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Research Article

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Screening of Sorghum Mutant Lines in Vitro and Greenhouse Against *Striga Hermonthica* Infestation

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Abstract

The parasitic weed, Striga hermonthica (Del.) Benth is a major constraint to cereal productions such as sorghum. In Burkina Faso, sorghum is the first of the cereals, in terms of cultivated areas and human consumption per capita. This study aimed to identify resistant lines by screening 31 sorghum mutant lines. Experimental assays were carried out in vitro and under greenhouse. The results shown that mutant lines SbEMS0937-1, SbEMS3105-2 were low producers of Striga seeds germination stimulant in vitro. There was a positive and significant correlation ($r = 0.72$; $p < 0.0001$) between the germination maximum distance (GMD) and the germination rates (GR) of the different sorghum varieties and mutant lines. In the greenhouse conditions, the mutant SbEMS2311-1 was leading with two resistant controls to having significantly low numbers (5 plants/pot) of Striga 60 DAS (Days After Sowing) and featured the lowest number of Striga 90 DAS (10 plants/pot). The sorghum production variables that are the weights of the stems, panicles, and grains and the plant height at 21 days after sowing (DAS) and at the harvest were all positively related. However, the emergence date and the number of Striga plants which emerged at 90 DAS were negatively correlated ($r = -0.21$; $p = 0.02$). Otherwise, the GMD in vitro was positively correlated with the number of the Striga plants emerged at 60 DAS and 90 DAS in greenhouse. These results revealed that the mutagenesis of the sorghum lead to resistance or tolerance to S. hermonthica. Therefore, the growing of each of the three resistant mutants should contribute to reducing highly the density of this pest plant in the sorghum field. Furthermore, the transfer of gene (s) inducing this Striga-resistance/tolerance from mutant lines could improve Sorghum varieties preferred by local farmers.

Keywords: Sorghum, *Striga hermonthica,* Resistance, Mutagenesis.

Introduction

The genus Striga from the Scrophulariaceae family includes the most devastating weeds of crops in the world. It is found in America, Asia, and Australia and especially in Africa. With the exception of S. euphrasioides, species of the genus Striga are epirhizal parasitic plants, unable to complete their biological cycle without an herbaceous angiosperm[1]. Striga is considered as a 'thief' of nutrients from its hosts, impairs the development of infested plants and makes them stunted as a result of its attachment to their root systems. Striga grows on all types of soil in Burkina Faso[2] the botanical characteristics of 13 species inventoried throughout the country have been described [3]. S. hermonthica, is the most economically important and widespread species in West, East and Central Africa. In West Africa, it infests 64% of the land sown for cereal production [4]. Burkina Faso is one of the countries in sub-Saharan Africa which has recorded significant losses in agricultural production due to Striga parasitism. In fact, an area of 1,319,000 ha is affected by the S. hermonthica infestation, causing an average loss of 710,000 to 820,000 t grains / year corresponding to 35-40% of sorghum and millet production[4]. These losses were estimated at 41 - 75% in the Central region by [5] and, at 28% to 55% in the East of the country by [6]. According to [7, 8], Striga can reduce host crop yields by more than half, and sometimes cause 100% crop loss. S. hermonthica affects sorghum, millet and maize and can also infest other plants, such as finger millet, rice, sugarcane, Sudanese grass [7]. These seeds can remain viable in the soil for more than 10 years [8]. In Burkina Faso, research was carried out on control methods against S. hermonthica [6, 9, 10, 11, 12]. Several

methods such as manual uprooting and weeding, the application of organic manure in the fields, the use crop rotation and planting, fallow have been developed [3]. Early sowing, hilling, the use of Striga ash, Acacia gourmaensis Bark bark powder and black goat fat are endogenous techniques for Striga control in eastern Burkina Faso [6]. Despite these endogenous methods, Striga is growing. Variety selection of host crops for their resistance to Striga would be the most economical means to control this parasite [13, 14]. The present study relates to the screening of sorghum mutant lines obtained by the induced mutagenesis of the variety BTX623. It thus aims to assess the resistance of these mutants to S. hermonthica in vitro and under greenhouse conditions with a view to contributing to the reduction of the damage caused by this parasitic plant.

Material and methods

Material

The screening of mutant lines and sorghum varieties under greenhouse conditions was carried out at the Kamboinsé research station in Ouagadougou, Burkina Faso. Thirty-one (31) mutant lines created from the BTX623 sorghum variety by mutation-induced under the effect of the mutagenic agent ethyl methane sulfonate (EMS) and seven (7) varieties namely Framida, ICSV 1049, SRN 39, Sariaso 14, Grinkan, BTX 623, and Macia were assessed for resistance to S. hermonthica. Striga Seeds collected from sorghum fields in the Kouaré village during the 2008-2009 agricultural campaign were used for screening trials in vitro and greenhouse conditions. Plastic pots with an upper diameter of 30 cm, a lower diameter of 22 cm, and a height of 30 cm with a total volume of 15 liters were used for the sorghum and S. hermonthica growing in greenhouse. The growing medium used is a mixture of two volumes of soil for one volume of sand (2v / 1v).

