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A 5×5 Diallel Analyses of some Agronomic Characters of Castor (*Ricinus communis* L.) Accessions in the Southern Guinea Savannah of Nigeria

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Abstract

An evaluation trial experiment was laid out at Akwanga and Lafia in Nasarawa State and Makurdi in Benue State. The parents and the F_1s were evaluated in a randomized complete block design of three replications. The plots were made up three rows of 1.5 m in length spaced 1.0 m apart. The rows were sown to four hills of two seeds each, spaced 0.5 m and thinned to single stand per hill. Data were recorded only on the four plants in the middle row of each plot. Griffing's method 2 model 1 was employed for analysis of combining ability. Additive and non-additive gene actions interplayed in agronomic characters of castor studied. Additive gene actions were recorded in number of nodes to primary panicle, height to primary panicle, plant height, days to50% flowering, days to 100% flowering, number of days to maturity and 100-seed weight. Leaf area, leaf length, number leaf lobes and seed yield ha^{-1} recorded non-additive gene actions. Various parents were either general combiners, specific combiners or both. To improve the yield of the crop, hybridization could be used to explore the non-additive or dominance gene action in the seed yield ha^{-1}. On the other hand, the crop seed yield ha^{-1}could be improved by producing a synthetic variety by exploiting the additive gene actions of other characters that have strong associations with seed yield ha^{-1}.

Keywords

Additive
Agronomic characters
Combiners
General
Non-additive
Ricinus communis

Introduction

Combining ability is the mean performance of a line in all its crosses with other lines (Falconer, 1989). Sprague and Tatum (1942) subdivided combining ability into general combining ability (gca) and specific combining ability (sca). 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).

General combing ability measures the additive or fixable gene actions while specific combining ability measures non-additive, non-fixable or dominant gene actions (Singh and Singh.,1979; Bhatt and Reddy, 1983). Combining ability estimates have been reported for both agronomic and seed yield components of castor. Highly significant gca, sca and reciprocal or maternal effects for days to flowering have been reported by Hooks et al. (1971) and Bhatt and Reddy (1983). Furthermore, gca, sca and reciprocal effects were reported to be significant for nodes to primary and secondary panicles and number of panicles per plant by Hooks et al. (1971). However, Ankineedu and Kulkarni (1967) earlier on reported the absence of maternal effects for both qualitative and quantitative characters of castor.

Seed yield per plant showed significant gca, sca and reciprocal effects as reported by Giriraj et al. (1973) and Bhatt and Reddy (1983), while earlier report by Hooks et al. (1971) showed non-significant gca effect for seed yield per plot.

Giriraj et al. (1973) further reported on seed yield that the best cross combination had a low x high general combining parents whereas high x high combiners gave low sca effects; indicating non-additive gene action in seed yield. Similar results in cowpea of low x high combiners reported by Zaveri et al. (1983) were attributed to dominance and epistasis gene action.

Giriraj et al. (1973) further recorded positive sca effects due to either low x low or low x high combiners for primary raceme length and high x low or low x low for number of capsules on primary raceme. The high sca effects of the latter were attributed to the fact that the trait might have a low additive x additive component. However, earlier, Singh and Singh (1979) recorded poor x poor (low x low) combiners in linseeds that were attributed to complementary gene action, while Manga and Sidhu (1979) attributed the high sca effects in 100-seed weight, to additive gene interaction. Furthermore, high sca effects due to high x high combiners were attributed to additive gene action and additive x additive gene interaction in Indian mustard (Dixit et al., 1983) and additive x additive type of gene interaction in *Gossypium arboreum* L. (Bhatade et al., 1983).

The type of breeding method chosen for use depends on the type of gene action(s) conditioning the character of interest. Uguru and Abuka (1998) suggested reciprocal recurrent selection method for number of capsules per plant, which exhibited additive gene action, and also due to the indeterminate nature of podding. Bhatt and Reddy (1983) suggested a biparental mating with reciprocal recurrent selection to exploit both fixable and non-fixable components simultaneously. Similar breeding methods were suggested for exploiting gca and sca components of gene actions for *Gossypium arboreum* L. (Duhoon and Singh, 1983) and in Indian mustard (Dixit et al., 1983).

