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Full Length Research Paper

Development of sorghum populations for resistance to *Striga hermonthica* in the Nigerian Sudan Savanna

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Six elite sorghum varieties, ICSV 111, ICSV 400, KSV 4, Gaya Early, CS 54, and CS 95 were used to improve *Striga* resistance through pedigree breeding. SRN 39 and IS 9830 varieties were confirmed resistant to *Striga hermonthica* (Del.) Benth in field trials. The two *Striga* resistance lines were crossed with the six elite varieties. Three hundred and sixty *Striga*-free plants from F_2s of good agronomic traits were identified, and selfed to produce F_3s. The number of selections varied from 12 (ICSV 400 x IS 9830) to 59 (ICSV 400 x SRN 39) per F_2 population. About 50% more plants were selected from the crosses involving SRN 39 as donor parent for *Striga* resistance than the crosses involving IS 9830. In addition, 58 out of the 100 plants selected were from a cross, ICSV 111 and SRN 39. Crosses from which *Striga* free plants were obtained were CS 54 x SRN 39 (12 plants selected), CS 95 x SRN 39 (9), ICSV 400 x SRN 39 (6), Gaya Early x IS 9830 (6), Gaya early x SRN 39 (5), and KSV 4 x IS 9830 (4). Crop syndrome reaction score was higher in 1995 (2.3 - 4.0) than in 1996 (1.0 - 2.7). Our results suggest that SRN 39 is a better donor parent for *Striga* resistance than IS 9830. ICSV 00090 NG, a cross between ICSV 111 and SRN 39 gave the highest grain yield of 2.02 t/ha in a replicated trial compared to the two parents, ICSV 111 (1.11 t/ha) and SRN 39 (0.86 t/ha). This variety combines potential for high yield and resistance to *Striga*. Our data indicates that the elite varieties can be improved for *Striga* resistance using pedigree breeding. A large F_2 population (500 to 1000 plants per cross) is recommended for the selection of transgressive segregants. Further efforts are required to back cross-promising segregants with established *Striga* resistant variety in order to develop durable *Striga* resistant varieties with acceptable agronomic traits.

Key words. Sorghum, *Striga hermonthica*, parasitic weed, resistance.

INTRODUCTION

Striga hermonthica (Del.) Benth. is the most destructive parasitic weed on cereals in western Africa, (Sauerborn, 1991). Grain losses on a regional scale average 5 - 15%, however, *Striga* can exert a much greater impact locally, sometimes resulting in total crop failure (Doggette, 1988; Riches and Parker, 1995). Up to 5% and 95% yield losses have been recorded for resistant and susceptible sorghum hybrids, respectively (Obilana, 1980). In Africa 21 million hectares of land are estimated to be infested with *Striga*, resulting in an annual grain yield loss of 4.1 million tons (Sauerborn, 1991) and an estimated overall loss of 7 billion US dollars in revenues to Africa (M'Boob, 1986).

Some of the recommended control options for *S. hermonthica* include: adequate land preparation, hand pulling, hoe weeding, use of trap and catch-crops, seed treatment, application of appropriate rate of nitrogen fertilizer, herbicide spray, use of biological control as well as host-plant resistance (Lagoke et al., 1988). Among these control methods, host-plant resistance is the most economic control measure since it is affordable to farmers and resistant cultivars can be grown without additional inputs (Hess and Ejeta, 1992). *Striga* has co-evolved with sorghum whose origin is Africa. The crop

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has developed various complex mechanisms of resistance to the parasite as a survival strategy (Riches, 1999). For example, the mechanism of resistance of SRN 39 to *Striga* species was observed to be a combination of low stimulant production, and restricted parasite development following attachment to host roots. These complex mechanisms have facilitated durable resistance of the cultivar in the field and it is currently being recommended for use in Sahel agro-ecological region of Western and Central Africa (WCA) (Bailey et al., 1995). The *Striga* resistant varieties such as SRN 39, and IS 9830 have undesirable traits such as low grain yield, short stature, and small grains, that limit their acceptance by farmers. Among the introductions of *Striga* resistant cultivars to WCA, Framida exhibited stable resistance to *S. hermonthica* under diverse conditions in addition to other important traits including stability of yield, good seedling establishment and resistance to grain mold and birds. However, due to its high tannin content and the brown seed color, the variety is not acceptable to majority of the farmers in WCA (Ramaiah, 1991). Crosses between resistance sources and adaptable elite varieties could result in varieties with combined characteristics of high productivity, acceptable grain and plant traits and resistant/tolerant to Striga. This paper describes screening to identify resistance sources to *S*. hermonthica and the transfer of resistant genes from these sources into elite sorghum lines.

