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Selection for seedling traits and its relationship to vigour and grain yield in sorghum (*Sorghum bicolor* (L) Moench)

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Sorghum, selection, coleopitle length, vigour, grain yield

1 SUMMARY

Ten Sorghum genotypes were germinated in the laboratory to assess variation in root and coleoptile lengths and its effect on vigour and grain yield. Selections were made for long and short root as well as long and short coleoptile. The selected plants were transferred to the screen house and maintained for three weeks after which they were transplanted to the field in a Randomized Complete Block Design (RCBD) with three replications during the 2007 and 2008 cropping season. The seedlings were visually scored for vigour two weeks after transplanting. Mean root and coleoptiles lengths varied significantly (P < 0.01) among the genotypes used. Cultivar Samsorg14 was significantly longer in root and coleoptile lengths (11.59cm and 4.52cm) than the rest of the genotypes. Among selections for long root (LR) and long coleoptiles (LC), samsorg40 and samsorg41 consistently had the shortest root (6.79cm, 5.50cm) and coleoptile(2.17cm,1.47cm) lengths. The field performance of the sub-populations revealed highly significant differences among cultivars SSV20018 and SSV20021 for vigour. In both cases, the long root sub-populations had the highest vigour. Long coleoptile was highly significantly correlated with vigour(R=0.98, 0.78) and grain yield (0.77, 0.69) both phenotypically and genotypically.

2 INTRODUCTION

Sorghum is a staple cereal in the diets of over 750 million people in Africa and India to whom it provides the bulk of the dietary energy and protein (Aribisala, 1989). Sorghum also contributes more energy and digestible protein in the diets of the majority of people in the sub-Saharan regions than those obtained from roots and tuber crops (Aba *et al.*2004). It is prepared as food and drinks, including unleavened or leavened bread, thick porridge ("Tuwo"), thin porridge ("Ogi" or "Akamu"), boiled or steamed cooked grains eaten with seasonings and spices, alcoholic drinks (e.g. "Burukutu", "Pito") and non alcoholic drinks ("Kunu") (Nwasike, 1987). The leaves and stalk are used as livestock feed and the stalk mainly for fencing, as fuel, or for making basket and huts in Northern Nigeria, among other uses (Aluko and Olugbemi, 1990). The emerging principal uses of sorghum as an industrial raw material include the production of biscuits and confectionery, beverages, weaning food, feeds and as malted drinks (Aribisala, 1989).Sorghum is recommended for infants, pregnant and lactating mothers, the elderly and convalescents (Obilana,2005). Grits, flour, cakes, wax, syrups, starch and meals from sorghum are now common items in the markets (Abu, 2008)

A number of factors affecting sorghum production have been identified. In arid and semi –arid areas where soils are often infertile and form crust after the rainy periods, seedling emergence is hampered resulting in poor stands and low yields (M'Ragwa *et a*l., 1995). Crop varieties with early seedling vigour and good establishment tend to maximize use of available soil water resulting in improved grain yield. Townley-Smith (1989) suggested that selection for a vigorous and deep penetrating root system on the basis of root length could be an easy way of selecting for drought resistance. Sunderman (1984) suggested that selection of lines with long coleoptiles in the laboratory would be an effective way of obtaining lines with better emergence.

Information on the variability for seedling root and coleoptile lengths and its effect on vigour is a useful tool in a breeding program since early vigour is considered an essential component of crop plant development under most environmental conditions (Ludlow and Muchow, 1990). This study was therefore initiated to select and determine the variation in seedling root and coleoptile lengths and to investigate the relationship between seedling traits and vigour as well as final grain yield.

3.0 MATERIALS AND METHODS

3.1 Study site: The experiments were conducted in the laboratory, green house and at the experimental farm of the Institute for Agricultural Research, Samaru, Zaria during the 2007 and 2008 cropping season of July-November,Southern guinea Savannah of Nigeria,11^0 11' N, 07^0 38' E, 686m above sea level.Samaru soils are mainly Affisols (Vallette and Ibanga,2004 Rev eds.).Periodic analyses of the soils indicated that these soils were sandy loam in texture with PH of 6.1and 6.0 in water for 2007 and 2008.Annual average rainfall of 219mm and 215mm, average relative humidity at 1600h of 80.9 and78.7%,average minimum temperature of 20.7^{0}c and 22^{0}c and average sunshine hours of 5.8 and6.1h were the environmental conditions for 2007 and 2008.About 50% of total area devoted to cereal crops in this region is occupied by sorghum. The area estimated at 6.68million hectares extend northwards from Lat8^{0}N to Lat14^{0}N(Aba *et al*, 2004).In 1978,total production was estimated at 4.8million tons(Obilana,1981).This figure has risen to about 7.0 tons annually(Obilana,2005).

