GENETIC VARIABILITY IN PLANT TYPES' OF SORGHUM {*Sorghum bicolor* (L.) MOENCH) DERIVED FROM GAMMA-RAY IRRADIATION

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ABSTRACT

Variability was created in an improved sorghum variety SK 5912 using gamma-ray irradiation (Cobalt source) ^{60}Co. The Mo seeds were advanced to M_y and from the M_3 family selections were made of 34 lines based on medium height, disease free plants and good yields. These were advanced to M_4 family lines. The M_4 families were harvested and threshed and were divided into three equal portions for evaluation. The materials were evaluated in the Institute for Agricultural Research Farms for three years (1989, 1990 and 1991). The objective was to determine the variations resulting from the gamma-ray irradiation using the multivariate analysis procedure of factor analysis. Fhenotypic correlations were computed for the individual and combined years using the component, of variance and convariances. Principal component analysis , procedure was used to extract factors (TC) that account for the variations in the plant types of sorghum using the twenty two characters evaluated. In 1989 non-reproductive structures (II) photosynthetic) accounted for 5.75% of the total variations in F,, I" leaf sheath, T^d intcrnode length, accounted for 2.24% of the total variation in F_2. In 1990, the same non-reproductive structures (12) accounted for 5.51% of the total variations in F,, and only the lengths of leaf blades accounted for 2.72% of the variations in F_2. In 1991 the lengths of five internodes accounted for 2. 75% of variation in F, while only lengtlis of the four leaf blades accounted for 2.25% of variations in F_2. In the combined component analysis lengths of five internodes accounted for 4.96% of the total variation in F,, while lengtlis of three leaf blades, grain wt/spikelet and Days to 50% flowering accounted for 2.60% of the variation in F_2. These results are useful in identifying the characters that give much variations and are correlated to the yield attributes, to be selected for in order to improve yield in the plant types, using recurrent selection procedure.

Keywords: Gamina-ray, irradiation, plant types, principal components

INTRODUCTION

Sorghum is one of the most important cereal crops in the semi-arid countries in West and Central Africa and is the basic staple food for human consumption. The estimated sorghum production in West and Central Africa by the year 2005 is put at about 14 MT (FAO/ICRISAT, 1996); while the corresponding population growth rate in the region is 2.9% per year. In West and Central Africa region as a whole, production grew at an annual rate of 1.76% with cultivated area growth contributing 72% of the total growth in production. The demand for cereals in West Africa calls for an increase in production of sorghum, one of the major cereals grown on the continent (FAO/ICRISAT, 1996). Breeding high yielding, disease and pests resistant cultivars is one approach to resolving cereal grain deficits. Effective utilization of variability in available lines in breeding progrmmes will enhance the development of new varieties with acceptable qualities acceptable to the end users. Sorghum populations grow in various environments, and therefore qualities have to adjust to many ecological niches. Correlation and principal component analysis have been used to assess similarities among mutant lines of sorghum irradiated with gamma-ray using cobalt sixty source (^{60}Co).

The objective of this, study was to evaluate the genetic diversity that arises due to irradiation so that such diverse lines and those with complementary characters can be used in recurrent selection procedure to develop new varieties.

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MATERIALS AND METHODS

An improved sorghum variety widely adopted in Nigeria, SK 5912 (short kaura) used for food and industrial purposes was irradiated using gamma-ray from cobalt source (^{60}Co).

The M_0 seeds were advanced to M_2, where ninety (90) family lines were selected based on medium height, disease and insect free plants and high yielding potential. The ninety family lines were advanced to M_3 where 34 family lines were again selected using the same criteria as above. The 34 family lines were advanced to M_4.

The 34 M_4 family lines were evaluated in the Institute for Agricultural Research Farms in Samaru for three years. The randomized complete block design (RCBD) was used, with four 6 m long row plots (net) and four replications. All trials were hand planted at a distance of 2.5 cm between plants and 75 cm between rows.

Sixty-four (64) kg N/ha was split applied at three weeks and six weeks after planting. Thirty-two (32) kg P_2O_5 was applied before ridging as single dose. Plants were thinned to two plants per hill at three weeks after sowing, weeds were controlled by hand weeding as necessary. Data was collected on ten randomly selected plants in each plot. Observations were made on 22 agronomic traits. A combined analysis of variance was conducted based on the means of ten plants. The year X entry interaction was used to test the entry effects. The phenotypic correlation between characters X and Y was calculated according to Singh and Choudhoury (1977),

$$r(X_1X_2) = \frac{COV\ X_1X_2}{\sqrt{V(X_1).V(X_2)}}$$

Principal component analysis was used to further study the traits of family lines according to Kendal (1961) procedure to see those concerned with explaining the variance-covariance structure through a few linear combinations of the original variables.

