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Grain yields of rust resistant promiscuous soybean lines in the Guinea savanna of Nigeria

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Abstract Soybean rust, caused by *Phakopsora pachyrhizi*, has become a threat to soybean production in west, central, east and southern Africa. This foliar disease can cause 40-80% yield loss under African conditions. IITA started to develop resistant lines for this disease since 2003 and a number of homozygous lines from the breeding program have reached line evaluation stage. Seventeen F_8 rust resistant lines derived from the cross TGx 1805-31F (rust susceptible elite line) with UG 5 (rust resistant line), together with three checks, were evaluated at five locations in Nigeria during the 2008 main growing season. The experiment was laid out in a randomized complete block design with four replications at Ibadan, Mokwa, Zaria, Kano and Book. Analysis of variance was carried out using PROC MIXED. Lines showed significant difference for grain yield at all locations except at Zaria. Combined analysis of variance over the five locations also showed highly significant differences. Seven lines gave significantly higher yields compared to the standard variety TGx 1485-1D. The mean yield of these lines ranged from 1951-2241 kg ha^{-1}, whilst TGx 1485-1D yielded 1699 kg ha^{-1}. The other standard check variety TGx 1019-2EN, which gave 1764 kg ha^{-1}, was also significantly outperformed by five lines. Line × location interaction was significant for grain yield which indicated changes in rank order of lines in different locations. Lines also differed significantly for fodder yield. The highest mean fodder yield of 2475 kg ha-1 was obtained from the standard variety TGx 1485-1D, but nine test lines gave a comparable fodder yield by being not significantly different from the check. Difference for mean 100-seed weight was also significant and 10 test lines gave large seeds (14-17 g) as compared to the checks (12-13 g). Of the test lines, TGx 1987-9F, TGx 1987-10F and TGx 1987-23F had relatively bigger seeds (16-18 g). In addition, the test lines also showed good nodulation, resistance to frogeye, bacterial pustule, pod shattering and lodging. All the lines matured on average in 89-97 days. Thus, three superior lines TGx 1987-62F, TGx 1987-10F and TGx 1987-9F will be considered for on-farm trials to expedite their release in Nigeria. Moreover, these lines would be of a great value to different parts of Africa where rust has become a limiting factor in soybean production.

Key words: Grain yield, IITA, promiscuous soybeans, rust resistant lines

Introduction

Soybean is increasingly becoming one of the most important crops of Africa. There is a growing demand for soybean for animal feed in Africa which includes poultry, dairy and aquaculture. While producing the cake for animal feed, the oil is used to reduce gaps in edible oils. Soybean with bout 40% protein and 20% oil is an important source of protein for direct consumptions by rural household in the form of maize-soy blends to make various kinds of foods. Soybean also increases the incomes of small scale farmers as it is a cash crop for domestic and export markets. In African rural settings, soybean stover is also used as livestock feed. It is also a crop that improves soil fertility by fixing 40-150 kg N ha^{-1} and thereby reduces nitrogenous fertilizer cost for subsequent cereal crops. From studies in West Africa, it is also known that soybean reduces striga population through suicidal germination (IITA, 1997; Carsky *et al*., 2000). In recent years it is also emerging as stock for biodiesel.

Total soybean production in Africa in 2007 was around 1.5 million tons from an area of 1.3 million ha (FAO, 2009). The major producer of soybean in Africa is Nigeria with a total output of 617,000 tons in 2007, which is 43% of Africa's total production. The next highest producer is South Africa (430,000 tons) followed by Uganda (176,000 tons), Zimbabwe (112,000 tons) and Malawi (71,000 tons). By world standard, soybean productivity in Africa is still low (around 1 ton/ha) and in some countries yields are as low as 0.5 ton/ha.

The low productivity of soybean in Africa could be attributed to lack of high yielding improved varieties, biotic and abiotic stresses and absence of crop management technologies. Among the biotic stresses, soybean rust caused by the fungus *Phakopsora pachyrhizi* is increasingly becoming one of the most important constraints to soybean production. This disease first appeared in Uganda in 1996 and subsequently in Rwanda, Zimbabwe and Zambia in 1998 (Levy, 2005). It was reported in South Africa in 2001 (Pretorius *et al*., 2001), Nigeria in 2001 (Akinsanmi, *et al*., 2001), Ghana in 2007 (Bandyopadhyay *et al*., 2007), and DR Congo in 2007 (Ojiambo *et al*., 2007). Soybean rust has now become endemic in major soybean growing areas of west, east and southern Africa. In Zimbabwe and South Africa it devastated large commercial soybean fields between 1998 and 2002 (Levy, 2005). Yield losses reported due to this diseases were 8 - 53% in Uganda in 1996 (Tukamuhabwa *et al*., 2001), 10 - 80% in Southern Africa (Caldwell & Liang, 2002) and 40 - 80% in Zimbabwe (Levy, 2005).

