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Nature of Inheritance and Genetic Components of Some Agronomic Traits in Sorghum

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Abstract: Factorial mating design was used to generate twenty-five hybrids from five male sterile (A- lines) and five male fertile (R-lines) parents. Ten parents and twenty five hybrids were evaluated in a Randomised Complete Block Design replicated 3 times. Analysis of variance showed significant differences between crosses (male × female interaction) for plant height, 1000 seed weight and grain yield. High heterotic value of 692.03% for grain yield was recorded. Hybrids that exhibited high heterotic value for grain yield, likewise has high heterotic value for yield components; panicle length, panicle weight, 1000 seed weight and number of seed per panicle. Narrow sense heritability was low for seedling vigour, days to 50% bloom plant height, panicle weight, number of seed/panicle and grain yield. Moderate heritability was obtained for panicle length and 1000 seed weight, thus preponderance of non-additive gene action for all traits studied. The best all round hybrids identified from this study are MA10×NR 71143, MA10×NR71146, MA10×NR71167 and 2219A×NR71167.

Key words: Gene action, heritability, hybrid vigour, improvement

Introduction

In Nigeria sorghum is grown in the savannah agro-ecological zones, mainly under rain fed conditions. Sorghum has an annual total production of 4.8 to 6 million tones and an average yield of 800 to 1087 kg ha^{-1} on about 6 million ha of arable land. It forms the staple food for millions of people in these area, the grains are used to produce various local foods and drinks. Sorghum is likewise an important raw material in the agro-industrial sector (Nwasike, 1982; Obilana, 1983; FAO, 1985).

The ban on the importation of other cereals like wheat, rice, barley and maize by the Federal Government makes it necessary to double the present level of sorghum production to meet the agro-industrial and consumption demand (Nwasike, 1987). The ultimate goal in crop improvement programme is to evolve cultivars that perform better than the existing ones. Heterosis is the main attention in hybridisation and hybridisation is one of the methods in crop improvement programme. Heterosis is the manifestation of vigour or fertility by crossing inbreeds, so the F_1 hybrids fall outside the range of the better parent. Numerous researchers like Quinby (1963), Rao (1979), Girko (1985), Kimbeng (1990) and Yeye and Showemimo (2002) have recorded this phenomenon in sorghum and pearl millet.

Generally, heritability is defined as the proportion of the observed total variability that is genetic. Biometrically it is a ratio of two components namely: genetic variance (δ^2_g) which is numerator and phenotypic variance (δ^2_{ph}) the denominator (Obilana and Fakorede, 1981). Differences occur between individuals of species in the expression of a particular trait. Such difference whether they arise mainly from genetic make up of individual or are due to environmental effects can be termed heritability. There are 2 main types of heritability: Broad and Narrow sense heritability, narrow sense heritability was

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used in this study because it determines the degree of resemblance between relatives and expresses its predictive advantage, thus the reliability of the phenotypic value as a measure of the breeding value in selection and improvement programmes (Jan-Orn, 1973; Falconer, 1981; Spavakov, 1988; Showemimo and Nwasike, 1996). Genetic components of variance give an indication of the gene effect controlling the trait of study, thus genetic information is important for crop improvement (Yeye and Showemimo, 2002; Showemimo, 2003, 2004).

The present study was designed to provide helpful genetic information in identifying varieties or hybrids with good agronomic performance and heritable qualities that will lead into formulating an appreciable and effective breeding programme to improved yield and good agronomic performance.

Materials and Methods

Twenty five hybrids obtained from crosses between 5 restorer lines (NR 71150, 71147, 71138, 71167 and 71143) and 5 male sterile lines (MA9 MA10, 2219A, M24264A and P. 954A) using a factorial mating design as described by design II of Comstock and Robinson (1952). The F_1 hybrids and their parents were grown in Samaru in a randomised complete block design with 3 replications. Each plot consist of 4 rows, each 6.0×0.75 cm and intra-spacing of stands 0.30 m. Each plot was over planted and thinned to 2 plants per stand two weeks after planting. Recommended agronomic practices were followed to archive a successful crop production. Data were collected and analysed on 10 plants per plot, data collected includes: Seedling vigour, Days to 50% bloom, plant height, panicle length, panicle weight, 1000 seed weight, number of seeds per panicle and grain yield.

