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Full-Length Research Paper

Combining Ability Analysis for Striga Tolerance among Pearl Millet (Pennisetum glaucum (L.) R. Br.) Inbreds in a Line × Tester Cross

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ABSTRACT: Pearl millet production has been constrained by *Striga hermonthica* in Sudan Savannah of Nigeria leading up to 10 – 95 % grain loss. Breeding for resistant hybrid would be a promising alternative for a reduction in cost of production and increased yield. The objectives of this study were to determine gene action and effects among parents and hybrid under striga. It was also to evaluate the response of pearl millet to *Striga hermonthica* and identify high yielding genotypes and hybrid under striga infestation. Twenty-nine F_1 hybrids and two checks were evaluated under Striga infestation in Bauchi and Maiduguri rainy season in a randomized complete block design. Data were collected on number of plant at emergence, days to first flowering, plant height, panicle length, number of plants at harvest, number of leaves/plant, number of panicle/plot, striga count at 90 days after sowing and grain yield. The general combining ability and specific combining ability variances were significant for most traits. The results revealed that both additive and non-additive genetic variances were important in determining the performance of the traits. However, non-additive genetic variances were preponderant than additive genetic variance in controlling the traits. The result indicated SOSAT C-88, LCIC 9702, Ex-Baga and PEO 5984 have been identified as good general combiners for some desirable traits especially for grain yield and resistance to striga. In another development, SOSAT C-88 × Ex-Monguno, LCIC 9702 × Ex-Gubio and PEO 5984 × Ex-Baga has been identified as good specific combiners for grain yield. The hybrids; SOSAT × Ex-Baga and Super SOSAT × PS202 are the best specific combiners for striga tolerance. Incidentally, the best specific combiners for striga tolerance and for grain yield were among the best grain yielders. The best parent in grain yield was Super SOSAT with 670.2 kg/ha. The best performing hybrids on the other hand were, SOSAT C88 × Ex-Monguno and SOSAT C88 × PS202 with grain yields of 591.7 and 591.2 kg/ha respectively. The superior materials identified can be used as future parents for the development of striga tolerant and high grain yielding pearl millet hybrids. There is a need however to identify suitable breeding strategy before any meaningful hybrid development programme in pearl millet for striga tolerance and better grain yield to be undertaken.

Keywords: Pearl millet, Striga, Line x tester, GCA and SCA

INTRODUCTION

Pearl millet known as *gero* in northern Nigeria is the sixth most important cereal cultivated as rain fed crop on about 26 million ha in arid and semi-arid areas of Africa and the Indian sub-continent (Atif *et al.* 2012). It is grown predominantly in Africa and Asia in over 40 countries as a staple grain and as source of feed and fuel and construction material. It has wide adaptability to local environments and grown in West Africa from the oases of the Sahara Desert under irrigation to northern Sahel under as little as 250 mm of rainfall per annum. Pearl millet can grow on hot and dry soils unfavorable to sorghum.

Its improvement program especially in Nigeria has been geared towards higher yield for human food which may likely play a major role in easing food shortage as population skyrockets. Izge, (2006) reported that the purpose for expanding pearl millet production in these regions to meet growing demand for food will depend on success of research, cultivation and hybrid development programs. Izge *et al*. (2005) reported higher potentials for making progress in the selection of desirable traits in pearl millet towards higher grain yield, because there are tremendous levels of genotypic variability existing among landraces.

Parasitic weed (*Striga hermonthica* Del. Benth.) has been a major biotic constraint among many others to pearl millet production, particularly in Northern Nigeria. The exceptional degree to which the weed damages pearl millet is one of several characteristics which make *Striga hermonthica* the most serious of all parasitic weeds (Parker and Riches, 1993). Estimated grain losses have been put between 10 - 95% depending on varietal reaction, ecology and cultural practices, Wilson *et al.* (2004). All the known methods of *Striga* control have shortcomings; conventional herbicides are prohibitive in cost and ineffective since damage is done before *Striga* emerges from the soil. Other disadvantages in the use of herbicides are pollution of environment, disturbance of ecological balance, toxicity to humans and money is spent and so there will be a drastic and massive increase in cost of production.

Measures that minimize impact on crop losses, deplete *Striga* seed bank in the soil, reduce further *Striga* seed production and diminish spread of *Striga* to farms are essential in their control. Host plant resistance or tolerance when effectively deployed offers many benefits with an insignificant increase in cost of production. The objectives of the study were therefore, to determine the combining ability variances and estimate the general combining ability effects of parents and the specific combining ability effects of hybrids under striga infestation in order to identify the mode of gene action determining resistance to striga and genotypes with good yield potential.

