

Performance of soybean genotypes (*Glycine Max* L.) against Asian rust (*Phakopsora Pachyrhizi* Syd.) in Cameroon

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Abstract

Asian rust caused by *Phakopsora pachirhizi*, which is a major constraint to production of soybean, causing 90% yield losses in field. Synthetic fungicides used to control this disease are environmentally degrading and have negative impact on the health of producers and consumers. The use of resistant soybean genotypes can be an effective control alternative. The aim of this work is to evaluate the tolerance of soybean varieties to Asian rust disease under natural conditions. Forty-three soybean varieties were screened using a completely randomized block design with three replicate. Incidence and severity of disease at 6, 8 and 10 weeks after sowing (WAS) and yields were evaluated. Results show that disease incidence of Asian rust was significantly higher in the local variety R3 (16.67%; 29.63%; 75.93%) at 6, 8 and 10 WAS respectively. At 6 and 8 WAS severity of disease was higher in local variety R3 (21.17% and 24.14% respectively). The variety TGX-2010-12F has the highest yield (1.17 t ha⁻¹) than the local variety R3 (0.17 t ha⁻¹). Principal component analysis realized with incidence, severity of disease at 6, 8, 10 WAS and yield shows that 12 varieties are highly susceptible to Asian rust, 12 varieties are moderately resistant, and 19 varieties are susceptible. This study shows that Asian rust attacks all soybean varieties in the field. Moderately resistant varieties, can be advised to growers with appropriate protection methods or be subject to varietal improvement through genetic techniques.

Keywords: Screening; Varieties; Asian rust; Resistance; Glycine max; Yield

1. Introduction

Soybean (*Glycine max* L.) is an annual plant belonging to the Fabaceae family. Originally from East Asia, soybean is cultivated for its seeds which are very rich in proteins (30 to 40%), lipids (20%), carbohydrates (35% including 20% fiber), minerals and vitamins (5%) [1]. Proteins play a role in regulating blood cholesterol, thereby contributing to reducing the risk of contracting cardiovascular disease [2]. Most of the soybeans produced worldwide are crushed to be transformed either into cake for animal feed, into oil for human consumption or used as an agrofuel. After palm oil, soybean oil is the second most consumed oil in the world [3]. In addition, the plant's ability to fix atmospheric nitrogen contributes significantly to improving soil fertility [4].

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Soybeans are present in more than 80 countries around the world, with the United States being the main producer, with production in 2019 estimated at around 85.6 million tons (Mt), and followed by Brazil with around 60.54 Mt and Argentina with around 36.37 Mt, [5]. On a global scale, statistics show that soybean is the first seed legume cultivated in the world and the fourth most important legume cultivated and consumed in Cameroon after groundnut, cowpea and bean [6]. In Cameroon, soybean is grown in his five agro-ecological zones. Despite the slight increase in yields observed, in 2018 and 2019 (1.3926 t/ha to 1.4450 t/ha) its production remains relatively low (23058 tonnes) [5] in relation to demand.

In spite of its socioeconomic importance and nutrition, soybean farming is facing several problems that largely explain the low yields. These problems include low soil fertility, pests and diseases [7]. Among the diseases, the most important are fungal origin, particularly Asian rust caused by *Phakopsora pachirhizi*, which is a major constraint to production, causing yield losses of up to 90% [8]. Disease control in the field is most often subject to the use of chemicals that are environmentally degrading and have negatively impact on the health of producers and consumers [9]. The scarcity of data referring to the resistance of (newly introduced) soybean varieties to Asian rust disease deserves special attention as an alternative to chemical control. In Cameroon, work on the susceptibility of these soybean varieties to Asian rust is very poorly documented. Only information on the adaptability of the varieties is available [10]. Therefore, it would be interesting to screen the forty-three soybean varieties newly introduced in Cameroon against Asian rust disease. The hypothesis being tested is that among the screened varieties, there is one with resistance to Asian rust disease in natural conditions. The general objective of this study is to identify soybean varieties showing resistance under the influence of Asian soybean rust in the locality of Mfou in Cameroon.

2. Material and methods

2.1. Materials

2.1.1. Study site

The work took place on a fallow land of 2 years old from May 26 to September 15, 2020 in the locality of Mfou. This locality is the capital of the Department of Mefou-et-Afamba, located in the Central Region of Cameroon. The geographical coordinates recorded using a GPS Garmin is: 3°45'27.048" North latitude; 11°37'38.532" East longitude, altitude ± 701m. This locality belongs to the agro-ecological zone 5 known as the bimodal rainfall zone. The average temperature is 25°C and the average annual rainfall is 1500-2000 mm [11, 12]. The prevailing climate is of the Guinean type. The soils are ferrallitic, acidic, clayey with a low nutrient retention capacity.