Heterosis effect was determined as increase or decrease of F_1 mean over that of the superior parent as follows:

$$H = \frac{F_1 - MSP}{MSP} \times 100$$

Where F_1 is mean performance of hybrid formed between i th and jth female parent, MSP is mean performance of superior parents of a common hybrid.

Narrow sense heritability was estimated using Grafius *et al*. (1952) formula.

$$h^2 = \frac{\delta_f^2 + \delta_m^2}{\delta_f^2 + \delta_m^2 + \delta_{mf}^2 + \delta_e^2 / r}$$

δ^2_f, δ^2_m and δ^2_{mf} are the genetic variances of female, male and male × female (hybrid) components respectively, δ^2_e is the variance due to error, while r is the number of replications.

Results

The analysis of variance (Table 1) shows significance for head weight (p = 0.05), while seedling vigour, plant height and 1000 seed weight were significant at p = 0.01 among the males. There was significant difference for plant height, days to 50% bloom and 1000 seed weight at p = 0.05 among the females. Head weight (p = 0.05) and grain yield (p = 0.01) were also significant. The crosses were significant for seedling vigour, days to 50% bloom, head length and 1000 seed weight at p = 0.05, however, plant height and grain yield were highly significant (p = 0.01).

Table 2 and 3 shows the average performance of the parents and hybrids, respectively. Hybrids 2219A × NR71167, MA9 × NR71143 and MA9 × NR71167 are the most vigorous hybrids while 2219A × NR71138 was the least vigorous cross. All crosses involving MA9 and 2426A as the female parents bloom late, MA10 × NR71147 and 2119A × NR71167 bloom early. Head length ranged

Table 1: Means squares from analysis of variance for the sorghum traits studied

Source of variation	df	Seedling vigour	Days to 50% bloom (cm)	Plant height (cm)	Head length (kg/plot)	Head weight (g)	1000 seed weight	No. of seeds/ head	Grain yield (kg ha^{-1})
Males	4	11.00**	54.10**	542.2**	14.07*	0.756	34128**	88351	699721
Females	4	2.67	18.10*	472.3*	26.16**	0.712	12.349*	215199	255738***
Males × Females (crosses)	16	6.63*	16.90*	77.3***	17.43*	0.5455	8.391*	460417	253035***
Residual	48	0.174	9.91	126.8	10.60	0.5832	6.243	657059	43091

*,**,*** Denote 0.10, 0.05 and 0.01 level of significance, respectively

Table 2: Average performance of 10 parents with respect to 8 traits

Parents	Seedling vigour	Days to 50% bloom (cm)	Plant height (cm)	Head length (kg plot^{-1})	Head weight (g)	1000 seed weight	No. of seeds/ head	Grain yield (kg ha^{-1})
MA9	2.67	71.67	109	25	1.14	17.23	1403.24	1015.56
MA10	3.33	74.67	114.33	25	0.45	13.07	920.79	867.41
2219A	2.00	77.00	91.67	24.33	0.54	16.39	1309.79	794.08
M24264A	2.33	78.00	98.00	22.67	0.34	15.93	756.91	961.48
P.954A	2.67	76.00	87.00	18.00	0.42	12.77	1059.27	1001.48
NR 71150	3.00	77.00	102.67	22.33	0.60	13.49	972.66	1210.37
NR 71147	1.67	83.00	100.33	24.33	0.27	11.11	1031.64	1052.96
NR 71138	2.00	83.00	113.00	20.33	0.60	15.95	1403.04	804.44
NR 71167	2.67	74.67	131.33	26.00	0.79	16.03	951.02	1125.18
NR 71143	3.00	74.67	124.33	20.33	1.61	20.17	1152.93	1183.70
SE	±0.82	±4.08	±6.95	±1.57	±0.28	±1.23	±59.87	±41.63
CV	27.67	7.80	21.20	19.47	30.07	31.68	33.86	34.78
LSD (0.05)	0.74	8.65	14.73	3.33	0.09	2.61	56.92	12.26