IITA embarked on breeding for rust resistance since 2002. Field and green house screening was carried out on a large number breeding lines and germplasm accessions from various sources. Some breeding lines and germplasm accessions (PI 594538A, PI 417089A, and UG-5) were identified that resisted the disease (IITA, 2003; Twizeyimana *et al*., 2008). UG5 was a germplasm accession obtained from Uganda. UG5 was subsequently used as a source of rust resistance in IITA's soybean breeding program to develop resistant lines. That effort led to the development rust resistant breeding lines that have reached variety trial at present. This study was aimed to assess the performance of rust resistant lines for grain yield under diverse environments in Nigeria.

Materials and methods

Crosses of UG5 (rust resistant germplasm) and TGx 1805-31F (susceptible elite line) were made in 2003 at IITA-Ibadan. Pedigree breeding method was followed to select and advance rust-resistant progenies where single plant selections were made in the F_2 generation under high disease pressure in the greenhouse, and selections in F_3 - F_5 generations were made in the field at IITA-Ibadan, which a hot spot location for soybean rust. Further, individual plant selections were bulked in F_6 and were subjected to further selection for resistance to pod shattering, desirable seed color and size. Sixty five F_7 lines were evaluated under field condition in preliminary yield trial (PYT) at IITA-Ibadan in 2007 (Tefera & Bandyopadhyay, 2008). Of these 17 superior yielding lines were identified and tested in advanced yield trial (AYT) trial at five locations in Nigeria in 2008 (Table 1). Two checks% TGx 1485-1D, rust susceptible and a widely grown early maturing variety, TGx 1019-2EN, and TGx 1740-2F were included in the trial. The trials were planted on June 25, June 28, June 30, July 3 and July 21, 2008 at Mokwa, Zaria, Gboko, Kano and Ibadan, respectively. Mokwa and Gboko are located in southern Guinea savanna and Zaria is located in northern Guinea savanna. Kano and Ibadan are located in the Sudan savanna and derived savanna, respectively (Table 2).

A randomized complete block design with four replications was used at Mokwa, Zaria and Kano and three replications at Ibadan and Gboko. Four-row plots spaced 75 cm apart and 6 m long were used. Seeds of each line were hand planted in 2-3 cm deep furrows and they were thinned to 5 cm between plants after seedling establishment in two weeks time. The trial received NPK (15:15:15) fertilizer at the rate of 100 kg/ha, but no rhizobia inoculum or fungicides were applied. During the course of the experiment weeds were controlled manually by hand weeding.

Data were collected on days to flowering (number of days from planting until 50% flowering), days to maturity (days from planting up to 95% maturity), plant height (height of main stem in cm from ground level to the tip of the stem), nodulation score, resistance to lodging, pod-shattering, bacterial pustule, frog eye leaf spot, grain yield, fodder yield and 100-seed weight. At pod filling stage (about 60 days from planting), five plants were dug-up from both ends of the central rows to determine nodulation score. The plants were visually rated for nodulation taking into account both size and number of nodules using a 1-5 score, where 1 stands for absence of nodulation and 5 stands for plenty of large nodules. Lodging, shattering, bacterial pustule and frog eye were assessed using 1 – 5 score where 1 = no lodging, no shattering and no disease infection while 5 = complete lodging, total shattering and very high disease infection. Pod-shattering was assessed by visual rating of border rows of plots two weeks after harvesting. At crop maturity 4 m length of the central two rows were harvested to measure grain and fodder yields. Harvest index was estimated as the ratio of grain yield to fodder yield plus grain yield. SAS Proc Mixed (SAS, 2003) was used to analyze data.

Results and discussion

Grain yield. The new genotypes developed from the breeding program for rust resistance showed good performance for grain yield at Gboko, Ibadan, Zaria and Mokwa with the exception of Kano (Table 3). Differences among genotypes were found to be significant in four locations out of five. The combined analysis of variance also showed a highly significant ($P<0.0001$) variation for genotypes, locations and genotype × location interactions, which indicated a change in genotypes rank order.

