Estimates of variability and genetic gains in cowpea (*Vigna unguiculata* (L.) Walp)

M. I. UGURU
Department of Crop Science, University of Nigeria, Nsukka, Nigeria

SUMMARY

The grain and vegetable cowpea types were hybridized with a view to estimating the genetic variability, heritability and expected genetic gains in their progenies. Whereas there was a wide range of variation in pod length, the variations in days to 50 per cent flowering, pods/plant, seeds/pod, 100-seed weight and grain yield were of low magnitude. There were indications of considerable dissimilarities in the loci of both cowpea types. Heritability values and genetic gains in days to 50 per cent flowering, pod length, seeds/pod, 100-seed weight and grain yield were higher in progenies from the hybridized vegetable and grain cowpeas than in the offspring from the cross between two grain cowpeas. The magnitude of the values of the estimates of heritability and genetic gain suggested that individual plant selection would be effective in crosses involving either two vegetable cowpeas or a vegetable and a grain cowpea.

Original scientific paper. Received 6 Sep 95; revised 29 Aug 96.

RÉSUMÉ

UGURU, M. I. : *Les estimations de la variabilité et des gains génétiques en dolique* (Vigna unguiculata *(L.) Walp)*. Les espèces de dolique grain et légume étaient hybridées en vue d' estimer la variabilité génétique, héritabilité et les gains génétiques espérés dans leurs progénitures. Tandis qu'il y avait un grand écart de variation dans la longueur de cosse, les variations en jours à 50 pour de floraison, cosses/plante, grains/cosse, le poids de 100-grains et le rendement de grain étaient de magnitude basse. Il y avaient des indications de dissemblances considérables dans le lieu géométrique de deux expèces de dolique. Les valeurs d' héritabilité et les gains génétiques en jours à 50 pourcent de floraison, longueur de cosse, grains/cosse, le poids de 100-grain et le rendement de grain étaient plus élevés en progénitures de légume hybridé et les doliques de grains que dans la progéniture provenant de l' hybride entre les deux grains doliques. La magnitude des valeurs des estimaitons d' héritabilité de gain génétique suggérait que la sélection de plante individuelle serait efficace dans les hybrides entraînant soit deux doliques légumes soit un légume et un grain dolique.

Introduction

Selection is an integral phase of any breeding programme and it has been applied, over the years, in the improvement of agricultural crops. However, the usual method of selecting from a mixed plant population on the basis of the phenotype only may not be very effective in isolating the best-performing lines. Because the full expression of a metric trait depends on the genotype, environment and on the combined effects of both components, there is always the risk of omitting superior lines whose potentials may have been suppressed by an unfavourable environment. On this premise, there is the need for information that will permit prediction of the genetic gains associated with traits under selection.

Two cowpea types, the grain and vegetable cowpeas, are cultivated in Nigeria (Uguru, 1996). The grain cowpea, grown for the dry grains and extensively cultivated in the semi-arid belt, is popularly consumed throughout the country. The cultivation of the vegetable cowpea is restricted to the derived savanna and the forest ecological zones where the pods are eaten green as a vegetable. Additionally, both cowpea types differ in many morphological features (Uguru & Uzo, 1991a; Uguru, 1995), in ecological requirements (Uguru, 1996) and in some yield-determining components (Uguru & Uzo, 1991b).

Hybridization of these two cowpea types would

increase the genetic base and create variability that would enhance cowpea improvement through selection. Thus, the knowledge of genetic coefficient of variation, heritability estimates and expected genetic gains in hybridized vegetable and grain cowpeas would be essential for starting an effective breeding programme. These considerations formed the basis of the work reported in this paper.

