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HETEROSIS AND INBREEDING DEPRESSION FOR SEED YIELD AND YIELD TRAITS IN COWPEA

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Abstract
Heterosis and inbreeding depression for yield and its component traits in cowpea were estimated at Joseph Sarwuan Tarka University, Makurdi, Nigeria involving P_1, P_2, F_1, F_2, BC_1, BC_2 generations of two crosses involving four varieties. The crosses were Cross I (UAM09 1055-6 x UAM09 1051-1) and Cross II (UAM09 1055-6 x UAM09 1051-1). The parents, P_1 had high fodder yield while P_2 had high seed yield. Randomized Complete Block Design with three replications was used. Data were obtained on number of branches, plant height, days to first flowering, days to maturity, number of pods per plant, pod length at maturity, 100-seed weight, seed yield, and harvest index. Heterosis for seed yield was observed due to heterosis in component characters viz: plant height, number of pods, pod length, number of branches, number of seeds per plant and harvest index which resulted in increased yield. So these characters should be considered while improving yield. Significant positive heterosis followed by presence of inbreeding depression observed in Cross II for plant height, seed yield, number of pods/plant and harvest index indicated the contribution of non-additive (dominance and additive x additive) gene effects in the inheritance of seed yield and its attributes. Hence, selection will be effective only in latter generations. Meanwhile, heterosis followed by absence of inbreeding depression observed in Cross I for plant height, number of seeds per plant, and harvest index, and in Cross II for days to flowering, days to maturity, pod length, number of branches and number of seeds per plant indicated that the absence of inbreeding depression and increase in performance of F_1 was accomplished by fixation of genes i.e. additive gene action.

***Keywords**:* heterosis, heterobeltiosis, inbreeding depression, traits

NB: Abstract is for oral presentation

Introduction
Cowpea, (*Vigna unguiculata* (L.) Walp. (2n=22) belongs to the family Fabaceae (Ibrahim *et al*., 2017; OECD, 2016). It is one of the most important legume crops in the world and it is a major food crop in Africa. The bulk of cowpea production and consumption is in sub-Saharan Africa (SSA) particularly West and Central Africa. Nigeria produces the most quantity of cowpea grains annually at approximately 2.14 million metric tonnes (FAOStat, 2017) and consumes more than 3.0 million metric tonnes.

The crop is of vital importance to the livelihood of millions of people in West and Central Africa. From its production, rural families derive food, animal feed and cash income. It provides nutritious grain and an inexpensive source of protein for both rural poor and urban consumers. Cowpea grain contains about 25% protein and 64% carbohydrate (Bressani, 1985) and therefore has a tremendous potential to contribute to the alleviation of malnutrition among resource-poor farmers. The exploitation of hybrid vigour as resource to increasing the yields of agricultural crops has become one of the most important technique in plant breeding. The heterosis expresses the superiority of F1hybrid over its parents in term of yield and other traits. However, in autogamous crop like cowpea the possibility of its commercial exploitation is rather remote particularly because of flower biology and the practical difficulties involved in hybrid seed production.

However, information about heterosis and inbreeding depression for the identification of potential crosses which can offer maximum chances of isolating transgressive segregates is crucial in self-pollinated crops. In the present study an attempt was made to estimate the extent of heterosis for seed yield and yield attributes in cowpea. In addition, inbreeding depression was also estimated for yield and yield attributes.

Materials and Methods

Geographic and Edaphic Details of the Experimental Area

The experiment was conducted at the Teaching and Research Farm of Joseph Saawuan Tarka University, Makurdi, (Latitude 7.41°N and Longitude 8.37°E at an elevation of 97 m above the sea level). Makurdi falls within the Southern Guinea Savannah Agro-ecological zone of Nigeria. The climatic environment of the study area was characterized by an annual rainfall of about 1330.20 mm and a mean annual temperature of about 27.80°C. The soil was classified as Typic Paleustalfs i.e. associated with moderately deep, well drained, fine loamy soils.

Experimental materials

Six generations *viz*: P_1, P_2, F_1, F_2, BC_1 and BC_2 of two crosses involving four varieties of cowpea constituted the experimental material. The parents were selected based on their differences in seed and fodder yield (i.e. P_1 had high fodder yield while P_2 had high seed yield).