2.1.2. Plant Material

The experiment involved 43 soybean seeds varieties, including 38 exotic and 5 local varieties (Table 1). The exotic varieties are newly introduced through collaboration between the Institute of Agricultural Research for Development (IARD) and the University of Illinois at the United States. The local varieties are from the IRAD breeding of Foubot (TGX-1835-10E; TGX 2007-8F) and Garoua (R3; R2; TGX 1448-2F) originating from the International Institute of Tropical Agriculture (IITA).

Table 1 Different soybean varieties and their origin

Varieties	Source	Exotic/Local	Maturity (days)
TGx2002-23DM	IITA (Zambia)	exotic	90 – 100
Afayak	CSIR-SARI (Ghana)	exotic	90 – 100
SoungPungun	CSIR-SARI (Ghana)	exotic	90 – 100
TGx2001-24DM	IITA (Zambia)	exotic	90 – 100
TGx2001-10DM	IITA (Zambia)	exotic	90 – 100
JENGUMA	CSIR-SARI (Ghana)	exotic	90 – 100
TGx2014-19FM	IITA (Zambia)	exotic	90 – 100
Maksoy 3N	U. Makerere (Uganda)	exotic	90 – 100
TGx2001-13DM	IITA (Zambia)	exotic	90 – 100

TGx1987-62F	IITA (Nigeria)	exotic	90 – 100
Maksoy 2N	U. Makerere (Uganda)	exotic	90 – 100
S1140-5-4	SeedCo (Zimbabwe)	exotic	90 – 100
DPSB 8	KALRO (Kenya)	exotic	90 – 100
SNKGM011	Sensako (South Africa)	exotic	90 – 100
SCS-1	EIAR (Ethiopia)	exotic	90 – 100
S1150-5-22	SeedCo (Zimbabwe)	exotic	90 – 100
Clark 63K	EIAR (Ethiopia)	exotic	90 – 100
TGx2006-3F	IITA (Nigeria)	exotic	90 – 100
TGx2008-4F	IITA (Nigeria)	exotic	101 – 110
SC Saga	SeedCo (Zimbabwe)	exotic	90 – 100
TGx1991-22F	DARS (Malawi)	exotic	90 – 100
R3	IITA(Cameroun)	local	110-120
TGX-1835-10E	IITA(Cameroun)	local	90 – 100
R2	IITA(Cameroun)	local	110-120
TGx-2001-8DM	IITA (Zambia)	exotic	90 – 100
TGx-2001-1DM	IITA (Zambia)	exotic	90 – 100
TGx-2002-1DM	IITA (Zambia)	exotic	90 – 100
TGX1485-1D	IITA (Nigeria)	exotic	90 – 100
TGX2004-10F	IITA (Nigeria)	exotic	101 – 110
TGX 2011-7F	IITA(Nigeria)	exotic	90 – 100
TGX 2010-3F	IITA(Nigeria)	exotic	90 – 100
TGX 2007-11F	IITA (Nigeria)	exotic	101 – 110
TGX 2004-3F	IITA(Nigeria)	exotic	90 - 100
TGX 2010-15F	IITA(Nigeria)	exotic	90 - 100
TGX 2011-3F	IITA (Nigeria)	exotic	90 – 100
TGX 2008-2F	IITA(Nigeria)	exotic	101 – 110
TGX 2004-13F	IITA (Nigeria)	exotic	90 - 100
TGX 2007-8F	IITA(Cameroun)	local	90 – 100
TGX 1448-2F	IITA(Cameroun)	local	90 – 100
TGX 2010-12F	IITA (Nigeria)	exotic	101 – 110
TGX 2002-14DM	IITA (Zambia)	exotic	90 – 100
TGX 2001-14DM	IITA (Zambia)	exotic	90 – 100
TGX 2010-11F	IITA (Nigeria)	exotic	90 – 100

2.2. Methods

2.2.1. Experimental design and culture conditions

The experimental design was a completely randomized blocks with three repetitions. The blocks (22.5 m x 5 m) consisted of 43 plots or experimental units which represent the varieties. Each block is spaced by 1 m and 0.5 m paths separated the plots. The varieties are sown manually 3 days after ploughing, with a distance of 0.5 m between rows and 0.5 m between bunches (68 800 plant ha⁻¹). Each row consisted of 9 bunches, i.e. 18 plants per row. A sarclo-buttague was carried out manually at 3 and 6 weeks after sowing (WAS). No fungal treatments or fertilizers were applied during the experiment. The contamination of the plot was done naturally by the pathogen.

