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Full Length Research Paper

Diallel analysis of six agronomic characters in *vigna unguiculata genotypes*

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A diallel study was conducted involving 8 genomic cowpea cultivars from diverse geographical origin to identify superior germplasm and develop high yielding varieties. The eight populations and their twenty eight crosses were evaluated in two locations. Data obtained for grain yield plant height, days to flowering, pod length, seed/pod and seed weight were analyzed with Gardner and Eberhart model II. General and specific combining abilities effect were highly significant (P<0.05) for the characters except for grain yield and plant height (GCA). There was a preponderance of dominance gene effects for most characters. Estimates of GCA and SCA effects showed that Ekp-br, 325, ILCA-12648, ILCA-12646 were generally good combiners for most of the yield attributes and can be included in future improvement programmes.

Key words: Additive effects**,** cowpea, diallel cross, dominance effects, yield characters.

INTRODUCTION

Most improvement programmes of many crops use diallel analyses as they provide breeders information on the genetic value of varieties as parents and to assess the gene action which can be directed at improving yield and other related quantitative characters (Viana et al., 2001). Therefore, an understanding of the genetic control of characters and role of nonallelic interaction is essential to the breeder when deciding on the selection method and breeding procedure to follow (Esmail, 2007). From diallel analysis, plant breeders are able to gather information on heterosis and effect due to maternal, general combining ability (GCA) and specific combining ability (SCA) of parents in crosses (Glover et al., 2005).

Diallel mating design is a type of mating systems in which a fixed set of parents are crossed in all possible combinations without reciprocals to produce a set of F_1 progenies using each line as both male and female parent (Ragsdale and Smith, 2003). Thus, the diallel mating systems have provided genetic understanding for a chosen set of parents (Murray et al., 2003) and have been used to study various characters in many crops. It has been utilized for cassava (*Manihot esculenta*), chickpea (*Cicer arietinum*), maize (*Zea mays*) common bean (*Phaseolus vulgaris*), soybean (*Glycine max*), cowpea (*Vigna unguiculata*) among others (Dhliwayo et al., 2005; Gwata et al., 2005; Jaramillo et al., 2005; Derera et al., 2007).

Cowpea *Vigna unguiculata* is native to West Africa where wild and weedy forms exist in many parts of the region (Ng and Marechal, 1985). In Nigeria, *Vigna unguiculata* is the most wide-spread and economically important of the cultivated subspecies. It is cultivated in both savanna through the sub-humid to the humid forest areas of the tropics (Summerfield et al., 1983; Ba et al., 2004), and grows vigorously in diverse environments where subsistence agriculture is practiced (Rachie and Silvestre, 1977). The crop expresses a high degree of genetic variability. Inheritance studies of various characters have been reported in cowpea. For instance, Singh and Jain (1972) reported that nonadditive gene effects condition number of seeds per pod while Kheradnam and Niknajad (1974) showed that both additive and dominance gene effects were involved. Such information is important during planning and execution of any hybridization programmes.

Several methods have been proposed for diallel analysis (Hayman, 1954; Griffing, 1956; Gardner and Eberhart, 1966). Among the various methods, the Gardner and Eberhart (1966) analysis II allows one to estimate heterosis effects from a fixed set of varieties when the parent populations and their crosses (excluding recipro-

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cals) are included in the analysis and provide information for both additive and dominance gene effects. Evaluation of GCA of each parent would help in developing superior genotypes while the SCA effect estimates the performance of crosses (Cruz and Regazzi, 1994). This research was conducted to determine the combining abilities of eight parental line cowpeas and to explore their potency in yield hybridization programme.

MATERIALS AND METHODS

Twenty eight crosses were developed among the eight cowpea lines according to Gardner and Eberhart diallel II (1966) in a mesh house in 2007. The crosses along with their parents were evaluated in two locations at Rubber Research Institute of Nigeria, Iyanomo, near Benin and Faculty of Agriculture Teaching and Research Farm, Ambrose Alli University, Ekpoma in 2008. Iyanomo is situated on latitude 6^o 09 24”N, longitude 5^o 35’ 37”E in a humid rainforest zone with an attitude of 304.8 m and Ekpoma is situated on latitude 6^o 08E, longitude 6^o 42’ N with an attitude of 460 m in a forest-savanna transition zone. Iyanomo location has a yearly rainfall of 2032-2540 mm (Olayide et al., 1979) while Ekpoma location has a yearly rainfall of 1200-1556 mm (Okaka and Remison, 1999). The eight parents seeds used were *Dan-Tamani, Ekp-br, 325, ILCA-12646, 53C, ILCA-12648, 53-C-82, ILCA-12665* (Table 1) and their F_1 crosses. A randomized complete block design in single row plots of 5 m length in three replications was adopted during the cropping season in April, 2008. The seeds of each entry were spaced at 60 cm between row and 30 cm within row. Parameters evaluated were on plant height, 50% flowering, pod length, seeds per pod, 100-seed weight and grain yield. Agronomic practice was adopted. Mean separation was performed with student-Newman-Kuel Test at 5% level. Analysis of variance was conducted using Gardner and Eberhart Model II to analyze GCA and SCA (Gardner and Eberhart, 1966; Gardner, 1967).