Table 3: Average performance of 25 hybrids with respect to eight traits

Hybrids	V_1	V_2	V_3 (cm)	V_4 (cm)	V_5 (kg plot^{-1})	V_6(g)	V_7	V_8 (kg ha^{-1})
MA9 ×NR71150	3.00	71.33	117	27.00	1.33	19.50	1567	905
" × " 71147	2.67	72.67	104.33	25.33	1.77	17.01	1485	1119
" × " 71138	2.67	73.67	123.00	25.33	1.32	19.67	1545	1430
" × " 71167	3.00	73.33	124.00	28.00	1.99	19.57	1867	911
" × " 71143	2.67	69.00	133.67	28.00	1.21	20.06	1387	859
MA10 × NR71150	2.33	73.33	129.33	24.33	0.40	20.84	1156	738
" × " 71147	3.33	63.33	134.33	28.33	1.71	16.50	1369	664
" × " 71138	2.33	72.33	147.67	24.67	0.97	18.71	618	976
" × " 71167	3.67	70.00	160.67	26.67	2.46	26.23	1303	2279
" × " 71143	3.67	68.67	168.33	28.00	2.29	21.00	1400	2299
2219A × NR71150	3.00	71.33	135.00	28.00	0.93	18.84	1203	904
" × " 71147	2.67	69.33	134.67	27.67	0.93	17.23	1072	867
" × " 71138	1.33	72.67	128.67	21.67	0.26	17.75	1109	938
" × " 71167	4.00	64.33	160.00	30.67	2.09	21.60	2457	2086
" × " 71143	2.00	80.00	116.67	24.00	0.93	18.87	3305	1496
24264A × NR71150	2.00	82.67	116.00	26.67	0.48	19.67	1727	563
" × " 71147	3.00	74.33	130.67	27.33	1.12	16.73	1352	853
" × " 71138	3.33	72.33	139.33	26.00	0.79	14.95	1090	796
" × " 71167	2.67	75.67	131.00	28.33	0.94	18.90	1485	893
" × " 71143	2.00	75.00	134.33	24.00	1.00	18.66	1597	425
P.954A × NR71150	2.00	73.33	119.00	22.00	0.44	17.60	848	532
" × " 71147	3.67	70.33	162.33	25.67	1.24	15.26	1298	430
" × " 71138	3.00	68.33	174.33	24.00	1.03	13.61	1204	785
" × " 71167	2.67	71.00	170.00	22.00	1.08	19.94	2229	840
" × " 71143	3.33	77.00	161.67	23.33	1.14	18.23	2217	853
SE	±1.083	±5.908	±20.66	±13.26	±0.14	±2.50	±10.6	±76.4
CV (%)	38	8.2	14.9	12.6	36	14.4	24	38.4
LSD (0.05)	2.12	11.58	40.49	25.9	0.50	4.9	588.78	286.54

V_1 = Seedling vigour, V_2 = Days to 50% bloom, V_3 = Plant height, V_4 = Head length, V_5 = Head weight, V_6 = 1000 seed weight, V_7 = No. of seeds/panicle and V_8 = Grain yield