2.2.2. Evaluation of the incidence and severity of Asian rust

Plants per plot was counted and noted. Diseased plants were identified and counted per experimental unit. The incidence of the disease was determined every two weeks according to the usual formula in plant pathology described by Tchoumakov and Zaharova [13]

$$I (\%) = \frac{\text{number of diseased plants}}{\text{Total number of plants per experimental unit}} \times 100$$

Table 2 Scale for estimating degrees of infection

Code	Severity (%)	Description	Grades
1	(0 %)	Total absence of symptoms	Immune/Disease Free
2	(0.6-1.99 %)	Infection occupying less than half the leaf area	Resistant
3	(2-6.99 %)	Infection covering two-quarters of the leaf area	Moderately Resistant
4	(7-17.9 %)	Infection covering more than two-quarters of the leaf area	Moderately Susceptible
5	(18-41.9 %)	Infection covering three – quarters of the leaf area	Susceptible
6	(42-78.5%)	Infection covering more three – quarters of the leaf area	Highly Susceptible

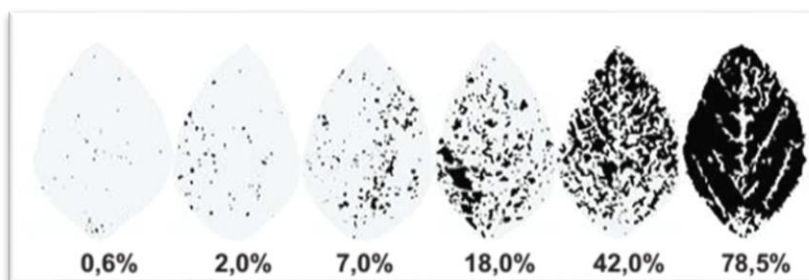


Figure 1 Diagrammatic scale of soybean (*Glycine max*) rust severity (percentage of diseased leaf area) [14]

The severity of the disease was taken every two weeks on ten plants labeled per treatment, the degrees of infection were attributed using the scale of 6 point (Fig.1) proposed by Godoy *et al.* [14] with some modification. The quantification of the disease was done by treatment and as a function of time. The severity of the disease was expressed by the formula described by Tchoumakov and Zaharova [13].

$$S = \sum (a \times b) / n \times 100$$

Where: $\sum (ab)$ = is the sum of the multiplications of the number of diseased plants, (a) = with the degree of corresponding infection, (b) = given in %, n= the number of diseased plants (Table 2).

2.2.3. Yield estimation of soybean varieties

The mature and half-dry pods of ten seedlings labeled by variety were harvested, then oven-dried (Selecta brand) until a constant weight was obtained. After hulling, the seeds obtained were weighed using a balance trade mark Sotorius (precision 0.001). Varietal yields were calculated according to the formula of Svecnjak *et al.* [15].

$$\text{Yield (t/ha)} = \frac{\text{PGEp} \times \text{N}}{\text{S}} \times 10000$$

Where: PGEp = weight of dry soybeans per plant, N = number of soybean plants per treated elementary plot, S = area of each elementary plot treated, 10000 m² = 1 hectare

2.2.4. Statistical analysis

Data on the epidemiological parameters (incidence and severity) and the yield of the different varieties were organized using the EXCEL 2010 spreadsheet (Microsoft office). These data were subjected to one-way analysis of variance (ANOVA) using R software version 3.5.1. The multiple comparisons of means were performed using the Last significant difference (LSD) test at $P < 0.05$ to separate them when the analysis of variance was significant. The principal component analysis and dendrograms were performed using the parameters incidence, severity and yield.

3. Results

3.1. Incidence of Asian soybean rust on screened varieties

Incidence of the disease of the 43 varieties observed during the data collection varies according to the varieties (Fig.2). At 6, 8 and 10 WAS ($P < 0.001$), the local variety R3 had the highest incidence of 16.67%; 29.63%; 75.93% respectively. It is followed by the variety S1150-5-22 with incidences of 12.96%; 25.93% at 6 and 8 WAS respectively. Varieties AFAYAK, JENGUMA, MAKSOY2N, MAKSOY3N, S1140-5-4, TGX-2001-1DM, TGX-2001-80M and TGX-2007-11F have zero incidences at 6 WAS. In contrast, at 10 WAS, they had incidence of 16.67, 25.93, 50, 55.56, 37.04, 48.15, 46.30, and 59.26%, respectively.