At Gboko, 15 test genotypes significantly ($P < 0.001$) differed in grain yield (2250 - 4333 kg/ha) from the standard early maturing check variety TGx 1485-1D (1722 kg/ha).The other check variety TGx 1019-2EN was also exceeded significantly (P= 0259 - 0.001) by six of the test genotypes (TGx 1987-65, TGx 1987-64F, TGx 1987-62F, TGx 1987-28F, TGx 1987-10F and TGx 1987-34F). Similarly, TGx 1485-1D was significantly (P= 0.0301 - 0.001) out yielded by 15 test genotypes that gave a grain yield range of 2113 - 2857 kg/ha at Ibadan. However, of these good yielding genotypes,

Table 1. Rust resistant early maturing F_8 lines evaluated for grain yield at five locations in Nigeria.

Genotype	Remark
TGx 1987-6F	Rust resistant F_8 line
TGx 1987-8F	Rust resistant F_8 line
TGx 1987-9F	Rust resistant F_8 line
TGx 1987-10F	Rust resistant F_8 line
TGx 1987-11F	Rust resistant F_8 line
TGx 1987-17F	Rust resistant F_8 line
TGx 1987-18F	Rust resistant F_8 line
TGx 1987-20F	Rust resistant F_8 line
TGx 1987-23F	Rust resistant F_8 line
TGx 1987-25F	Rust resistant F_8 line
TGx 1987-28F	Rust resistant F_8 line
TGx 1987-31F	Rust resistant F_8 line
TGx 1987-32F	Rust resistant F_8 line
TGx 1987-34F	Rust resistant F_8 line
TGx 1987-62F	Rust resistant F_8 line
TGx 1987-64F	Rust resistant F_8 line
TGx 1987-65F	Rust resistant F_8 line
TGx 1740-2F	Promising early elite line
TGx 1019-2EN	Early maturing check variety
TGx 1485-1D	Early maturing check variety

Table 2. Some characteristics of the soybean trial sites in Nigeria.

Location	Coordinates	Elevation (masl)	Rainfall (long-term average) (mm)	Vegetation
Ibadan	7°23'N, 3°55'E	275	1011	Derived savanna
Mokwa	6°5'N, 9°48'E	308	900	Southern Guinea savanna
Gboko	7°19'N, 9°00'E	350	1500	Southern Guinea savanna
Zaria	11°11'N, 7°38'E	685	1100	Northern Guinea savanna
Kano (Minjibir)	12°47N, 9°2E	700	600	Sudan savanna

Table 3. Mean performance of early maturing soybean lines for grain yield (kg/ha) at five locations in the Guinea savanna of Nigeria in 2008.

Genotype	Gboko	Ibadan	Zaria	Mokwa	Kano	Mean
TGx 1987-62F	3167	2590	2630	1691	1125	2241
TGx 1987-10F	3056	2506	2542	1974	729	2161
TGx 1987-65F	4333	2185	1704	1697	750	2135
TGx 1987-9F	2833	2653	2237	1743	854	2064
TGx 1987-23F	2444	2857	2012	1815	1021	2030
TGx 1987-18F	2833	2430	2230	1462	875	1966
TGx 1987-64F	4167	2294	1412	1235	646	1951
TGx 1987-34F	3056	2119	2080	1505	917	1938
TGx 1987-20F	3000	2271	2251	1514	622	1932
TGx 1740-2F	2944	1748	2127	1777	979	1915
TGx 1987-28F	3111	2158	1930	1550	792	1911
TGx 1987-11F	2833	2335	2159	1376	562	1850
TGx 1987-8F	2000	2443	1925	1777	1083	1846
TGx 1987-32F	2722	2277	1951	1472	687	1822
TGx 1019-2EN	2722	1893	1941	1515	750	1764
TGx 1485-1D	1722	1447	1610	2172	1542	1699
TGx 1987-31F	2250	2375	1902	1250	667	1689
TGx 1987-17F	1833	1839	1865	1762	1062	1672
TGx 1987-25F	2144	2113	2273	1145	500	1635
TGx 1987-6F	2456	1598	1715	1618	583	1594
Mean	2781	2207	2025	1603	837	1891
SE	105	216	287	181	173	92
CV (%)	6	16	28	23	40	22
P (Genotype)	<.0001	0.0030	0.4048	0.0289	0.0135	<.0001
P (Location)						<.0001
P (G × L)						<.0001

only TGx 1987-23F, TGx 1987-9F, TGx 1987-62F and TGx 1987-10F significantly (P = 0.0449 - 0.0024) exceeded TGx 1019-2EN. At Mokwa, no test genotype significantly outperformed the check varieties, but the grain yields of eight test genotypes were comparable to TGx 1485-1D. The check variety gave the top yield at Kano, but TGx 1987-62F and TGx 1987-8F gave a comparable yield to this check variety.

