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RESEARCH PAPER

Screening of maize (*Zea mays* L.) genotype for tolerance to *Striga hermonthica* (Del.) Benth

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Abstract

***Striga hermonthica* (Del.) Benth. is a major biotic constraint to cereal production in Africa. It infests fields and compromises the production of maize, one of the staple food crops of the country's populations. Maize is the second most important cereal crop produced in Burkina Faso. This study aims to contribute to the improvement of maize productivity through integrated pest management against *S. hermonthica* in Burkina Faso. Four (04) varieties and four (04) lines of maize were evaluated for their tolerance to *S. hermonthica in vitro* and *in vivo*. They were evaluated by the Agar gel test method in the laboratory and by artificial infestation of pots with Striga seeds. The *in vitro* test revealed that the variety Espoir (1.66 mm) as well as the lines TZI 18 (3.37 mm), ELN45-1-1-1 (8.59 mm) and FBML 10 (4.33 mm) can be considered as tolerant as they have a maximum germination distance of Striga seeds lower than 10 mm. *In vivo* tests confirmed the tolerance of FBML 10 due to late Striga emergence (77.6 Days) and TZI 18 due to low Striga biomass (0 g/pot) at harvest. These results will allow confirming the resistance of these lines and maize varieties in multilocation trials.**

Keywords: maize, line, variety, resistance, tolerance, *Striga hermonthica*, Burkina Faso

Introduction

Burkina Faso is an essentially agricultural country and its main productive sector of the economy is dominated by small family farms. It provides employment to more than 80% of the population and contributes more than 30% of the Gross Domestic Product (CNRST, 2005). The main crops grown are cereals, market gardening and some cash crops.

During the 2019-2020 season, 4,272,786 hectares were planted to cereal crops. Maize, with a higher potential yield than other cereals (Sanou, 1996), ranks second with a national production of 1,710,898 tons (DGESS/MAAH, 2020). The main constraints to agricultural production in Burkina Faso are drought, low soil fertility and weeds (Waddington *et al*., 2010). Concerning weeds and parasitic plants, in particular *Striga hermonthica* (Del.) Benth. and *Striga asiatica* (L.) Kuntze, are the most widespread and economically important parasitic weed species (Rodenburg *et al*., 2011; Spallek *et al*, 2013). Striga parasitizes major annual crops such as sorghum, rice, millet, and maize and negatively affects their growth and yield (Webb and Smith 1996; Frost *et al.,* 1997; Gurney *et al.,* 1999). Severe infestation of these crops can result in a 50-100% loss of production (Doggett 1988, Watson *et al.* 2007, Sunda *et al.* 2012). The financial loss caused by Striga spp. is estimated at seven billion US dollars per year and the infestation affects the lives of over 100 million people in Africa (Badu-Apraku and Akinwale ,2011). One of the most effective control methods is varietal selection, as it is inexpensive and does not require special skills from farmers (Olivier *et al.,* 1992, Diagne 1999). It is therefore necessary to identify cultivars with resistance potential in order to answer the questions of the national breeding program (Olivier *et al.,* 1992).

It is for this reason that this study entitled screening of Maize genotypes for tolerance to Striga. The objective of this study is to screen some maize lines and varieties for Striga tolerance.

Materials and methods

Study area

The study was conducted at research station of National Institute of Environment and Agriculture Research (INERA) at Farako-Bâ station (4°20' west longitude, 11°06' north latitude and 405 m altitude). The station is located 10 km south-west of Bobo-Dioulasso on the national road n°7 linking Bobo-Dioulasso to Banfora (Figure 1). The climate of the area is of the South Sudanese type (Guinko, 1984), characterized by the alternation of two seasons: a rainy season lasting 5 to 6 months with a rainfall varying between 950 mm and 1100 mm and a dry season from November to April.