Materials and methods

The materials used in this investigation comprised two accessions of grain cowpea, AD-36-W (Vita 7) and AD-36-W_B (Mazan), and two accessions of vegetable cowpea, AE-36-C and AN-16-D, selected from the cowpea germplasm of the Department of Crop Science, University of Nigeria, Nsukka. These accessions were selfed for four generations between 1985 and 1991 in the research farm of the Faculty of Agriculture, University of Nigeria, Nsukka. Each accession was planted in an unreplicated 16 row plot, 12 m in length. The inter-and intra-row spacings were 90 cm and 30 cm respectively (Enyi, 1971). Data for the parental variances in days to 50 per cent flowering, pod length, pods/plant, seeds/pod, 100-seed weight and grain yield were collected from the last generation of selfing. The variances were determined according to Little & Hills (1978).

Three crosses were made among the accessions as shown below:

i. AD-36-W × AE-36-C
ii. AD-36-W_B × AD-36-W
iii. AE-36-C × AN-16-D

The seeds from the crosses were planted for the determination of the F_1 variances, and the F_2 generations were obtained by allowing natural self-pollination of the three F_1 populations. The F_1 and F_2 families were grown in two separate unreplicated plots. Entries were grown in 16-row plots 12 m long with 90 cm spacing between rows and 30 cm spacing within rows. Each plot measured 172.8 m^2. Data for the F_1 and F_2 variances were collected from 520 plants in the middle 14 rows. Measurements were made on days to 50 per cent flowering, pod length (cm), pods/plant, seeds/pod, 100-seed weight (g) and grain yield (t/ha). A 5 per cent selection intensity in the F_2 families, was used to estimate the best 26 plants in the characters measured.

The number of days from planting to the day one-half of the plant population produced flowers was recorded as days to 50 per cent flowering. Pod length was measured in centimetres, and counts were made for pods/plant and seeds/pod. One hundred-seed weight (100-seed weight) was obtained by weighing 100 seeds randomly picked from the selected plants. The grain yield per hectare, was obtained by multiplying the number of grains, harvested from each plant and air-dried, by the total plant population in one hectare.

The variances of the F_1 and F_2 populations were calculated according to Little & Hills (1978). The estimation of the environmental, genotypic and phenotypic variances as well as the broad sense heritability were done according to Poehlman (1987).

Phenotypic variance $(\sigma^2 ph) = \sigma^2 F_2$

Environmental variance $(\sigma^2 e) = (\sigma^2 P_1 + \sigma^2 P_2 + \sigma^2 F_1)/3$

Genotypic variance $(\sigma^2 g) = \sigma^2 F_2 - \sigma^2 e$

Broad sense heritability $(h^2) = (\sigma^2 F_2 - \sigma^2 e)/\sigma^2 F_2$

where P_1 and P_2 refer to Parent 1 and Parent 2 respectively; $\sigma^2 F_1$ and $\sigma^2 F_2$ refer to variances of F_1 and F_2 generations, respectively.

Estimates of the expected genetic gain from selection (ΔG) were calculated according to Johnson, Robinson & Comstock (1955) as

$$\Delta G = h^2 K \sigma F_2$$

where h^2 = broad sense heritability.

K = selection intensity. K was given the value of 2.06 which is its expectation in the case of 5 per cent selection in large samples from a normally distributed population (Allard, 1960).

σF_2 = phenotypic standard deviation of the original population before selection.

Estimates of the expected genetic gain as percentage of the mean G(per cent) were calculated according to Kaul & Bahn (1974) as follows:

$$G(\text{per cent}) = (\Delta G/\overline{X}) \times 100$$

where $\overline{X}$ is the original population mean before selection. Phenotypic and genotypic coefficients

of variation were estimated according to Burton & DeVane (1953).