RESULTS

The analysis of variance for the individual years is given in Table 1. All the entries showed highly significant (0.01) means squares for all characters in 1989, except of spikelet which was not significant.

In 1990 the results followed a similar trend as in the previous year with all the characters giving highly significant means squares while width of spikelet was also non-significant. Similar results were obtained in 1991 as was the case in the two previous years (1989 and 1990). In the combined analysis, all traits also gave highly significant (0.01) mean squares except for width of spikelet that was non-significant. The year X entry interaction was highly significant (0.01) except for width of spikelet that was non-significant.

Variance components

Seven of the characters, grain weight per spikelet, spikelet number per panicle, length of 2nd, 3rd and 4th leaf blades, and lengths of 1st and 2nd leaf sheaths had genotypic variances of 124.14, 195.33, 23.87, 23.45, 22.75, 18.39 and 15.93, respectively while fifteen characters had genotypic variances below 10. Only three characters, protein percent, grain weight per spikelet and length of spikelet had phenotypic variances below 10 (2.26, 0.49 and 4.57, respectively, while eighteen characters had phenotypic variances above 10, with grain weight per plant, spikelet number per panicle length of 1st, 2nd, 3rd and 4th leaf blades giving high phenotypic variances (652.39, 725.28, 154.33, 69.56, 89.75, 59.80 and 81.91, respectively).

Error variances were high for grain weight plant, spikelet number per panicle and lengths of 1st, 2nd and 4th leaf blades and leaf angle in degrees (528.30, 529.90, 65.70, 65.70, 58.30 and 126.70, respectively).

Genotype X year interaction variances were high for grain weight per plant and spikelet number per panicle (54.39 and 47.48 respectively). Most other characters had low (>10.0) interaction variances.

Principal component analysis

This procedure grouped the twenty two (22) characters into twenty two components with eighteen values lying between 0.01 to 4.96. By considering only the seven components with eighteen value greater than 1.00, more than 68% of the total variation could be explained (Table 4). The first principal component (F_1) accounted for 22.56% of the total variation and it is equally associated with lengths of 1st, 2nd, 3rd and 4th leaf sheath and lengths of 1st, 2nd, 3rd and 4th internodes. F_2 consisted mainly of grain weight/spikelet, Days to 50% flowering, length of spikelet, lengths of 1st, 2nd and 3rd leaf blades and accounted for 11.85% of the total variation. The F_3 which accounted for 10.02% of the total variation is consisted of lengths of 1st, 2nd and 3rd leaf blades. The fourth component F_4, consisted only length of 4th leaf blade which is unique and accounted for 6.76% of the total variation. The F_5 consisted of grain weight/plant, length of panicle and spikelet number/panicle which equally accounted for 6.29% of the total variation. The 6th (F_6) component consisted of only protein percentage, which is also unique and it accounted for 5.74% of the total variations. And lastly the seventh component (F_7) accounts for 1.10% of the total variation made up by only grain weight/spikelet.

Table 1. Mean squares for 22 characters of 35 plant types of sorghum in 1989, 1990 and 1991

Sources of variation	Df	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
													1989										
Reps	3																						
Entries	34	344.33	922.0**	33.4**	1011.5**	0.45**	40.9**	6.3**	0.004	74.5**	50.5**	96.6**	121.9**	114.9**	87.9**	48.6**	32.9**	28.6**	37.9**	43.9**	49.4**	55.3**	[illegible]
Error	102	1390.59	976.8	12.5	7333.3	0.29	3.1	2.6	0.003	68.2	35.3	34.2	54.2	31.4	26.0	16.1	12.5	11.0	6.7	6.0	7.5	4.9	[illegible]
													1990										
Reps	3																						
Entries	34	346.4	762.6**	41.2**	1157.2**	0.7**	34.3**	10.5**	0.003	131.4**	111.1**	74.9**	97.4**	19.3**	18.1	14.7**	43.6**	13.5**	16.5**	14.6**	12.9**	10.8**	[illegible]
Error	102	1390.4	565.76	9.1	578.0	0.4	13.8	1.6	0.002	105.5	75.5	67.4	90.9	6.7	9.6	10.4	17.3	5.3	5.2	7.0	8.7	8.2	[illegible]
													1991										
Reps	3																						
Entries	34	346.3	831.8**	9.3**	582.5**	0.7**	7.2**	3.6**	0.002	42.1**	128.4**	162.2**	83.0**	36.8**	41.7**	21.1**	11.2**	18.1**	3.9**	3.1**	4.7**	5.4**	[illegible]
Error	102	1390.4	376.6	7.7	376.6	0.5	4.2	1.9	0.003	8.9	7.1	7.1	30.4	18.3	6.3	5.1	4.4	7.4	3.7	1.8	2.8	2.5	[illegible]

*, ** significant at 5% and 1% probability, respectively.