MATERIALS AND METHODS

Nursery trial through line × tester mating design was conducted in 2017 dry season at the Lushi Irrigation Station, Bauchi. The area is located on latitude 10° 18′ N; 9° 50′ E at an altitude of 628 m above sea level. In 2018 raining season, the 20 F_1s, and the parents were evaluated in two locations viz: Bauchi and Maiduguri. The pearl millet cultivars; PEO 5984, Super SOSAT, SOSAT C-88, Ex-Borno and LCIC 9702 were obtained from the mandate Research Institute, the Lake Chad Research Institute in Maiduguri, Nigeria. In addition, wild millet *Monodi* having Striga resistance genes was obtained from International Crop Research Institute of the Semi-Arid Tropics (ICRISAT) in Niamey. The three local ones were named Ex-Monguno, Ex-Baga, and Ex-Gubio based on the locations they were obtained from. The wild millet obtained from ICRISAT Niamey was PS202. The wild millets were used as males as well as testers. The cultivars were used as females as well as lines. The pearl millet commercials cultivars obtained from LCRI Maiduguri and ICRISAT and the wild types are described in (Table 1).

Nursery experiment was conducted during dry season of 2017 to form initial F_1 population through line × tester mating. The procedure was as described in the work of Izge, (2006). The 20 F_1 including nine parental lines were grown on a striga infested field for evaluation at Bauchi and Maiduguri, Nigeria during cropping season of 2018. The treatments were laid out in a randomized complete block design made up of three replications. Data collection was carried out on number of plants at emergence, days to first flowering, days to 100 % flowering, plant height, panicle length, number of plant at harvest, number of leaves/plant, number of panicle/plot, striga count at 90 days after sowing, 1000 grain weight and on grain yield. Data collected were analyzed using Statistical Analysis System (SAS) as described by Singh and Chaudhary (1985).

RESULTS AND DISCUSSION

The mean squares from analysis of variance across locations are presented in (Table 2). The results indicated that there were significant or highly significant differences across locations in number of panicle/plot (14941.0**) and at 90 DAS (338.1**), however all other remaining traits did not show any significant difference across locations. The result also indicated that significant or highly significant differences existed in number of plant at emergence (154.07**) and number of panicle/plot (900.55*). Number of plant at harvest was significantly different (38.9*) for line × tester interaction across locations. There was however, significant difference in number of leaves per plant (2.43*) and striga count at 90 DAS (10520.82*) in location × line × tester interaction. All other traits did not show any significant differ difference for location × line × tester interaction.

Falconer (1989) and Izge *et al*. (2005) reported similar result and found tremendous levels of genetic variability among maize and pearl millets. It is important to note that the amount of genetic improvement that can be obtained by selection among number of hybrids has been reported to be dependent on the amount of variability existing in a population. The result also indicated the influence of environment on the performance of genotypes in respect of days to first flowering, days to 100 % flowering, plant height and striga count at 90 DAS as their replication × location interaction was significant. Similar result was

Table 1: Description of cultivars and the wild lines used in the study.

Lines	Source	Description
*Ex-Borno	LCRI	Medium maturing/medium sized seeds and adapted to the Sahel region of Nigeria.
*SOSAT C-88	LCRI	Long/compacted panicle, early maturing and large seeded.
*Super SOSAT	LCRI	Long panicle and meduim maturing.
*LCIC 9702	LCRI	Long compacted panicle, early maturing and large seeded.
*PEO 5984	LCRI	Medium maturing, medium sized and compacted panicle.
Testers		
**PS 202	ICRISAT	Short and small seeded panicle, hairy, profuse tillers and Striga resistant.
*Ex-Gubio	LCRI	Medium height and small yellow-seeded panicle, profuse tillers, late maturing and tolerant to Striga.
*Ex-Baga	LCRI	Medium and small brown-seeded panicle, profuse tillers, late maturing and tolerant to Striga.
*Ex-Monguno	LCRI	Medium and small purple-seeded panicle, hairy, profuse tillers and tolerant to Striga.

Source: *LCRI Maiduguri, Nigeria, ** ICRISAT Niamey, Niger Republic.

reported by Drabo, (2016). Therefore, this set of population can be exploited for genetic improvement of pearl millet for striga tolerance and grain yield.

