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Potential for soybean rust tolerance among elite soybean lines in Uganda

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ABSTRACT

Soybean rust, (*Phakopsora pachyrhizi*), currently the most devastating disease of soybeans worldwide, is known to challenge single resistance genes deployed against it and therefore, disease tolerance is indisputably the most viable measure in controlling the pathogen. Studies were conducted at Namulonge in Central Uganda to assess the level of tolerance to soybean rust among selected elite soybean lines. Seven elite lines together with three local checks were tested in a split-plot design where some plots were protected with fungicide to estimate the level of tolerance to soybean rust. The experiment was conducted for three cropping seasons beginning second rains of 2005. A rust tolerance index (RTI) was computed for each test line as the ratio of yield from unprotected plots to yield from protected plots. The study showed that high levels of tolerance to soybean rust were present in the test lines. The soybean lines that showed high levels of tolerance included MNG 10.3 and MNG 3.26 all showing RTIs higher than 0.93. These lines also out-yielded the local checks by about 400 kg ha^{-1} and are recommended for multi-location testing.

1. Introduction

Soybean, *Glycine max*, has been dubbed a crop of the future for sub-Saharan Africa for enhancing food security and incomes of rural households (Keyser and Li, 1992; Ogoke et al., 2003). The crop is important particularly for its high protein content (40%), high quality vegetable oil (20%) and its short growth period (McKevith, 2005). Worldwide production of soybean is threatened by the Asian soybean rust, caused by *Phakopsora pachyrhizi* Sydow, a disease previously only known to the Orient. Soybean rust was first reported in Uganda in 1996 but has now spread to all soybean growing countries in Africa, South America and North America (Anon, 2001; Rossi, 2003; Levy, 2005; Schneider et al., 2005). The use of fungicides is effective against soybean rust but their use among resource poor farmers is limited due to associated high costs and technical knowledge limitations (Kawuki et al., 2004; Dorrance et al., 2007). Host plant resistance is the best long-term strategy for managing the disease in endemic areas as it provides the cheapest and most sustainable alternative.

Breeding for resistance to soybean rust is complicated by the aggressiveness of the rust pathogen. *P. pachyrhizi*, the causal agent of soybean rust is known to have multiple virulence genes that are reported to challenge single resistance genes deployed to control the disease (Hartwig and Bromfield, 1983; Bromfield, 1984; AVRDC, 1992; Hartman, 1995; Oloka et al., 2008). As a consequence, soybean rust resistance breeding efforts now focus on other resistance mechanisms such as partial resistance (rate reducing resistance) and tolerance in the management of the disease. Partial resistance occurs in situations when the rate of rust development is slowed down in a particular genotype. Lines with partial resistance in field evaluations are rated as moderately resistant because few rust lesions (usually non-sporulating) develop on soybean plants in the course of crop growth and development (Hartman et al., 2005).

Rust tolerance, which is yielding ability under rust stress, is a strategy of selecting lines with high yield potential and less yield loss from soybean rust and the strategy is considered more durable than specific resistance since it eliminates chances of resistance break down (Kawuki et al., 2004; Hartman et al., 2005). Rust tolerance has been used in Asia to minimize losses attributed to soybean rust (AVRDC, 1992). The Department of Crop Science at Makerere University, Kampala and the National Agricultural Research Organisation, Uganda identified seven soybean lines in 2004 which showed high yields under severe rust pressure, suggesting good levels of tolerance to soybean rust in these materials under Namulonge conditions. The objectives of this study were to: (1) evaluate the level of tolerance to soybean rust among

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selected elite soybean lines in Uganda, and (2) assess the potential of the elite lines in management of soybean rust in the tropics.

2. Materials and methods

An experiment was set up at the National Crops Resources Research Institute in Namulonge for three cropping seasons beginning second rains of 2005. Namulonge is located in central Uganda at 00°32′N and 32°37′E at an elevation of 1150 m above sea level. The area experiences a bimodal rainfall distribution (average total annual rainfall of 1100 mm) with a general wet and mild dry climate and slightly humid conditions (average 65% relative humidity). There was less rainfall (peak at 116 mm for the month of September 2005) in the second rains of 2005 than the first rains of 2006 (peak at 149 mm in April) while the second rains of 2006 had the highest rainfall amounts (peak at 232 mm in November 2006). Maximum temperatures for the two seasons of 2006 were comparable, averaging 28.5 °C while slightly higher maximum temperatures (average 30 °C) were observed during the second season of 2005.

A total of seven elite soybean lines, derived from crosses between a rust susceptible line (Duiker) and a rust resistant line (TGX 1835-10E), and three local checks were included in the study. The local checks were the moderately resistant cultivars Maksoy 1N and Namsoy 4M and a rust susceptible cultivar, Nam 1. The elite lines were selected for high yields under natural soybean rust pressure. Planting was done on 15 September 2005 for the second rains of 2005 (2005B), on 28 February 2006 for the first rains of 2006 (2006A) and on 15 September 2006 for the second rains of 2006 (2006B).

For each season, the test materials were established in a split-plot design with three replicates. Each entry was represented by three 5 m rows spaced 60 cm apart with an intra-row spacing of 5 cm. The main plots were the rust protected and unprotected treatments while the genotypes constituted the sub-plots. The highly rust susceptible check Nam 1 was planted around the test plots as a spreader line.