Results and discussion

The extent of observed variability in the six characteristics studied: days to 50 per cent flowering, pod length, pods/plant, seeds/pod, 100-seed weight and grain yield is given in Table 1. A wide range of variation was observed in pod length in all the crosses. The variation in the other characters were of lower magnitude. The estimates of parental and F_1 variance components for the different characters are presented in Table 2. As expected, the variance values are low because the parents must have approached a considerable level of homozygosity after four generations of selfing and all plants in a hybrid between two pure lines are genetically identical. The variances due to the phenotype, genotype and environment, and the heritability in the broad sense are given in Table 3. The estimates of the phenotypic and genotypic coefficient of variations, the genetic gains expressed as such and also as a percentage of the mean are shown in Table 4. There was a wide variation in the genotypic coefficient of variation among characters studied; the least was 4.8 for days to 50 per cent flowering in Cross II and the highest was 26.5 for grain yield in Cross I. Burton (1952) postulated that the genotypic coefficient of variation measures the amount of variability available for selection and provides a measure to compare the genetic variability present in various characters and populations. Genetic coefficient of variation together with the heritability estimates would give the best picture of the amount of genetic gain to be expected from selection (Burton, 1952). Johnson, Robinson & Comstock

TABLE 1

Quantitative Variation in the Three F_2 Populations of Cowpea

Character	*Cross*	*F_2 mean+SE*	*Range*
Days to 50% flowering	i*)	43.0+0.69	39-46
	ii	47.0+0.62	41-55
	iii	45.0+0.58	40-52
Pod length (cm)	i	17.5+6.68	6.0-34.6
	ii	12.9+5.92	7.2-28.1
	iii	14.2+5.11	6.3-34.2
Pods/Plant	i	45.0+0.63	36-54
	ii	53.0+0.47	49-57
	iii	36.0+0.53	28-43
Seeds/Pod	i	10.0+0.49	8-13
	ii	7.0+0.31	5-9
	iii	11.0+0.43	7-14
100-seed weight (g)	i	14.9+0.30	13.4-15.3
	ii	10.9+0.38	9.1-11.4
	iii	11.2+0.41	9.9-12.0
Grain yield ($t\,ha^{-1}$)	i	1.69+0.21	1.10-1.79
	ii	1.95+0.17	1.58-2.46
	iii	1.79+0.16	1.51-2.23

*) i = AD-36-W × AE-36-C
ii = AD-36-W_B × AD-36-W
iii = AE-36-C × AN-16-D

TABLE 2

Estimates of Parental and F_1 Variance Components for the Different Characters

Character	*Cross*	σ^2P_1	σ^2P_2	σ^2P_2
Days to 50% flowering	i*)	0.89	0.72	1.39
	ii	1.36	1.40	0.60
	iii	4.60	5.30	5.30
Pod length (cm)	i	0.75	0.82	0.83
	ii	2.10	1.96	2.60
	iii	1.15	1.08	0.86
Pods/Plant	i	6.95	8.78	10.10
	ii	2.06	3.00	2.50
	iii	4.50	3.80	4.84
Seeds/Pod	i	0.38	0.42	0.46
	ii	0.23	0.29	0.23
	iii	0.41	0.53	0.44
100-seed weight (g)	i	0.26	0.35	0.29
	ii	0.66	0.58	0.65
	iii	2.50	2.80	1.30
Grain yield ($t\,ha^{-1}$)	i	0.08	0.16	0.03
	ii	0.10	0.06	0.02
	iii	0.10	0.18	0.32

*) i = AD-36-W × AE-36-C
i i = AD-36-W_B × AD-36-W
iii = AE-36-C × AN-16-D

TABLE 3

Estimates of Phenotypic (σ^2ph), Genotypic (σ^2g) and Environmental (σ^2e) Variance Components and Broad Sense Heritability (h^2) Values for the Different Characters

Character	*Cross*	σ^2ph	σ^2g	σ^2e	h^2 (%)
Days to 50% flowering	i*)	14.00	13.00	1.00	93
	ii	6.20	5.08	1.12	82
	iii	24.20	19.00	5.20	79
Pod length (cm)	i	12.90	12.10	0.80	94
	ii	9.12	6.90	2.22	76
	iii	7.18	6.15	1.03	86
Pods/Plant	i	23.00	14.40	8.60	63
	ii	14.28	12.30	2.52	83
	iii	20.08	15.70	4.38	78
Seeds/Pod	i	4.90	4.50	0.40	92
	ii	0.73	0.48	0.25	66
	iii	2.26	1.80	0.46	80
100-seed weight (g)	i	7.10	6.80	0.30	96
	ii	2.30	1.67	0.63	73
	iii	10.60	8.40	2.20	79
Grain yield (t ha^{-1})	i	0.29	0.20	0.09	69
	ii	0.14	0.08	0.06	50
	iii	0.41	0.21	0.20	51