Crossing Technique

The F_1 hybrids were generated from the above two single crosses between August, 2017 and April, 2018. Selfing of the F_1 to produce F_2 as well as backcrossing of the F_1 were done between August, 2018 and April, 2019. The crosses were carried out in the green house of Joseph Saawuan Tarka University, Makurdi, Nigeria. The crossing work was done by emasculation of the flower in the evening followed by artificial pollination next day morning. The seeds of individual parental lines, F_2 seeds from selfed F_1 plants seeds including backcrosses were harvested separately and labelled accordingly.

Experimental Design, Evaluation and Agronomic Practices

The six generations (P_1, P_2, F_1, F_2, BC_1, and BC_2) of each cross were grown in a Randomized Complete-Block Design with three replications in Teaching and Research Farm, Joseph Saawuan Tarka University, Makurdi. Parental lines and the F_1s were grown in two-row plots while the F_2 families and the BC_1 and BC_2 were grown in four-row plots, each of 4m length. The planting was be done in 25th August, 2019. Recommended agronomic practices were followed throughout the cropping season.

Data Collection

In each replication, 5 plants from the P_1, P_2 and F_1 generations (the non-segregating generations), and 100 from F_2 plants, 18 plants from the BC_1 plants and 17 plants from BC_2 plants (F_2, BC_1 and BC_2 being the segregating generations) were randomly selected and observations were recorded on per plant basis for the following characters:

i. Plant height at maturity,
ii. Days to first flowering,
iii. Days to maturity,
iv. 100-seed weight: weight (g) of 100 seeds,
v. Seed yield: Total dry grain weight in grams per plant,
vi. Pod length at maturity,
vii. Number of pods per plant at maturity,

viii. Number of branches: total number of primary branches per plant,
ix. Number of seeds per plant,
x. Harvest index.

Statistical analysis
Estimation of heterosis
Heterosis expressed as percent increase or decrease of F_1 hybrid over its mid-parent (relative heterosis) and over its better or superior parent (heterobeltiosis) were computed as follows:Heterosis (h_1) = $\frac{\overline{F_1} - \overline{MP}}{\overline{MP}}$ x 100

Heterobeltiosis (h_2%) = $\frac{\overline{F_1} - \overline{BP}}{\overline{BP}}$ x 100

Where,
$\overline{F_1}$ = Mean performance of the F_1 hybrid over three replications

$\overline{MP}$ = Mean value of the parents (P_1 and P_2) of a hybrid over three replications

$\overline{BP}$= Mean value of better parent over three replications

Estimation of inbreeding depression
Inbreeding depression was computed by using the following formulae:

Inbreeding depression (%)

= t (h_1) = $\frac{\overline{F_1} - \overline{F_2}}{\overline{F_1}}$ x 100

Results and Discussion

Heterosis and Inbreeding Depression
The extent of heterosis i.e. mid parent (relative heterosis) and better parent heterosis (heterobeltiosis) as well as inbreeding depression (ID) were estimated for all the characters under study. The results for each character for the two crosses are presented in Table 1.

Plant height (cm) at maturity
There was significant difference for this trait in both Cross I (IT89KD-288 x UAM10 2021-1) and Cross II (UAM09 1055-6 x UAM09 1051-1). Heterobeltiosis (better parent heterosis) and inbreeding depression recorded non-significant difference in both crosses for this trait. Mid parent heterosis ranged from 0.14 in Cross I (IT89KD-288 x UAM10 2021-1) to 1.34% in Cross II (UAM09 1055-6 x UAM09 1051-1) while better parent heterosis ranged from 7.21% in Cross I (IT89KD-288 x UAM10 2021-1) to 136.57% in Cross II (UAM09 1055-6 x UAM09 1051-1). Estimates of inbreeding depression ranged from 19.45% in Cross I (IT89KD-288 x UAM10 2021-1) to 53.94% in Cross II (UAM09 1055-6 x UAM09 1051-1). Similar results were reported by Joseph and Santoshkumar (2000), Pal *et al.* (2003), Lal *et al.* (2007), Patel *et al.* (2009), Yadav *et al.* (2010), Adeyanju (2012),Patel *et al.* (2013), Tchiagam *et al.* (2015).

