffing, 1956). Dominance and additive gene actions are effectively used for the improvement of hybrids (Kumar, Reddy, Naik, Parveen, & Subbaiah, 2012). Assessment of crosses among inbred lines is a significant step towards the development of hybrid varieties in maize (Hallauer, 1990). This process should be accomplished through evaluation of all possible crosses (diallel mating), where the qualities of each inbred line can be determined, thus, the present study involving 8 x 8 diallel mating system was carried out to determine gene action involved in controlling some agronomic traits of interest and advice on appropriate breeding procedures for the development of new cultivars.

MATERIALS AND METHODS

The parental materials comprised of eight varieties, which were crossed in a complete diallel pattern. The crossing was made in all possible combinations which generated crosses, reciprocals, and selfs at Samaru-Zaria in April 2010. Eighty-one varieties comprising the crosses, reciprocals, selfs, parents and nine checks were evaluated at Kadawa in two sowing dates (environments) at three months interval beginning from January 2011. The sowing dates were considered as separate environments. The 81 entries were arranged in 9 x 9 lattice design with three replications in each environment. One row of 5m long spaced 0.75m apart was used as a plot. Three seeds were planted at intra row spacing of 50cm and later thinned to two plants per hill. Three hoe weeding was carried out, first one at two weeks after planting, second at four weeks after planting and earthing up at six weeks after planting with a split fertilizer application of compound fertilizer (NPK 20:10:10) as basal dressing and urea (46 % N) as top dressing, giving a total plant nutrient of 120 kg N, 60 kg P_2O_5 and 60 kg K_2O per hectare. Data were collected for: Days to 50% pollen shed (Daf), days to 50% silking (Das), plant height (PH) (cm), days to maturity (DM), kernels per row (KPR) and grain yield per hectare (Gy) (kg).

Data Analysis

Griffing analysis of variance was used for estimation of GCA, SCA and reciprocal effects for studied quantitative traits of maize. The data were analyzed using the diallel technique for analysis of general and specific combining ability and components of variance (Griffing, 1956; Method 1, Model 1). Combining Ability Estimation was conducted according to Kempthorne, (1956); Matzinger, Sprague, & Cockerham, (1959) from which the Component due to GCA was determined using the formula below:

$$\sigma^2{}_g = m_g - m_e/2n = 1/_{n-1}\sum g^2{}_i$$

Component due to SCA was determined using the formula below:

$$\sigma^2{}_s = m_s - m_e = 2/n(n-1)\sum\sum s^2{}_{ij}$$

Component due to reciprocal was determined using the formula below:

$$\sigma^2{}_r = m_r - m_e/2 = 2/n(n-1)\sum g^2{}_i$$

Where:

$\sigma^2{}_g =$ Variance due to GCA effect

$\sigma^2{}_s =$ Variance due to SCA effects

$\sigma^2{}_r =$ Variance due to reciprocal effects

$g_i =$ The GCA effects of the i^{th} parent

$s_{ij} =$ The SCA effects of the cross ixj

$r_{\mathrm{ij}} =$ A measure of the reciprocal effect

The ratio of GCA variance to SCA variance was calculated using (Singh and Chaudhary, 1985 formula:

$$(1/n-1)\sum_i \mathrm{g}_\mathrm{i}^2/(2/n(n-1)\Sigma\sum_{i<j}s_{ij}^2 = (m_g - m_e/2n)/(m_s - m_e)$$

.

RESULTS AND DISCUSSIONS

Results

The Variances' components were significantly (p≤0.01) different for almost all traits study in all environments and combined (Table not presented). The components for GCA variance, SCA variance, reciprocal variance, and GCA/SCA variance ratios for fifteen traits measured at environments one, two and combined across environments are presented in Tables 1, 2 and 3, respectively. Table 1 shows positive GCA/SCA ratios for all the characters except days to 50% tasselling, days to 50% silk, ear height, and ear diameter. GCA variances were higher than SCA variances for all traits except plant height, a number of days to maturity, ear length, kernel row number, and threshing percentage. High reciprocal variances were observed for plant height, ear height, and days to maturity, number of kernels per row, threshing percentage and grain yield. Positive GCA/SCA ratios were observed at environment two (Table 2) for a number of leaves per plant, plant height, ear height, ear length, number of kernels per row, ear diameter, cob diameter, cob weight, and threshing percentage. GCA variances were higher than SCA variances for all characters except days to maturity, ear length, number of kernels per row, cob diameter, cob weight, and threshing percentage. High reciprocal variances were observed for days to 50% silk, plant height, ear height and a number of kernels per row.