3.2 Seed preparation: The planting materials consisted of ten sorghum genotypes. Five of these were released by the international Crop Research Institute for Sem Arid Tropics(ICRISAT-lines) and the remaining five were obtained from Institute for Agricultural Research(IAR)Samaru, Zaria, through selection from local collections of 'Kaura' developed through mutation breeding, pedigree or pure line selection. The seeds were in store for only a year. They were selected because brewers use them to produce affordable beers and high food value (malting and baking quality). Furthermore some these varieties especially samsorg40 and 41 have over the years showed poor vigour even though they were extensively cultivated by Nigerian farmers. Before seeding, the seeds were surface sterilized by dipping in 0.6% sodium hypochlorite for 1-2minutes and rinsed several times with distilled water. One hundred seeds were planted in sand trays spaced at 1-cm interval at 2-cm depth and watered daily. Separate trays for separate varieties were used but the soil and the condition under which they were planted were the same. After germination on the third day, seedling roots were carefully separated from the soil by removing the sand from the roots and coleoptile lengths were measured using a ruler. The length of each seedling root was measured.

Coleoptile length was measured between the scutellum and apex of the plumule. Selection was then carried out for seedling root while ignoring the length of the coleoptiles on one hand and on the other hand, sorting was made into long and short coleoptile while ignoring the root lengths. The sorting was done for each genotype. There were five sub-populations, long root (LR), short root (SR), long coleoptile (LC), short coleoptile (SC) and the unselected (US).

Figure 1: Seedling root and coleoptile sorted into long and short

Figure 2: Coleoptile length measured from scutellum and apex of the plumule

The derived sub-populations were planted in plastic containers filled with moist sand, labeled and placed in the green house for three weeks. The selected sub-populations were planted in the field in a Randomized Complete Block Design (RCBD) with three replications. Two row plots, 3.5m long with 0.75m and 0.30m inter and intra-row spacing, respectively, were used for each selected population. Fertilization and other standard cultural practices for sorghum production were carried out as recommended.

3.3 Data collection and analysis: Data on vigour was based on vigour scores on a scale of 1 (most vigorous) to 9 (least vigorous) two weeks after transplanting to the field.

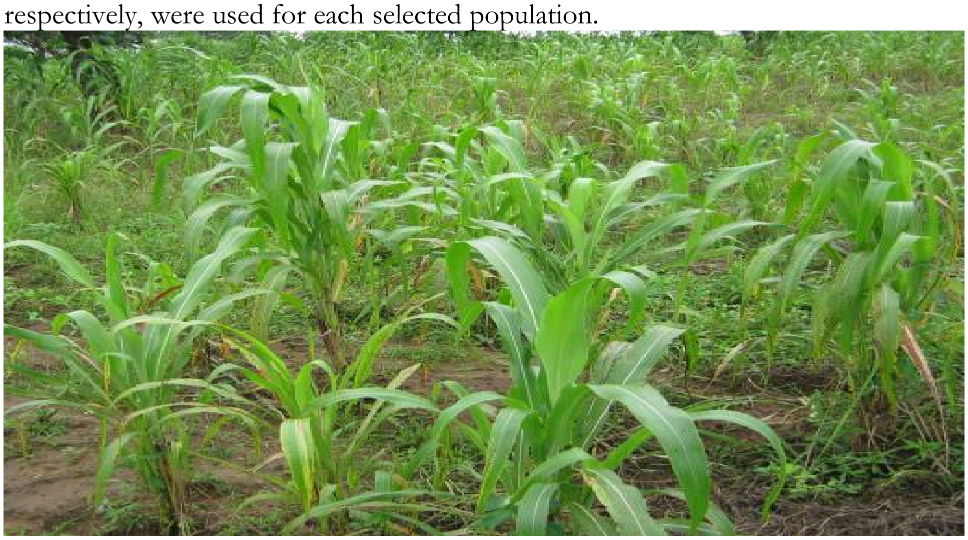

Figure 3: variation in field performance of ten sorghum genotypes scored visually based on vigour