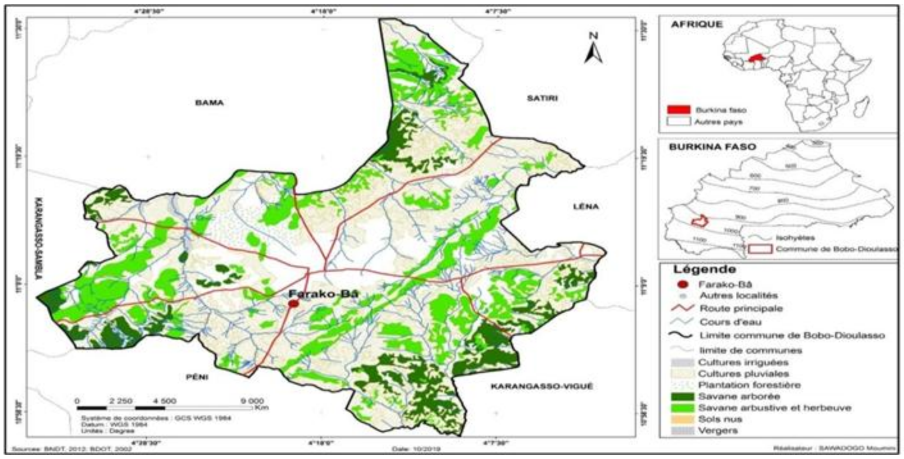

Figure 1: Map of the geographical location of the Farako-Bâ research station

Vegetative material

The plant material used was a composite sample of *Striga* seeds and maize. The *Striga* seeds were collected during the 2017 in rainy season from farmers' fields in the villages of Samagan (11°08' N; 4°19' W), Banakélédaga (11°19'N; 4°19' W) and Farako-Ba (11°06' N; 4°20' W). As for maize, they are composed of four (04) lines and four (04) varieties (Table 1) from traditional cereals program of INERA

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Table 1: Maize genotypes screened

Treatments	Charateristics	Cycle of maturity
FBML 10	Line	85-95 days
ELN41-1-1-4	Line	85-97 days
ELN45-1-1-1	Line	85-95 days
TZI 18	Line	85-95 days
Komsaya	V. Hybrid	97 days
SR 21	V. Composite	85-97 days
Wari	V. Composite	97days
Espoir	V. Composite	97days

Method of maize seeds Germination

Maize seeds were soaked in 25 mL of a 1% sodium hypochlorite (NaOCl) solution for 15 minutes and rinsed at least 3 times before being soaked for 5 hours in sterile distilled water. The grains were then transferred to Petri dishes containing moistened filter paper. The dishes were sealed with plastic straps and the whole set was incubated for 48 hours at the ambient temperature of the laboratory, which varies between 20 and 30°C. The most vigorous seedlings were used for the Agar gel test (Hess *et al.,*1992).

Conditioning of Striga seeds

Striga seeds were sterilized with 70 % ethanol and 1% sodium hypochlorite (NaOCl) successively for 3 and 5 minutes. Two drops of Tween 80 were added to the bleach to lower the surface tension. After sterilization, the *Striga* seeds were rinsed at least three times with sterile distilled water before use. The sterilized *Striga* seeds were placed in sterile Erlenmeyer flask containing sterile distilled water. The contents were stirred to thoroughly immerse the *Striga* seeds. The Erlenmeyer flask was then covered with aluminium foil and placed in an incubator at 28°C for 08 days. During conditioning, the water was changed every two days to avoid pathogen development (Hess *et al.,*1992).

Agar gel test

An amount of 1 mL of the solution consisting of sterile distilled water and conditioned *Striga* seeds was pipetted into a 9 cm diameter Petri dish. Agar was prepared at a concentration of 0.7% and autoclaved at 120°C for 15 minutes. It was then cooled to about 40°C and poured over the *Striga* seeds in the Petri dish so that the seeds were evenly distributed at the bottom of the Petri dish. After the Agar solution has solidified, the radicles of 2 germinating maize seeds (48 hours) are buried in the Agar in an opposite position, at the edge of the Petri dish. The Petri dishes containing the *Striga* seeds and maize seedlings were sealed with para film and incubated at 28°C for 72 hours. After 3 days of incubation, each Petri dish was observed on the bottom side under a binocular loupe to visualise the germinated *Striga* seeds in the Agar (Hess *et al.,*1992). Three Petri dishes were used per maize line and variety, replicated three times.

Experimental design, data collection and statistical analysis

The experimental set-up *in vitro* and *in vivo* is a randomised block of three replicates and seven treatments (03 lines and 04 maize varieties). In each block, there are seven (07) pots each representing one treatment.