Materials and methods

From a germplasm collected from Southern Guinea Savannah and characterized in the University of Agriculture Makurdi Teaching and Research Farm, five selected castor accessions were crossed in all possible combinations excluding reciprocals. An evaluation trial experiment was laid out at Akwanga and Lafia in Nasarawa State and Makurdi in Benue State. The parents and the F_1s were evaluated in a randomized complete block design of three replications. The plots were made up three rows of 1.5 m in length spaced 1.0 m apart. The rows were sown to four hills of two seeds each, spaced 0.5 m and thinned to single stand per hill. Data were recorded only on the four plants in the middle row of each plot.

Leaf area (LA) was mean area of four plants measured linearly at the 6th to the 10th node. The maximum length (L) and width (W) of the palmate were taken and their product was multiplied by a constant (A=0.55LW), following the procedure of Jain and Misra (1966). Leaf length (LL) was mean length of four plants, measured linearly from the base of the petiole to the tip of the longest leaf lobe of the palmate.

The number of days to 50% flowering (D50F) was obtained as the number of days it took half of the sampled plants to produce floralbuds on the primary panicle in each plot. However, the number of days to 100% flowering (D100F) was obtained as the mean number of days taken by the four sampled plants from planting to the production of the floral buds on the primary panicle.

The number of nodes to primary panicle (NNPP) was recorded as the mean number of nodes from the first seed –leaf to the node before the primary panicle of the four sampled plants, while the height to the primary panicle (HPP) was recorded as the mean height from the surface of the soil to the node before the primary panicle of the four plants. However, number of days to maturity (NDM) was recorded as the mean number of days from planting to the first sign of drying of capsules on the primary panicle of the four sampled plants.

Hundred-seed weight (SW100) was obtained as the mean weight of 100 selected healthy seeds of the four plants while seed yield ha^{-1} (SYH) was obtained as the product of the mean seed yield per plant and $10000m^2$ divided by inter-row spacing multiplied by intra-row and number of the plant per hill. For instance, seed yield ha^{-1} was obtained conventionally through dividing a hectare ($10,000m^2$) by inter-row, multiply by intra-row and plant per hill to give plant population in a hectare through solid cropping. The plant population was then multiplied by mean seed weight per plant. In the current study, seed yield ha^{-1} was estimated as shown below:

$$\text{Seed yield ha}^{-1} = \frac{10000m^2}{1m \times 0.5m \times 1} \times \text{Mean seed wt. per plant}$$

Griffing's (1956) method 2 model 1 was used for the diallel analysis.

The mathematical model for the combining ability was assumed to be:

$$X_{ij} = \mu + g_i + g_j + s_{ij} + \frac{1\ \Sigma\ \Sigma\ e_{ijkl}}{bc_{kl}}$$

ij=1,⋯, p,
κ=1...b,
l=1...c,

where, μ is the population mean, g_i (g_j) is the gca effect, s_{ij} is the sca effect such that $s_{ij} = s_{ji}$, and e_{ijkl} is the environmental effect associated with ijkl individual observation, b is the blocks and c observation.

The estimate of gca and sca sum of squares; variance components; gca and sca effects; standard errors; critical difference were calculated using Griffing's (1956) formulae below:

Estimation of gca and sca sum squares;

$$\text{SS due to gca} = 1/(n+2)[\sum(Y_{i.}+Y_{ii})^2 - 4/nY..^2]$$

$$\text{SS due to sca} = \sum\sum Y^2_{ij} - 1/(n+2)\sum(Y_{i.}+Y_{ii})^2 + 2/(n+1)(n+2)Y..^2$$

Variance components of gca and sca based on model 1;

$$\text{Variance due to gca} = 1/(n-1)\sum g_i^2 = (Mg-M'e)/(n+2)$$

$$\text{Variance due to sca} = 2/n(n-1)\sum\sum s^2_{ij} = (Ms-M'e)$$

Estimation of gca and sca effects:

$$gi = 1/(n+2)[\sum(Yi.+yii)-2/nY..]$$

$$S_{ij} = Y_{ij}\ 1/(n+2)\ (Y_{i.} - Y_{.j} + Y_{jj}) + 2/(n+1)(n+2)\ Y..$$

Estimation of standard errors:

$$S.E.\ (g_i) = [(n-1\sigma_e^2/n(n+2)]^{0.5}$$
$$S.E.\ (s_{ij}) = [(n^2+n+2)\sigma_e^2/(n+1)(n+2)]^{0.5}$$

Estimation of critical difference (CD);
$CD_{0.05}$ =S.E.×$t_{0.05}$ and $CD_{0.01}$ =S.E.×$t_{0.01}$.