Analysis of variance for combining ability, estimates of genetic variance and proportional contribution to total variance at Bauchi and Maiduguri combined are presented in (Table 3). The results indicated that there was significant or highly significant difference in GCA effect for lines in number of plant at emergence (154.07**), days to first flowering (266.89**), days to 100 % flowering (277.18**) and number of plants at harvest (151.76*). The GCA variance for testers however indicated no significant difference in all traits. The lines × tester SCA effect was highly significant (33.97**) for days to first flowering. All other traits were not statistically significant.

The genetic components of variance on the other hand shows that covariance of half sib for lines was highest in grain yield (7074.21) followed by plant height (78.30) and number of panicles/plants (41.49). The covariance of half sibs for testers shows that plant height had highest value of 22.17 followed by number of panicles/plant with value of 5.42. The result also indicated that the covariance of full sib was higher in grain yield, striga count at 90 DAS, number of panicles/plant and days to first flowering, with values of 10930.62, 642.17, 105.64 and 31.09 respectively.

The combining ability variances indicated that SCA variances were higher than GCA variances in all traits, except in plant height, number of plants at harvest and grain yield indicating the preponderance of SCA or non-additive effects over GCA or additive effects in control of most of the traits.

Significant mean squares observed among parents and hybrids for different agronomic traits imply that both parents and hybrids derived from them would most likely respond to selection. The observed significance therefore could be attributable to the kind of genetic differences in the parents. The variation among hybrids could be a result of gene action. Falconer (1989) and Izge *et al*. (2005) have reported similar result and found astounding level of genetic variability among crop plants. The amount of genetic improvement that can be obtained by selection among hybrids would be dependent on the amount of variability.

The result of proportional contribution to the total variance shows that the contributions of lines were greater than for tester or line × tester in all the traits. In the same vein, the contributions of line × tester to total variance were greater than in testers in all traits. The ratio of GCA: SCA variance was less than unity for all the traits thereby indicating the preponderance of non-additive genetic effect in the expression of these traits. This result is in accordance with the findings of Bachkar *et al*. (2014) and Chittora and Patel, (2016).

The significant mean squares observed in GCA of parents and SCA of hybrids for some traits shows the importance of additive and non-additive genetic effects in their inheritance. A similar finding was reported by Azhaguvel and Jayaraman (1998). This further confirms the presence of genetic variability in the materials evaluated and it means therefore that the materials could be used for improvement in grain yield and other desirable agronomic traits.

The results for GCA effects are presented in (Table 4). Note that negative effects for days to first flowering and striga count at 90 DAS are desirable as these traits are important in breeding programmes. Significant GCA effects for these traits were also recorded by Khan and Dubey (2015) and Nandaniya *et al*. (2016).

Table 2: Mean square from a line × tester analysis of variance in traits of pearl millet across locations in 2018

Traits	DF	NPE	DFF	DHF	PLH	PNL	NLP	NPP	STC90	NPH	TGW	GRY
Source of Variation												
Location	1	880.21	1591.41	907.5	13568.13	85.01	267.01	14941.01**	86779.41**	1435.21	338.1**	207954.3
Rep. × Location	4	13.43	94.82**	83.12**	1956.36*	8.88	0.43	491.67	20140.98**	10.92	17.33	541373.9
Hybrid	19	60.39	83.55	73.14	762.32	23.57	1.39	525.5	10819.86*	58.97	37.05	59871.69
Line	4	154.07**	266.89	277.18	1430.64	27.43	1.08	900.55*	4489.35	151.76	49.67	129960.1
Tester	3	31.88	37.43	9.43	956.6	29.81	1.32	516.5	1972.82	15.54	36.25	25629.16
Line × tester	12	36.3	33.97	21.05	490.98	20.72	1.51	402.73	15141.78	38.9*	33.24	45069.52
Loc × Hybrid	19	18.96	16.99	14.78	535.08	16.78	2.36	506.11	7896.67	21.82	35.52*	33321.09
Loc × Line	4	36.73	11.01	9.48	510.2	10.36	2.97	533.82	5560.72	29.48	20.45	39830.18
Loc × Tester	3	24.23	11.25	8.9	304.73	29.1	1.28	302.94	514.7	35.83	52.01*	39522.27
Loc × Line × Tester	12	11.72	20.41	18.02	600.96	15.84	2.43*	547.67	10520.82*	15.77	36.42*	29601.1
Error	76	27.95	21	15.59	795.04	17.64	1.23	343.54	5604.1	20.04	37.15	32671.18

Key:
NPE= Number of Plants at Emergence
DFF= Days to First Flowering
DHF= Days to 100 % Flowering
PLH= Plant Height
PNL= Panicle Length
NLP= Number of Leaves/Plant
NPP= Number of Panicles/Plant
NPH= Number of Plants at Harvest
STC90= Striga Count at 90 Days after Sowing
TGW= 1000 Grain Weight
GRY= Grain Yield

