

Genetic studies and transgressive segregation for large seeds in cowpea

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Abstract

Two cowpea (*Vigna unguiculata* L. Walp) varieties, *Kanannado* and IT97D-941-1 with average seed size of 27.0 g 100⁻¹ seeds and 15 g 100⁻¹ seeds, respectively, were crossed in the screenhouse. Sufficient backcrosses, F₁, and F₂ populations together with the parentals were planted in the field and grown to maturity. Data for 100 seed weight was analysed to determine how this trait can best be improved and also to further understand type of gene effects controlling this trait. Transgressive segregation for large seed was observed in the F₂ and backcross progeny to the large seeded parent. Large seed was found to be dominant over small seed. Results of the genetic analyses showed the involvement of non-allelic gene interaction in control of this trait. This result further revealed the additive (d) and additive x dominance (j) gene effects as the most important in determining seed size in cowpea. The dominance (h) and dominance x dominance (l) effects were also important but to a lesser extent. Seven gene pairs were estimated to be involved in the control of seed size in cowpea. A narrow sense heritability of 44.2% was estimated for this trait. Genetic advance from F₂ to F₁ was estimated as 4.3 g increases in seed size with 5% selection intensity. Selection for transgressive segregates seems to be the best approach for improving seed size in cowpea.

Key words: Additive, dominance, heritability, seed size, segregation, transgressive, *Vigna unguiculata*

Introduction

Cowpea (*Vigna unguiculata*) is an important grain legume in the semi-arid tropics. The crop is an important component of the farming systems of West Africa. It provides a cheap source of food and fodder to millions of people in the semi-arid tropics. This crop also helps in sustaining the productivity of otherwise marginal soils in semi-arid environments. Cowpea grain size is important in determining consumer preference. In West Africa, large grains, with white or brown rough testa is preferred (Drabo *et al.*, 1984).

Genetic studies of seed size have revealed conflicting results with regard to the type of gene action involved in the inheritance of the trait in cowpea. Brittingham (1951) and Agble (1972) reported heterosis for seed size in cowpea. Agble (1972) concluded that seed size is controlled by non-additive gene action. Drabo *et al.* (1984) concluded that seed size is inherited quantitatively and that gene action is predominantly additive, but dominance and additive x additive interaction were also significant. With regard to the dominance of the trait, Aryeetey and Laing (1973) and also Leleji (1976) reported dominance of small over large seed size. Similarly, Drabo *et al.* (1984) reported partial dominance of small over large seed. These conflicting results on seed size suggest that the genetics of this trait need to be further investigated, more so, that these conclusions seem to depend on parents used. For

example, the largest seed parent in Agble (1972) was 19.9 g 100⁻¹ seeds. This was about 6 g lighter than the largest seeded parent of Drabo *et al.* (1984).

Transgressive segregation has been used to explain niche divergence and phenotypic novelty in plant hybrids. Studies in numerous plant species indicate that the phenomenon of transgressive segregation is frequent in plants. Shepherd (1974) reported transgressive segregation for resistance to root-knot nematode in cotton while Cantrell *et al.* (2000) reported transgressive segregation for stomatal conductance in the same crop. In barley, transgressive segregation was reported for some crossability traits in a cross between *Hordeum bulbosum* and *H. vulgare* (Salvo and Snape, 2001). Similarly, Flood and Hallorn (1984) and Yadav *et al.* (1998) reported transgressive segregation for field resistance to leaf rust and days to ear emergence, respectively in wheat. Transgressive segregation for partial resistance to *Sclerotinia sclerotiorum* was observed in soybean by Hoffman *et al.* (1999). However, there is limited information on this phenomenon in cowpea. We noticed in our routine breeding work that certain crosses give rise to F₂ plants with seeds larger than either of the parents suggesting transgressive segregation for this trait. This work is aimed at elucidating the genetics of large seed size and also reporting on the phenomenon of transgressive segregation for large seed size in order to recommend an appropriate breeding method to improve this trait in cowpea.

