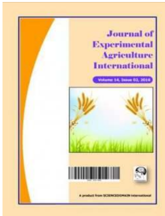

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Genetic Variation for Yield and Yield Components in Sole Soybean and Soybean/Celosia Inter-Crop in Makurdi (Southern Guinea Savanna Ecology), Nigeria

G. O. S. Ojo[1*] and A. Odoba[2]

[1]Department of Crop Production, Federal University of Agriculture, P.M.B. 2373, Makurdi, 970001, Nigeria.
[2]National Cereals Research Institute, Badegi, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Author GOSO designed the study, wrote the protocol and the first draft of the manuscript. Author GOSO managed the literature searches and analysed of the study. Both authors performed the field experiments. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: To determine genetic variation in soybean grown alone and in soybean/celosia intercrop system, and to provide information on the appropriate system to concentrate in a breeding programme.

Study Design: The experimental design was a randomized complete block design (RCBD) with three replications for each of the cropping systems in each of the years.

Place and Duration of Study: Field experiments were carried out at the Teaching and Research Farm of the Federal University of Agriculture, Makurdi, Nigeria, during the cropping seasons of 2006 and 2008.

Methodology: Twenty - five to thirty - nine improved varieties of soybean were evaluated in sole and soybean/celosia intercrop for each of the years. Data were taken on days to flowering, plant

**Corresponding author: E-mail: gosojo2001@yahoo.com;*

height, number of pods/plant, 100 – seed weight and grain yield for soybean in both cropping systems. Data were analysed using analysis of variance and components of genetic variation.

Results: Highly significant difference in varieties was observed for all the traits studied in the sole and intercrop soybean for each of the years with significantly higher grain yield in 2008 compared to 2006 in both the sole and intercrop soybean due to planting at the recommended planting date for soybean in 2008.Genetic variance was higher than error variance for all the traits in the sole soybean except 100 – seed weight in 2006. Genetic variance in the intercrop soybean was lower than the error variance for three out of the five traits studied leading to proportionally lower heritability estimate and genetic advance for almost all the traits in intercrop soybean compared to sole soybean system.

Conclusion: The evaluated varieties of soybean are genetically diverse. A faster progress in selection will be achieved in the sole soybean and should be adopted in the selection of soybean genotypes for soybean/celosia intercrop system.

Keywords: Sole soybean; soybean/celosia intercrop; heritability; GA.

1. INTRODUCTION

Soybean is a very important oil seed crop and virtually every part of it is utilized for human and livestock consumption in Nigeria. Encouraged by the breeding effort and release of improved high yielding varieties of soybean by the International Institute for Tropical Agriculture (IITA), farmers extensively cultivate it in commercial quantities on most arable lands within the Northern and Southern Guinea Savanna ecologies of Nigeria. While most research work on the improvement of soybean is carried out in sole crop, the end users of this research effort are small scale farmers who prefer to grow the crop in mixtures.

The practice of mixed intercropping is very common in Africa and had been described by Muoneke et al. [1] as very popular among small scale farmers in West Africa.

Most research work on soybean in mixed intercropping in Nigeria, are concentrated on soybean/maize intercrop systems [2-6] and soybean with other cereals.

Though vegetables are seen in mixtures with soybean on farmers' fields in Nigeria, there is dearth of information from research in this area in the southern Guinea Savanna ecology particularly on vegetable crops that are rarely cultivated. Most leafy vegetables in Nigeria produce their harvestable portion that are rich in nutrients in less than two months and complete their life cycle far ahead of soybean if planted at the same time. Moreover, vegetable crops roots are not elaborate enough to elicit stiff competition with soybean. It is therefore important to intensify research studies involving vegetables in crop mixtures with a view of reducing yield depression of the main crop (soybean) and enhance overall return on investment.