Methods

The screening in vitro

The screening in vitro is carried out using the gel-agar method [8]. Striga seeds were disinfected with 70° ethanol and 1% sodium hypochlorite (NaOCl) respectively for 3 min and 5 min. Two drops of Tween 80 were added to the NaOCl solution to lower the seeds surface tension. After sterilization, Striga seeds were rinsed at least three times with sterile distilled water before being packaged with sterile distilled water and incubated at 28 ° C for 8 days. Sorghum seeds were also disinfected with 1% sodium hypochlorite for 15 min. They were then rinsed at least 3 times with sterile distilled water. The disinfected seeds were transferred to Petri dishes (9 cm ø) containing moistened filter paper. The dishes were sealed and the whole was incubated at laboratory room temperature (20 °C - 30 °C) for 24 h, after which sorghum seedlings were obtained.

One milliliter of the solution including sterile distilled water and conditioned Striga seeds was pipetted and placed in a Petri dish (9 cm ø). The agar culture medium (Agar 0.7%) sterilized and cooled to approximately 50 °C was poured into the Petri dish containing the preparation of the Striga seeds so as to obtain a homogeneous distribution of the seeds at the dish bottom. The radicles of 2 vigorous sorghum seedlings were buried in the solidified agar medium in the opposite position. Petri dishes containing the whole Striga seeds - sorghum seedlings were sealed and incubated at 28 °C for 72 h. After that, each Petri dish was observed under a binocular magnifying glass to visualize Striga germinated seeds. Three Petri dishes were used per mutant line or sorghum variety and per test and the test was repeated three times under the same conditions. The Germination Maximum Distance (GMD) that is the greatest distance (in cm) between the sorghum seedling root and the Striga germinating seed is measured in each Petri dish of the gel Agar essay (Figure 1). Sorghum seedlings are classified as low germination stimulant producers if the GMD is less than 1 cm and high stimulant producers if the GMD is greater than or equal to 1 cm.

Screening under Greenhouse Conditions

Before sorghum varieties and mutant lines sowing in greenhouse, the pots were artificially infested with S. hermonthica seeds according to the method of [15]. Which gives an infestation rate of 5 x 103 seeds of S. hermonthica / pot. The sowing was carried out at the rate of four seeds / pot and then seeded to 2 sorghum plants / pot, 21 days after sowing (DAS). Each pot constituted one replicate and the whole was arranged in a completely randomized Fisher block with 4 replicates. The pots were watered each 48h at the rate of 2 l / pot. The parameters measured during the greenhouse screening are: date of the Striga seedling emergence, the number of Striga plants emerged 60 and 90 DAS, the Striga dry biomass at the sorghum harvest, the weight of sorghum panicles and grains.

Data analysis

Data statistical analysis was performed using Gen Stat 10.3 software. The ANOVA (analysis of variance) followed by the comparison of the means for each variable was carried out using Fisher test at the 5% threshold. Graphs were made from the results of the ANOVA, using the Excel spreadsheet. PCA (Principal Component Analysis) of the variables measured on sorghum as well as on Striga was carried out and the correlations between the variables were determined with the JMP 16 software.

Results

Ability of the Sorghum Mutant Seedlings to Produce Striga Germination Stimulant in Vitro

The averages of the germination maximum distance (GMD) of the Striga germinated seeds are presented in Figure 1. GMDs less than 1 cm were obtained with eight mutant line seedlings and three varieties which are therefore classified as low producers of Striga seed germination stimulant. The others are considered strong stimulant producers. The ANOVA showed the existence of a significant difference ($P<0.001$) between the sorghum mutant lines or varieties compared to the germination rates of the seeds of Striga recorded under the Agar gel conditions. The highest germination rate (13.15%) was recorded with the mutant line SbEMS3609-1.

This rate is statistically equivalent to those obtained with 23 other mutant lines and four sorghum varieties. The Framida and SRN39 varieties did not induce any Striga seed germination (Figure 2).