The variables measured on *Striga* and maize concerned *in vitro* and *in vivo* data are:

Date of first emergence of *Striga;*
Number of *Striga* plants at 45, 60 and 75 days after *Striga* emergence;
Dry biomass of *Striga* at harvest (g/m²);
Date of male and female flowering diameter of the maize stalks at 45, 60 and 75 days before harvest
Height (cm) of the plants at15, 30, 45 and 60 days before harvest;
The severity of *Striga* symptoms in maize at 45, 60 and 70 days after harvest was estimated using the Kim (1991) rating scale (Table 2);
Grain yield (kg/ha).

Data were entered and organized using Excel spreadsheets. Analysis of variance was performed using R software version 6.1, and means were separated using Tukey's test at the 5% threshold.

Table 2: Symptomatology scale used to measure tolerance of maize and rice to *Striga hermonthica*

Degree	Description of symptoms			
	Leaf area burnt (%)	Necrosis	Growth of the plant*	Yield of ears of maize*.
1	0	0	unaffected	unaffected
2	10	some points	unaffected	unaffected
3	20	points		unaffected
4	30	points		
5	40	points		
6	50	gray dots		
7	60	many points		
8	70	many points		
9	100	many points	premature death	no heads and tassels

***** *The increasing number of signs - reflects an increasingly strong effect on plant growth and ear yield*

Results

In vitro screening of maize genotype

The results of the statistical analysis showed that there was no significant difference (P>0.05) between treatments for the Maximum Germination Distance (MGD) of Striga seeds (Figure 2) under the effect of germination stimulants. The variety Espoir as well as the lines TZI 18; ELN45-1-1-1 and FBML 10 used obtained a MGD lower than 10 mm (MGD <10 mm). The varieties Komsaya; SR 21 and Wari obtained a MGD of more than 10 mm (DMG>10 mm) (Figure 3).
The analysis of variance shows that there was no significant difference (P>0.05) between the treatments regarding the number of germinated Striga seeds. Nevertheless, the line ELN45-1-1-1 obtained the highest numerical value (11 germinated seeds) while the variety Espoir recorded the lowest number of germinated seeds (0.33) (Figure 4).

Figure 2: Germination distance between a germinated *Striga* seed and the main maize radicle, Farako-Bâ, 2018

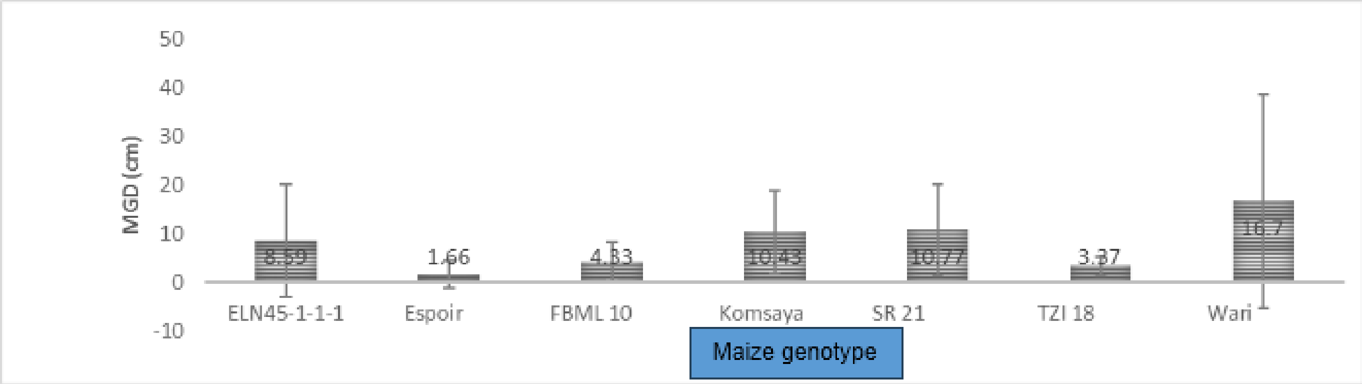

Figure 3: Distance (cm) between a germinated Striga seed and the main radicle of the maize genotype (MGD) according to treatments.