Table 4: Heterosis of hybrids over superior parent (%SP) for all traits measure

Hybrids	V_1	V_2	V_3 (cm)	V_4(cm)	V_5 (kg plot^{-1})	V_6(gm)	V_7	V_8 (kg ha^{-1})
MA9 × NR71150	0.00	-7.36	13.96	8.00	16.62	-11.51	11.67	-1.15
" × " 71147	-19.98	-5.62	1.62	1.32	194.03	26.12	52.67	172.68
" × " 71138	-11.10	-4.32	34.18	4.11	118.41	20.01	17.96	247.56
" × " 71167	0.00	-5.99	39.33	23.51	229.52	10.30	91.95	121.99
" × " 71143	-11.10	-10.39	53.64	25.38	100.66	33.91	30.94	109.32
MA10 × NR71150	-12.53	-11.65	28.90	-2.68	-64.74	-19.69	-17.62	-19.39
" × " 71147	0.00	-20.08	33.88	13.32	291.39	26.28	32.70	80.73
" × " 71138	16.65	-12.86	61.09	1.40	78.64	14.15	-50.82	147.67
" × " 71167	57.18	-3.61	80.53	9.62	325.66	1.88	26.30	692.03
" × " 71143	37.50	-17.27	93.48	15.08	445.24	40.96	32.17	396.79
2219A × NR71150	12.49	-14.06	23.87	12.00	-18.90	9.33	-14.27	-1.26
" × " 71147	-19.98	-16.47	19.17	10.68	54.23	14.95	-23.59	-0.03
" × " 71138	-33.35	-12.45	40.37	-10.93	-56.88	8.03	-20.96	208.10
" × " 71167	71.45	-22.49	79.78	35.31	246.60	35.42	3.85	256.72
" × " 71143	-25.01	-3.61	34.10	7.48	54.23	5.77	135.56	62.92
24264A × NR71150	-25.01	10.72	6.42	2.58	-58.28	-3.27	23.07	-71.27
" × " 71147	-9.99	-0.45	14.29	5.12	42.15	4.37	42.16	62.42
" × " 71138	66.65	-6.06	51.99	0.00	-0.38	-8.79	-16.78	-43.64
" × " 71167	14.32	-2.99	47.19	8.96	18.99	5.43	56.15	127.16
" × " 71143	-25.01	-1.32	54.40	-7.69	26.58	16.41	50.76	-19.08
P.954A × NR71150	-33.33	-2.33	9.17	-12.00	-72.67	-17.71	-39.57	-61.55
" × " 71147	10.02	-5.81	41.98	2.68	-22.98	-14.44	1.53	-11.11
" × " 71138	0.00	-11.26	90.17	-1.36	-35.84	-12.71	-8.08	-43.27
" × " 71167	-11.10	-8.97	91.01	-2.94	-33.11	-16.03	110.68	-24.84
" × " 71143	11.10	1.32	85.83	14.76	-29.01	-14.14	92.29	-74.49

V_1 = Seedling vigour, V_2 = Days to 50% bloom, V_3 = Plant height, V_4 = Head length, V_5 = Head weight, V_6 = 1000 seed weight, V_7 = Number of seeds/panicle and V_8 = Grain yield

Table 5: Estimates of genetic components of variance, heritability (%) and coefficient of variation (%) for eight agronomic traits of sorghum

	Seedling vigour	Days to 50% bloom (cm)	Plant height (cm)	Head length (kg plot^{-1})	Head weight (gm)	1000 seed weight	No. of seeds/ head	Grain yield (kg ha^{-1})
δ^2_m	0.029	2.48	20.99	0.44	0.014	1.716	-24804.4	29779.066
δ^2_f	-0.026	0.08	16.33	1.249	-0.0155	0.2638	-16347.867	180.2
δ^2_{mf}	-0.170	-6.0	-66.5	-1.057	-0.0125	-0.716	-65547.33	-59291.67
δ^2_A	0.0002	0.16	2.33	0.1057	-0.0115	0.124	-2572.017	1872.45
δ^2_D	-0.170	-6.0	-66.5	-1.057	-0.0125	0.716	-65547.33	-59291.67
δ^2_A/δ^2_D	-0.0012	-0.027	-0.035	-0.0994	0.92	0.173	0.039	-0.0316
h^2(ns)	1.34	31.23	33.00	40.46	-0.83	41.45	-36.64	26.21
CV (%)	31.67	6.4	15.36	14.24	17.69	22.97	27.39	34.76

between 22 and 31 cm, more than half of the hybrids have longer panicles than their parents. MA9 × NR71150 had the least head weight (0.40 g), while MA10 × NR71167 highest seed weight (2.5 g), the parental range for head weight is 0.27-1.61 kg plot^{-1}. All the hybrids were taller than their superior parent. Hybrid 2219A × NR 71167 has the highest seed weight of 28.23 g, while the least was 13.61 g recorded for hybrids and ranged between 11.11 and 20.17 g for their parents. Three hybrids notably 2219A × NR71143, 2219A × NR71167 and P.954 × NR71167 have the highest number of seed per head. MA10 × NR 71146, MA10 × NR71167 and 2219A × NR71167 yielded over 2 tonnes which is more than any of the hybrid and their parents.