3.2. Severity of Asian rust of screening varieties

The severity of the disease observed during the different data collection varies according to the varieties (Fig.3). Significant differences ($P < 0.001$) were recorded between the severities of the different varieties over time. The local variety R3 had the highest severity of 21.17% and 24.14% respectively at 6WAS and 8WAS, while at 6WAS, the varieties AFAYAK, JENUMA, MAKSOY2N, MAKSOY3N, S1140-5-4, TGX-1448-2E, TGX-2001-1DM, TGX-2001-24DM, TGX-2001-80M and TGX-2007-11F had zero severity. At 10WAS the varietyTGX-2002-14DM had the highest severity of 59.26% compared to the variety TGX-2001-1DM which had the lowest severity of 10%

3.3. Yield of screened soybean varieties

Yield results for soybean varieties in natural infection conditions vary by variety (Fig.4). The analysis of variance found a significant difference between varieties ($P < 0.05$) on grain yields in t ha⁻¹. TGX-2010-12F (1.17 t ha⁻¹), TGX-2010-3F (0.78 t ha⁻¹) had the highest yields while R3 (0.17 t ha⁻¹) and R2 (0.19 t ha⁻¹) had the lowest yields. However, the variety TGX-2010-3F (0.78 t ha⁻¹) and CLARK-63K (0.779 t ha⁻¹) are not statistically different.

3.4. Multivariate analysis

3.4.1. Principal component analysis

S.6.WAS: severity six days after sowing; S.8.WAS: severity eight days after sowing; S.10.WAS: severity ten days after sowing; I.6.WAS: incidence six days after sowing; I.8.WAS: incidence eight days after sowing; I.10.WAS: incidence ten days after sowing.