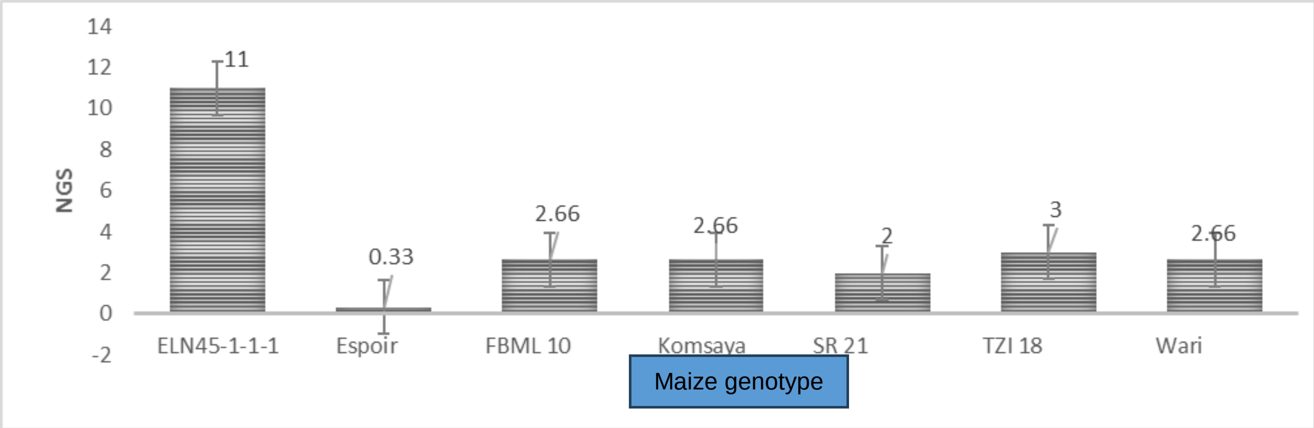

Figure 4: Number of germinated *Striga* seeds (NGS) according to treatments

In screening of maize genotype vivo

The analysis of variance showed a significant difference ($p < 0.05$) between the treatments for the date of first emergence of Striga (DFE). The first emergence of Striga hermonthica were observed with the Espoir variety at 48 Days After Sowing (DAS) while the last emergences of Striga hermonthica were recorded with the FBML 10 line at 77.66 DAS on average (Figure 5). It should be noted that no Striga emerged at ELN41-1-1-4 and TZI 18.

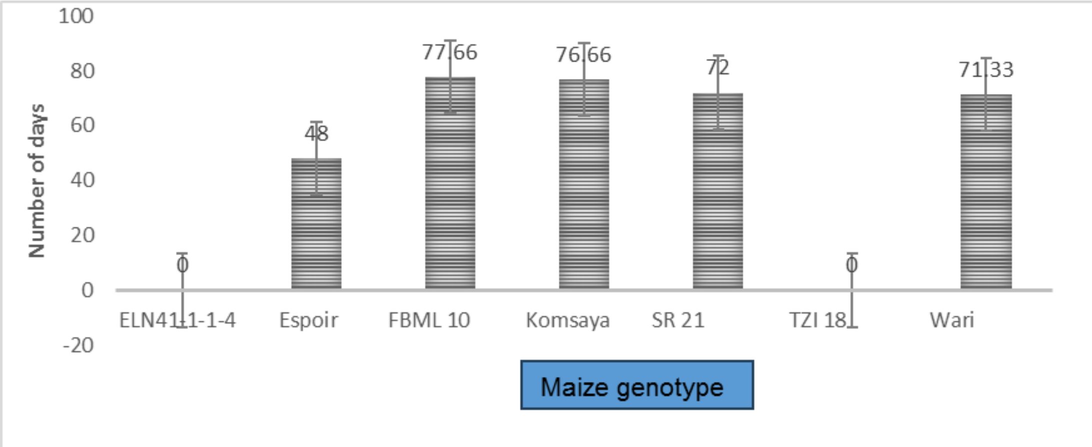

Figure 5: Date of First Emergence (DFE) of Striga assessed in pots

Regarding the number of germinated Striga, the anova showed no significant difference between treatments at 60 and 75 DAS (Table 3). Only the variety Wari recorded an average of 0.33 germinated Striga per pot at 60 DAS. However, at 75 DAS, the variety SR 21 had the highest value (4.33) of Striga.