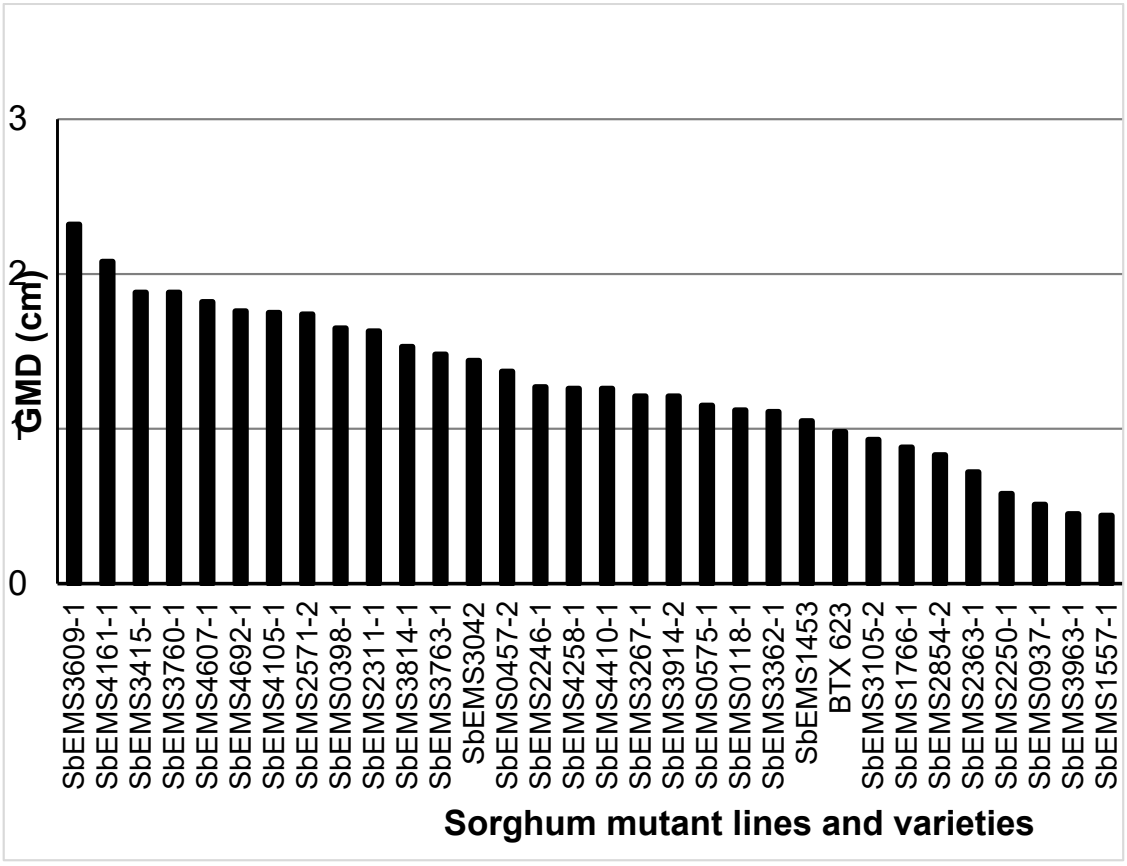

Figure 1: Means of Striga germination distances in vitro according to sorghum mutant lines/varieties