MATERIALS AND METHODS

The trials were conducted in *Striga* sick plot at Bagauda located in the Sudan Savanna agro-ecological zone of Nigeria (11° 53'N, 8° 14'E) at a mean altitude of 440 m above sea level. Soil type is a plinthic luvisol with an average depth of 90 cm. Eighteen sorghum entries/introductions were evaluated in a randomized block design with three replications in 1995 and 20 entries in 1996. Gaya Early and Bagauda Farafara were used as local checks in both years. Trials were established in July in 1995 and 1996. In 1995, the gross plot size consisted of 6 rows of 4 m long ridges, and the net plot size was 12.75 m^2 while in 1996 the gross plot size consisted of 2 rows of 5 m long ridges, and the net plot size was 7.125 m^2. The number of *Striga* plants was converted from 12.75 m^2 to facilitate comparison (Table 1).

Two *Striga* resistant lines (SRN 39 and IS 9830), four varieties from Nigeria (KSV 4, ICSV 111, ICSV 400 and Gaya Early), and two selections from Cameroon (CS 54 and CS 95) were sown at Dadin-Kowa, Gombe State in January, 1996 to produce crosses between *Striga* resistant lines and elite varieties (ICSV 111, ICSV 400, KSV 4, Gaya Early, CS 54, and CS 95) using double plastic bag technique. Eleven F_1 crosses along with female parents were sown at Bagauda during the 1996 main season to identify true hybrids. Ten crosses were found to be true hybrids, and were further advanced to F_2s by selfing individual plants panicle**.** Ten F_2 populations, each with 600 plants, were sown in *Striga* sick plot at Bagauda in June 1997 to identify *Striga* free plants. *Striga* count was carried out at maturity. Three hundred and sixty *Striga* free plants with good agronomic traits were identified, and then selfed to produce F_3s. The 360 F_3 progenies were sown in *Striga* sick plot at Bagauda in June 1998 to identify resistant progenies and to advance selected 100 plants from 62 progenies to F_4s. The list of crosses, total number of F_3 progenies, and selected number of F_3 progenies are presented in Table 2. A preliminary evaluation trial consisting of 30 F_6 *Striga* resistant lines along with their parents were established in Minjibir in July 2000. The trial was established in a randomised block design consisting of three replicates.

Striga seeds were inoculated in planting hills at sowing. Each hill of about 3 cm deep and 5 cm wide received one full coca-cola bottle cap of *Striga* seeds. In all the trials, intra-row spacing was 25 cm while inter-row spacing was 75 cm. First weeding was done with hoe while subsequent weeding was by hand pulling to avoid tampering with *Striga* plants. Basal application of fertilizer NPK 15:15:15 was done at the rate of 300 kg ha^{-1} by broadcasting uniformly and thereafter incorporated into the soil. Calcium ammonium nitrate (CAN) was applied three weeks after sowing at the rate of 100 kg ha^{-1}. In trials conducted from 1995 to 1998 data collected were *Striga* count at 90 days after sowing (DAS), grain yield and crop damage score. Crop syndrome reaction score was taken on a scale of 1-9 where 1 = healthy plants and 9 = completely dead plants. In 2000, data collected include grain yield, time to 50% bloom, plant height, panicle length, threshing percentage and grain mass (Table 3). All data were analysed using Genstat 5 release 3.2 statistical packages 1989 (Lawes Agricultural Trust, Rothamstead Experimental station) following standard analysis of variance procedures (Gomez and Gomez, 1984).