Results

The mean square estimates for combining ability of some agronomic characters are presented in Table 1. General combining ability (gca) was significant in leaf area, number of leaf lobes, number of nodes and height to primary panicle plant height, days to 50 and 100% flowering, number of days to maturity and 100-seed weight, whereas specific combining ability (sca) was significant in leaf area, leaf length, number of leaf lobes number of nodes to primary panicle, 100-seed weight and seed yield ha^{-1}.

The genetic components of variance for some parent and hybrid families are also presented in Table 1. This revealed both additive and non-additive gene actions in the characters. However, number of nodes and height to primary panicle, plant height, days to 50 and 100% flowering, number of days to maturity and 100-seed weight were controlled by predominantly additive gene actions while leaf area, leaf length, number of leaf lobes and seed yield ha^{-1} were controlled by non-additive gene actions.

From the estimates of gca and sca components of variance and their ratios, additive gene action was preponderant in seven characters, namely: number of nodes and height to primary panicle, days to 50 and 100% flowering, number of days to maturity, plant height and 100-seed weight. Contrarily, non-additive gene action was preponderant in leaf area, leaf length, leaf lobes and seed yield ha^{-1}.

Table 1. Mean square estimates and genetic components of variance from combining ability analyses for some agronomic characters in five selected castor accessions.

Sources of variation	df	LA (cm^2)	LL (cm)	NLL	NNPP	HPP (cm)	PH (cm)	D50F	D100F	NDM	SW100 (g)	SYH (kg)
gca	4	13118.85**	8.35	0.013*	4.53**	445.72**	533.37**	34.30**	31.98**	20.20**	1.08**	4998.96
sca	10	5540.43*	9.35*	0.011*	0.25*	16.80	123.78	2.71	3.05	2.07	0.16*	21539.36
error	28	2170.66	4.05	0.004	0.07	13.77	97.97	1.34	2.58	1.04	0.06	7968.71
Genetic components												
gca		1564.03	0.62	0.001	0.64	61.71	62.20	4.70	4.20	2.74	0.15	-424.15
sca		3369.77	5.30	0.007	0.18	3.02	25.81	1.37	0.47	1.03	0.11	13570.65
gca/sca		0.46	0.12	0.18	3.56	20.43	2.41	3.43	8.94	2.66	1.36	-0.03

*, ** = Significant at probability levels of 0.05 and 0.01 respectively;

LA = Leaf area.
LL = Leaf length.
NLL = No. of leaf lobes.
gca = General Combining Ability.
sca = Specific Combining Ability.
D100F = Days to 100% flowering.
NNPP = Number of nodes to primary panicle.
HPP = Height to primary panicle.
NDM = Number of days to maturity.
D5OF = Days to 50% flowering.
SW100 = 100-Seed weight.
SYH = Seed yield ha^{-1}.

Table 2. General combining ability effects on some agronomic traits in five selected castor accessions.

Accessions	LA (cm^2)	LL (cm)	NLL	NNPP	HPP (cm)	PH (cm)	D50F	D100F	NDM	SW100 (g)	SYH (kg)
Ac.3	-44.45*	-1.49	0.051	-0.96**	-7.98**	-16.91**	-2.19**	-2.26*	-2.06**	-0.25*	18.64
Ac.6	50.38*	1.54	0.021	-0.04	-0.07	5.90	0.93	0.20	-0.46	0.21	0.59
Ac.9	37.87	0.42	0.013	0.16	0.49	-14.55*	1.66*	2.08*	1.31*	0.55**	-16.08
Ac.10	-39.07	-0.37	0.022	-0.46**	-5.23*	6.69	2.56**	-2.11*	-0.92	-0.48**	-35.08
Ac.34	-4.73	0.32	0.062*	1.24**	12.79**	18.87**	2.16**	2.09*	2.13**	-0.01	31.93
$CD^{0.05}$	43.72	1.89	0.06	0.25	3.48	9.29	1.09	1.51	0.96	0.22	83.77
$CD^{0.01}$	72.51	3.13	0.10	0.41	5.78	15.41	1.80	2.50	1.59	0.37	138.94