Celosia argentea is a cultivated annual edible leafy vegetable of the *Amaranthaceae* family that is an essential component of people's diet in Nigeria and other parts of West Africa [7]. Celosia is also medicinal [8] and traditionally used as an antidote for snake-poison, anti-ulcer and in the treatment of eye diseases, glandular swellings, eczema and constipation [9]. Unfortunately, this highly nutritious and medicinal vegetable crop is rarely cultivated in some parts of the southern Guinea Savanna of Nigeria, particularly, Benue State (the food basket state). However, because of its nature of seed dispersal (shattering), celosia is abundantly available in Benue State where it exists as weed and as a volunteer crop that is often harvested and used in the preparation of vegetable soup due to its nutritional value. The cultivation of celosia in Benue State needs to be encouraged through its integration into the popular cropping systems in the area (mixed intercropping) as a companion crop without sacrificing the yield of the main crop.

It is a common trend in most research works on cropping system to concentrate on system productivity with little or no effort to study genetic variation in diverse genotypes towards selecting the most productive genotypes to adopt in mixed intercropping. Hence, only few plant-breeding investigations have been done in intercropping [10]. However the selection of an appropriate variety is important for the success of the intercrop [11] and can be achieved through studies on genetic variation in sole and intercrop production systems.

The current research was therefore initiated to determine genetic variation for grain yield and yield components in sole soybean and soybean intercropped with celosia. The cropping system to select soybean variety for integration into soybean/celosia mixed intercropping was also determined.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiments were carried out during the rain fed cropping seasons of 2006 and 2008 within the months of June to November at the Teaching and Research Farm of the Federal University of Agriculture, Makurdi (lat. 7°41' N, long. 8°28' E, 97m asl.), Nigeria. The location falls within the southern Guinea Savanna agro-ecological zone of Nigeria.

2.2 Soybean Genotypes

A total of twenty five (25) to thirty nine (39) varieties of soybean were used for the experiments. The soybean varieties were all improved varieties obtained from IITA, Ibadan, Nigeria.

2.3 Experimental Layout

Due to the problem of seed viability observed in some plots, some entries were eliminated from the experiments and this led to differences in the number of varieties of soybean evaluated for each of the experiments (39 in 2006 sole, 37 in 2006 intercrop, 29 in 2008 sole, and 25 in 2008 intercrop). All soybean varieties were planted out in a randomized complete block design (RCBD) with three replications on the 30^{th} and 2^{nd} July, for the 2006 and 2008 evaluations respectively.

Celosia (*Celosia argentea*) seeds were planted in the nursery on the date of planting of soybean and transplanted to the field when the seedlings were two and a half weeks old. Seeds of soybean were drilled into the crest of the ridges at a depth of 2 cm and later thinned down to 26 plants per meter after emergence while celosia seedlings were transplanted to the right side of each ridge at an intra row spacing of 50cm. Each plot consisted of 4 ridges of 4m length, spaced 0.75m apart, giving a plot area of 12 m^2.

The field was manually weeded at two and six weeks after planting (WAP). Compound fertilizer (NP K 15 – 15 – 15) was combined with single superphosphate fertilizer (SSP) and applied at the rate of 15 kg total N, 42 kg% P_2O_5 and 15 kg% K_2O per hectare, immediately after the first weeding at 2 WAP. Harvesting of soybean was on a per plot basis, depending on the maturity date of each variety. Soybean harvesting was carried out within the months of October and November of each year. Pods of the harvested soybean were threshed, winnowed and the clean grains weighed. Grain yield of the soybean from each plot was extrapolated to grain yield/ha. Celosia harvesting commenced at 4 weeks after transplanting (WAT) and continued at weekly interval for six weeks in each of the years.

2.4 Data Recording and Analysis

Data was taken on soybean for:

(i) Days to flowering, as number of days from planting to the day of flowering of 50% of the plants within a plot
(ii) Plant height at maturity, from the mean of ten randomly selected plants in each plot
(iii) Number of pods per plant, determined from the mean of five randomly selected plants in each plot.
(iv) 100-seed weight, determined from the mean of duplicate 100 seed-weights taken from seed lot of each plot
(v) Grain yield in tons/ha, estimated from grain yield per plot.