Across locations, the top five high yield lines were TGx 1987 series (62F, 10F, 65F, 9Fand 23F) and they were statistically different (P = 0.0358 - 0.001) from both check varieties. Since high yielding ability is very important for small scale farmers, these genotypes have a potential to be varieties in Nigeria after on-farm testing. The highest mean grain yield was obtained from Gboko followed by Ibadan, Zaria, and Mokwa. The lowest yield was obtained from the drought prone location, Kano (Table 3). Comparison of location mean grain yields revealed that with the exception of Ibadan vs Zaria, the other possible combinations of locations were significantly (P < 0.001) different from one another.

Other agronomic traits. In terms of fodder (stover) yields, genotypes that gave the highest grain yield were comparable to TGx 1485-1D (Table 4). However, TGx 1987-8F, TGx 1987-23F and TGx 1987-62F exceeded the other check (TGx 1019-2EN) significantly (P = 0.0391 - 0.0115). There was no statistical difference among genotypes for harvest index. It ranged from 0.37 to 0.44. However, locations differed significantly (P < 0.001) for harvest index. The highest value of 0.47 was obtained from Mokwa and the lowest 0.34 from Kano. Because of terminal moisture stress, genotypes tend to mature faster and grain yields were low in this location. Hence, many pods were not able to fill after a huge biomass was formed before the reproductive stage.

Pertaining to phenological development, the checks TGx 1485-1D and TGx 1019-2EN were found to be early in

Table 4. Mean performance of early maturing soybean lines for eight traits in the Guinea savanna of Nigeria in 2008.

Genotype	Fodder yield† (kg/ha)	Days to flower	Days to mature	Plant height (cm)	100 seed weight§ (g)	Lodging score	Nodule score	Shattering score	Harvest index
TGx 1987-62F	2304	45	92	56	10	1.9	3.1	1.7	0.44
TGx 1987-10F	2222	47	94	53	13	1.6	2.7	1.8	0.42
TGx 1987-65F	1979	44	94	53	11	1.6	2.8	1.6	0.40
TGx 1987-9F	2229	48	95	51	12	1.5	2.7	1.6	0.41
TGx 1987-23F	2389	47	94	60	13	1.8	3.1	2.6	0.40
TGx 1987-18F	2021	46	94	49	11	1.5	2.7	2	0.42
TGx 1987-64F	1826	48	93	61	10	1.5	2.6	1.8	0.37
TGx 1987-34F	2174	44	90	53	10	1.8	3.1	1.4	0.40
TGx 1987-20F	1929	46	91	46	10	1.9	2.9	1.6	0.41
TGx 1740-2F	2076	40	92	62	12	1.5	3.0	1.7	0.43
TGx 1987-28F	2264	46	93	64	11	2.1	3.0	2.7	0.39
TGx 1987-11F	1678	45	91	47	11	2.1	2.7	2.2	0.43
TGx 1987-8F	2410	47	96	55	12	1.7	2.7	1.8	0.41
TGx 1987-32F	1861	44	89	51	11	1.9	3.4	2.1	0.42
TGx 1019-2EN	1795	42	97	65	12	1.7	2.8	1.5	0.43
TGx 1485-1D	2467	41	92	42	12	1.3	2.8	1.4	0.39
TGx 1987-31F	1771	46	95	54	11	1.9	2.8	1.4	0.40
TGx 1987-17F	2167	46	91	53	10	2	2.8	2.3	0.42
TGx 1987-25F	1833	46	90	51	12	1.5	2.8	2.1	0.40
TGx 1987-6F	1882	46	92	43	11	1.6	2.9	1.3	0.40
Mean	2064	45	93	53	11	1.7		1.8	0.41
SE	171	0.5	0.6	2	0.4	0.1	0.2	0.2	0.02
CV (%)	28	5	2	17	13	35	26	33	17
P (G)	0.0109	<.0001	<.0001	<.0001	<.0001	0.0021	0.1111	<.0001	0.8509
P (L)	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0003	<.0001
P (G x L)	0.0721	<.0001	<.0001	<.0001	<.0001	0.0079	0.0471	0.0025	0.5508

†Data from three locations (Kano, Mokwa and Zaria). §Data from four locations (Ibadan, Mokwa, Zaria, and Kano).

flowering (40-42 days) as compared to the test genotypes which took 44 to 48 days and these differences were significant (P = 0.0133 - 0.001). In general, all genotypes in this test matured in less than 100 days. Among the checks, TGx 1019-2EN was the latest (97 days) and all other genotypes were significantly early maturing in comparison to this genotype. TGx 1485-1D was one of the early maturing genotype, but TGx 1987-32F and TGx 1987-34F were the earliest and significantly (P= 0.0011 and P=0.0489, respectively) different from this check variety.