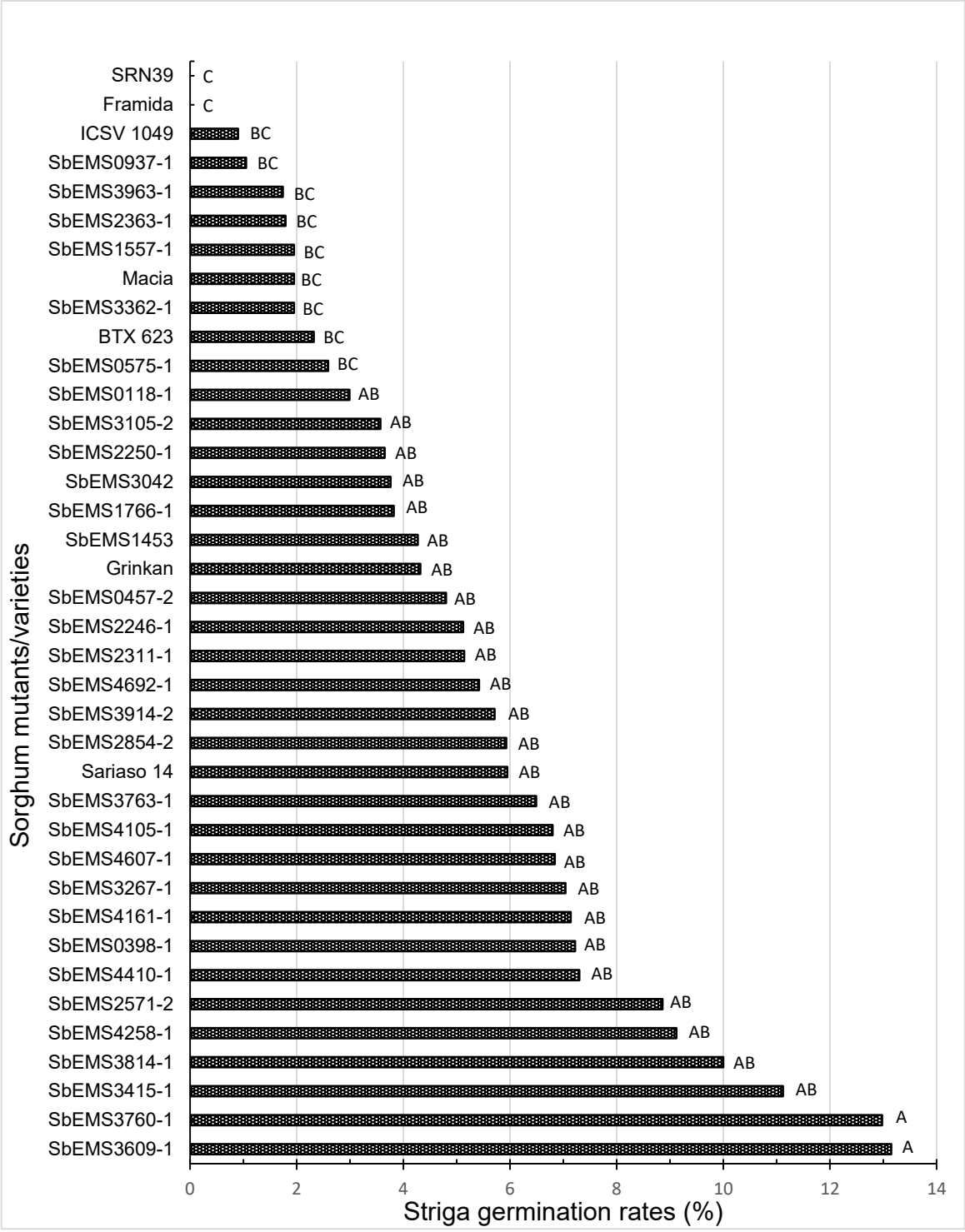

Figure 2: Comparison of the averages of Striga germination rates according to the sorghum mutant lines/varieties

Means followed by the same alphabet letters are not significantly different.

Figure 3 shows a linear relationship between GMD and (GR) germination rates recorded with the different sorghum varieties and mutant lines. A positive ($r = 0.72$) and significant ($p < 0.0001$) correlation was revealed between these two parameters. The same is true for the correlation between GMD and time to the first germination were observed ($r = 0.70$ and $p < 0.0001$).