RESULTS

Gene Action on Characters

The analysis of variance (Table 2) showed the mean squares for six characters. Significant differences (P<0.05) among the group of genotypes revealed considerable genetic variations among parents and hybrids.

There were significant differences among the parental and hybrids for the characters evaluated (Table 3). The mean performance revealed that among the parents, *ILCA-12646* produced the tallest plants (102.4 cm) and highest grain yield (1723.4 kg/ha) while Ekp-br had the longest pods (19.73 cm). The mean performance of crosses showed that cross *ILCA-12646 x ILCA-12648* had the highest mean grain yield (4664.9 kg/ha) followed by *Ekp-br x ILCA-12646* (3584.8 kg/ha). Longest pods were produced by *Dan-Tamani* x *Ekp-br (*18.0 cm*)* while the tallest plants were from *ILCA-12646 x ILCA-12665 (*116.8 cm).

The GCA effect of the eight parental lines for the characters evaluated is presented in Table 4. Estimates of GCA effects showed that three cultivars had positive significant values while five had negative significant values for plant height. Cultivar 53C had the highest negative value for the character. *ILCA-12648* was the best combiner for flowering while *325* and *53C* were the worst combiners for the character. *Ekp-br* had the highest GCA value for pod length while *ILCA-12648* was the best combiner for seeds/pod. For seed weight character, *325* and *Ekp-br* only had positive significant GCA effects. Two cultivars namely *ILCA-12646* and *Dan-Tamani* showed significant GCA values for grain yield.

The SCA estimates (Table 5) indicated that *Dan-Tamani x 325*, *325 x ILCA-12648* and *325 x ILCA-12665* were good crosses to reduce plant height. The highest significant positive SCA value was found in *ILCA-12646 x ILCA-12648* and *ILCA-12646 x 53C*. Only one cross (*325 x ILCA-12665*) indicated significant negative SCA value for days to flowering while three crosses showed significant SCA values for pod length. The cross *Dan-Tamani x 53-C-82* had the highest positive SCA estimate for the character and surprisingly pod length for which one of the parents showed negative significant GCA effects. Highest negative SCA effect for the character was found in *Dan-Tamani x 53C*. Significant SCA values for seeds/pod were observed in twelve crosses. The highest negative SCA value was in *ILCA-12648 x 53-C-82* followed by crosses *53-C-82 x ILCA-12665* and *53C x 53-C-82*. The cross *Dan-Tamani x ILCA-12665* had the highest significant negative SCA effects for seed weight. For grain yield character, crosses- *Dan-Tamani x 325* and *Dan-Tamani x Ekp-br* indicated significant positive SCA effects while *Dan-Tamani x ILCA-12665* expressed the lowest negative value for the character.

DISCUSSION

Highly significant differences were observed among the entries for the characters evaluated in this study. The high GCA and SCA mean squares for the six characters showed considerable genetic diversity and the importance of both additive and dominance gene effects among the parents and their respective progenies. It further revealed that genetic gain is feasible through selection over segregating population. However, SCA effect was higher which conversely revealed the preponderance of dominance gene effects for the characters.

Table 1. Geographical origin code of genotypes used.

Genotypes	Geographical origin code
Dan-Tamani	Nigeria
325	United States of America
53C	South Africa
53-C-82	South Africa
ILCA-12646	Not Available
ILCA-12648	Not Available
ILCA-12665	Not Available
Ekpoma (brown)*	Ekpoma

***Local cultivar.**

Table 2. GCA and SCA mean squares for six cowpea characters from 8x8 diallel cross.