RESULTS

The data on *Striga* count, grain yield and crop damage score at Bagauda during 1995 and 1996 main seasons are presented in Table 1. Crop syndrome reaction score was higher in 1995 ranging between 2.3 - 4.0, than in 1996 that ranges from 1.0 - 2.7. Framida red, KSV 4 and CS 95 gave lower crop reaction score and produced higher grain yield than local checks in both years. Although, KSV 4 supported high *Striga* plant in both years, it possesses low crop reaction score. The local checks, Bagauda Farafara, and Gaya Early, and an improved variety, KSV 8, were highly susceptible to *Striga.* Bagauda Farafara supported more number of *Striga* plants than Gaya Early. Although Bagauda Farafara supported the highest *Striga* plants, it registered low crop reaction score of 2.0 in 1996. ICSV 400 produced higher grain yields than the locals in 1996, in spite of supporting high *Striga* emergence. ICSV 111 supported fewer *Striga* emergence and produced higher grain yield than the checks in 1996. Similarly, ICSV 901 NG supported fewer *Striga* emergence than Gaya Early and produced higher grain yield than the two local checks in 1995. The two varieties from Cameroon, CS 54 and CS 95, were moderately susceptible to *Striga* in both years. S 35 produced higher grain yield and supported lower *Striga* plants in 1996 when compared to local checks. Six entries; KSV 4, Gaya Early, ICSV 111, ICSV 400, CS 54, and CS 95 were consequently identified as a new varieties which exhibits promise for tolerance to *Striga* infestation.

In both years, ICSV 1007 BF consistently supported fewer *Striga* emergence and produced similar grain yield as the local checks. SRN 39 and IS 9830 supported fewer *Striga* emergence and produced higher grain yield in both years than Bagauda Farafara.

Table 1. Performance of sorghum lines in Striga infested plot at Bagauda, Nigeria, 1995 and 1996 main seasons.

Entry	1995			1996		
	Striga plants/12.75 m^2	**Grain yield (t-ha^1)**	**Crop reaction score**	**Striga plants/12.75 m^2**	**Grain yield (t-ha^1)**	**Crop reaction score**
SRN 39	49.7	0.98	3.0	78.7	0.73	1.9
IS 9830	43.0	0.72	3.0	68.0	1.11	1.7
Framida Red	61.7	1.68	2.7	68.0	1.69	1.0
ICSV 1007 BF	34.3	1.03	3.3	14.3	0.41	-
SAR 37	51.7	0.35	3.0	-	-	-
SAR 33	55.7	0.70	2.3	-	-	2.0
ICSV 901 NG	58.3	1.77	-	-	-	1.7
ICSV 1156	66.7	0.94	3.0	-	-	-
ICSV 1079 BF	71.0	1.17	3.0	53.7	1.33	2.0
SAR 16	73.7	0.83	3.7	-	-	-
IS 1260	85.3	1.19	3.0	-	-	1.7
ICSV 902 NG	102.0	0.93	2.7	-	-	-
S 35	115.0	1.22	3.3	48.3	1.17	-
ICSV 111	-	-	-	57.3	1.56	-
ICSV 400	-	-	-	227.4	1.44	-
KSV 4	100.7	1.38	4.0	100.2	1.67	2.7
CS 54	86.0	1.16	4.0	68.0	0.71	2.7
CS 95	91.7	1.28	2.7	87.7	0.86	1.3
Gaya Early	141.0	0.25	-	157.5	0.55	-
Bag Farafara	114.3	0.63	-	349.9	0.27	2.0
SE	**±21.08**	**±0.217**	**±1.35**	**±29.0**	**±0.224**	**±0.51**
Mean	**79.0**	**1.01**	**3.11**	**83.0**	**0.91**	**1.88**
CV (%)	**46.0**	**37.30**		**60.4**	**42.60**	

Table 2. Number of total and selected F_3 progenies (derived from crosses between *Striga* resistant and elite varieties), sown at Bagauda, 1997 main season.

Crosses	Total F_3 progenies	Striga count (Mean over total progenies)	Selected F_3 progenies	Striga count (Mean over selected progenies)
CS 54 x SRN 39	37	325	7 (12)*	166
CS 95 x SRN 39	23	236	8 (9)	211
ICSV111 x SRN 39	56	52	30 (58)	50
ICSV400 x SRN 39	59	107	6 (6)	100
GayaEarlyxSRN 39	40	59	4 (5)	37
KSV 4 x IS 9830	59	40	4 (4)	69
CS 54 x IS 9830	23	68	0 (0)	-
ICSV 111 x IS 9830	22	32	0 (0)	-
ICSV 400 x IS 9830	12	150	0 (0)	-
GayaEarlyxIS 9830	29	100	3 (6)	135
Total	**360**		**62 (100)**	

Numbers of selected plants are given in parenthesis.