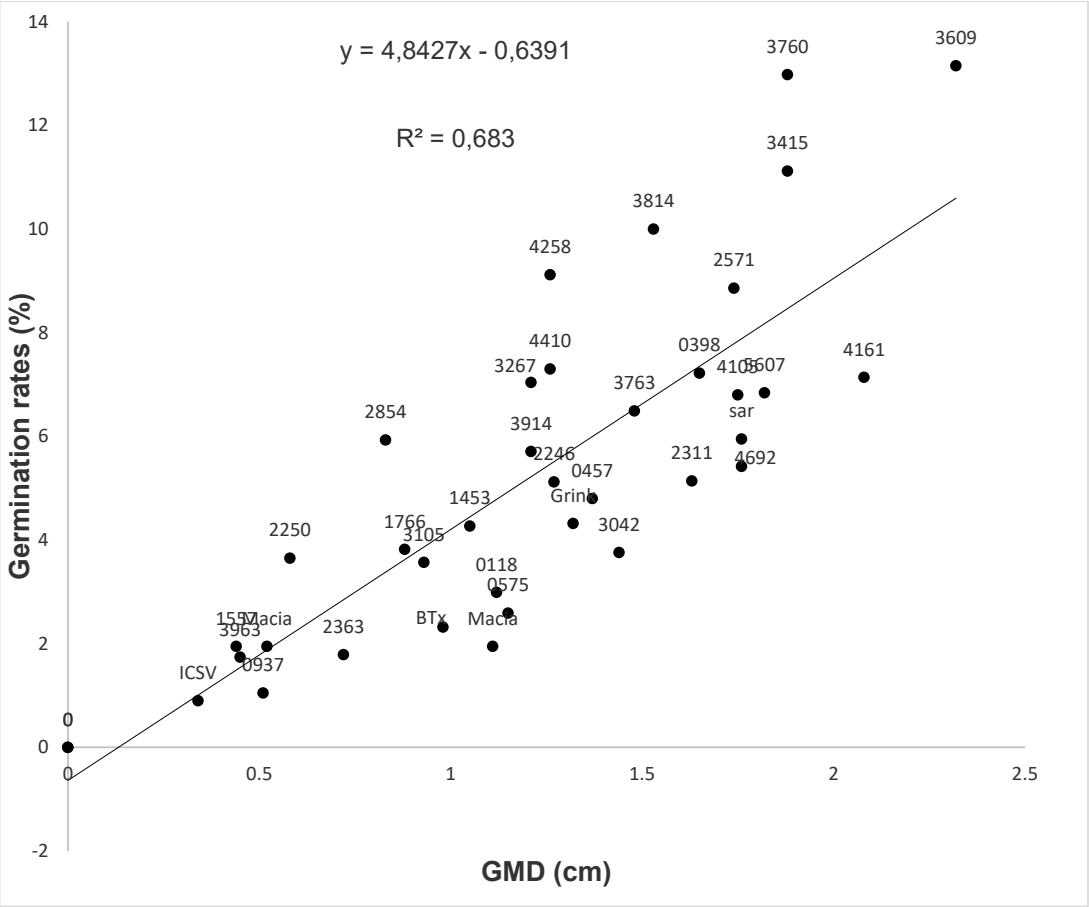

Figure 3: Correlation between Striga germination rates and germination maximum distances (GMD) obtained with the sorghum mutant lines/ varieties in vitro.

NB: The full name of each mutant line is made up of the numbers in the figure, preceded by SbEMS; BTx=BTx623; Grink = Grinkan; ICSV= ICSV 1049; Sar = Sariaso 14

Infestation State of the Sorghum Mutant Lines and Varieties by Striga hermonthica in the Greenhouse Conditions

The results of analysis of variance (ANOVA) of the emergence date of the S. hermonthica plants (Em D) in the pots, the number of these plants at 60 days after sowing (N Strg 60DAS) and 90 days after Sowing (N Strg 90DAS) are presented by Figure 4. On the one hand, the emergence period varied between 29 and 51 DAS and has not shown significant differences between the means ($p = 0.052$). On the other hand, the numbers of S. hermonthica at 60 and 90 DAS presented significant differences with probabilities (P) that were respectively 0.039 and 0.015. The mutants SBEMS3362-1, SBEMS4607-1, and the variety ICSV1049 induced emergence periods greater than or equal to 50 DAS (Figure 4). In addition, the number of Striga plants emerged 60 DAS in the pots of the SBEMS3609-1 mutant line (94 plants/pot) was higher than those recorded with the other sorghum mutants and varieties. Among the mutant lines, SBEMS2311-1 was the least infested 60 DAS (5 plants/pot) and 90 DAS (10 plants/pot). The highest infestation was observed at 90 DAS with SBEMS2250-1 (161 plants/pot) and five other mutants. On the Framida variety, the number of Striga plants emerged 60 DAS (92 plants/pot) has dropped (49 plants/pot) at 90 DAS following the plant's mortality.

The ANOVA has also revealed significant differences between the sorghum varieties and mutant lines, compared to the weights of the panicles (Sorg Pan W), the weight of grains (Sorg grns W), and the weights of the stems (W Sorg Stems) whose probabilities were all $p < 0.001$ (Figure 5). The production of 17 sorghum mutant lines and seven varieties was the least affected by the infestation of S. hermonthica. The grain yields of three SRN39, Framida, and ICSV1049 varieties were significantly the highest (Figure 5). As for the dry weights of S. hermonthica (Strg W), there have been no significant differences and the probability obtained was 0.30 (Figure 5).

The results on the number of sorghum plants at 21 days after sowing (N_Sorg_21D) presented significant differences including $p < 0.001$ while at the harvest the averages (N_Sorg_Harv) were not statistically different including $p = 0.67$ (figure 6). Regarding the height of sorghum plants, ANOVA has still shown significant differences with $p < 0.001$ (Figure 7). At 21 days after sowing, the height of the Framida variety was significantly higher than those

of the mutant lines SBEMS 2311-1, SBEMS 3362-1, SBEMS 3105-2, and SBEMS 3914-2. At the harvest, the varieties Framida and ICSV 1049 were significantly higher than Sorghum's other varieties and mutants.