Source	Df	GY	HSW	NS/P	PL	DTF	PH
Replication	2	61.10*	5.67	0.82	3.27*	26.1*	82.63
Genotype	35	34.57	45.45*	40.13*	73.12*	659.24*	1432.38*
GCA	7	88.67	9.57*	21.61*	20.44*	80.29*	309.48
SCA	27	20.55*	56.39*	44.08*	88.08*	789.25*	1762.99*
GCA x SCA	1	33.82	1.21	63.19*	37.87	1201.78	366.19
Error	72	23.84	2.52	4.23	2.43	215.06	147.44

*significant at P<0.05

GY = grain yield, HSW= hundred seed weight, NSP = number of seeds per pod, PL= pod length, DTF = days to flowering, PH=plant height.

The role of dominance gene effects for plant height has been reported in snap bean (Rodriguez et al., 1998) which supports the result in this study. However, Kalpande et al. (2008) reported significant positive GCA and SCA effect for plant height in maize thus suggesting that both additive and dominance genes control the character. Such diversity in result would have arisen from variations in the environmental and genetic constitution of the crop species used in the various studies.

The existence of both additive and dominance gene effects detected in the genetic control of the characters in the set of genotypes studied implies that both gene effects should be considered in developing strategies for the selection of superior lines (Ortegon-Morales and Escobedo-Mendoza, 1993; Skoric *et al.,* 2000). However, parents may not necessarily have high GCA during breeding because the dominance gene effects could also be exploited to enhance these characters (Arunga *et al*., 2010). *Vigna unguiculata* is a self-fertilizing crop and autogamous crop plants are homozygous and as a consequent, do not make use of the dominance gene effects at individual loci (Moreno-Gonzaled and Cubero, 1993). Therefore, crosses involving genotypes with greater magnitude of GCA should be potentially superior for the selection of lines in advanced generations (Franco et al., 2001).

Results from this investigation showed that SCA effect in some crosses impacted on cross's grain yield. For example, *Ekp-br* had better GCA effects for most of the yield attributes than *ILCA-12646* but its cross with *53-C-82* had lower grain yield (344.6 kg/ha) than the cross between *ILCA-12646 x 53-C-82* (667.4 kg/ha) because the cross lack positive SCA effects. This indicates the importance of dominance gene effect in the determination of some crosses final grain yield. It also means that cross's grain yield cannot be based on GCA effects alone. Grain yield GCA effects of individual parents and the SCA effects of their progenies are directly related to the GCA and SCA effects respectively of the yield attributes. Higher number of the yield attributes with significantly positive GCA effects leads to higher positive grain yield GCA effects. Sharma *et al*. (1982) reported that good general combiners for grain yield were also generally good in performance for various yield attributes. However, the significance of the GCA effects would indicate that at least one of the lines differ in content of favourable genes with additive effects while the significance of SCA indicates that there is complementation between lines at loci with some degree of non-additive effects (Medici *et al*., 2004). Usually, selecting inbred lines with characters complementary to each other will lead to a better chance of obtaining a

Table 3. Mean performance of parents and their crosses for six characters in cowpea.