*) i = AD-36-W × AE-36-C
ii = AD-36-W_B × AD-36-W
iii = AE-36-C × AN-16-D

TABLE 4

Estimates of Phenotypic Coefficient of Variation (PCV), Genotypic Coefficient of Variation (GCV), Expected Genetic Gain (ΔG), and Expected Gain as per cent of the Mean (G (per cent)) for the different Characters

Character	*Cross*	*PCV%*	*GCV%*	ΔG	*G (%)*
Days to 50% flowering	i*)	9.0	8.0	7.16	16.7
	ii	5.3	4.8	4.21	9.0
	iii	10.9	9.6	8.00	19.3
Pod length (cm)	i	20.3	19.6	6.95	39.3
	ii	23.4	20.4	4.73	36.7
	iii	18.0	16.6	4.70	31.9
Pods/Plant	i	10.7	8.4	6.22	13.8
	ii	7.3	6.6	6.58	12.5
	iii	12.4	11.0	7.20	20.0
Seeds/Pod	i	22.1	21.2	4.20	42.0
	ii	22.2	9.9	1.16	16.6
	iii	13.7	12.2	2.50	22.5
100-seed weight (g)	i	17.9	17.5	5.26	35.0
	ii	14.0	11.9	2.28	20.7
	iii	29.1	25.8	5.30	47.0
Grain yield (t ha^{-1})	i	31.8	26.5	0.77	45.6
	ii	19.2	14.5	0.44	22.5
	iii	35.8	25.6	0.67	37.6

*) i = AD-36-W × AE-36-C
ii = AD-36-W_B × AD-36-W
iii = AE-36-C × AN-16-D

(1955), in their study on soybean, cautioned that heritability values as well as estimates of genetic gains are more useful that heritability values alone. Thus, the parallelism as expressed in the magnitudes of the values of heritability and genetic gain would suggest that breeding for pod length, seeds/pod, and 100-seed weight would be more fruitful than pods/plant and days to 50 per cent flowering. Grain yield in this context did not appear to be of much consequence. Its relatively lower heritability values accompanied by high genetic gains suggest the influence of both the additive and non-additive gene effects (Pause, 1957; Uguru & Uzo, 1991a) in its expression. Previous workers on cowpea (Agble, 1972; Aryertey & Laing, 1973; Bordia, Yadavendra & Kumar, 1973; Angadi, Subramani & Kulkarni, 1978; Jagadish, 1986) have also reported that seed yield is influenced by environmental factors.

Although the high heritability values for days to 50 per cent flowering and pods/plant would suggest that the phenotype would give a near-perfect measure of the genotypic value, it is not an adequate measure of the genetic gain that would result from selecting the best-performing lines. This could be explained by the non-linear relationship between broad sense heritability and the genotypic component arising from the genetic differences among the segregating progenies (Johnson, Robinson & Comstock, 1955; Hayman, 1958; Uguru, 1994). The lower genetic gains in respect of both characters would seem to predict a little scope for improvement in the traits.

The high genotypic coefficient of variation

(Table 4) in the traits in the crosses involving the vegetable cowpea as parents (Cross I and Cross III) are indications of considerable dissimilarities in most of the parental loci. The heritability values and genetic gains in days to 50 per cent flowering, pod length, seeds/pod, 100-seed weight and grain yield were higher in the progenies from the hybridized vegetable and grain cowpea (Cross I) than in the offspring from the cross between two grain cowpeas (Cross II). The values of heritability and genetic gains in the progenies of the former (Cross I) and in the progenies from the within-type cross between two vegetable cowpeas (Cross III) are, however, of comparable magnitude.