The rust protected plots were sprayed with the systemic fungicide *Score* (active ingredient *difenoconazole*) at 1 ml l^{-1} at R3 growth stage (beginning of pod formation) and at R6 (full seed formation) (Tukamuhabwa et al., 2001). Fungicides were applied to enable computation of rust tolerance indices from yields of protected and unprotected plots. Rust assessment was conducted on the unprotected plots at growth stages R2 (full bloom), R4 (full pod) and at R6 (full seed) using a 0–9 severity scale modified from Kawuki et al. (2003) where 0 = no visible rust symptoms, and 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0 indicate 10% to 80% disease severity and 9 = 90% disease severity plus defoliation based on number and distribution of rust spots on leaves. At maturity, all plots were harvested, sun dried, threshed and seed yield per plot and moisture content established. Yield values from each plot were standardised to 12% moisture content and converted to yield per hectare.

Rust tolerance was quantified using the rust tolerance index (RTI) computed from:

$$\text{RTI} = \frac{\text{Yield from rust unprotected plots}}{\text{Yield from rust protected plots}}$$

(Adapted from Kawuki et al., 2003).

Results for each season were analysed separately and also combined over seasons. Rust tolerance indices, rust severities and seed yield were subjected to analysis of variance (ANOVA) in Genstat 9th Edition (Lawes Agricultural Trust, Rothamstead, UK) to test for differences in rust reaction and yield among the test materials. Rust severities were angular transformed in order to normalise the data prior to ANOVA (Sokal and Rohlf, 1995). Lines with RTIs higher than susceptible checks were categorised as rust tolerant materials. Mean RTIs and seed yield were separated using Least Significant Difference (LSD) of means at the 5% level of significance.

3. Results

3.1. Rust severities on test lines

During the three seasons, no rust symptoms were observed on any plot at growth stage R2. Variations were observed in rust severity ($P < 0.001$) among the test lines except at growth stage R4 during 2005B and 2006A (Table 1). During 2005B, at R4, rust was observed on many lines except MNG 8.24, Maksoy 1N and MNG 9.17. Highest rust severity was observed on line MNG 3.26. At R6, rust severity increased considerably in all test lines. The lowest rust severities were observed in lines MNG 10.3, Maksoy 1N, Namsoy 4M and MNG 4.19 while Nam 1 had the highest rust severity.

During 2006A, at R4, rust lesions were observed from only five test lines. The susceptible local check, Nam 1 also showed no rust lesions at this stage. The highest rust severities were observed in lines MNG 3.26 and MNG 8.24. At R6, differences ($P < 0.001$) were observed in reaction to rust among the test lines. The lowest rust severities were observed in line MNG 10.3 and in the cultivars Maksoy 1N and Namsoy 4M while the highest rust scores were observed in the susceptible check, Nam 1 and in lines MNG 9.17 and MNG 8.6(B).

During 2006B, at R4, no rust symptoms were observed on lines MNG 8.24, MNG 10.3, MNG 4.19, and on the cultivars Maksoy 1N and Namsoy 4M. There were differences in rust reaction ($P < 0.001$) among the test lines at both R4 and R6 growth stages. Lines that showed very high rust scores at R6 included MNG 9.17, Nam 1, MNG 8.6(B) and MNG 8.22 with mean rust score of over 7.0.

Across seasons, the lowest rust severities at R6 were observed on lines MNG 10.3, MNG 8.24, MNG 4.19 and in the cultivars Maksoy 1N and Namsoy 4M. The susceptible check, Nam 1 and line MNG 8.6(B) showed the highest rust severity. Rust was more severe, though not significant, during the two cropping seasons of 2006 than during the second rains of 2005.

3.2. Effect of rust control on yield

The application of the systemic fungicide, *Score* on soybean lines improved the yield ($P < 0.05$) of soybean during the three cropping

Table 1
Rust severities on test soybean lines under natural *Phakopsora pachyrhizi* infection at Namulonge, Uganda during growing seasons beginning with second rains of 2005 (2005B), first rains of 2006 (2006A), and second rains of 2006 (2006B).

Line	Rust severity (0–9 scale)							
	2005B		2006A		2006B		Mean	
	R4	R6	R4	R6	R4	R6	R4	R6
MNG 8.24	0.0	2.5	1.0	3.2	0.0	2.3	0.33	2.7
MNG 8.22	0.3	3.2	0.0	5.2	5.0	8.7	1.8	5.7
MNG 10.3	0.3	2.0	0.3	2.8	0.0	0.0	0.22	1.6
MNG 8.6(B)	0.3	5.3	0.0	6.2	4.5	8.7	1.6	6.7
Maksoy 1N	0.0	2.0	0.3	1.7	0.0	0.0	0.11	1.2
Nam 1	0.3	6.2	0.0	6.8	4.3	7.7	1.6	6.9
Namsoy 4M	0.3	2.0	0.0	1.7	0.0	1.3	0.11	1.7
MNG 3.26	1.2	4.7	1.3	4.8	3.7	6.2	2.1	5.2
MNG 4.19	0.5	2.0	0.0	4.0	0.0	2.3	0.17	2.8
MNG 9.17	0.0	3.5	0.3	6.5	2.8	7.2	1.1	5.7
Mean	0.33	3.33	0.33	4.28	2.03	4.43	0.90	4.02
F-prob[a]	0.306	<0.001	0.236	<0.001	<0.001	<0.001	<0.001	<0.001

[a] ANOVA was carried out on angular transformed values.