Regarding the dry biomass of Striga at harvest, there was a significant difference ($p<0.05$) between treatments (Table 3). Indeed, Espoir variety obtained the highest dry biomass of Striga (1.73 g/pot) and however, *ELN41-1-1-4 and TZI 18* (0 g/pot) had the lowest Striga biomass.

The analysis revealed a significant difference between the treatments ($p < 0.05$) for the interval between male and female flowering of the maize plants (Table 3). The interval is ranging from 3.66 to 13 days. The varieties Espoir and Wari that recorded a significant flowering gap of 13 days while TZI 18 obtained a much lower flowering gap (3.66 days).

Regarding the degree of severity of Striga symptoms on leaves, we observe an evolution of symptoms according to the observation period at 45, 60 and 75 days (Figure 6).The highest degree of severity (7.6) was obtained at 70 DAS with the TZI 18 treatment. While SR 21 treatment had the lowest degree of severity (3.3) during all observation periods.

Principal component analysis shows that there is a correlation between the variables of Striga and maize varieties and lines (Figure 7). The first two axes represent 52.48% of EcartMF: interval between male and female floraison

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Table 3: Number of germinated and dry biomass of Striga *in pots*

Maize genotype	***Number of germinated Striga***		***Dry biomass of Striga***	*EcartMF*
	60 DAS	75 DAS	(g/pot)	
ELN41-1-1-4	00±00	00^{a}±00	00±00	9.33^{ab}±1.52
Espoir	00±00	1.73^{b}±0.05	3.33±4.04	13^{b}±4.58
FBML 10	00±00	0.5^{ab}±0.7	2.33± 2.51	7^{ab}±2.64
Komsaya	00±00	0.77^{ab}±0.8	1±1	10^{ab}±1.73
SR 21	00±00	1.37^{ab}±1.1	4.33±3.51	12^{ab}±1
TZI 18	00±00	00^{a}±00	00±00	3.66^{a}±3.21
Wari	0.33±0.57	1.2^{ab} ±0.34	1.33±1.15	13^{b}±4.35
Average	0.048	0.8	1.76	9.71
CV (%)	458.3	74.7	131.1	31
Probability	0.463	0.0175	0.238	0.0168

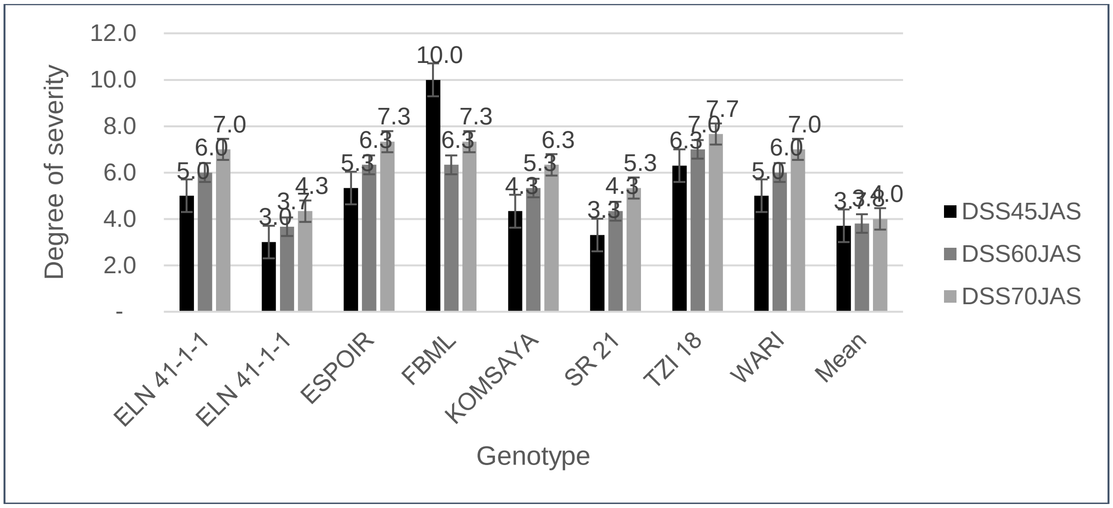

Figure 6: Degree of severity of Striga symptoms on tested genotypes leaves in pots
Legend: SLS: Severity of leaf striga symptoms