Table 3: Analysis of variance, estimates of genetic variance and proportional contribution to total variance in pearl millet across locations in 2018

Source of Variation	DF	Traits										
		NPE	DFF	DHF	PLH	PNL	NLP	NPP	NPH	STC 90	TGW	GRY
Replication	2	18.78	181.76**	167.89**	6065.81**	33.63	3.005	754.30	14.07	51546.10**	1.07	600312.53**
Lines (GCA)	4	154.07**	266.89**	277.18**	1430.64	27.43	1.07	900.55	151.76*	4489.35	49.07	129960.09
Testers (GCA)	3	31.88	37.43	9.43	956.60	29.81	1.32	516.50	15.54	1972.83	36.25	25629.16
L × T (SCA)	12	36.30	33.97**	21.05	490.98	20.72	1.51	402.73	38.90	15141.78	33.24	45069.52
Error	60	20.37	13.67	11.58	969.70	16.95	1.29	275.97	17.04	5700.41	26.72	32238.35
Genetic Components of Variance												
Cov HS Lines		9.81	19.41	21.34	78.30	0.56	-0.04	41.49	9.41	-887.70	1.32	7074.21

Table 3:Contd

Cov HS Tester	-0.21	0.17	-0.55	22.17	0.43	-0.01	5.42	-1.11	-627.09	0.14	-925.73
Cov FS	16.95	31.09	28.27	-13.08	2.92	0.01	105.64	16.40	642.17	4.12	10930.62
σ^2 GCA	2.28	4.64	4.95	23.16	0.22	-0.01	10.96	1.10	-34.48	0.34	1484.85
σ^2 SCA	21.23	27.05	12.63	-638.28	5.02	0.30	169.00	-29.15	12588.49	8.69	1.71
GCA:SCA	0.11	0.17	0.37	0.07	0.04	-0.03	0.06	0.04	-0.03	0.04	868.33
					Proportional Contribution to Total Variance						
Lines	53.71	67.25	79.78	39.51	24.50	16.27	36.08	54.18	8.74	27.88	45.70
Tester	8.33	7.07	2.04	19.81	19.97	14.98	15.52	4.16	2.88	15.45	6.76
Lines × Testers	37.96	25.68	18.18	40.68	55.52	68.75	48.40	41.66	88.39	56.67	47.54

Key:
NPE= Number of Plants at Emergence
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DHF= Days to 100 % Flowering
PLH= Plant Height
PNL= Panicle Length
NLP= Number of Leaves/Plant
NPP= Number of Panicles/Plant
NPH= Number of Plants at Harvest
STC90= Striga Count at 90 Days after Sowing
TGW= 1000 Grain Weight
GRY= Grain Yield

Table 4: General combining ability effects for some traits in pearl millet evaluated across locations in 2018

Genotypes	NPE	DFF	DHF	PLH	PNL	NLP	NPP	STC 90	NPH	TGW	GRY
Testers											
PS 202	-0.8	-1.04	-0.48	-3.37	0.51	-0.09	-0.341	9.38	-0.49	-0.60	39.63
Ex-Baga	-1.08	-0.88	-0.48	4.53	-1.49	-0.06	5.96	4.18	0.11	1.64	-2.41
Ex-Gubio	0.23	1.13	0.55	5.03	0.41	-0.16	-2.08	-6.49	-0.59	-0.42	-30.74
Ex-Monguno	1.33	0.79	0.42	-6.20	0.58	0.31	-0.48	-7.06	0.98	-0.62	-6.48
SE±	1.39	1.14	1.05	9.61	1.27	0.35	5.13	23.30	1.27	1.60	5.54
Lines											
PEO 5984	1.72	-5.01	-5.18	-1.14	-1.73	-0.19	2.14	0.92	2.57	-0.86	9.40
Super SOSAT	0.09	2.61	2.82	-3.77	0.14	6.23	-3.82	-5.67	0.07	-0.39	-0.98
SOSAT C-88	0.84	-0.02	0.48	11.78	0.81	0.23	-0.11	18.29	0.78	2.54	64.90
Ex-Borno	-4.37	3.40	3.10	-0.27	-0.15	-0.19	-7.15	-18.78	-4.18	-0.53	-122.31
LCIC 9702	1.72	-0.98	-1.23	1.40	0.93	-0.07	8.93	5.25	0.78	-0.76	48.98
SE±	1.84	1.51	1.39	12.71	1.68	0.46	6.78	30.59	1.69	2.11	7.33