Table 1: Estimate of mid parent heterosis (MPH), better parent heterosis (BPH) and inbreeding depression (I.D.) in two crosses of cowpea for plant height, days to first flowering, days to maturity, 100-seed weight, seed yield, pod length, number of pods per plant, number of branches, number of seeds per plant and harvest index

Estimate (%)	Plant height	Days to first flowering	Days to maturity	100-seed weight	Seed yield	Pod length	Number of pods per plant	Number of branches	Number of seeds per plant	Harvest index
Cross I (IT89KD-288 x UAM10 2021-1)										
MPH	0.14*	-0.05	-0.05	-0.04	-0.42*	0.05	-0.01	0.09	0.03*	-0.38*
BPH	7.21	-15.66	-12.56	-5.90**	-24.93	-0.20*	-8.81	0.00	-0.31	-42.63*
I.D.	19.45	-4.27	-13.27*	-10.54**	14.69	0.53	30.61	7.21**	1.70	-6.37
Cross II (UAM09 1055-6 x UAM09 1051-1)										
MPH	1.34*	-0.08**	-0.06**	-0.04**	0.67**	0.04**	0.80**	0.13*	0.09**	0.05**
BPH	136.57	-15.16	-11.28	-19.96*	30.15	3.51	63.30	8.47	5.79**	-1.25
I.D.	53.94*	-0.65	-4.94	-5.53	40.79*	3.41	1.66**	-7.27	3.45	23.02*

*,** = significant difference at 5% and 1% level of probability respectively

Days to flowering

The results for this trait in both crosses are presented in Table 1. Negative heterosis is desirable in this trait. Mid parent heterosis and better parent heterosis ranged from -0.05% in Cross II (UAM09 1055-6 x UAM09 1051-1) to -0.087% in Cross I (IT89KD-288 x UAM10 2021-1) and -15.16% in Cross II (UAM09 1055-6 x UAM09 1051-1) to –15.66% in Cross I (IT89KD-288 x UAM10 2021-1) respectively. Inbreeding depression ranged from -0.65% in Cross II (UAM09 1055-6 x UAM09 1051-1) to - 4.77% in Cross I (IT89KD-288 x UAM10 2021-1). Table 1 also shows that only mid parent heterosis in Cross II (UAM09 1055-6 x UAM09 1051-1) recorded highly significant difference. Better parent heterosis and inbreeding depression recorded non-significant difference in both crosses. The negative heterosis for this trait is desirable since it offers the breeder with the opportunity for developing cowpea that flowers early. Similar results were reported by Joseph and Santoshkumar (2000), Mehta *et al.* (2000), Pal *et al.* (2003), Lal *et al.* (2007), Patel *et al*. (2013), Nautiyal *et al.* (2015) and Pathak (2015).

Days to maturity

Estimates of mid parent heterosis better parent heterosis and inbreeding depression for days to maturity in the two crosses are presented in Table 1. Negative heterosis is also desirable for this trait. The table shows that mid parent heterosis ranged from -0.05% in Cross I (IT89KD-288 x UAM10 2021-1) to -0.06% in Cross II (UAM09 1055-6 x UAM09 1051-1) while better parent heterosis ranged from - 12.56% in Cross I (IT89KD-288 x UAM10 2021-1) to -11.28% in Cross II (UAM09 1055-6 x UAM09 1051-1). Inbreeding depression ranged from -4.94% in Cross II (UAM09 1055-6 x UAM09 1051-1) to - 13.27% in Cross I (IT89KD-288 x UAM10 2021-1). Highly significant difference was recorded in Cross II (UAM09 1055-6 x UAM09 1051-1) in estimate of mid parent heterosis. Other estimates recorded non-significant differences for both crosses for this trait. The negative heterosis for this trait is desirable since it offers the breeder with the opportunity for developing cowpea that matures early. Similar results were reported by Joseph and Santoshkumar (2000), Pal *et al.* (2003), Lal *et al.* (2007), Patel *et al*. (2009), Aremu and Adewale (2010), Adeyanju (2012), Kajale *et al.* (2013), Patel *et al*. (2013), Nautiyal *et al*. (2015).

One-hundred seed weight

Results for 100-seed weight is presented in Table 1. The results show that significant difference was recorded in estimate of inbreeding depression in Cross I (IT89KD-288 x UAM10 2021-1). The results also show that better parent heterosis recorded highly significant difference in Cross I while in Cross II (UAM09 1055-6 x UAM09 1051-1) mid parent heterosis recorded highly significant difference for hundred seed weight. The results further revealed that mid parent heterosis was -0.04% in both crosses. However, better parent heterosis ranged from -1996% in Cross II (UAM 09 1055-6 x UAM09 1051-1) to -5.9% in Cross I (IT89KD-288 x UAM10 2021-1)). Inbreeding depression ranged from -5.53% (Cross II) to 10.54% in Cross I (IT89KD-288 x UAM10 2021-1). Similar results were reported by Joseph and Santoshkumar (2000), Cheralu *et al.* (2002), Pal *et al.* (2003), Lal *et al.* (2007), Patel *et al*. (2009), Aremu and Adewale (2010), Rashwan (2010), Yadav *et al.* (2010), Adeyanju (2012), Kajale *et al.* (2013),Patel *et al*. (2013), Nautiyal *et al*. (2015).