Materials and methods

A cross between two parents, IT87D - 941-1, an improved variety developed by the International Institute of Tropical Agriculture (IITA), Nigeria, with seed size of about 15 g 100⁻¹ seeds and a large seeded (27 g 100⁻¹ seeds) local land race, Kanannado, from northern Nigeria, was made, to study the genetics of seed size. The crosses were made in the screenhouse at the IITA Kano Station, Nigeria. Sufficient F₁, backcross and F₂ populations were generated. The parents, F₁, backcross and F₂ populations were planted in the field in a completely randomised design. Plot size depended on seed availability. For example, there were 44 plants of kanannado, 65 plants of IT87D-941-1 and 283 plants of the F₂ population. All recommended management practices were observed and plants were grown to maturity. At maturity, pods were harvested on a plant basis within each population. The pods were threshed and the weights of 100 seeds recorded for each plant three times with replacement. This means that 100 seeds were counted, weighed recorded and then put back into the container before another random set of 100 seeds was counted and weighed again. Means of the three weights was recorded as the 100 seed weight for that plant. Generation means were obtained as the average weight of each population. The significance of additive and dominance gene effects in the inheritance of seed weight was tested using the ABC scaling test (Mather, 1949) and joint scaling test (Cavalli, 1952).

Results

Mean, range and variance of the 100 seed weight of the various populations for the cross IT87D-941-1 x Kanannado are presented in Table 1. The large seeded parent, Kanannado with 27 g 100⁻¹ seeds was about 12 g heavier than the small seeded parent IT87D-941-1. The F₁ mean (28 g 100⁻¹ seeds) was as large as the large seeded parent Kanannado ($P > 5\%$) suggesting complete dominance of large seed over small seed size. Similarly, the F₂ mean and the mean of the backcross to the large seeded parent were closer to the large seeded parent. This dominance of large seed size is at variance with findings of Aryeety and Laing (1973), Leleji (1976) and Drabo *et al.* (1984) who reported dominance of small seed size. This finding is also different from that of Agble (1972) who observed heterosis of both large and small size in some crosses of cowpea.

Transgressive segregation for large seed size was observed in the F₂. Segregates with seed size well outside the range of the large seeded parent (31 – 38 g 100⁻¹ seeds) were observed in the F₂ (Fig.1). These segregates whose seed size was larger than three standard deviation units of the larger parent, Kanannado, i.e., 35g 100⁻¹ seed, were regarded as transgressive segregates. Similar segregation pattern

was also observed in the backcross to the large seeded parent (Fig.1). Frequencies of this category of segregates were 4% and 6% in the F_2 and the backcross to the large seeded parent, respectively. We also observed that when random F_3 population was produced for a different trait, frequency of transgressive segregates was relatively higher than that in the F_2 generation. The presence of this phenomenon indicates that genes increasing seed size are dispersed between the parents and that IT87D-941-1, even though small seeded, also possesses some of the genes that condition large seed. This suggests that delaying selection for large seed until F_3 may yield better result. However, there was no transgressive segregation for small seed in this cross. Neither Agble (1972) nor Aryeteey and Laing

Table1. Range, population size, variance and mean of seed size for different genetic populations derived from the cross involving a large and small seeded parents, Kanannado and IT87D-941-1, respectively.

Generations	Range	Number of plants	Variance	Mean seed size (g/100 seeds) \pm SE
Kanannado	21.5-32.3	44	7.37	27.0 \pm 0.41
IT87D-941-1	11.6-17.0	65	1.72	15.2 \pm 0.17
F_1	25.5-32.5	32	3.67	28.0 \pm 0.35
Kanannado x F_1	18.5-42.5	46	29.01	27.1 \pm 0.80
IT87D-941-1 x F_1	14.5-27.5	48	7.36	18.1 \pm 0.39
F_2	15.0-38.9	283	22.63	24.0 \pm 0.30