Five plants in each sub population were tagged randomly and data on grain yield (weight of grain yield per plot and expressed in kg/ha) was obtained. The general statistical procedure for analyzing the variability followed Shivaji and Gritton (1978). The linear statistical model used for analysis was:

$$X_{ijk} = \mu + G_{ij} + R_j + E_{ijk}$$

Where;

X_{ijk} = K^{th} performance of i^{th} entry in j^{th} replication

μ = Overall mean

G_{ij} = effect of the j^{th} replication

E_{ijk} = random experimental error

i= 1, 2, 3 . . . 5 (sub population)

j = 1, 2, 3 (replications)

4 RESULTS AND DISCUSSION

The analysis of variance for seedling root and coleoptile lengths selected as long and short in the laboratory is presented in Table 1. Highly significant differences were recorded among the genotypes used. Mean root and coleoptile lengths varied significantly among the genotypes (Table 2). Among the selection for long root (LR), samsorg14 was significantly longer than the remaining genotypes. The shortest seedling root length was recorded for Samsorg40 and Samsorg41. Among the short root (SR), NRL -2, Samsorg40 and 41 had the shortest roots (3.69cm,3.91cm and 3.95cm) respectively.

Table 1: Mean squares estimates of analysis for root and coleoptile lengths of Nigerian sorghum varieties' seedlings germinated in the laboratory.

Source	df	Long root	Short root	Long coleoptile	Short coleoptile	Unselected
Replication	2	0.016	.003	.296	.001	.005
Genotypes	9	6.50**	3.76	2.43	.168	1.016
Genotypes x **year**	9	0.39	.056	.12	.013	.72
Error	18	0.095	.086	.018	.016	.013

** =Significant at p=0.01% level of probability

Significant variation was also observed for mean coleoptile lengths. Samsorg14 had the longest coleoptile among selection for long coleoptiles. In the selection for short coleoptile (SC), Samsorg41 had the shortest coleoptile (0.63cm). This highly significant variation in mean root and coleoptile lengths observed among the genotypes suggest that with its extensive root lengths, improved seedling vigour can be achieved especially if Samsorg14 is crossed with other genotypes. The small / short seedling root and coleoptile lengths recorded for Samsorg40 and Samsorg41may be responsible for their poor vigour and emergence problems.

Table 2: Mean root and coleoptile lengths (cm) of ten Nigerian sorghum genotypes.

Genotype	Long root (cm)	Short root (cm)	Long coleoptile(cm)	Short coleoptile (cm)
Samsorg 3	9.38[b]	4.93[b]	2.92[c]	1.20[ab]
Samsorg 14	11.59[a]	6.11[a]	4.52[a]	1.39[a]
Samsorg 17	8.82[c]	6.12[a]	2.55[d]	0.88[d]
Samsorg 40	6.79[e]	3.91[cd]	2.17[f]	1.03[bc]
Samsorg 41	5.5ef	3.95[cd]	1.47[g]	0.63[d]
SSV20016	6.96[e]	5.26[b]	3.23[b]	1.03[bc]
SSV20018	8.73[c]	4.27[c]	3.20[b]	1.09[bc]
SSV20021	9.37[b]	4.10[c]	2.94[c]	1.00[bc]
NRL 2	8.19[d]	3.69[d]	2.32[ef]	0.91[cd]
NRL 3	9.84[b]	5.27[b]	2.40[de]	0.95[bc]
SE ±	0.23	0.91	0.08	0.13
CV%	2.6	4.03	3.04	12.82

Means with the same letters in a column are not significantly different from each other at P=0.05.