PH = Plant height.
LA = Leaf area.
LL = Leaf length.
NLL = Number of leaf lobes.
NNPP = Number of nodes to primary panicles.
HPP = Height to primary panicle.
D50F = Days to 50 % flowering
D100F = Days to 100% flowering
NDM = Number of days to maturity
SW100 = 100 Seed weight.
SYH = Seed yield ha^{-1}.

Table 3. Specific combining ability effects on some agronomic traits in selected castor accessions.

Crosses	LA (cm^2)	LL (cm)	NLL	NNPP	HPP (cm)	PH (cm)	D50F	D100F	NDM	SW100	SYH (kg)
Ac.×Ac.6	121.39*	5.40*	0.150	-0.40	1.62	17.08	-2.21	-2.35	-0.39	0.46	140.84
Ac.3×Ac.9	-8.42	0.72	0.047	-0.07	0.31	1.49	-2.22	-1.97	-0.24	0.28	109.91
Ac.3×Ac.10	-13.59	-0.02	-0.027	0.04	2.45	5.60	-0.41	0.07	-0.08	0.17	148.47
Ac.3×Ac.34	77.34	2.35	0.053	-0.41	-3.16	3.43	-1.06	-1.12	-1.55	0.13	-32.78
Ac.6×Ac.9	100.30	2.47	0.077	-0.38	1.40	6.68	2.06	1.38	1.77	-0.11	-85.12
Ac.6×Ac.10	17.08	0.95	0.063	-0.15	1.80	6.45	-0.94	-0.19	-0.45	0.24	20.00
Ac.6×Ac.34	31.76	-0.09	0.113	-0.01	0.59	9.10	-0.61	-0.67	-0.22	0.42	171.97
Ac.9×Ac.10	-28.92	-1.70	-0.050	0.92*	-16.60**	-1.74	-0.29	0.79	-0.86	0.10	34.73
Ac.9×Ac.34	23.51	-1.07	0.140	-0.13	7.78	5.92	-1.56	-1.95	-2.65*	0.38	146.97
Ac.10×Ac.34	-5.26	0.34	0.045	-0.60	-4.30	-6.62	-0.29	-0.29	0.32	-0.05	37.43
$CD^{0.05}$	112.89	4.88	0.16	0.63	8.99	23.98	2.80	3.89	2.47	0.57	216.30
$CD^{0.01}$	187.23	8.09	0.26	1.05	14.91	39.78	4.65	6.46	4.10	0.95	358.74

*,** = Significant at probability levels of 0.05 and 0.01, respectively;

NNPP = number of nodes to primary panicle.
LA = leaf area
NDM = number of days to maturity
PH = plant height
NLL = number of leaf lobes
SYH = seed yield ha^{-1}
D100F = days to 100% flowering
HPP = height to primary panicle
LL = leaf length
SW100 = 100-seed weight
D50F = days to 50% flowering

The general combining ability (gca) effects are presented in Tables 2. Accessions Ac.3 and Ac,6 showed significant either positive or negative effects for leaf area. However, Ac.6 and Ac.9 were the good general combiners, although Ac.9 recorded non-significant effect. Similarly, Ac.6 and Ac.9 were good general combiners for leaf length. However, all the accessions recorded non-significant effects for the character. In the number of leaf lobes Ac.34 showed significant effect and it was the best general combiner.

In number of nodes to primary panicle and height to primary panicle Ac.3, Ac.10 and Ac.34 recorded significant gca effects as well as being good general combiners. In plant height Ac.3, Ac.9 and Ac.34 recorded significant gca effect as well as being good general combiners.