I
1. Protein percent
2. Grain weight per plant
3. Length of panicle
4. Spikelet number per panicle
5. Grain weight per spikelet
6. Days to 50% flowering
7. Length of spikelet
8. Width of spikelet

II
9. Length of first leaf blade
10. Length of second leaf blade
11. Length of third leaf blade
12. Length of fourth leaf blade
13. Length of first leaf sheath
14. Length of second leaf sheath
15. Length of third leaf sheath
16. Length of fourth leaf sheath

III
17. Length of firstt internode
18. Length of second internode
19. Length of third internode
20. Length of fourth internode
21. Length of fifth internode
22. Leaf angle in degrees.

Table 2. Mean squares for 22 characters of 345 plant types of sorghum for the combined years 1989, 1990 and 1991

Sources of variation	Df	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Reps x yr																							
Entries	34	76.0**	1024.8**	744.6**	1311.3**	0.66**	7071.7**	13.9**	0.005	81.1**	134.1**	130.2**	149.3**	95.9**	79.7**	34.9**	32.2**	30.2**	35.6**	35.2**	32.6**	38.9**	188.9*
Ent x yr	68	4.8**	45.8**	19.7**	719.9**	0.64**	33.1**	3.2**	0.003	83.5**	77.9**	106.8**	76.6**	37.5**	34.0**	24.7**	23.3**	14.9**	11.5**	13.2**	17.3**	16.1**	126.7*
Error	312	0.5	528.3	10.0	529.9	0.4	7.1	2.1	0.003	65.7	65.7	36.4	58.3	20.5	16.1	12.1	14.0	9.3	5.6	5.2	6.6	5.2	142.8
Total	419																						

*, ** significant at 5% and 1% probability, respectively.

I

1. Protein percent
2. Grain weight per plant
3. Length of panicle
4. Spikelet number per panicle
5. Grain weight per spikelet
6. Days to 50% flowering

II

7. Length of spikelet
8. Width of spikelet
9. Length at 1st leaf blade
10. Length at 2nd leaf blade
11. Length at 3rd leaf blade
12. Length at 4th leaf blade
13. Length at 1st leaf sheath
14. Length at 2nd leaf sheath
15. Length at 3rd leaf sheath
16. Length at 3rd leaf sheath

III

17. Length at 1st internode
18. Length at 2nd internode
19. Length at 3rd internode
20. Length at 4th internode
21. Length of 5th internode
22. Leaf angle in degrees.

Table 3. The genotypic (σ^2 g), phenotypic (σ^2 ph) and error variance (σ^2 e) estimates of 22 characters of plant types grown in three years (1989, 1990 and 1991) combined

Character	(σ^2 g)	(σ^2 ph)	(σ^2 e)	(σ^2 gy)
Protein percent (%)	1.76	2.26	0.50	1.06
Grain weight/plant	124.14	652.39	528.30	54.391
Length of panicle	8.68	18.68	10.00	2.40
Spikelet number/panicle	195.33	725.28	529.90	47.48
Grain weight/spikelet	0.058	0.49	0.40	0.05
Days to 50% flowering	6.49	13.60	7.10	0.49
Length of spikelet	2.48	4.57	2.10	0.28
Width of spikelet	0.0004	0.003	0.003	0.003
Length of first leaf blade	3.85	69.56	65.70	4.44
Length of second leaf blade	23.87	89.57	65.70	9.84
Length of third leaf blade	23.45	59.80	36.40	17.61
Length of fourth leaf blade	22.75	81.01	58.30	4.57
Length of first leaf sheath	18.39	39.39	20.50	4.23
Length of second leaf sheath	15.93	31.97	16.10	4.49
Length of third leaf sheath	5.72	17.83	12.10	3.15
Length of fourth leaf sheath	4.54	18.56	14.00	2.31
Length of first leaf internode	5.22	14.53	9.30	1.41
Length of second leaf internode	7.49	13.12	5.60	1.45
Length of third leaf internode	7.48	12.72	5.24	1.99
Length of fourth leaf internode	6.57	13.25	6.60	2.67
Length of fifth leaf internode	8.45	13.65	5.20	2.73
Leaf angle in degrees	11.54	154.33	126.70	- 4.27

DISCUSSION

There was highly significant effect for 21 of the 22 characters measured. Thus, is indicating large diversities in the traits studied. This is useful information for any breeding programme which requires high variability within the traits for effective improvement of any the of them. There were also highly significant year X entry effect for all the characters except for width of spikelet. This is indicating that the number of years used for evaluating the lines was adequate for measuring the genetic diversity among the lines, which is similar to the results obtained by Quendeba *et al.* (1996) when he evaluated some West African millet landraces. The low genetic variation observed with the width of spikelet might be due to similar values obtained for the trait in most of the measurements resulting in non-significant differences in value or due to large error variance which might be close to the g x e variance (Opeke and Fakorede, 1986). The large variability in the mutant family lines evaluated for most of the traits is also indicative that it wold be possible to develop improved cultivars directly from these lines (Quendeba *et al.*, 1996).