Plant height ranged from 42 - 65 cm, the shortest being the widely grown check variety TGx 1485-1D and the tallest is the other check TGx 1019-2EN, which is not a widely grown variety. Among the test genotypes, the high yielding lines TGx 1987-62F, TGx 1987-65F, TGx 1987-10F and TGx 1987-9F were having intermediate heights (51-56 cm) and these differences were significantly different from both checks. Genotype differences for 100 seed weight was highly significant (P<0.001) and it ranged from 10 - 13 g. One of the top yielding genotype (TGx 1987-10F) had a significantly (P=0.0062) higher seed weight as compared to both checks and the rest of the test genotypes. Generally, the promiscuously nodulating TGx varieties and lines have low (less than 15 g) 100 seed weight because they were selected for low seed weight to improve seed viability and shattering resistance.

Lodging scores ranged from 1.3 - 2.1 and such difference was significant among the genotypes. The high yielding test genotypes showed resistance to lodging similar to the released varieties. The difference between the checks and the best yielding genotypes was not significant and for both the checks and the best yielding lines it ranged from 1.3 - 1.6. Genotypes did not differ for nodule score. All test genotypes including the checks showed a good level of nodulation that ranged from 3 to 4. Almost all the genotypes had a good level of pod shattering. It ranged from 1.3 (TGx 1987-6F) to 2.7 (TGx 1987-28F) and such differences were found to be significant (P < 0.001). The check varieties have shown a high level of resistance to shattering (1.4 - 1.5) and the high yielding genotypes such as TGx 1987-62F, TGx 1987-10F, TGx 1987-65F and TGx 1987-9F also had high level of resistance with scores ranging from 1.6 - 1.8, and these scores were not significantly different from the checks. The high level of resistance to pod shattering in these genotypes is not unexpected as the breeding program screened these lines for pod shattering resistance before they entered variety trials.

Bacterial pustule and frog eye diseases. Genotypes differed significantly (P<0.001) for bacterial pustule (Table 5). Scores for this disease ranged from 1.1 to 3.9 and the released check varieties TGx 1485-1D and TGx 1019-2EN have shown good level of resistance to this disease with a score of 1.1 and 1.3, respectively. Among the high yielding genotypes, TGx 1987-62F, TGx 1987-9F and TGx

Table 5. Mean performance of early maturing soybean lines for bacterial pustule and frog eye leaf spot in the Guinea savanna of Nigeria in 2008.

Genotype	Bacterial pustule†	Frog eye§
TGx 1987-62F	1.2	1.1
TGx 1987-10F	1.4	1.3
TGx 1987-65F	3.4	3.0
TGx 1987-9F	1.4	1.2
TGx 1987-23F	1.2	1.1
TGx 1987-18F	3.4	3.0
TGx 1987-64F	3.9	3.0
TGx 1987-34F	2.6	2.3
TGx 1987-20F	1.5	1.0
TGx 1740-2F	1.4	1.0
TGx 1987-28F	1.2	1.0
TGx 1987-11F	3.7	2.7
TGx 1987-8F	1.5	1.0
TGx 1987-32F	1.8	1.3
TGx 1019-2EN	1.1	1.0
TGx 1485-1D	1.3	1.2
TGx 1987-31F	3.1	3.0
TGx 1987-17F	2.4	2.3
TGx 1987-25F	1.5	1.1
TGx 1987-6F	1.5	1.5
Mean	2.0	1.7
SE	0.2	0.1
CV (%)	33	22
P (G)	<.0001	<.0001
P (L)	0.0044	<.0001
P (G x L)	<.0001	<.0001

†Scores of 1 -5 (1 = resistant and 5 = susceptible) from four locations (Ibadan, Mokwa, Zaria, Kano).
§Scores of 1 -5 (1 = resistant and 5 = susceptible) from three locations (Mokwa, Zaria and Kano).