Genotypes	GY(kg/ha)	HSW(g)	NS/P	PL(cm)	DTF	PH(cm)
Dan-Tamani	706.40	9.00	12.53	14.83	50.0	41.27
Ekp-br	499.90	13.57	14.13	19.73	52.0	61.93
325	261.90	14.93	7.53	15.63	42.3	51.87
ILCA-12646	1723.80	11.27	12.50	16.90	42.7	51.87
53C	219.50	11.10	9.60	11.10	42.3	30.33
ILCA-12648	383.00	10.93	16.37	15.50	57.3	46.93
53-C-82	125.40	9.70	7.40	10.63	45.3	48.93
ILCA-12665	199.20	9.53	11.80	13.30	47.0	83.67
Dan-Tamani x Ekp-br	1818.10	11.77	15.13	18.00	46.7	85.67
Dan-Tamani x 325	683.00	11.10	10.57	15.50	46.7	52.80
Dan-Tamani x ILCA-12646	0.00	0.00	0.00	0.00	0.0	0.00
Dan-Tamani x 53C	685.30	10.97	10.40	12.77	49.0	42.80
Dan-Tamani x ILCA-12648	0.00	0.00	0.00	0.00	0.0	0.00
Dan-Tamani x 53-C-82	286.00	10.90	8.17	12.97	49.7	34.90
Dan-Tamani x 12665	830.90	9.53	11.20	13.50	39.0	84.40
Ekp-br x 325	668.60	13.27	9.90	16.93	46.3	43.57
Ekp-br x ILCA-12646	3584.80	13.90	14.93	20.00	44.7	77.73
Ekp-br x 53C	668.90	13.30	9.70	14.17	45.3	42.33
Ekp-br x ILCA-12648	0.00	0.00	0.00	0.00	0.0	0.00
Ekp-br x 53-C-82	344.60	14.10	11.40	16.70	46.0	43.43
Ekp-br x ILCA-12665	2258.30	13.07	13.33	16.97	43.0	89.73
325 x ILCA-12646	2300.60	15.10	11.27	16.30	45.3	85.47
325 x 53c	430.70	12.13	9.40	13.67	46.7	47.00
325 x ILCA-12648	559.60	12.77	13.27	16.40	46.3	49.37
325 x 53-C-82	2042.00	13.97	7.77	13.27	44.0	49.37
325 x ILCA-12665	1359.30	11.93	10.70	15.13	37.0	54.17
ILCA-12646 x 53C	543.90	14.07	11.53	17.13	50.3	60.43
ILCA-12646 x ILCA-12648	4664.90	12.87	13.80	17.67	55.0	55.00
ILCA-12646 x 53-C-82	667.40	14.13	11.00	16.23	41.0	61.63
ILCA-12646 x ILCA-12665	1479.50	11.63	11.47	15.97	39.3	116.80
53C x ILCA-12648	0.00	0.00	0.00	0.00	0.0	0.00
53C x 53-C-52	637.70	11.03	9.20	12.17	46.3	67.43
53C x ILCA-12665	1546.10	10.53	12.53	13.93	52.0	49.57
ILCA-12648 x 53-C-82	385.20	12.63	9.33	13.93	52.0	49.57
ILCA-12648 x ILCA-12665	1996.10	10.57	13.07	14.57	48.3	83.30
53-C-82 x ILCA-12665	633.50	11.07	9.27	12.23	38.3	81.27
Parent mean	**514.90**	**11.25**	**11.48**	**14.70**	**47.30**	**59.42**
Cross mean	**1140.49**	**10.58**	**9.58**	**13.10**	**38.69**	**54.99**

GY = grain yield, HSW= hundred seed weight, NSP = number of seeds per pod, PL= pod length, DTF = days to flowering, PH=plant height.

Table 4. GCA effects for 8 parental lines of cowpea.

Parent	GY	HSW	NS/P	PL	DTF	PH
Dan-Tamani	191.50	-2.25	1.05	0.13	2.67	-8.15
Ekp-br	-15.00	2.32	2.65	5.03	4.67	2.51
325	-298.00	3.68	-3.95	0.97	-5.30	-7.55
ILCA-12646	1208.90	0.02	1.02	2.20	-4.66	42.98
53C	-295.40	-0.15	1.88	-3.60	-5.00	-29.10
ILCA-12648	-131.90	-0.32	4.89	0.80	10.00	-12.49
53-C-82	-389.50	-1.55	-4.08	4.02	-2.00	-10.47
ILCA-12665	-315.70	-1.72	0.32	-1.40	-0.33	24.25

GY = grain yield, HSW= hundred seed weight, NSP = number of seeds per pod, PL= pod length, DTF = days to flowering, PH=plant height.

Table 5. SCA effects for 28 progenies of cowpea.