Key:

NPE= Number of Plants at Emergence
DFF= Days to First Flowering
DHF= Days to 100 % Flowering
PLH= Plant Height
PNL= Panicle Length
NLP= Number of Leaves/Plant
NPP= Number of Panicles/Plant
NPH= Number of Plants at Harvest
STC90= Striga Count at 90 Days after Sowing
TGW= 1000 Grain Weight
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The result indicated that Ex-Baga is the best general combiner among testers with desirable performance in days to first flowering, days to 100 % flowering, plant height, number of panicles/plant, number of plant at harvest, number of plants at harvest and 1000 grain weight. The second best general combiner is Ex-Monguno with desirable performance in 5 traits. The results also indicated that the best general combiners among lines are SOSAT C-88 and LCIC 9702 with desirable combining ability effect in eight traits each. Both SOSAT C-88 and LCIC 9702 are excellent general combiners for grain yield among the testers with combining ability values of 64.9 and 48.98 respectively. The worst general combiner among all the lines and the testers is Ex-Borno, while the best general combiner for grain yield among the testers is PS 202 with a value of 39.63. Negative GCA effect for days to first flowering or days 100 % flowering implies that the parents when crossed to another parent with negative GCA effect would produce hybrids that would mature earlier. This has been reported by Martinez *et al*. (1993).

Specific combing ability effects

The specific combining ability effects of the hybrids are presented in (Table 5). The result showed that the hybrids Super SOSAT-C88 × Ex-Gubio, Ex-Borno × Ex-Gubio and SOSAT C-88 × Ex-Monguno are the best specific combiners as all of them were able to combine very well in five different traits. The best specific combiners for grain yield were; SOSAT C-88 × Ex-Monguno, LCIC 9702 × Ex-Gubio and PEO5984 × Ex-Baga. The best specific combiners for striga tolerance on the other hand were; SOSAT C-88 × Ex-Baga and PEO5984 × Ex-Baga. The result shows that the best specific combiners in striga tolerance were not among the best specific combiners for grain yield. SOSAT C-88, LCIC 9702 and PEO 5984 were among the best general combiners that produced among the best hybrids in striga tolerance and grain yield. Similar results have been found to confirm that best general combiners are likely to produce best hybrids when they are crossed together. Specific combing ability effects are used to identify the best cross-combination in hybrid production as reported by Izge *et al.* (2007). This study identifies a number of desirable hybrids for some of the traits that can be utilized for improvement of pearl millet grain yield.

Mean performance of lines, testers and hybrids across locations

The mean performance of traits among lines, testers and their hybrids across locations are presented in (Table 6). The results indicated that significant differences were found in all traits among testers, lines and hybrids. The result shows that PS 202 had the highest number of plants at emergence (22.17) among the testers, while SOSAT C-88 had the highest among the lines (23.67) which is the same for hybrid LCIC9702 × Ex-Gubio that had the highest number of plants at emergence among the hybrids. Incidentally, SOSAT C-88 and LCIC 9702 have been reported as the best general combiners in this study. The result further indicated that P202 had the highest number

Table 5: Specific combining ability effects of F_1 hybrids for ten traits of pearl millet at Bauchi and Maiduguri combined