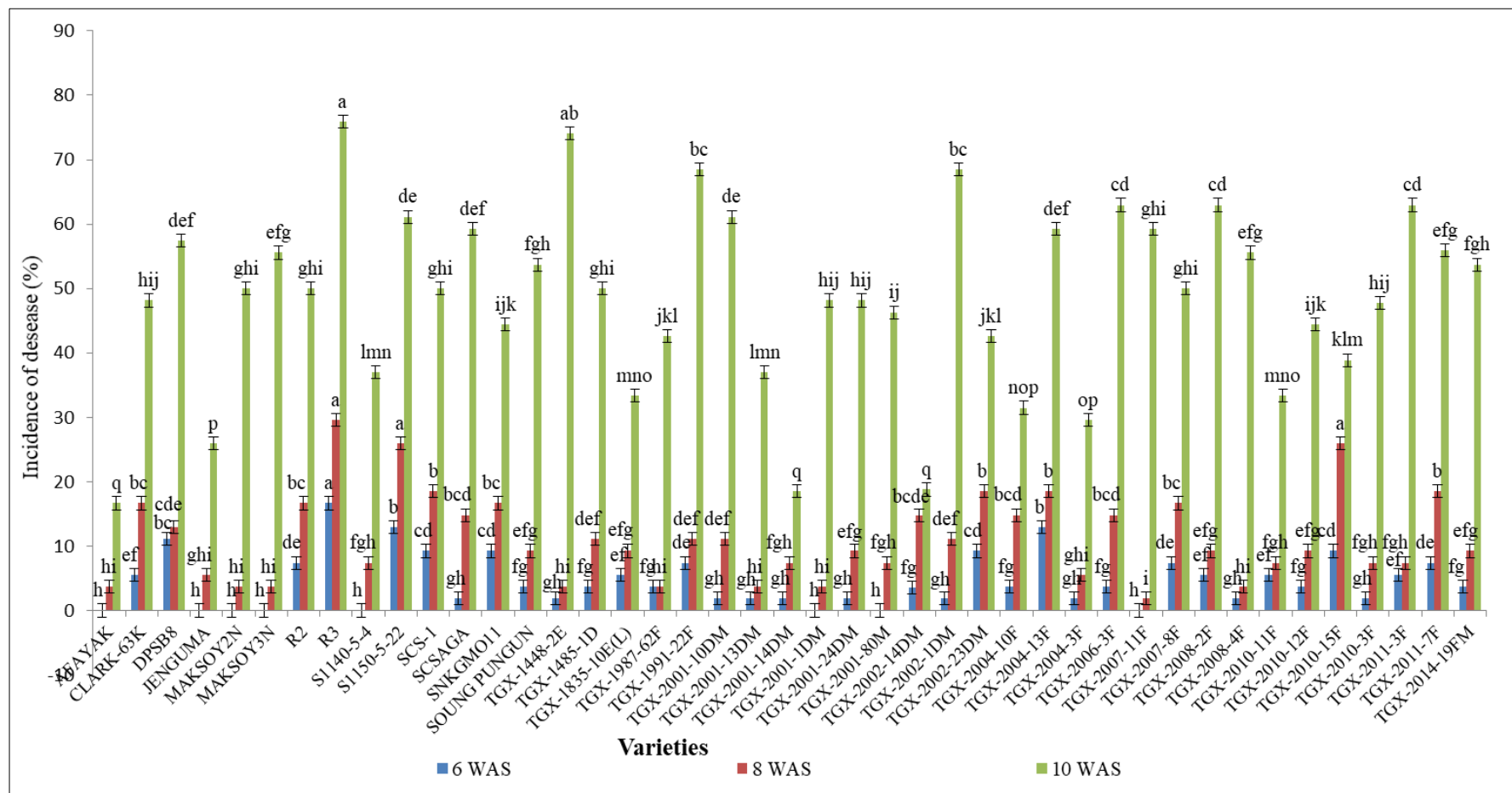


Figure 1 Incidence of Asian soybean rust in different varieties by time

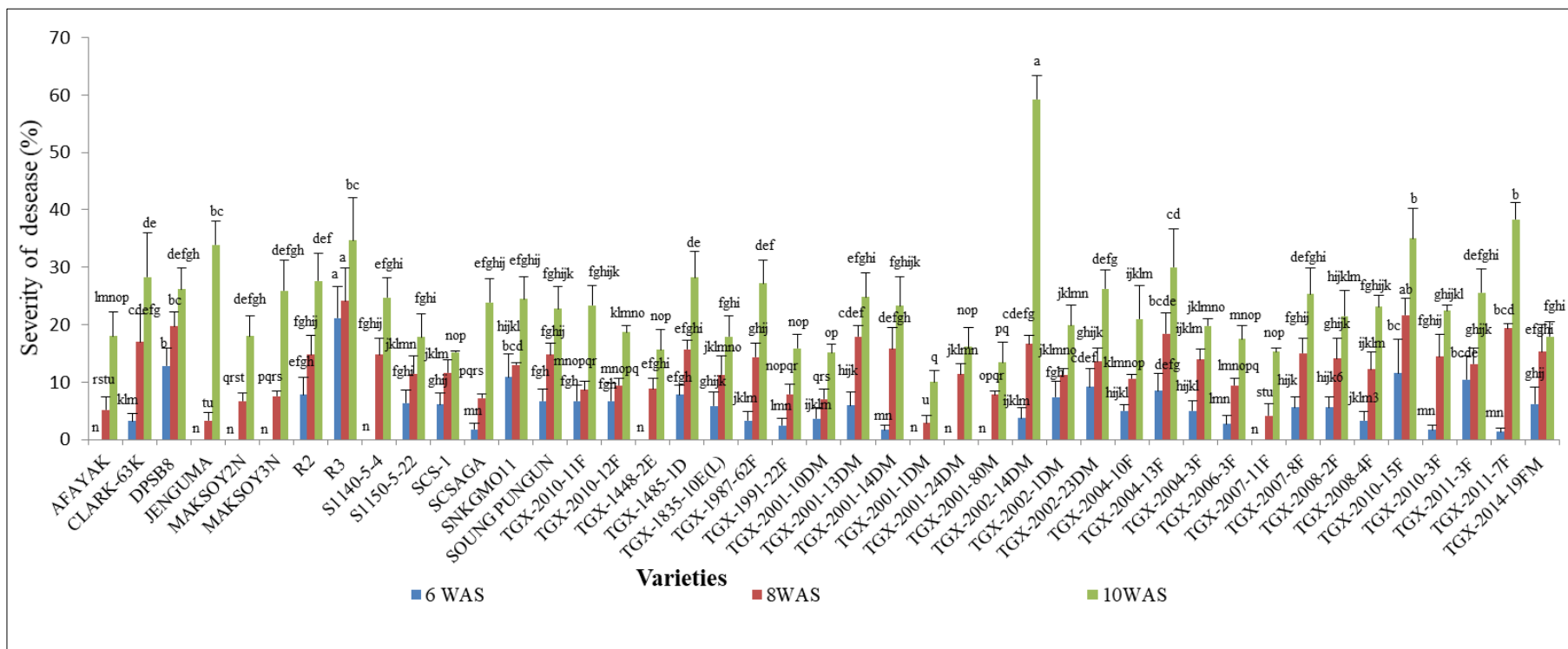


Figure 2 Severity of the Asian soybean rust on varieties by time

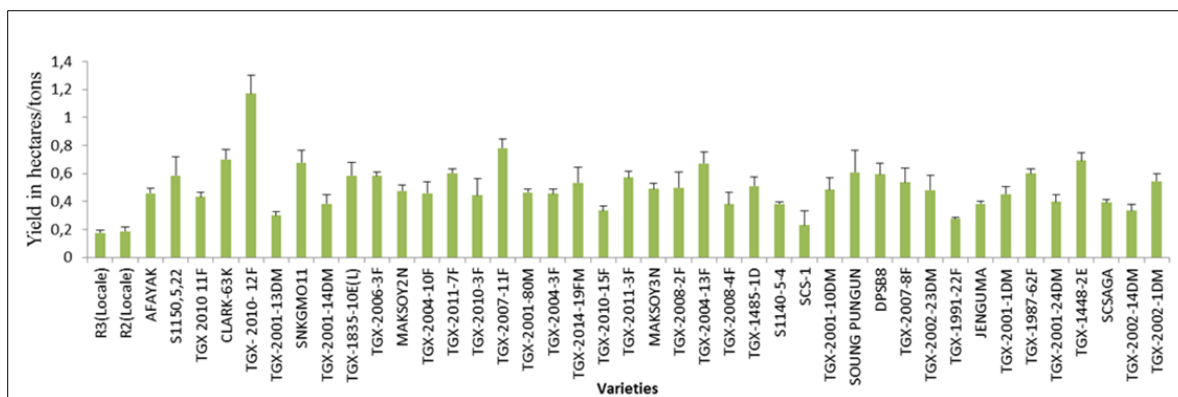


Figure 3 Yield of soybean varieties in natural infection condition

Principal component analysis (PCA) is used to group the screened soybean varieties on the basis of three variables namely incidence, severity and yield (Fig.5). The variables are well represented through the circle of correlations with a good rate of return of information on dimension 1 (46, 58%) and dimension 2 (15, 01%) for a total of 61.58%. Some varieties including TGX-2010-12F, TGX-2010-3F CLARK-63K and TGX-2002-23DM are close in Yield with low susceptibility to Asian soybean rust disease. Other varieties are the intermediate varieties and finally the varieties that show low yields in relation to their susceptibility to the disease.