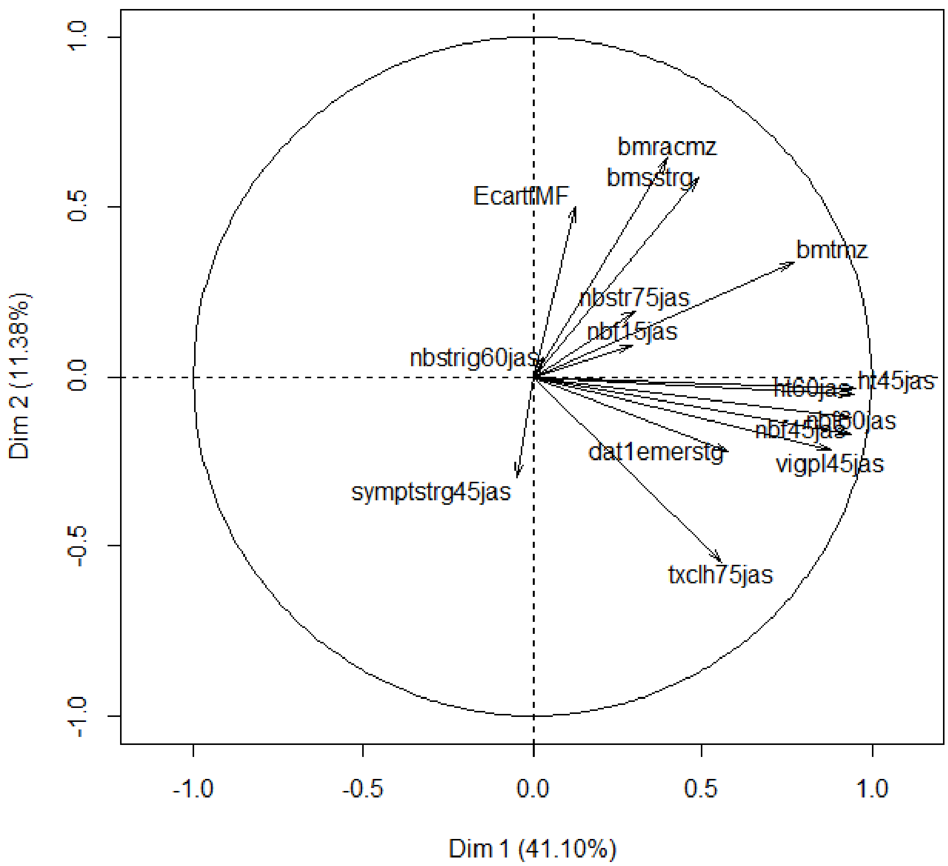

Figure 7: Principal component analysis of Striga infestation and agromorphological variables of maize

Legend: Bmtmz : Total maize biomass; dat1emerstg : Date of first emergence of Striga; ht45jas : Plant height at 45 DAS; ht60jas : Plant height at 60 DAS; nbf15jas : Number of leaves at 15 DAS; nbf45jas : Number of leaves at 45; nbf60jas : Number of leaves at 60; nbstrg75jas : Number of striga at 75 DAS;nbstrig60jas :Number of striga at 60 DAS symptstrg45jas : Symptom of at 45 DAS striga;txclh75jas :Chlorophyll rate of maize at 75 DAS;vigpl45jas :Plant vigor at 45 DAS;vigpl60jas : Plant vigor at 60 DAS ; vigpl75jas : Plant vigor at 75 DAS; EcartMF : interval between male and female floraison

Discussion

Two groups are obtained according to their MGD. Indeed, the variety Espoir as well as the lines FBML 10 and ELN45-1-1-1 used obtained a MGD < 10 mm while Komsaya, SR 21 and Wari recorded a MGD >10 mm. Similar results with a MGD of less than 10 mm were obtained with two mutant rice lines irradiated at a dose of 300 Gy (Sanou *et al.,* 2022). Thus the first group would be tolerant lines and varieties and the second group that of the sensitive varieties by their capacity of strong production of stimulants of germination of the *Striga* seeds. Indeed, according to Cubero *et al* (1994) and Doggett (1988), the low production of germination stimulants marked by a low MGD (< 10 mm) indicates a form of resistance of the host plant to *Striga* infestation. Moreover, Haussmann *et al* (2000) reported in a similar study on sorghum varieties MGDs ranging from 0 to 21.6 mm, i.e. a dispersion of 21.6. In the present study, a lower dispersion of 16.7 mm was obtained. Thus, maize would be less susceptible than sorghum under controlled conditions. The line ELN45-1-1-1 which had a DMG <10 mm obtained the highest number of germinated *Striga*. The other lines and varieties Espoir, SR 21, FBML 10, Wari, Komsaya as well as TZI 18 had a lower-than-average number of germinated Striga (3.5).