Table 3. Performance of F_6 *Striga* Progenies at Minjibir, Nigeria, 2000 main season.

(ICSV 00 xxx NG)	Crosses	Grain yield (t ha-^{1})	Time to 50% bloom (days)	Plant height (cm)	Plant length (cm)	Threshing (%) (g-^{1000})	Grain mass
-	Gaya Eearly	0.40	89.4	248	34.4	68	27
-	CS 54	0.71	71.5	182	22.2	64	25
-	SRN 39	0.86	70.6	137	24.3	65	25
-	CS 95	1.07	69.4	187	23.0	66	26
-	ICSV 111	1.11	71.7	153	23.3	62	24
090	(ICSV 111 X SRN 39)	2.02	65.3	148	23.7	78	24
079	(ICSV 111 X SRN 39)	1.65	73.0	128	27.0	68	23
094	(ICSV 111 X SRN 39)	1.61	77.0	126	21.7	73	25
081	(ICSV 111 X SRN 39)	1.52	69.0	175	23.0	67	24
092	(ICSV 111 X SRN 39)	1.43	77.3	114	23.3	70	22
077	(CS 54 X SRN 39)	1.37	77.3	107	22.3	69	20
095	(ICSV 111 X SRN 39)	1.30	76.7	109	24.3	63	19
071	(CS 54 X SRN 39)	1.29	79.0	105	22.3	70	22
091	(CSV 111 X SRN 39)	1.25	79.3	98	22.3	69	23
073	(CS 54 X SRN 39)	1.23	77.7	144	21.0	64	21
074	(CS 54 X SRN 39)	1.23	78.7	156	20.3	61	21
093	(ICSV 111 X SRN 39)	1.16	78.7	165	20.7	72	24
088	(ICSV 111 X SRN 39)	1.14	80.0	153	19.3	68	24
084	(ICSV 111 X SRN 39)	1.14	75.7	158	23.7	67	26
089	(ICSV 111 X SRN 39)	1.14	74.3	106	21.3	57	21
082	(ICSV 111 X SRN 39)	1.11	79.3	127	20.3	75	23
080	(ICSV 111 X SRN 39)	1.09	69.3	155	23.0	69	23
083	(ICSV 111 X SRN 39)	1.04	78.7	127	21.7	66	21
069	(CS 54 X SRN 39)	1.03	78.3	129	20.3	66	22
097	(GayaEarly X SRN 39)	1.03	72.0	220	28.7	70	29
087	(ICSV 111 X SRN 39)	1.00	80.0	163	19.0	63	24
067	(CS 54 X SRN 39)	1.00	80.0	109	23.3	63	22
076	(CS 54 X SRN 39)	0.95	80.0	169	20.3	66	22
086	(ICSV 111 X SRN 39)	0.93	80.7	104	23.0	61	23
085	(ICSV 111 X SRN 39)	0.84	79.3	112	22.0	65	22
072	(CS 54 X SRN 39)	0.79	79.3	82	24.3	66	17
068	(CS 54 X SRN 39)	0.72	80.0	105	19.3	57	23
075	(CS 54 X SRN 39)	0.70	81.3	151	21.3	67	24
070	(CS 54 X SRN 39)	0.66	80.0	139	21.7	61	22
096	(GayaEarly X SRN 39)	0.42	79.7	244	26.3	58	26
SE		**±0.267**	**±2.26**	**±10.2**	**±1.34**	**±4.9**	**±1.2**
Mean		**1.19**	**77.1**	**148**	**24.0**	**65**	**24**
CV (%)		**38.7**	**5.1**	**11.9**	**9.7**	**13.1**	**8.8**

Two hundred and fifteen *Striga* free plants were selected from five F_2 populations involving SRN 39 as donor parent, whereas only 145 plants were selected from five F_2 populations involving IS 9830 as donor parent (Table 2). The F_2 populations derived from crosses involving SRN 39 had lower incidence of *Striga* than the other crosses.

One hundred plants from 62 progenies were selected out of 360 F_3 progenies during 1998 main season (Table 2). The majority of the plants (58 out of 100) selected were from a cross derived by crossing ICSV 111 and SRN 39. The other crosses from which *Striga* free plants were obtained included CS 54 x SRN 39 (12 plants selected), CS 95 x SRN 39 (9), ICSV 400 x SRN 39 (6), Gaya Early x IS 9830 (6), Gaya early x SRN 39 (5), and KSV 4 x IS 9830 (4). It is interesting to note that the mean *Striga* count for total F_3 progenies was similar to the selected progenies for most of the crosses. This could be because at the time of selection, both *Striga* emergence and agronomic traits were considered. Perhaps one backcrossing will improve the chances of selection of *Striga* resistance combined with high yield.