Crosses	GY	HSW	NS/P	PL	DTF	PH
Dan-Tamani x Ekp-br	2.050	1.017	0.222	0.225	0.145	0.014
Dan-Tamani x 325	2.208	2.191	1.095	0.500	0.164	-0.712
Dan-Tamani x ILCA-12646	0.000	0.000	0.000	0.000	0.000	0.000
Dan-Tamani x 53C	-0.003	2.823	1.282	-6.897	0.113	-0.011
Dan-Tamani x ILCA-12648	0.000	0.000	0.000	0.000	0.000	0.000
Dan-Tamani x 53-C-82	-0.001	3.341	-1.029	82.35	0.108	-0.065
Dan-Tamani x ILCA-12665	-0.004	-1.28	0.709	2.333	1.177	0.043
Ekp-br x 325	-0.002	0.459	2.583	0.320	0.152	-0.116
Ekp-br x ILCA-12646	-0.001	0.377	0.23	0.181	0.185	0.055
Ekp-br x 53C	-0.003	0.458	4.348	1.047	0.172	-0.104
Ekp-br x ILCA-12648	0.000	0.000	0.000	0.000	0.000	0.000
Ekp-br x 53-C-82	-0.002	0.355	0.639	0.34	0.158	-0.101
Ekp-br x ILCA-12665	-0.001	0.499	0.324	0.317	0.25	0.036
325 x ILCA-12646	0.001	0.278	0.683	0.2	0.172	0.41
325 x 53C	-0.002	0.79	7.0	1.779	0.145	-0.168
325 x ILCA-12648	-0.002	0.565	0.33	0.369	0.152	-4.947
325 x 53-C-82	0.002	0.369	-0.777	4.035	0.209	-0.244
325 x ILCA-12665	0.008	0.902	0.985	0.585	-1.386	-3.05
ILCA-12646 x 53C	-0.002	0.358	0.6	0.305	0.103	1.418
ILCA-12646 x ILCA-12648	0.004	0.541	0.29	0.27	0.075	3.153
ILCA-12646 x 53-C-82	-0.002	0.352	0.778	0.389	0.413	0.181
ILCA-12646 x ILCA-12665	0.005	1.146	0.617	0.422	0.921	0.021
53C x ILCA-12648	0.000	0.000	0.000	0.000	0.000	0.000
53C x 53-C-82	-0.002	2.492	-6.14	-1.622	0.152	0.099
53C x ILCA-12665	0.004	116.67	0.403	1.523	15.556	0.058
ILCA-12648 x 53-C-82	-0.002	0.603	-16.471	1.523	0.09	-0.254
ILCA-12648 x ILCA-12665	0.002	25.0	0.348	0.788	0.123	0.044
53-C-82 x ILCA-12665	0.002	2.31	-9.272	-1.757	3.333	0.048

GY = grain yield, HSW= hundred seed weight, NSP = number of seeds per pod, PL= pod length, DTF = days to flowering, PH=plant height.

hybrid with higher grain yield (Fan et al., 2008). This phenomenon was observed in the crosses between *Dan-Tanani x Ekp-br* and *Dan-Tamani x 325*. Their GCA effects for yield attributes seem complementary to each other. Thus, selecting inbred with positive GCA effects for all or most of yield attributes should have a greater chance of producing hybrids with higher grain yield.

The study revealed that a number of the cowpea lines had negative GCA effects for days to flowering, an indication that dominance gene action controlled the character. However, *ILCA-12648* expressed the largest GCA effect for this character while the least was in *ILCA-12665*. Both genotypes are indeterminate in growth. One dominant gene had been reported to control the indeterminate character in common bean (Koinage *et al*., 1996). Indeterminate cowpeas allow harvesting over long time and thus increase the total yield. Based on this feature, the cultivar can be explored for varietal improvement for different combinations. Genotype *ILCA-12648* had the largest GCA estimate for seeds/pod. Also, most crosses expressed positive SCA effects. Thus, both additive and dominance gene action are involved in the inheritance of the character. The result in this study agrees with those of Kheradnam and Niknajad (1974) in cowpea, Iqbal *et al*. (2005) and Khan *et al*. (2005) for number of bolls/plant in cotton. Seed weight in cowpea is important as it directly influence productivity (Gomes, 2003). The cultivar *325* expressed the largest GCA effects for seed weight. Majority of the F_1 hybrids showed significant positive SCA effects which indicated that additive gene action controlled seed weight character in cowpea (Gomes, 2003). Similar findings had been reported in cotton bolls weight (Bherad *et al*., 2000; Lyanar *et al*., 2005).

The predominance and magnitude of GCA estimates indicate the importance of additive gene effects in the determination of pod length. Pod length is an important character in cowpea which directly influences the final grain yield. This is because the longer the pod in most cases, the more seeds that would be produced. *Ekp-br* exhibited the largest GCA effects for pod length. Pod length has been found to be controlled by additive gene action than dominance gene effects in cowpea (Ogunbodede and Fatunla, 1985). Therefore to improve pod quality, other parents with favourable characters have to be included in the improvement programme. A number of the crosses revealed negative SCA effects for pod length eventhough most parental strains exhibited positive GCA effects. Hallauer and Miranda Filho (1988) pointed out that external environmental factors such as weather, soil and pest probably have a greater effect on single crosses than other types of crosses. Single crosses usually interact more with the environment than double crosses (Troyer, 1996).

CONCLUSION

The predominance of both additive and dominance gene effects involvement in the characters studied should be borne in mind when developing improvement programmes in selecting superior lines. In this study, the best general combiners were *Ekp-br* for pod length, *325* for seed weight, *ILCA-12648* for days to flowering and seeds/pod. These cultivars can be incorporated into cowpea improvement programme in the future.

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