State of Sorghum Mutant Lines and Varieties Infestation by Striga hermonthica under Greenhouse Conditions

The analysis of variance (ANOVA) of the emergence date (Em D) of S. hermonthica plants in the pots, the number of these plants at 60 days after sowing (N Strg 60DAS) and 90 days after sowing (N Strg 90DAS) are shown in Figure 4. The time to emergence varied between 29 and 51 DAS without significant differences between the means ($p = 0.052$). However, the numbers of S. hermonthica at 60 and 90 DAS showed significant differences with respective probabilities (P) of 0.039 and 0.015. The mutants SbEMS3362-1 and SbEMS4607-1 and ICSV1049 variety induced emergence times greater than or equal to 50 DAS (Figure 4). Furthermore, the number of Striga plants that emerged 60 DAS in the pots of the mutant line SbEMS3609-1 (94 plants/pot) was higher than those recorded with the other mutant lines and the 4 varieties. Among the mutant lines, SbEMS2311-1 was the least infested 60 DAS (5 plants/pot) and 90 DAS (10 plants/pot). The strongest infestation was observed at 90 DAS with the SbEMS2250-1 line (161 plants/pot) and five other mutants. On the Framida variety, the number of emerged Striga plants 60 DAS (92 plants/pot) decreased (49 plants/pot 90 DAS) following plant mortality.

The ANOVA also revealed significant differences between the mutant/ varieties of sorghum, with respect to the weight of the panicles (Sorg Pan W), the weight of the grains (Sorg grns W), and the weight of the stems (W sorg stems) whose probabilities were all $P<0.001$ (Figure 5). The production of 17 sorghum mutant lines and seven varieties was least affected by S. hermonthica infestation. Grain yields of three varieties SRN39, Framida, and ICSV1049 were significantly the highest (Figure 5). As for the dry weights of S. hermonthica (Strg W), there were no significant differences and the probability obtained was 0.30 (Figure 5).

The results on the number of sorghum plants at 21 days after sowing (N_sorg_21D) showed significant differences including $P<0.001$ while at harvest the means (N_sorg_Harv) were not statistically different including $P= 0.67$ (Figure 6). Regarding the height of sorghum plants, ANOVA again showed significant differences with $P <0.001$ (Figure 7). At 21 days after sowing, the height of the Framida variety stem was significantly higher than those of the mutant lines SbEMS 2311-1, SbEMS 3362-1, SbEMS 3105-2, and SbEMS 3914-2. At harvest, the Framida and ICSV 1049 varieties were significantly taller than the other sorghum mutants and varieties.

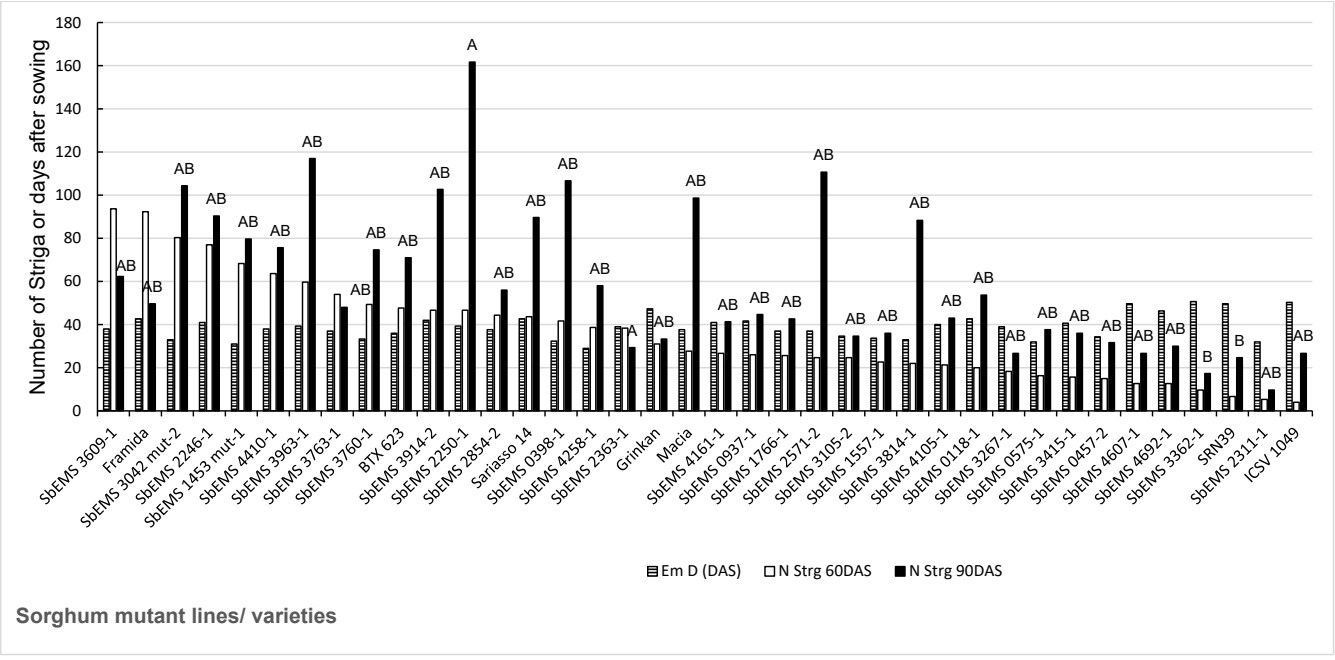

Figure 4: Comparison of the means of the emergence date of S. hermonthica plants Em D (DAS), number of these plants at 60 days after sowing (N Strg 60DAS) and at 90 days after sowing (N Strg 90DAS).