The combined data (Table 3) revealed positive GCA/SCA ratios for plant height, ear height, number of ears per plot, number of kernels per row, ear diameter, cob weight, threshing percentage, and grain yield. GCA variances were higher than SCA variances for all the traits except plant height, ear height, ear length, number of kernels per row, ear diameter, cob diameter, cob weight, threshing percentage, and grain yield. High reciprocal variances were observed for plant height, ear height, number of kernels per row, threshing percentage and grain yield.

DISCUSSION

It was reported by El-Shouny, El-Bagoury, El-Sherbieny, & Al-Ahmad, (2003); Ojo, Adedzwa, & Bello, (2007); Vacaro, Barbosa Neto, Pegoraro, Nuss, & Conceição, (2002) that additive genetic action was more important for maize traits suggesting for rapid improvement in selection. However, Abdel-Moneam, Attia, El-Emery, & Fayed, (2009); Choudhary, Chaudhary, & Sharma, (2000) showed that dominance gene effect was important in the inheritance of maize characters. Nonadditive gene effects for grain yield were found to be significant in maize (Kalla, Kumar, & Basandrai, 2001) indicating several combinations among the parental lines by their mean performance and genetic nature had the potential for the development of more yielding and earlier genotypes. A relatively large GCA/SCA variance ratio suggests the importance of additive gene effects while a low ratio implies the presence of dominant and/or epistatic gene effects (Griffing, 1956). Additivity shows that the performance of heterozygote is intermediate to that of the homozygote, therefore, an intermediate heterozygote reflects no-dominance of one allele over the other. The departure of the heterozygote (Aa) from the mean of two homozygotes (AA or aa) at a locus reflects the extent of dominance. The results for environments one, two and combined across environments, revealed that the magnitudes of GCA components were much higher than that of SCA for days to 50% tasselling, days to 50% silk, number of leaves per plant and number of kernels per row indicating the predominance of additive gene action controlling the traits contrary to the findings of (Aliu, Rusinovci, Fetahu, & Rozman, 2016; Murtadha, Ariyo, & Alghamdi, 2018), although similar findings were reported with regards to kernels per row (Vacaro et al., 2002) Where SCA is small relative to GCA, performance of single cross progeny can be predicted on the basis of the GCA of the parents. Those traits having higher SCA components to that of GCA were controlled by the non-additive type of gene action. Aliu et al., (2016) reported similar findings of SCA components, which were much higher than that of GCA in all most all crosses indicating a predominance of non-additive gene action. Non-additive gene action for grain yield in maize was also reported by Das and Islam (1994) and Roy, Ahmed, Hussain, & Hoque, (1998). Less than one ratio of GCA: SCA was also reported by Murtadha et al., (2018) in maize, indicating that the component that goes to SCA was higher than that of GCA in all environments for all characters revealed that these traits were purely under dominance effect of gene and that, selection for these traits should be performed using recurrent selection method. This observation was in agreement with reports of Abdel-Moneam et al., (2009). Abdel-Moneam, Sultan, Sadek, & Shalof, (2015) also reported that GCA/SCA was less than unity for all studied traits, indicating that the non-additive genetic effects were more important and played the major role in all studied traits. Similar findings were reported by El-Hosary, (1989); Soliman, Nofal, & El-Azeem, (2005). The variance components due to reciprocals were high for plant height, ear height and grain yield for both environments and combined across environments indicating the importance of maternal effects for these characters.