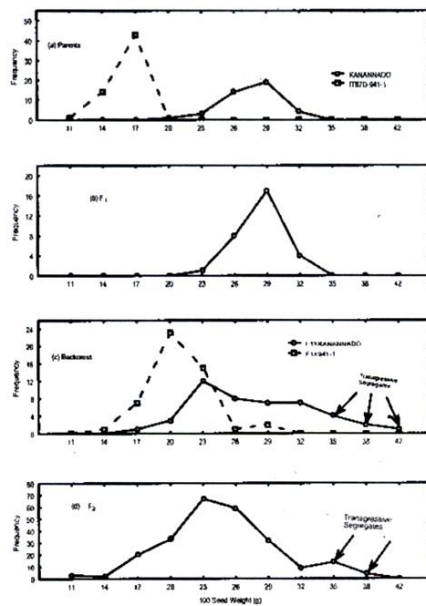


Figure 1. Frequency distribution of different classes of 100 seed weight for (a) Parent, (b) F_1 , (c) backcross and (d) F_2 populations for the cross IT87D-941-1 x Kanannado.

(1973) reported transgressive segregation for large seed. This finding of transgressive segregation for large seed is also at variance with that of Leleji (1976) and Sene (1968) who reported no transgressive segregation for large seed size. However, Brittingham (1951) has reported a similar transgressive segregation for large seeds in *Vigna sesquipedalis* (kidney beans). Reports of transgressive segregation in *Vigna unguiculata* is very limited.

Both the ABC scaling tests of Mather (1949) and the joint scaling test of Cavalli (1952) were significantly larger than zero (Table 2), suggesting the presence of epistatic gene action. The result showed that in addition to the high significance of the additive gene effect, the additive x dominance gene interaction effect was also highly significant explaining the presence of transgressive segregation observed in this data. The dominance as well as the dominance x dominance interaction was also significant (Table 2) and are of equal magnitude. The additive x additive gene effect, even though significant, is negative and can be said to reduce seed size. The additive x additive and dominance x dominance effects, being of equal magnitude and of opposing signs, cancel each other out. Therefore, these results suggest that the forms of gene action conditioning large seed size are the additive (*d*), dominance (*h*) and additive x dominance (*j*) gene effects. In previous studies, Drabo *et al.* (1984) reported that only the additive x additive interaction effect (*i*) was significant. A narrow sense heritability of 44.2 % was estimated (Table 2). This means that with 5% selection intensity genetic advance from the F_2 to the F_3 generation will be 4.31g. This estimate of 44% is much less than the 75% reported by Drabo *et al.* (1984). However, the expected genetic advance estimated in this work is relatively larger than that of Drabo and co-workers. This also implies that a significant improvement of seed size can be achieved even in early generations. Number of effective factors were estimated to be 6.96, suggesting that at least seven genes are involved in the control of seed size. Although this number is close to those reported by Sene (1968) and Drabo *et al.* (1984), who concluded six and eight gene pairs, respectively, to be involved in the control of this trait, it is however, lower than the ten gene pairs reported by Aryeetey and Laing (1973). Each of these genes reported here is estimated to contribute an increase of about 0.84g, a value less than the 1.1g average effect reported by Sene (1968) and Drabo *et al.* (1984). This data show that genetics of seed size in cowpea may be more complex than earlier thought. Hybridisation and selection of transgressive segregates from crosses involving

Table 2. Estimates of genetic parameters under different models for the cross involving large and small seeded parents of cowpea, Kanannado and IT87D-941-1, respectively.

Model	Effect estimates
Mather (1949)	
A	0.80 ± 0.16 *
B	-2.80 ± 0.29**
C	-2.16 ± 0.61**
Hayman (1958)	
m = Mean	24.01 ± 0.13**
d = Additive effect	9.00 ± 0.41**
h = Dominance	5.50 ± 1.030**
i = Additive x Additive	-5.60 ± 0.99**
j = Additive x Dominance	3.10 ± 0.43**
l = Dominance x Dominance	5.40 ± 1.820**
Cavalli (1952)	
m = Mean	20.553 ± 0.126**
d = Additive effect	4.99 ± 0.128**
h = Dominance	6.90 ± 0.251**
Narrow sense Heritability	44.2%

* Significant at 5%, ** Significant at 1%.

parents with dispersive genes, where frequency of transgressive segregation is expected to be high (Jinks and Pooni, 1976 and 1980), seem to be the most promising approach to developing larger seeded varieties in this crop.

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