Data were subjected to Analysis of Variance procedures using the General Linear Model of SAS (2007). Components of genetic variation for each experiment were estimated according to Allard [12] as presented below:

$$\boldsymbol{\delta^2_g} = \text{MS variety} - \text{MS error/r}$$

$$\boldsymbol{\delta^2_e} = \text{MS error}$$

$$\boldsymbol{\delta^2_{ph}} = \boldsymbol{\delta^2_g} + \boldsymbol{\delta^2_e}$$

Where: $\boldsymbol{\delta^2_g}$, $\boldsymbol{\delta^2_e}$ and $\boldsymbol{\delta^2_{ph}}$ are components of variance for genotype (variety), error and phenotype, respectively.

Broad sense heritability ($\mathbf{H_{BS}}$) was calculated as the ratio of the genotypic variance to phenotypic variance using the formula of Allard [12]:

$$\boldsymbol{\delta^2_g / \delta^2_{ph}} \times 100$$

Where, $\mathbf{H_{BS}}$ = broad sense heritability (%), $\boldsymbol{\delta^2_g}$ = genotypic variance, $\boldsymbol{\delta^2_{ph}}$ = phenotypic variance.

PCV (phenotypic coefficient of variation) and GCV (genotypic coefficient of variation) were calculated from the formula:

PCV (%) = (phenotypic standard deviation/mean) X (100/1);

GCV (%) = (genotypic standard deviation/mean) X (100/1)

Genetic advance (GA) as percentage of the mean was calculated at 10% selection intensity (I=1.76).

3. RESULTS

Higher amounts of rainfall were received in 2006 compared to 2008 (Table 1). Data from the experiments were analysed separately for the sole soybean and the soybean/celosia intercrop systems for each of the years due to inconsistent number of varieties across years and cropping systems.

Highly significant variety effect in soybean was observed for all the traits (days to flowering, plant height, number of pods/plant, 100 seed weight and grain yield) in both cropping systems for each of the two years (Tables 2 and 3).

Intercropped soybean system was slightly earlier and taller, with fewer number of pods/plant compared to the sole soybean in both years (Tables 4 and 5). The 100 seed weight and grain yield were also lower in value in the intercropped soybean compared to the sole soybean in both years. Genetic variance for days to flowering was higher than error variance, with high heritability for both the sole and intercropped soybean in each of the years. While higher genetic variance was observed in the sole soybean for all the traits except 100seed weight in 2006, the pattern in the intercropped soybean was completely different. Error variance was higher than genetic variance for plant height, number of pods/plant and 100 seed weight for the intercrop soybean in 2006. In the 2008 however, higher genetic variance was observed for all the traits in the sole soybean while error variance was higher than genetic variance for number of pods/plant, 100 seed weight and grain yield in the intercrop soybean. Genetic coefficient of variation (GCV) was higher in the sole compared to the intercrop soybean for days to flowering, 100 – seed weight and grain yield in 2006 and 2008. Plant height and number of pods/plant however, recorded higher GCV in the intercrop soybean compared to the sole in both years. Heritability estimate was higher in the sole soybean compared to the intercrop soybean in both years except days to flowering in 2006. Genetic advance was generally higher in the sole soybean compared to the intercrop soybean, except number of pods/plant in 2006 and plant height in 2008. The

Table 1. Meteorological data for Makurdi in 2006 and 2008

Year	Mean annual rainfall (mm)	Mean annual temperature (℃)	Mean annual relative humidity (%)	Mean annual evaporation (mm)
2006	1343	23.1 (min.) – 33.3 (max.)	50.2 @1500 GMT – 65.9 @0900 GMT	4.6
2008	1050.7	21.4 (min.) – 33.5 (max.)	51.4 @1500 GMT – 69.2 @0900 GMT	4.7