It is evident from this study that progenies from parents with considerable varition are more endowed with higher genetic gains than descendants from parents with very minor dissimilarities in most of their loci. On this premise, it is reasonable to conclude that individual plant selection for pod length, seeds/pod and seed size (100-seed weight) would be satisfactorily effective in crosses involving either two vegetable cowpeas or a vegetable and a grain cowpea.

Acknowledgement

The author is indebted to the Senate Research Grant Committee, University of Nigeria, Nsukka, for its financial support through a research grant awarded for the research.

REFERENCES

Agble, F. (1972) Seed size heterosis in cowpeas (*Vigna unguiculata* (L.) Walp). *Ghana J. Sci.* **12**, 30-33.

Allard, R. W. (1960) *Principles of plant breeding.* New York: John Wiley and Sons Inc.

Angadi, S. P., Subramani, A. & Kulkarni, J. (1978) Genetic variability for some quantitative traits in cowpea. *Agric. Res. J. Kerala* **16**, 60-62.

Aryeetey, A. N. & Laing, E. (1973) Inheritance of yield components and their correlation with yield in cowpea (*Vigna unguiculata* (L.) Walp). *Euphytica* **22**, 386-392.

Bordia, P. C., Yadavendra, J. P. & Kumar, S. (1973) Genetic variability and correlation studies in cowpea (*Vigna sinensis* (L.)). *Rajasthan J. agric. Sci.* **4**, 39-44.

Burton, G. W. (1952) Quantitative inheritance in grasses. *Proc. 6th Int. Grassl. Congr.* **1**, 227-283.

Enyi, B. A. C. (1971) A spacing/planting trial with cowpea (*Vigna unguiculata*). *Ghana J. Sci.* **13**, 78-88.

Hayman, B. J. (1958) The separation of epistatic from additive and dominance variation in generation means. *Heredity* **12**, 371-390.

Jagadish, M. (1986) Path analysis and selection indices in three F_2 populations of cowpea. *Indian Mysore J. agric. Sci.* **18**, 322-323.

Johnson, A. W., Robinson, H. F. & Comstock, R. E. (1955) Estimates of genetic and environmental variability in soybean. *Agron. J.* **47**, 314-318.

Kaul, M. L. H. & Bhan, A. K. (1974) Studies of some genetic parameters of rice. *Theor. appl. Genet.* **44**, 178-183.

Little, T. M. & Hills, F. G. (1978) *Agricultural experimentation, design and analysis.* New York: John Wiley and Sons Inc.

Pause, V. G. (1957) Genetics of quantitative characters in relation to plant breeding. *Indian J. Genet.* **17**, 318-328.

Poehlman, J. M. (1987) *Breeding field crops*, 3rd ed. New York: Page Van Nostrand, Reinbold Press.

Uguru, M. I. (1994) Heritable relationships and variability of yield and yield components in vegetable cowpea (*Vigna unguiculata* (L.) Walp). *Afr. Crop Sci. J.* **3**, *23-28.*

Uguru, M. I. (1995) Genetics and association studies of pod shape in cowpea. *Bionature* **15**, 23-27.

Uguru, M. I. (1996) A note on the Nigerian vegetable cowpea. *Genet. Resour. Crop Evolut.* **43**, 125-128.

Uguru, M. I. & Uzo, J. O. (1991a) Studies of gene action for some yield attributes in hybridized vegetable and grain cowpeas (*Vigna unguiculata* (L.) Walp). *Biol. Zent bl.* **110**, 231-237.

Uguru, M. I. & Uzo, J. O. (1991b) Segregation pattern of decumbent, climbing and bushy growth habits in *Vigna unguiculata* (L.) Walp. *Pl. Breed.* **107**, 173-176.