Hybrids	NPE	DFF	DHF	PLH	PNL	NLP	NPP	STC 90	NPH	TGW	GRY
PEO 5984 × PS 202	0.52	1.58	0.98	16.24	2.53	-0.24	3.83	12.58	-0.13	-0.83	-0.33
Super SOSAT × PS 202	-0.03	3.13	1.32	-7.13	-0.34	-0.16	2.45	-51.83	-0.62	0.42	-18.13
SOSAT C88 × PS 202	3.89	-0.42	1.32	2.49	0.16	0.18	2.41	49.88	2.66	-1.56	70.33
Ex-Borno × PS 202	-3.23	-0.83	-0.64	3.87	0.62	0.43	-1.05	31.46	-0.88	0.82	-34.29
LCIC 9702 × PS 202	-1.15	-3.46	-2.98	-15.47	-0.97	-0.20	-7.63	-42.08	-1.01	1.14	-17.58
PEO 5984 × Ex-Baga	0.62	0.25	0.15	0.51	-1.47	0.23	-2.88	10.95	3.60	-1.24	77.86
Super SOSAT × Ex-Baga	1.41	-2.54	-1.52	5.97	0.33	-0.69	-7.92	101.37	1.27	-2.37	-54.26
SOSAT C88 × Ex-Baga	0.49	-0.75	-1.35	-2.08	0.66	0.31	-6.13	-59.09	-0.94	5.91	-18.96
Ex-Borno × Ex-Baga	-0.63	1.83	1.86	-4.87	0.12	0.06	-4.25	-37.34	-2.28	-0.73	60.40
LCIC 9702 × Ex-Baga	-1.88	1.21	0.86	0.47	0.37	0.10	21.17	-15.88	-1.44	-1.57	-65.05
PEO 5984 × Ex-Gubio	-1.02	1.42	0.78	-6.49	0.97	0.66	-0.34	-21.88	-2.70	1.49	-11.63
Super SOSAT × Ex-Gubio	0.78	-1.54	-1.05	1.80	0.93	0.41	2.78	-31.30	-0.03	1.44	38.58
SOSAT C88 × Ex-Gubio	-4.31	2.08	1.78	-5.58	0.43	-0.43	-0.59	-19.76	-3.58	-2.67	-168.30
Ex-Borno × Ex-Gubio	2.07	-2.00	-1.68	-0.37	-1.78	-0.18	3.78	15.49	3.22	0.24	32.58
LCIC 9702 × Ex-Gubio	2.48	0.04	0.16	10.63	-0.53	-0.47	-5.63	57.45	3.09	-0.49	108.78
PEO 5984 × Ex-Monguno	-0.12	-3.25	-1.92	-10.26	-2.03	-0.64	-0.61	-01.65	-0.77	0.58	-65.90
Super SOSAT × Ex-Monguno	-2.16	0.96	1.25	-0.63	-0.91	0.44	2.68	-18.23	-0.06	0.52	33.81
SOSAT C88 × Ex-Monguno	-0.08	-0.92	-1.75	5.16	-1.24	-0.06	4.31	28.98	1.86	-1.68	116.93
Ex-Borno × Ex-Monguno	1.80	1.00	0.46	1.37	1.05	-0.31	1.52	-09.61	0.15	-0.33	-58.69
LCIC 9702 × Ex-Monguno	0.55	2.21	1.96	4.37	3.13	0.57	-7.90	0.52	-0.64	0.92	-26.16
SE±	3.69	3.02	2.78	25.43	3.36	0.93	13.56	61.65		4.22	146.60

Key:
NPE= Number of Plants at Emergence
DFF= Days to First Flowering
DHF= Days to 100 % Flowering
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PNL= Panicle Length
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TGW= 1000 Grain Weight
GRY= Grain Yield

of days to first flowering (69 days) which also had the longest days to 100 % flowering (75 days) among testers. SOSAT C-88 had the longest days to first flowering and also days to 100 % flowering with values of 66 and 70 days respectively. The hybrid that had the highest number of days to first flowering was Ex-Borno × Ex-Monguno 70 days. While, hybrids with longest days to 100 % flowering were Ex-Borno × Ex-Baga, Super SOSAT × Ex-Monguno and Ex-Borno × Ex-Monguno each with 75 days. Super SOSAT had the highest number of leaves/plant, highest number of striga count at 90 DAS and highest grain yield of 670.2 kg/ha. This could mean that Super SOSAT is striga tolerant and

Table 6: Mean performance of pearl millet parental lines, their hybrids in some traits across locations in 2018.