Source: Annual Abstract of Statistics, 2012, Federal Republic of Nigeria

Table 2. Mean squares for grain yield and other agronomic traits in sole crop of soybean and soybean/celosia intercrop evaluated in Makurdi during the 2006 rain fed cropping season

Source of variation	Df	Days to flowering	Plant height at maturity	Number of pods/plant	100 – seed weight	Grain yield
			2006 Sole crop			
Reps	2	3.21	9.39	160.11	2.12	0.96
Variety	38	87.83**	68.04**	998.26**	16.42**	5.58**
Error	76	2.62	5.23	201.62	4.99	1.13
			2006 Intercrop			
Reps	2	2.14	83.56	851.14*	2.67	0.91
Variety	36	52.24**	131.37**	824.79**	10.38*	1.56**
Error	72	1.27	45.87	240.70	6.23	0.32

Table 3. Mean squares for grain yield and other agronomic traits in sole crop of soybean and soybean/celosia intercrop evaluated in Makurdi during the 2008 rain fed cropping season

Source of variation	Df	Days to flowering	Plant height at maturity	Number of pods/plant	100 – seed weight	Grain yield
2008 Sole crop						
Reps	2	3.65	7.76	98.90	1.87	1.02
Variety	28	65.21**	45.56**	573.27**	22.11**	6.43**
Error	56	1.99	5.02	112.63	4.88	1.08
2008 Intercrop						
Reps	2	11.37*	239.28*	357.10	1.32	1.15
Variety	24	35.53**	312.83**	1036.98**	11.61**	1.45**
Error	48	2.56	55.59	443.63	2.98	0.38

Table 4. Means, range, variance components, coefficients of variation, heritability and genetic advance for grain yield and other agronomic traits in sole crop of soybean and soybean/celosia intercrop evaluated in Makurdi during the 2006 rain fed cropping season

	Days to flowering	Plant height at maturity	Number of pods/plant	100 – seed weight	Grain yield
2006 Sole soybean					
Range	40.50 – 54.50	40.12 – 55.21	50.14 – 145.10	11.00 – 20.11	1.98 – 3.94
Mean	46.23	49.45	75.88	14.95	2.98
$δ^2_g$	28.40	20.94	265.55	3.81	1.48
$δ^2_e$	2.62	5.23	201.62	4.99	1.13
$δ^2_{ph}$	31.02	26.17	467.17	8.80	2.61
GCV (%)	11.53	9.25	21.48	13.06	40.82
PCV (%)	12.05	10.35	28.48	19.84	54.21
H_{BS} (%)	91.55	80.12	56.84	43.30	56.70
GA (%)	19.41	14.57	28.50	15.12	54.11
2006 Intercrop soybean					
Range	39.00 – 55.67	28.90 – 56.00	11.23 – 75.33	9.83 – 17.53	1.20 – 3.63
Mean	45.11	41.98	41.77	12.95	2.68
$δ^2_g$	16.99	28.50	194.70	1.38	0.41
$δ^2_e$	1.27	45.87	240.70	6.23	0.32
$δ^2_{ph}$	18.26	74.37	435.40	7.61	0.73
GCV (%)	9.14	12.72	33.41	9.09	28.22
PCV (%)	9.47	20.54	49.95	21.30	37.46
H_{BS} (%)	92.94	38.32	44.72	18.13	56.16
GA (%)	15.51	13.86	39.32	6.80	37.04

Mean performance of the intercrop soybean as a percentage (%) of the sole soybean is presented in Table 6. The mean performance of the intercrop soybean as a% of the sole soybean, ranged from 55.05% for number of pods/plant to 97.58% for days to flowering in 2006. A narrow range in the mean performance of the intercrop soybean as a (%) of the sole soybean was observed in 2008, as it ranged from 83.72% for number of pods/plant to 97.23% for days to flowering.