Hybrid MA10 × NR 71167 has the highest positive heterosis for grain yield while the lowest heterosis was obtained for P. 954 × NR71143 as seen in Table 4. High heterotic value of 135.56% was obtained for number of seeds/head. The highest heterotic effect for 1000 seed weight was expressed in MA10 × NR 71143. For head weight hybrid MA10 × NR71143 showed highest heterotic value of 445.24%. Heterotic value of 35.31% was recorded in hybrid 2219A × NR71167 for head weight, while hybrid MA10 × NR71143 has the highest heterotic value of 93.48% for plant height. Heterotic value of 10.72% was recorded for days to 50% bloom in M24264A × NR71150, while 71.45% was recorded in 2219A × NR 71167 for seedling vigour.

Negative heterosis was however recorded in 12 hybrids for seedling vigour in Table 4. All hybrids showed negative heterosis except one for days to 50% bloom. No negative heterosis was recorded for plant height, 6 hybrids showed negative heterosis for head length, 10 hybrids showed negative heterosis value for head weight. One thousand seed weight showed negative heterosis in 9 hybrids, while 8 hybrids showed negative heterosis for number of seeds/panicle and 12 out of the 25 hybrids showed negative heterosis for grain yield.

In Table 5 estimates of genetic components of variance, heritability and coefficient of variation were shown. The male component of variance was larger in magnitude than those for females for all the traits except for number of seeds/panicle. There was preponderance of non additive over additive component of variance for all the traits, as indicated by the δ^2_A/δ^2_D ratio. However, variance component due to average additive effect of genes were predominant for all characters except 1000 seed weight. Narrow sense heritability estimates in Table 5 were as low as -36.64% for number of seeds/head and as high as 41.45% for 1000 seed weight. Heritability estimates were moderate for grain yield (26.21%), days to 50% bloom (31.23%), plant height (33%), head length (40.46%) and 1000 seed weight (41.45%). Heritability were low for number of seed/head (-36.64%), head weight (-0.83%) and seedling vigour (1.34%).

Discussion

The 10 parents and their 25 hybrids exhibited variability in the traits studied as seen by the analysis of variance, their mean agronomic performance and coefficient of variation. Generally 80% of the hybrids performed better than their parental combination especially for yield and yield components. Thus, these sorghum entries have sufficient variability for selection and subsequent crop improvement. Nwasike and Oyejola (1989), Showemimo and Nwasike (1996), Yeye and Showemimo, (2002) reported similar observation in millet and sorghum with emphasis on quantitative and complex traits like yield and yield components.

The highest positive heterosis obtained in this study is for grain yield (692.03%) over the superior parent, it is evident that, the factors that contribute to grain yield include plant height, head length, head weight, earlier flowering, number of seeds/head and 1000 seed weight. Since hybrid that showed high heterosis for yield also showed high heterosis for these characters. Plant breeders are usually interested in the amount of heterosis that is useful in crop improvements, thus the particular hybrid that differs significantly are of ultimate importance. Such hybrids and their parents are selected for hybrid programmes (Spavakov, 1988; Kimbeng, 1990; Showemimo and Nwasike, 1996).

In this study, the hybrids that perform well based on their mean performance and heterosis includes: MA10 × NR71167 exhibited highest heterosis for grain yield; 2219A × NR71143 notably highest heterosis for 1000 seed weight, head weight and plant height; 2219A × NR71167 expressed highest heterotic value for head length and seedling vigour, while M24264A × NR71150 exhibited highest heterosis for days to 50%. It is therefore noteworthy that the best and most consistent hybrids that performed well across all the characters studied are MA10 × NR 71143, MA10 × NR71146, MA10 × NR71167 and 2219A × NR71167.

Most of the traits studied are influenced by non-additive gene effect, while characters like head length and 1000 seed weight with moderate heritability has both additive and non additive gene effect, thus, these traits are heritable and can easily selected in a crop improvement program. However, the δ^2_A/δ^2_D ratio and heritability estimates for all the traits studied are under non-additive gene effect therefore, pedigree breeding program of crop improvement that utilizes the genetic information herein will be appropriate.

In conclusion, the identification of the best hybrids that perform well across all characters studied and the much needed genetic information of the traits studied, the choice of an appropriate and efficient breeding programme for crop improvement is no longer a problem. Since heterosis and heritability are fixable, hybridization, recurrent selection or modified pedigree breeding method can be used for desired agronomic traits improvement especially for yield and yield components based on the genetic information obtained herein.

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