Seed yield

Results for this trait is presented in Table 1. The table shows that mid parent heterosis ranged from -0.42% in Cross I (IT89KD-288 x UAM10 2021-1) to 0.67% in Cross II (UAM 09 1055-6 x UAM09 1051-1) while better parent heterosis ranged from -24.93% in Cross I (IT89KD-288 x UAM10 2021-1)) to 30.15% in Cross II (UAM09 1055-6 x UAM09 1051-1). Inbreeding depression ranged from 14.69% in Cross I (IT89KD-288 x UAM10 2021-1) to 40.79% in Cross II (UAM09 1055-6 x UAM09 1051-1). The results further revealed that highly significant difference was recorded in estimate of mid parent heterosis in Cross II (UAM09 1055-6 x UAM09 1051-1) while significant difference was recorded for inbreeding depression in Cross II (UAM09 1055-6 x UAM09 1051-1) for this traits. All the three estimates recorded non-significant difference for this trait in Cross I (IT89KD-288 x UAM10 2021-1). Similar results were reported by Joseph and Santoshkumar (2000), Cheralu *et al.* (2002), Pal *et al.* (2003), Lal *et al.* (2007), Patel *et al*. (2009), Aremu and Adewale (2010), Rashwan (2010), Yadav *et al.* (2010), Adeyanju (2012), Kajale *et al.* (2013),Patel *et al*. (2013), Nautiyal *et al*. (2015).

Pod Length

Results for pod length are presented in Table 8. The table shows that mid parent heterosis ranged from 0.04% in Cross II (UAM09 1055-6 x UAM09 1051-1) to 0.05% in Cross I (IT89KD-288 x UAM10 2021-1) while better parent heterosis ranged from 0.20% in Cross I to 3.51% in Cross II. Inbreeding depression ranged from 0.53% in Cross I (IT89KD-288 x UAM10 2021-1) to 3.41% in Cross II (UAM09 1055-6 x UAM09 1051-1). Table 8 also shows that better parent heterosis was significant in Cross I (IT89KD-288 x UAM10 2021-1) while mid parent heterosis was highly significant for this trait in Cross II (UAM09 1055-6 x UAM09 1051-1). All other estimates recorded non-significant difference for this trait. Similar results were reported by Joseph and Santoshkumar (2000), Pal *et al.* (2003), Lal *et al.* (2007), Patel *et al*. (2009), Yadav *et al.* (2010), Tchiagam *et al.* (2011), Adeyanju (2012), Kajale *et al.* (2013), Patel *et al*. (2013), Nautiyal *et al*. (2015).

Number of pods per plant

Results for this trait is presented in Table 8. The results show that mid parent heterosis ranged from -0.01% in cross I (IT89KD-288 x UAM10 2021-1)) to 0.80% in Cross II (UAM09 1055-6 x UAM09 1051-1) while better parent heterosis ranged from -8.81% in Cross I to 63.30% in Cross II. On the other hand, inbreeding depression ranged from 1.66% in Cross II to 30.61% in Cross I (IT89KD-288 x UAM10 2021-1). The results further show that mid parent heterosis recorded highly significant difference in Cross II whereas all the other estimates recorded non-significant differences for this trait. Similar results were reported by Joseph and Santoshkumar (2000), Pal *et al.* (2003), Lal *et al.* (2007), Patel *et al*. (2009), Aremu and Adewale (2010), Rashwan (2010), Yadav *et al.* (2010), Adeyanju (2012), Kajale *et al.* (2013),Patel *et al*. (2013), Nautiyal *et al*. (2015).