NB: Sticks of the same color followed by the same letter are not significantly different at the 5% level according to the Student-Newman-Keuls test.

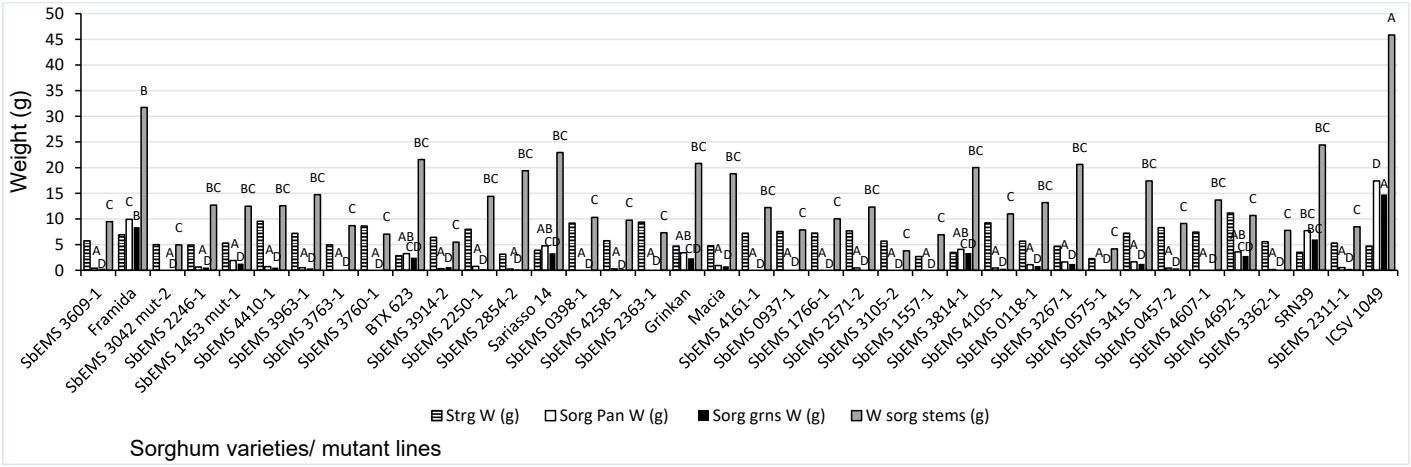

Figure 5: comparison of the means of sorghum production parameters and S. hermonthica biomass.

Sorg Pan W (g) = Weight of sorghum panicles in grams; Sorg grns W (g) = Weight of sorghum grains in grams;
W sorg stems (g) = Dry weight of sorghum stems in grams; Strg W (g) = Dry weight of S. hermonthica plants in grams
NB: Sticks of the same color followed by the same letter are not significantly different at the 5% level according to the Student-Newman-Keuls test.