Genotypic variances were high for grain weight/plant, spikelet number/panicle, which are yield components. This shows that there is promise in improving yield using these mutant family lines, and confirming the results of the analysis of variance. Similarly, high phenotypic, error and genotype X year interaction variances were also observed for the same traits. The high phenotypic variances obtained indicate that the traits were influenced by changes in the years during evaluation, suggesting that such traits should be selected for in specific years when they perform well (Allard and Bardshow 1964 and Aba, 1998). These traits also include length of 1st, 2nd, 3rd and 4th leaf blades and yield components.

Results from principal component analysis showed that all the vegetative structures were grouped together in the first (F_1) factor. where they accounted for 22.56% of the total variation of 68%. This is suggesting that they could be selected for along side the yield components if they are positively correlated. The second component (F_2) was made up with grain weight/spikelet, Days to 50% flowering, and length of spikelet and lengths of 1st, 2nd and 3rd leaf blades, (non-reproductive structures) accounting for 11.85% of the total variation. These traits could be selected for, together, towards improving yield. The third (F_3) and fourth (F_4) components which accounted for 10.02 and 6.76% (or 16.78%) of the total variation is made up with non-reproductive structures again, which sows that they are very important variables to be used during any improvement programme using these family lines. Components, five (F_5) and six (F_6) accounted for 6.29 and 5.74% variability, equally made up with grain weight/plant, length of panicle, spikelet number/panicle and protein percentage respectively.

Table 4. Principal components (F) for the combined three (3) years data

Test	F1	F2	F3	F4	F5	F6	F7	C²
1	0.017	0.087	0.195	0.020	-0.011	0.688	-0.029	0.521
2	-0.112	0.191	0.096	0.315	0.644	-0.216	0.332	0.729
3	0.142	0.121	0.219	0.046	0.423	0.451	-0.192	0.654
4	-0.194	-0.152	0.356	0.175	0.488	-0.351	-0.241	0.578
5	-0.161	0.434	-0.247	0.380	0.184	-0.083	0.520	0.730
6	-0.453	0.551	-0.022	-0.464	-0.031	0.051	0.125	0.742
7	0.333	0.442	-0.029	-0.046	0.309	-0.537	0.108	0.705
8	-0.005	0.157	0.162	0.183	0.200	-0.123	-0.200	0.179
9	-0.176	0.429	0.639	-0.322	-0.000	-0.133	-0.034	0.750
10	0.022	0.669	0.500	0.052	-0.188	-0.026	-0.020	0.738
11	0.185	0.449	0.463	0.338	-0.345	+0.043	-0.127	0.703
12	0.364	0.347	0.181	0.565	-0.293	-0.004	-0.154	0.714
13	0.691	-0.472	0.041	0.361	-0.019	+0.002	-0.008	0.833
14	0.748	-0.363	0.299	0.040	0.047	-0.022	0.168	0.813
15	0.710	-0.300	0.360	-0.075	-0.112	-0.003	0.323	0.846
16	0.589	-0.078	0.374	-0.277	-0.057	+0.064	0.445	0.775
17	0.594	0.181	-0.292	-0.040	0.082	-0.069	-0.289	0.791
18	0.685	0.303	-0.323	-0.082	0.088	-0.170	-0.204	0.736
19	0.700	0.307	-0.270	-0.158	0.103	-0.200	-0.071	0.681
20	0.705	0.216	-0.231	-0.179	0.043	-0.220	-0.039	0.639
21	0.704	0.240	-0.186	-0.176	-0.002	-0.125	0.067	0.639
22	-0.101	0.295	-0.526	0.333	-0.312	-0.037	0.235	0.620
Eigen value	4.963	2.608	2.204	1.488	1.384	1.264	1.105	=15.0154
Total var.	22.560	11.850	10.020	6.760	6.290	5.740		
Common var	33.05	17.37	14.67	9.90	9.22	8.22	7.36	=100.00

A significant amount of genetic diversity was observed in most traits in the 34 mutant family lines evaluated. These results would be useful in any breeding programme to improve productivity in the sorghum mutant lines. The diversity could be effectively manipulated using recurrent selection method to develop improved cultivars and composites.

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