Number of branches per plant

Results for this trait is presented in Table 1. The results show that mid parent heterosis ranged from 0.09% in Cross I (IT89KD-288 x UAM10 2021-1) to 0.13% in Cross II (UAM09 1055-6 x UAM09 1051-1). While there was no better parent heterosis for this trait in Cross I (IT89KD-288 x UAM10 2021-1), Cross II (UAM09 1055-6 x UAM09 1051-1) recorded 8.47% better parent heterosis for this trait. Inbreeding depression ranged from -7.27% in Cross II (UAM09 1055-6 x UAM09 1051-1) to 7.21% in Cross I (IT89KD-288 x UAM10 2021-1). The results further revealed that only mid parent heterosis in Cross II recorded significant differences. All the other estimates recorded non-significant differences. Similar results were reported by Joseph and Santoshkumar (2000), Pal *et al.* (2003), Lal *et al.* (2007), Patel *et al*. (2009), Adeyanju (2012), Kajale *et al.* (2013), Patel *et al*. (2013), Nautiyal *et al*. (2015).

Number of seeds per plant

Results for this trait are presented in Table 1. Mid parent heterosis ranged from 0.03% in Cross I (IT89KD-288 x UAM10 2021-1) to 0.09% in Cross II (UAM09 1055-6 x UAM09 1051-1) while better parent heterosis ranged from -0.31% in Cross I to 5.79% in Cross II. Inbreeding depression on the other hand ranged from 1.70% in Cross I (IT89KD-288 x UAM10 2021-1) to 3.45% in Cross II (UAM09 1055-6 x UAM09 1051-1). The results further revealed that none of the estimates in Cross I for this trait show significant difference while in Cross II both mid and better parent heterosis show highly significant differences. Inbreeding depression did not show any significant difference in Cross II. Similar results were reported by Joseph and Santoshkumar (2000), Pal *et al.* (2003), Lal *et al.* (2007), Patel *et al*. (2009), Aremu and Adewale (2010), Rashwan (2010), Tchiagam *et al.* (2011), Adeyanju (2012), Kajale *et al.* (2013),Patel *et al*. (2013), Nautiyal *et al*. (2015).

Harvest index

The results for this trait are presented in Table 1. The results show that mid parent heterosis ranged from -0.38% in Cross I to 0.05% in cross II (UAM09 1055-6 x UAM09 1051-1) while better parent heterosis ranged from -42.63% in Cross I (IT89KD-288 x UAM10 2021-1) to -1.25% in Cross II (UAM09 1055-6 x UAM09 1051-1). Inbreeding depression on the other hand ranged from -6.37% in Cross I to 23.02% in Cross II. The results further shows that only better parent heterosis estimates in Cross I (IT89KD-288 x UAM10 2021-1) recorded significant difference. All the other remaining estimates recorded non-significant differences. Similar results were reported by Joseph and Santoshkumar (2000), Pal *et al.* (2003), Lal *et al.* (2007), Patel *et al.* (2009), Adeyanju (2012), Kajale *et al.* (2013), Patel *et al*. (2013), Nautiyal *et al*. (2015).

In the present investigation, heterosis for seed yield was observed due to heterosis in component characters *viz*. plant height, number of pods, pod length, number of branches, number of seeds per plant and harvest index which resulted in increased yield. So these characters should be given due consideration while improving yield.

In general, significant positive heterosis followed by presence of inbreeding depression were observed in Cross II (UAM09 1055-6 x UAM09 1051-1) for plant height, seed yield, number of pods/plant and harvest index. This indicated the contribution of non-additive (dominance and additive x additive) gene effects in the inheritance seed yield and its attributes. Hence, selection will be effective only in latter generations. Meanwhile, heterosis followed by absence of inbreeding depression were observed in Cross I (IT89KD-288 x UAM10 2021-1) for plant height, number of seeds per plant, and harvest index while in Cross II (UAM09 1055-6 x UAM09 1051-1), there were observed for days to flowering, days to maturity, pod length, number of branches and nuber of seeds per plant. This indicated that the absence of inbreeding depression and increase in performance of F_1 was accomplished by fixation of genes i.e. additive gene action.

Conclusion and Recommendation

Heterosis for seed yield and its attributes were observed in Cross II (UAM09 1055-6 x UAM09 1051-1) than in Cross I (IT89KD-288 x UAM10 2021-1). However, considering the cleistogamous flower, self-pollination nature and absence of commercially exploitable male sterility system in cowpea, heterosis per se may be of limited value. Thus, Cross II (UAM09 1055-6 x UAM09 1051-1) showing high heterosis and less inbreeding could be utilized for improvement in seed yield in cowpea through selection in advance generation.

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