4. DISCUSSION

The highly significant variety effect observed for all the characters evaluated across the cropping systems in both years (2006 and 2008) is an indication of genetic diversity in the soybean genotypes used for the experiment. The higher grain yield recorded for the 2008 compared to the 2006 despite higher amount of rainfall in 2006, could be attributed to early planting in the 2008 which was within the recommended date of 15th June to 15th July in the location of the experiment. The 55% observed as the mean performance of the intercrop soybean as a percentage of the sole soybean for number of pods/plant in 2006 is consistent with previous findings [1] in soybean/maize intercrop within the same ecology of the current research. The higher performance of the intercrop as a percentage of the sole crop observed for grain yield in the current work is higher than the values obtained by Muoneke et al. [1] and Ali et al. [2] in soybean/maize intercrop within the same ecology. It is also higher than the values obtained by Raji [4] in the derived savanna of south west Nigeria. The lower depression in the yield of soybean due to intercropping in the present findings compared to the previous could be attributed to differences in the shading effect, root biology and life cycle of the respective companion crop. Maize is a bigger crop with a longer period of life cycle and therefore exhibit higher shading effect and stiffer root competition over a longer period of time in a soybean/maize intercrop compared to celosia in a soybean/celosia intercrop system.

The proportionally higher genetic variance compared to error variance in the sole soybean is an indication that the performance of the soybean genotypes was less influenced by the environment unlike in the intercrop soybean. Moreover, a faster progress in selection will be achieved in the sole soybean in view of the higher heritability estimate and genetic advance observed for almost all the traits in both years compared to intercrop soybean. Selection of soybean genotypes for adoption in soybean/celosia intercrop should therefore be concentrated in the sole soybean.

Table 5. Means, range, variance components, coefficients of variation, heritability and genetic advance for grain yield and other agronomic traits in sole crop of soybean and soybean/celosia intercrop evaluated in Makurdi during the 2008 rain fed cropping season

	Days to flowering	Plant height at maturity	Number of pods/plant	100 – seed weight	Grain yield
		2008 Sole soybean			
Range	41.01 – 53.81	39.01 – 53.98	49.08 – 150.42	12.01 – 19.06	2.02 – 4.18
Mean	45.92	50.42	83.46	15.01	3.02
δ^2_g	21.07	13.51	153.54	5.74	1.78
δ^2_e	1.99	5.02	112.63	4.88	1.08
δ^2_{ph}	23.07	18.53	266.17	10.62	2.86
GCV (%)	10.00	7.29	14.85	15.96	44.18
PCV (%)	10.46	8.54	19.55	21.71	56.00
H_{BS} (%)	91.33	72.91	57.68	54.05	62.24
GA (%)	19.68	10.96	19.85	20.65	61.34
		2008 Intercrop soybean			
Range	38.00 – 54.00	26.00 – 72.43	37.67 – 116.70	9.90 – 18.80	1.61 – 3.85
Mean	44.65	43.59	69.87	12.88	2.73
δ^2_g	10.99	85.75	197.78	2.88	0.36
δ^2_e	2.56	55.59	443.63	2.98	0.38
δ^2_{ph}	13.55	141.34	641.41	5.85	0.74
GCV (%)	7.43	21.24	20.13	13.93	21.89
PCV(%)	8.24	27.27	36.25	18.89	31.48
H_{BS} (%)	81.11	60.67	30.84	49.23	48.65
GA (%)	11.77	29.12	19.67	17.21	26.98

Table 6. Mean performance of intercrop soybean as a percentage (%) of sole soybean

Year	Days to flowering	Plant height at maturity	Number of pods/plant	100 – seed weight	Grain yield
2006	97.58	84.89	55.05	86.62	89.93
2008	97.23	86.45	83.72	85.81	90.40

5. CONCLUSION

A faster progress in selection will be achieved in the sole soybean in view of the higher heritability estimate and genetic advance observed for almost all the traits in both years compared to intercrop soybean. The sole soybean should be adopted in the selection of soybean genotypes for soybean/celosia intercrop system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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