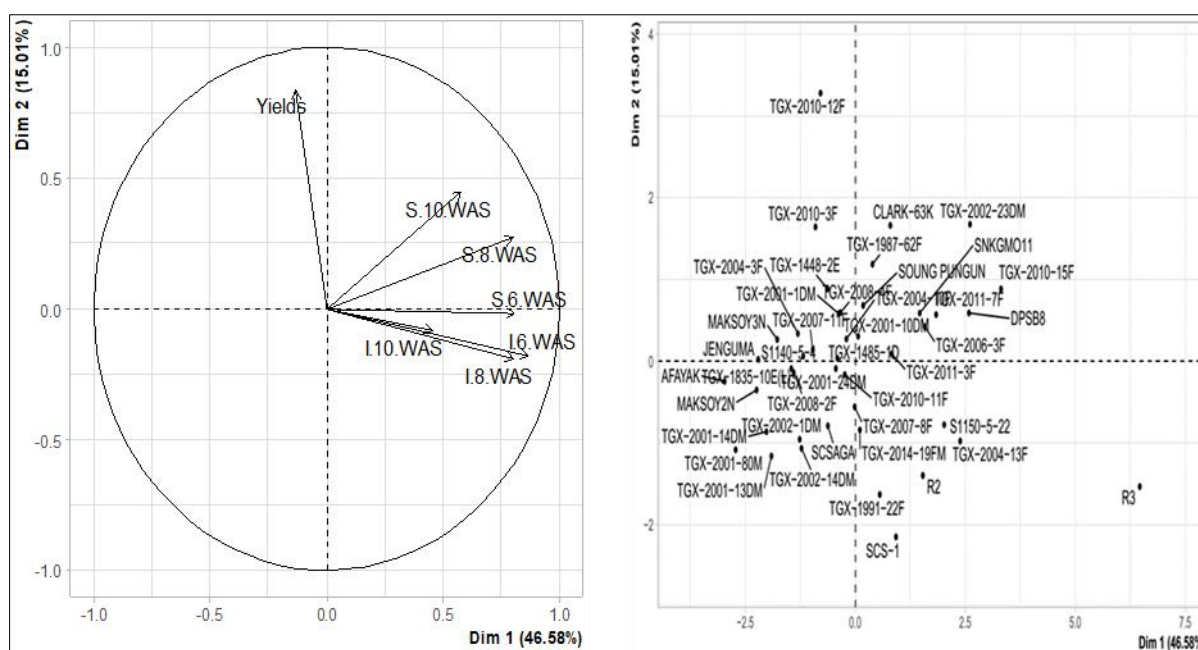


Figure 4 Principal Component analysis between soybean varieties and the studied parameters

3.4.2. Clustering of varieties according to epidemiological parameters and yield

Taking into account the different parameters of the study, namely incidence, severity and performance, a dendrogram was carried out (Fig.5). Three groups emerge from the classification. The first group consists of 12 varieties that are highly susceptible to Asian rust and have very low yields (R3, SCS-1, TGX-2002-23DM, R2, TGX-2014-19FM, TGX-2011-7F etc). The second group consists of 12 varieties which are moderately resistant to Asian rust and have very high yield. Among these are the varieties TGX-2010-12F, TGX-2010-3F CLARK-63K and TGX-2002-23DM, TGX-2007-11F, TGX-2008-4F, SOUNG POUNGUN. The third group consists of the varieties SCSAGA, MAKSOY2N, MAKSOY3N, TGX-2002-80M, AFAYAK etc. which are susceptible and have a low yield.

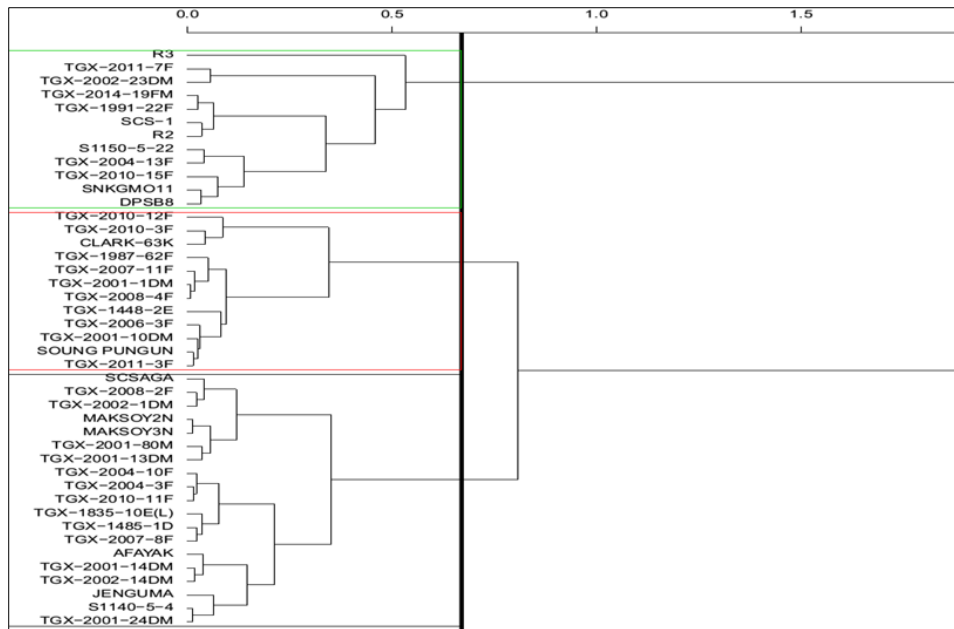


Figure 5 Dendrogram of screening varieties according to incidence, severity and yield

4. Discussion

Soybean is cultivated for its seeds that are very rich in protein, fat and trace elements [2]. Soybeans face Asian rust disease in the field, which can cause yield losses of up to 90% if no sanitary action is taken [8]. There is an extensive literature describing the use of synthetic pesticides to mitigate the effects of this disease on yield. This study predicts that newly introduced soybean varieties in Cameroon that have not been previously studied compared to three local varieties most commonly grown by farmers may have different susceptibility to the disease in the field. Varietal selection is most often used to control crop diseases and pests [16, 17]. As a result, the identification of soybean varieties with yield resistance to Asian soybean rust has been studied.