Regarding days to 50% flowering, days to 100% flowering and number of days to maturity, Ac.3, Ac.9, Ac.10 and Ac.34 recorded significant either positive or negative gca effects, with the exception of Ac.10 in number of days to maturity. Accession Ac.3 and Ac.10 were the good general combiners for the three characters.

For 100-seed weight Ac.3, Ac.9 and Ac.10 recorded significant either positive or negative gca effects. However, the good general combiner was Ac.9. In seed yield ha-1 none of the accessions had significant gca effect. However the good general combiner were Ac.3 and Ac.34.

Specific combining ability (sca) effects are presented in Table 3. In leaf area and leaf length, hybrid Ac.3×Ac.6 recorded positive significant sca effects. The high sca effects in these characters were due to combination of low × high general combiners. The sca effects in number of leaf lobes showed none of the hybrids recorded significant effect.

Number of nodes to primary panicle and height to primary panicle revealed that hybrid Ac.9 × Ac.10 had either positive or negative sca effects. The sca effects were due to combination of low × high general combiners. The hybrids revealed non-significant sca effects for plant height. However, the high sca effects, though non-significant, were due to combinations of either low × high and high × high general combiners. In days to 50 and 100% flowering all the hybrids had non-significant sca effects. However, the high sca effects for hybrids Ac.× Ac.6, Ac.3 × Ac.9 and Ac.9 × Ac.34 were due to combinations of low × high as well as high × high general combiners. In number of days to maturity hybrid Ac.9 × Ac.34had significant sca effect. The sca effect was due to combination of high × high general combiners.

All the hybrids recorded non-significant sca effects for both 100-seed weight and seed yield ha^{-1}. However, the high (non-significant) sca effects were as a results of combinations of low × high general combiners for the two characters.

Seed yield $ha\text{-}^{1}$ exhibited non-additive gene action from gca/sca ratio, pointing to the fact that improvement of the crop could be achieved through hybridization. Improvement of the crop through seed yield *per se* may not be feasible, due to low heritability. However, some characters which may have high heritability estimates and significant correlation coefficients with seed yield ha^{-1}, could be used for selection in the crop improvement programmes.

Discussion

Additive and non-additive gene actions interplayed in these agronomic characters of castor. Additive gene actions, recorded as gca / sca ratios, were exhibited by number of nodes to primary panicle, height to primary panicle, plant height, days to 50% flowering, days to 100% flowering, number of days to maturity and 100-seed weight. In the same vein, non-additive gene actions were recorded for leaf area, leaf length number of leaf lobes and seed yield ha^{-1}. Similarly additive gene actions were reported in 100-seed weight, number of capsules as well as, contrary to this study, seed yield by Giriraj et al. (1973). However, Bhatt and Reddy (1983) earlier on reported additive gene actions for days to flowering and non-additive gene actions for seed yield per plant in line with the current study.

Various parents were good general combiners, specific combiners or both as reported by Giriraj et al. (1973). A closer look at some of the characters revealed that the sca effects were as a result of low general combiners × high general combiners in leaf area, leaf length, leaf lobe, 100-seed weight and seed yield ha^{-1}. This is an indication of either non-additive gene actions, in agreement with Giriraj et al. (1973) or epitasis in agreement with Zaveri et al. (1983)

findings. High sca effects as a result of low × low general combiners in node and height to primary panicle indicated complementary gene actions or low additive × additive components as earlier reported by Singh and Singh (1979) in linseed and Giriraj et al. (1973) in castor, respectively. The sca effects due to either low × high or high × high general combiners in days to 50 and 100% flowering as well as days to maturity indicated either additive or high additive × additive gene interaction. However, high sca effects as a result of high × high general combiners were earlier on, attributed to additive x additive in castor (Giriraj et al., 1973) and *Gossypium arboreum* L. (Bhatade et al., 1983) as well as additive and additive × additive in Indian mustard (Dixit et al., 1983).

In conclusion, seed yield ha^{-1} exhibited non-additive gene action from gca/sca ratio, pointing to the fact that improvement of the crop could be achieved through hybridization. Improvement of the crop through seed yield *per se* may not be feasible, due to low heritability. Synthetic varieties could be produced from the accessions that are general combiners.

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