Table 1: Estimates of combining ability variance components for fifteen agronomic characters for environment one

Characters	Daf	Das	NL	PH	EH	DM	Ep	EL
GCA	0.16	0.49	0.02	29.88	13.24	1.42	-0.13	0.47
SCA	-4.39	-8.51	0.02	32.75	-13.08	8.27	-11.93	0.48
Reciprocal	1.25	-1.22	0.48	65.58	47.65	6.06	0.36	1.10
GCA/SCA Ratio	-0.04	-0.06	1.25	0.91	-1.01	0.17	0.01	0.99

Table 1: Estimates of combining ability variance components for fifteen agronomic characters for environment one (Continued)

Characters	KRN	KPR	ED	CD	Cw	Tp	Gy
GCA	0.05	3.78	0.04	-0.0021	0.06	8.61	374090
SCA	0.06	0.77	-0.04	-0.03	0.0014	47.91	289785
Reciprocal	0.01	8.45	0.001	-0.02	0.16	53.76	805168
GCA/SCA Ratio	0.89	4.91	-1.07	0.07	41.49	0.18	1.29

KEY: df: Degrees of freedom, Daf: Days to flower, Das: Days to silk, NL: Number of leaves, PH: Plant height, EH: Ear height, DM: Days to maturity, Ep: Ears per plot, EL: Ear length, KRN: Kernel row number, KPR: Kernels per row, ED: Ear diameter, CD: Cob diameter, CW: Cob weight, Tp: Threshing percentage, Gy: Grain yield/ha

Table 2: Estimates of combining ability variance components for fifteen agronomic characters for environment two

Characters	Daf	Das	NL	PH	EH	DM	Stnd	Ep	EL
GCA	-0.44	-0.60	-0.10	-21.08	15.55	-0.03	5.16	5.0667	0.49
SCA	8.34	4.47	-0.27	-173.17	11.66	13.05	29.06	-2.399	6.73
Reciprocal	4.47	6.17	0.05	33.44	35.61	1.80	16.77	-1.258	2.05
GCA/SCA Ratio	-0.05	-0.13	0.36	0.12	1.33	-0.002	0.18	-2.112	0.07

Table 2: Estimates of combining ability variance components for fifteen agronomic characters for environment two (Continued)

Characters	KRN	KPR	ED	CD	Cw	Tp	Gy
GCA	0.18	6.29	-0.81	0.004	0.03	15.50	46702.81
SCA	-0.41	7.54	-15.12	0.02	0.06	1433	-1874452
Reciprocal	0.20	19.89	-7.61	0.01	0.03	-2077	-812747
GCA/SCA Ratio	-0.43	0.83	0.05	0.19	0.53	0.01	-0.03

KEY: df: Degrees of freedom, Daf: Days to flower, Das: Days to silk, NL: Number of leaves, PH: Plant height, EH: Ear height, DM: Days to maturity, Ep: Ears per plot, EL: Ear length, KRN: Kernel row number, KPR: Kernels per row, ED: Ear diameter, CD: Cob diameter, CW: Cob weight, Tp: Threshing percentage, Gy: Grain yield/ha

Table 3: Estimates of combining ability variance components across environments for fifteen agronomic characters

Characters	Daf	Das	NL	PH	EH	DM	Ep	EL
GCA	1.32	13.66	0.02	4.35	11.75	0.43	2.52	-0.05
SCA	-4.63	-76.35	-2.12	321.47	94.26	-1.51	0.76	6.86
Reciprocal	-0.44	-11.30	-0.86	57.55	13.47	1.40	3.63	0.90
GCA/SCA Ratio	-0.29	-0.18	-0.01	0.01	0.13	-0.29	3.34	-0.01

Table 3: Estimates of combining ability variance components across environments for fifteen agronomic characters (Continued)

Characters	KRN	KPR	ED	CD	Cw	Tp	Gy
GCA	0.19	4.26	0.25	-0.001	0.03	11	113557
SCA	-0.04	18.27	3.29	0.001	0.07	147.51	450055
Reciprocal	0.38	23.49	-1.94	0.002	0.12	64.19	653354
GCA/SCA Ratio	-4.86	0.23	0.08	-1.13	0.39	0.08	0.25

KEY: df: Degrees of freedom, Daf: Days to flower, Das: Days to silk, NL: Number of leaves, PH: Plant height, EH: Ear height, DM: Days to maturity, Ep: Ears per plot, EL: Ear length, KRN: Kernel row number, KPR: Kernels per row, ED: Ear diameter, CD: Cob diameter, CW: Cob weight, Tp: Threshing percentage, Gy: Grain yield/h

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