Genotypes	NPE	DFF	DHF	PLH	PNL	NLP	NPP	STC 90	NPH	TGW	GRY
Testers											
PS 202	22.17a-d	69.17a-d	74.67a-c	172.17a-d	24.50a-d	8.50a-d	27.33bc	62.00d-f	17.17b-e	9.61b	360.7b-g
Ex-Baga	18.50b-f	67.33a-f	72.50a-f	170.83a-d	26.17ab	8.67a-d	23.83c	48.50ef	13.83c-g	8.49b	459.0a-g
Ex-Gubio	21.50a-e	68.17a-e	73.67a-e	186.50a-c	22.67ab	9.00a-c	29.00bc	59.33d-f	16.83b-f	10.07b	372.2b-g
Ex-Monguno	20.33b-e	67.33a-f	72.50a-f	176.67a-d	25.56ab	8.33a-d	35.67bc	39.50f	17.17b-e	8.53b	400.2b-g
Lines											
PEO5984	22.50a-d	56.33j	61.67k	155.83cd	20.67c-e	7.83cd	34.33bc	61.83d-f	18.17b-d	9.56b	476.3a-f
Super SOSAT	22.33a-d	64.00e-i	68.50f-j	191.67ab	23.33b-e	9.33a	37.67bc	202.50a	18.33b-d	10.75b	670.2a
SOSAT C88	23.67ab	65.83a-f	70.17c-h	196.50a	24.50a-d	8.00b-d	31.17bc	98.00c-f	18.00b-d	9.17b	521.0a-e
Ex-Borno	19.33b-e	63.33e-i	69.67e-i	162.83a-d	22.00b-e	7.83cd	26.67bc	40.83f	14.00c-g	9.56b	306.3d-g
LCIC 970 2	21.83a-e	60.50g-j	65.33i-k	165.83a-d	22.00b-e	7.67d	34.83bc	88.67c-f	17.33b-d	8.34b	556.3a-c
Hybrids											
PEO 5984×PS 202	21.00a-e	60.50g-j	66.17h-k	178.50a-d	24.67a-d	7.83cd	33.33bc	109.17b-f	17.17b-e	7.58b	465.0a-g
Super SOSAT×PS 202	18.83b-e	69.67ab	74.50a-d	160.50b-d	23.67a-d	8.33a-d	26.00bc	38.17f	14.17c-g	9.29b	436.8a-g
SOSAT C88×PS 202	23.50a-c	63.50e-i	72.17a-f	185.67a-c	24.83a-d	8.67a-d	29.67bc	163.83a-c	18.17b-d	10.24b	591.2ab
Ex-Borno×PS 202	11.17g	66.50a-f	72.83a-f	175.00a-d	24.33a-d	8.50a-d	19.17c	108.33b-f	9.67gh	9.56b	299.3e-g
LCIC 9702×PS 202	19.33b-e	59.50h-j	66.17h-k	157.33b-d	21.83b-e	8.00b-d	28.67bc	58.83d-f	14.50c-g	9.65b	587.3a-f
PEO 5984×Ex-Baga	20.50b-e	59.33ij	65.33i-k	170.67a-d	18.67e	8.33a-d	36.00bc	102.33b-f	21.50ab	9.41b	501.2a-f
Super SOSAT×Ex-Baga	19.67b-e	64.17e-i	71.67a-f	181.50a-d	22.33b-e	7.83cd	25.00bc	186.17ab	16.67b-f	8.74b	358.7b-g
SOSAT C88×Ex-Baga	19.50b-e	63.33e-i	69.50f-i	189.00a-c	23.33a-e	8.83a-d	30.50bc	49.67ef	15.17c-f	19.95a	459.8a-g
Ex-Borno×Ex-Baga	13.17g	69.33a-c	75.33a	174.17a-d	21.83b-e	8.17a-d	25.33bc	34.33f	8.67h	10.24b	352.0c-g
LCIC 9702×Ex-Baga	18.00c-f	64.33d-h	70.00c-h	181.17a-d	23.17b-e	8.33a-d	66.83a	79.83c-f	14.67c-g	9.18b	397.8b-g
PEO 5984×Ex-Gubio	20.17b-e	20.50f-i	67.00g-j	164.17a-d	23.00b-e	8.67a-d	30.50bc	58.83d-f	14.50c-g	10.07b	383.3b-g
Super SOSAT×Ex-Gubio	20.33b-e	67.17a-f	73.17a-e	177.83a-d	24.83a-d	8.33a-d	27.67bc	42.83ef	14.67c-g	10.48b	423.2b-g
SOSAT C88×Ex-Gubio	16.00e-g	68.17a-e	73.67a-e	186.00a-c	25.00a-c	8.00b-d	28.00bc	78.33d-f	11.83gh	9.30b	282.2g
Ex-Borno×Ex-Gubio	17.17d-f	67.50a-e	72.83a-f	179.17a-d	21.83b-e	7.83cd	25.33bc	76.50d-f	13.67g-h	9.15b	295.8e-g
LCIC 9702×Ex-Gubio	23.67ab	65.17b-g	70.33b-h	191.83ab	24.17a-d	7.67d	32.00bc	142.50a-d	18.50a-d	8.19b	543.3a-d
PEO 5984×Ex-Monguno	22.17a-d	57.50j	64.17jk	149.17d	20.17de	7.83cd	31.83bc	78.50c-f	18.00b-d	8.96b	353.3c-g
Super SOSAT×Ex-Monguno	18.50b-f	69.33a-c	75.33a	164.17a-d	23.17b-e	9.33a	29.17bc	55.33ef	15.67c-f	9.33b	442.7a-g
SOSAT C88×Ex-Monguno	21.33a-e	64.83b-g	70.00d-h	185.50a-c	23.50a-d	8.83a-d	34.50bc	126.50a-e	18.83a-c	10.10b	591.7ab
Ex-Borno×Ex-Monguno	18.00c-f	70.17a	74.84ab	169.67a-d	24.83a-d	8.17a-d	24.67c	50.83ef	12.67e-h	8.37b	436.8a-g
LCIC 9702×Ex-Monguno	22.83a-c	67.00a-f	72.00a-f	174.33a-d	28.00a	9.17ab	31.33bc	85.00c-f	16.67c-f	9.40b	432.7a-g
S E±	1.98	1.76	1.65	12.71	1.71	0.45	6.71	30.53	1.81	2.04	84.92