Results from Table 3, shows that cross involving ICSV 111 as female parent and SRN 39 as male parent gave higher grain yield and good grain mass than other cross combinations. ICSV 00090 NG gave the highest grain yield of 2.02 t/ha compared to the two parents, ICSV 111 and SRN 39 with grain yield each of 1.11 t/ha and 0.86

t/ha respectively. Among all the crosses ICSV 00090 NG also possess the highest threshing percentage of 78 and look promising because of its good grain yield and generally crosses made with ICSV 111 gave progenies that supported fewer *Striga* plants. Crosses between CS 54 and SRN 39 gave the lowest grain yield and grain mass. ICSV 00097 NG, a cross between Gaya Early and SRN 39, gave the highest grain mass of 29. In general, crosses generated gave higher grain yield than their respective parents, probably because agronomic scores were considered along with *Striga* free plant during the selection process.

DISCUSSION

Based on low *Striga* count, SRN 39, IS 9830, ICSV 1007 BF, and Framida were identified as resistant to *Striga*. These four entries were reported resistant to *Striga* by Murty et al. (1995) based on three years results at Bagauda. Framida red produced higher grain yield and supported fewer *Striga* plants than the two checks in both years. Earlier reports by Ramaiah (1991) and later by Lagoke et al. (1999) have confirmed the stability of resistance in Framida red across locations and years. This variety has been used to develop *Striga* resistant materials including ICSV 1007 BF. It has been shown that single recessive gene controls resistance in SRN 39 (Hess and Ejeta, 1992). The mechanism of resistance to *Striga* was also attributed to low germination stimulant production (Hess et al., 1992) and post-infection growth inhibition (Bailey et al., 1995). IS 9830 and SRN 39 have also been reported to have adoption problem in various parts of sub-saharan Africa due to small grain size and low grain yield (Ramaiah, 1991; Lagoke et al., 1994). These varieties were, however, adopted by farmers in Sudan (Obilana and Reddy, 1999). These two varieties were selected as source parents for improvement of the elite varieties because of their stable resistance to *S. hermonthica*. ICSV 111 supported fewer *Striga* plants and produced higher grain yield than checks. Murty *et al*. (1995), also found that ICSV 111 was similar to SRN 39, ICSV 1007 BF, IS 9830, and Framida for resistance to *Striga.* Our observation that local checks of long duration types supported higher *Striga* plants than test varieties and possesses low crop syndrome score is in line with earlier reports indicating that local sorghum varieties, especially landraces which have a longer growing season usually support higher *Striga* incidence because of longer period of exposure of the *Striga* seeds and plants to the land races than improved short season types (Talleyrand et al., 1991; Kureh et al., 1999). Ejeta et al (1991) noted that *Striga* tolerant genotypes permit and support as many *Striga* plants as susceptible genotypes but do not show a concomitant reduction in grain production or overall productivity.

The results suggest that SRN 39 is a better donor parent for *Striga* resistance than IS 9830. Riches (1999) had indicated that the combination of low stimulant production with post-infection cellular resistance observed in SRN 39 is likely to be durable in the field, unlike in IS 9830 that only produces low germination stimulant. The segregants derived from crosses with SRN 39 appear to be morphologically superior to IS 9830. The results also suggest that ICSV 111 supported fewer *Striga* emergence than ICSV 400. This finding was also supported by the mean *Striga* emergence in F_3 progenies derived from crosses involving ICSV 111 and ICSV 400 with SRN 39 and ICSV 9830. CS 54 and 95 were moderately susceptible to *Striga,* and F_3 progenies derived from crosses involving these lines and SRN 39 supported more *Striga* shoot. ICSV 00090 NG possesses superior agronomic traits than the two parents. It appears that the elite varieties can be improved for *Striga* resistance using pedigree breeding with one or two back crossing. Obilana (1984) reported that segregation in later generations allowed resistant types to be recovered following pedegree breeding. In future, marker-assisted selection could be used to accelerate the selection process for improvement of *Striga* resistance in sorghum varieties.

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