The Agar gel test alone would not be sufficient to conclude that crop varieties are resistant to *Striga* because resistance observed in controlled environments is not always expressed in exactly the same way in the field (Omanya *et al.,* 2001). Thus, it's necessary to make a screening in pot.

The number of germinated Striga is low overall but this seems to be related to the pot screening method. The size of the pots could be the cause. The same observation was made by Olivier *et al* (1992) in a similar study conducted on sorghum. The total number of germinated Striga plants ranged from 1 to 4.3 plants/pot with dry biomasses ranging from 0.5 to 1.7 g/pot. The low secretion of germination stimulant is a resistance factor and is manifested by a low germination rate of Striga. In addition, it is thought to be due to a dominant genetic trait governed by a single gene that is qualitatively inherited (Hess and Ejeta, 1992; Botanga *et al*., 2003). FBML10 (77.66 JAS) and Komsaya (76.66 JAS) with late emergence appear to have this low Striga germination stimulant producing trait as they had the latest emergence dates. However, Striga symptoms were more severe in FBLM 10 than in Komsaya.

The total maize biomass recorded here are relatively low (FBML10: 27.6 g/pot and Komsaya: 28.33 g/pot). Knowing that resistance can be accompanied by poor yield, this line and variety can be given some level of resistance. FBML 10 (0.5g/pot) and Komsaya (0.77g/pot) could therefore be considered tolerant as they also have a low dry biomass of Striga. According to Cubero *et al* (1994), the resistance mechanisms range from low germination stimulation to physiological disruption of pest function. Our results corroborate those of Sanou (2011) and Naitormmbaide et al. (2015), who respectively highlighted in a pot experiment the sorghum variety F2-20 and maize as resistant to Striga hermonthica through low germination stimulation production and low Striga dry biomass.

Tolerance is defined by Marley (2002) as a variety that has the ability to resist heavy infestation of Striga without reducing its yield like the susceptible control. The varieties SR 21 and Wari are characterized by low germination stimulant production. They have a high Striga biomass and an above average total maize biomass, confirming their good tolerance level. For ELN41-1-1-4 and TZI 18 no Striga emerged from the soil but showed above average levels of Striga symptoms. Striga could have had a holoparasitic phase during the infestation of these two lines. Indeed, according to Patrick and André (1993), only 10-30% of root-bound Striga emerge from the host plant. In addition, TZI 18 had the lowest male to female flowering interval (3.66 days). This gives it an aptitude for drought tolerance. The Espoir variety could be considered as susceptible in view of the results obtained in pots. It seems to have a strong stimulating character of *Striga hermonthica* germination because it obtained an early emergence of Striga. It also has the highest dry biomass of Striga. In addition to being heavily infested compared to the average, it has high symptom severity and low total corn biomass. The physiological and morphological parameters, namely the interval between male and female flowering, are correlated with the number of Striga at 75 DAS and the date of first emergence of Striga, respectively. We can consider these two parameters as a potential selection criterion for maize lines and varieties tolerant to striga.

Conclusion and perspectives

This study allowed us to identify the tolerance abilities to *Striga hermonthica* of already popularized varieties and maize lines registered in the varietal selection process with respect to bio aggressors and diseases. It was found that some varieties and lines possess tolerance abilities to *Striga hermonthica*. These are Espoir, TZI 18, ELN45-1-1-1 and FBML 10 in the *in vitro* test and Komsaya and FBML 10 in the *in vivo* experiments. It was found that the physiological parameters of maize, mainly the flowering interval between males and females, can be a criterion for the selection of striga tolerant lines and varieties. However, since Striga resistance is related to pre- and post-attachment infestation, it is necessary to conduct multilocation trials to confirm the suitability of the identified varieties and lines.

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