1987-10F were found to be resistant to this disease with low scores (1.2 - 1.4) similar to the check varieties. However, one of the high yielding genotypes (TGx 1987-65F) had a fairly high level of infection with a score of 3.4, which was significantly different from the checks and the other high yielding genotypes. The check varieties were also found to be resistant to frog eye leaf spot. Three of the high yielding genotypes also showed good resistance to this disease with scores of 1.1 - 1.3. A number of the test genotypes also showed high level of resistance to this disease, but TGx 1987-65F had high score (3) for this disease.

Location effects. Fodder yield was assessed at three locations (Kano, Mokwa and Zaria) and these locations differed significantly. The highest mean yield of 2641 kg/ha was obtained from Zaria followed by Mokwa (1732 kg/ha) and Kano (1618 kg/ha) (Data not shown). The yield from Zaria was significantly (P<0.001) higher than that of Kano and Mokwa while the latter two did not differ significantly. Locations showed a highly significant difference for mean days taken to flowering. Genotypes took 38 days on average to flower at Gboko whilst 52 days were required at Zaria. In the other three locations, genotypes took 45 days to flower. Average maturity dates of genotypes on location basis also showed a highly significant difference. Genotypes matured in 84 and 85 days at Kano and Gboko, respectively, while mean maturity date was 102 days at Zaria the remaining locations being intermediate.

Locations showed a striking difference for plant height as well. Average height at Gboko was 33 cm while the highest mean of 72 cm was obtained at Ibadan. Quite similar to Gboko, mean height from Kano was 35 cm. Average heights at Mokwa and Zaria were 61 and 66 cm, respectively. The drought prone location (Kano) gave small sized seeds (9 g/100 seeds) as compared to Ibadan, which was 13 g. These two locations differed significantly from each other (P<0.001) and from Mokwa (11.8 g) and Zaria (11.7 g). Location means for lodging resistance ranged from 1.1 (Zaria) to 2.2 (Gboko) and overall genotypes have shown good performance for this trait. Location means were found to be significant for nodulation score, the lowest being 3 and the highest 3.6. In general, nodulation was satisfactory in all locations. For pod-shattering, locations differed significantly. Mean scores from Gboko, Ibadan and Zaria were less than 2 while average figures from Mokwa and Zaria were 2.2 and 2.3, respectively. Overall, pod shattering resistance of the genotypes in all locations seems to be satisfactory.

Location means also differed for bacterial pustule and frog eye diseases. However, the incidence of bacterial pustule is lower in all locations. Similarly, location means for frog eye also differed significantly in this study. The highest mean score (2.6) was from Kano while the lowest was from Zaria (1.2).

Discussion and conclusion

Soybean rust is widely spread in soybean producing areas of Nigeria. Since Nigeria produces nearly 43% of the Africa's total soybean grain, this disease will bring a major disaster unless it is checked. Among the options available to manage this disease, development of resistant varieties is the most viable option (Hartman *et al.*, 2005). More than a dozen IITA developed soybean lines have been released in many countries of Africa mainly Nigeria over the past three decades of soybean breeding. However, all of these varieties and breeding lines were found to be susceptible to the disease. Prior to the development of the rust resistant lines reported in this paper, IITA's effort in screening breeding lines and germplasm has resulted in the identification of a rust resistant line TGx 1835-10E, which was released in Nigeria in 2009 (http://www.iita.org/cms/details/news_feature_details.aspx? articleid= 2517&zoneid=342). This variety is the only rust resistant variety in Nigeria at present. However, it is not as high yielder as the current lines in the Guinea savanna of Nigeria.

The high yielding lines presented in this paper are capable of giving 2.5 – 4 t ha $^{-1}$ in rust prone areas of Nigeria and considering all locations they give more than 2 tons per hectare, which is way above the existing early maturing soybean variety. Because of genotype by environment interaction, the best lines have not exceeded the check in rust free locations such as Kano. The presence

of genotype by environment interaction in dual-purpose soybeans grown in Mokwa and Zaria has also been reported by Dashiell *et al*. (2001) previously. However, investigation carried out in early maturing varieties of soybean at Mokwa and Zaria in two years did not result in variety by environment interaction for grain yield (Tefera *et al.*, 2009).

Since deploying rust resistant soybean varieties in the disease prone areas of Nigeria such as the moist savanna and derived savanna zones is absolutely necessary, the high yielding lines identified in this study are of a great importance. It is therefore essential to carry out on-farm trials on TGx 1987-62F, TGx 1987-10F and TGx 1987-9F to ascertain their merits and release them for large scale production in Nigeria. These lines have shown satisfactory agronomic merits and are also resistant to bacterial pustule and frog-eye leaf spot.

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