The field performance of the selected sub-population with respect to vigour and grain yield is presented in Table 3. Significant differences were observed among cultivars SSv20018 and SSv20021.
This result revealed that improved vigour and early stand establishment can be attained through selection for longer root and coleoptiles. The populations selected for long root have higher vigour than the short root sub – populations but, were statistically not significant, however, it is worthy of consideration particularly in a breeding programme. Selection for long root or long coleoptile translated into slightly higher grain yield in all the genotypes. Although the differences in grain yield were not statistically significant, from the farmer's point of view, this is highly valuable. In Samsorg40 and Samsorg41, the sub- populations were not significantly different from each other in vigour and grain yield, but the long seedling traits resulted into the highest vigour and grain yield compared to the rest of the populations, suggesting that longer seedling traits were important for achieving higher vigour and grain yield.
Phenotypic correlation coefficient between long root and vigour was highly significant(0.77) p=0.01 (Table 4).Correlation of vigour, grain yield with short root was non- significant. The highly significant genetic correlation detected between long root and vigour (0.76), grain yield (0.88) suggests that genetic factors were responsible for those associations hence long root trait must be considered when selecting for improved vigour. Long coleoptiles had a highly significant (P = 0.01) genotypic and phenotypic correlation with vigour and grain yield. This implies that opportunity exist to improve these components through selection for long coleoptiles.

Table 3: Mean performance on the field of ten Nigerian sorghum genotype selected for superior root and coleoptiles lengths.

Genotypes	Sub-Population	Vigour	Grain yield kg/ ha
Samsorg 3	LR	5.50	1826.67
	SR	6.50	1539.05
	LC	4.50	1627.30
	SC	6.50	1429.21
	US	6.00	1533.33
Samsorg 14	LR	4.50	2786.039
	SR	5.24	2437.469
	LC	4.24	2572.709
	SC	5.0	2128.23 ab
	US	4.75	2021.59ab
Samsorg 17	LR	4.00	2005.719
	SR	6.25	1643.17ab
	LC	4.75	1933.97 a
	SC	5.50	1526.35 ab
	US	8.75	1598.10ab
Samsorg 40	LR	4.75	759.36
	SR	6.75	659.05
	LC	4.50	732.70
	SC	7.50	677.4
	US	6.50	669.21
Samsorg 41	LR	3.00	798.23
	SR	4.00	645.71
	LC	3.50	711.75
	SC	5.00	695.24
	US	5.50	673.02
SSV20016	LR	4.00	2457.14
	SR	6.25	2355.56
	LC	4.75	2438.10
	SC	5.50	2158.73

	US	5.75	2069.84
SSV20021	LR	3.35 [a]	3930.16
	SR	6.50[b]	2692.06
	LC	3.75a	2761.90
	SC	5.00[ab]	2603.17
	US	5.00[ab]	2196.83
NRL	LR	4.75	1358.73
	SR	5.00	1138.41
	LC	4.30	1584.74
	SC	4.75	1314.92
	US	6.50	1294.60
NRL3	LR	4.50	1574.60
	SR	4.50	1288.89
	LC	4.25	1314.29
	SC	5.75	1104.76
	US	4.75	1231.75

Table 4: Phenotypic, genotypic and environmental correlations between seedling traits and field characters of ten Nigerian sorghum genotypes evaluated over two years.

Traits	Correlations	Long root	Short root	Long coleoptile	Short coleoptile
Vigour	rph	0.77**	0.13ns	0.98**	0.10ns
	rg	0.76**	0.15ns	0.78**	0.12ns
	re	0.14ns	0.07ns	0.17ns	-0.17ns
Days to 50% flowering.					
	rph	0.73**	0.10ns	0.87**	0.27ns
	rg	0.68**	-0.04	0.88**	0.34ns
	re	0.06ns	-0.57	0.05ns	0.15ns
Plant height (cm)					
	rph	0.82**	0.12ns	0.86**	0.02ns
	rg	0.80**	0.11ns	0.77**	0.06ns
	re	0.14ns	-0.36ns	-0.19ns	-0.03ns
Panicle length (cm)					
	rph	0.42*	0.11ns	0.50*	0.06ns
	rg	-0.26ns	0.13ns	0.52*	0.07ns
	re	0.05ns	0.06ns	0.02ns	-0.28ns
Stem girth (cm)					
	rph	0.86**	0.44ns	0.43*	0.13ns
	rg	-0.07ns	0.17ns	0.37*	-0.75**
	re	-0.05ns	0.03ns	0.12ns	0.08ns
Grain yield Kg/ha					
	rph	0.72**	0.02	0.77**	0.02ns
	rg	0.88**	0.09ns	0.69**	0.005ns
	re	0.12ns	0.005	-0.06ns	0.005ns

*, ** Significant at P = 0.05 and 0.01% level of probability respectively. ns- Not significant.

rph=phenotypic correlation, rg=genotypic correlation, re=environmental correlation

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