Results obtained on the incidence and severity of Asian soybean rust disease on the 43 varieties show that the disease varies between varieties over time. R3 and TGX-1448-2E had the highest incidence compared to the other varieties. The variation in incidence by variety over time could be due to the availability of inocula and different host-variety interactions. Mahesha *et al.* [18] working on the evaluation of 204 soybean genotypes under controlled conditions against major diseases reported several genotypes with multiple sources of resistance. This could also be due to favorable climatic conditions (increased wind intensity, rainfall) that favour successive natural inoculation. Indeed, Luck *et al.* [19] demonstrated that the increase in climatic and meteorological events accentuates the dispersion of *phakospora pachyrhizi* spores (the causal agent of rust) in the field. The high incidence in some varieties compared to others could be due to the susceptibility of these varieties compared to others, or to environmental conditions as presented by Schilling [20].

With regard to severity, the highest values are obtained in varieties TGX-2002-14DM and TGX-2011-7F, in contrast to varieties AFAYAK, JENUMA, MAKSOY2N, MAKSOY3N, S1140-5-4, TGX-2001-1DM, TGX-2001-24DM, which show zero incidence and severity at 6 WAS. The variation in severity from one variety to another can be justified by the virulence of the strains and environmental conditions as disease development results from the dynamic interaction between the host plant, the pathogen and the environment [21]. The high severity of Asian rust in some varieties could also be due to the variability of pathogenic strains of *Phakospora pachyrhizi*. According to Ddamulira *et al.* [22], pathogen change is one of the causes of different strains in different agro-ecological zones. The fact that AFAYAK, JENUMA, MAKSOY2N, MAKSOY3N, S1140-5-4, TGX-1448-2E, TGX-2001-1DM, TGX-2001-24DM varieties have zero severity at 6 WAS could be due to the presence of disease resistance genes in their genotypes. Indeed, work on the identification of multiple sources of disease resistance in cultivated and wild soybean has been undertaken by many researchers [23, 18, 24].

The yields obtained vary according to the varieties. The low yields recorded in general and in particular in varieties R3 and R2 could be due to disease pressure that would reduce the leaf area of the plants and consequently reduce photosynthetic activity (Ngueguim [25, 26]. It could also be related to the improved characteristics of the different

varieties, which would explain why some varieties have high (TGX-2010-12F) and some low yields (TGX-2010-12F). Senan *et al.* [27] working on the performance of six tomato cultivars against spoon leaf yellowing, bacterial wilt and root-knot nematodes showed that a difference in yield between varieties in the same season is due to the variety itself.

The dendrogram carried out according to the three parameters (incidence, severity and yield) allowed to group them in moderately resistant, susceptible and highly susceptible varieties. This could be justified by the approximation of the averages of the incidences, severities and yields of the different varieties. These results are different from those of Bachkar *et al.* [28] Zade *et al.* [29], which working on Screening of 36 soybean genotypes against mosaic virus, on Screening of 33 genotypes against alternaria leaf spot disease respectively obtained four group (resistant, moderately resistant moderately susceptible and susceptible) and those of Chavan *et al.* [30], which working on Screening of 40 soybean genotypes against *Colletotrichum truncatum* group them in moderately resistant, moderately susceptible, susceptible and highly susceptible.

5. Conclusion

The main objective of this study was to evaluate the susceptibility of 43 soybean varieties under natural infection conditions against Asian soybean rust on yield. It was found that variety R3 and TGX-1448-2E had the highest incidence. Varieties TGX-2002-14DM and TGX-2011-7F show the highest severity to Asian rust disease at 10WAS; unlike varieties AFAYAK, JENUMA, MAKSOY2N, MAKSOY3N, S1140-5-4, TGX-1448-2E, TGX-2001-1DM, TGX-2001-24DM which have zero incidence and severity at 6WAS. Varieties TGX-2010-12F (1.17 t/ha), TGX-2010-3F (0.78 t/ha) have the highest yields, unlike variety R3 (0.17t/ha.). The dendrogram has allowed to group them into highly susceptible (R3, SCS-1), moderately resistant (TGX-2010-12F, TGX-2010-3F) and susceptible (AFAYAK, TGX-1835-10E) varieties. These moderately resistant varieties, can be advised to growers with appropriate protection methods or be subject to varietal improvement through genetic techniques.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors: Gbaporo Gbaporo F.C, Heu A, Mboussi SB, Ngatsi Zemko P, Kuate Tueguem WN, Dida Lontsi SL, Kamtchoum S, Ambang zachée declare that they have no conflict of interest.

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