was able to give the highest yield despite highest number of striga count. SOSAT C-88 on the other handed had the tallest plant considering all the entries. The mean performance among the hybrids indicated that SOSAT C-88 × PS 202 and SOSAT C-88 × Ex-Monguno produced the highest grain yield of 591.2 and 591.7 kg/ha respectively. The result for plant height indicated that the tester Ex-Gubio and Ex-Monguno were the tallest plant with 186.50 cm and 176.67 cm respectively. The tallest plants among the lines were; SOSAT-C88 (196.50 cm) and Super SOSAT (191.67 cm). The results also show that LCIC 9702 × Ex-Gubio (191.83 cm), SOSAT-C88 × Ex-Baga (189.00 cm), SOSAT-C88 × PS202 (185.67 cm), SOSAT-C88×Ex-Monguno (185.5 cm) and Super SOSAT × Ex-Baga (181.50 cm) as the tallest hybrids. The result also indicated that the number of plants at harvest were significantly different among parents and hybrids. The testers PS202 and Ex-Monguno had the highest number of plants at harvest. On the other hand, Super SOSAT, PEO5984 and SOSAT-C88 both had 18 plants each at harvest among the lines. The hybrid that produced the highest number of plant at harvest was PEO5984 × Ex-Baga. Incidentally, among all the hybrids that produced the higher number of plants at harvest PEO 5984 was one of the parents. Ex-Gubio and Super SOSAT produced the highest number of leaves/plant among the parents. Super SOSAT × Ex-Monguno and LCIC 9702 × Ex-Monguno on the other hand produced the highest amount of leaves among the hybrids. The tester Ex-Monguno had 36 number of panicles/plot which was the highest among the lines while, Super SOSAT gave the highest number of panicles of 38 among testers. The hybrids LCIC 9702 × Ex-Baga, had the highest number of 67 panicles/plot. The result for 1000 grain weight shows that Super SOSAT had the heaviest grain of 10.75 among parents while SOSAT × Ex-Baga had the heaviest of 19.95 grams among hybrids.

LCIC 9702 × Ex-Gubio, PEO5984 × Ex-Monguno and Super SOSAT × Ex-Monguno which had highest establishment count could be explored for developing adaptable cultivars. The potential for early maturity exist in the parental lines and their hybrids especially PEO5984 and PEO5984 × Ex-Gubio. These hybrids could be subjected to further selection to obtain very early and extra early maturity varieties because early maturity varieties are essential for successful production in marginal rainfall areas. The result is in accordance with (Olaoye *et al.* 2015). The study found that parental lines and hybrids that produced high grain yield also recorded higher number of panicles which translated in most cases to higher total grain yield. This result is in agreement with that of Dhillon *et al*. (1977) and Ouendeba *et al*. (1993).

Conclusion

Population generated through line × tester breeding was evaluated at Bauchi and Maiduguri, north eastern Nigeria in 2019 cropping season in a Randomized Complete Block Design. The results found existence of tremendous amount of genetic variability among materials evaluated. It follows that additive and non-additive genetic effects were important in inheritance of traits, but non-additive genetic effects were the most preponderant. It was further found out that SOSAT C88, LCIC9702, EX-Baga and PEO 5984 were the best general combiners especially in terms of grain yield and striga tolerance. SOSAT C88 × Ex-Monguno, LCIC 9702 × Ex-Gubio and PEO 5984 × Ex-Baga are the best, better and good specific combiners in terms of grain yield in that order. The best performing parent in grain yield was Super SOSAT with 670.2 kg/ha. On the other hand, the best performing hybrids in grain yield were; SOSAT C88 × Ex-Monguno and SOSAT C88 × PS 202 with 591.7 and 591.2 kg/ha of grain yield respectively. The best grain yielding hybrids had always SOSAT C88 as one of its parents. The superior performing parents and hybrids in terms of grain yield and striga tolerance needs further evaluation and extensive hybrid development strategy before it could be released to farmers for use.

Disclosure of conflict of interest

None

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