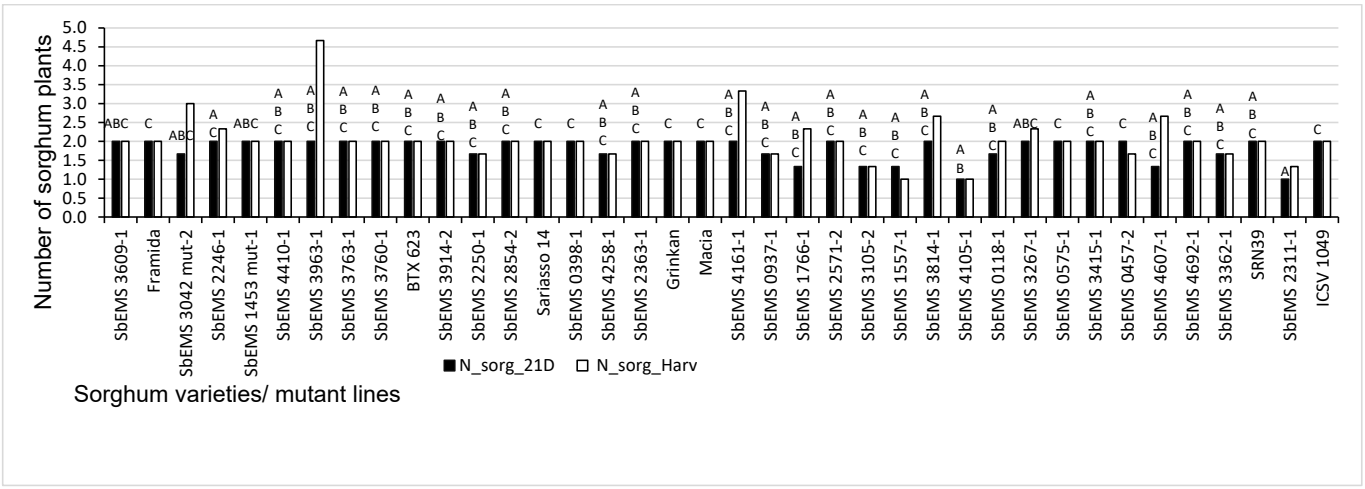

Figure 6: Comparison of the means of the number of sorghum plants at 21 days (N_sorg_21D) and at harvest (N_sorg_Harv)

NB: Sticks of the same color followed by the same letter are not significantly different at the 5% level according to the Student-Newman-Keuls test.

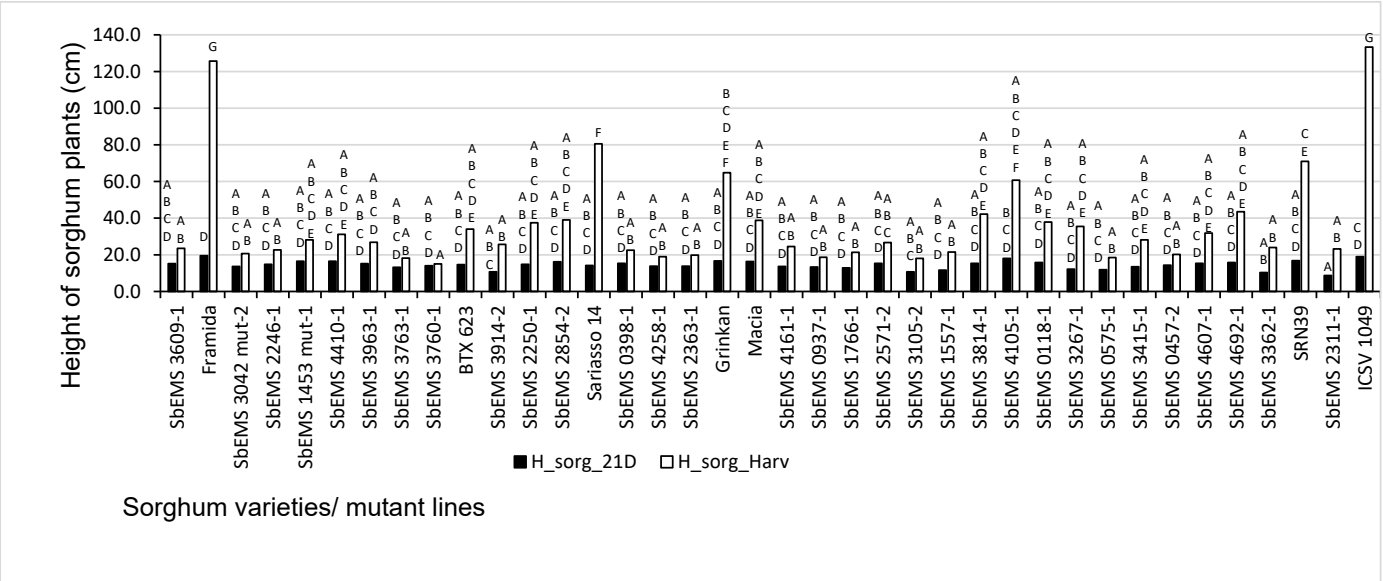

Figure 7: Comparison of the means of sorghum plants height at 21 days (H_sorg_21D) and at harvest (H_sorg_Harv).
NB: Sticks of the same color followed by the same letter are not significantly different at the 5% level according to the Student-Newman-Keuls test.

Relationship between Striga Infestation and Sorghum Production under Greenhouse Conditions

The two axes (PC#1 and PC#2) of the principal component analysis explained respectively 36.1% and 18.1% of the total variance of the variables measured in the greenhouse (Figure 8). The sorghum production variables of plant height (21 DAS and at harvest), stem, panicle, and grain weight were all positively related. For example, the correlation between sorghum plant height at harvest and sorghum grain weight is strongly positive with a correlation coefficient, r = 0.82, and very significant ($p < 0.0001$). Sorghum stem dry weight was positively related to both panicle and grain weight with r=0.72 and P<0.0001 for both correlations. The highest correlation coefficient (r=0.99) with high significance (p<0.0001) was observed between panicle weight and grain weight of sorghum However, the emergence date and number of emerged Striga plants at 90 DAS were negatively correlated (r = -0.21; p = 0.02).

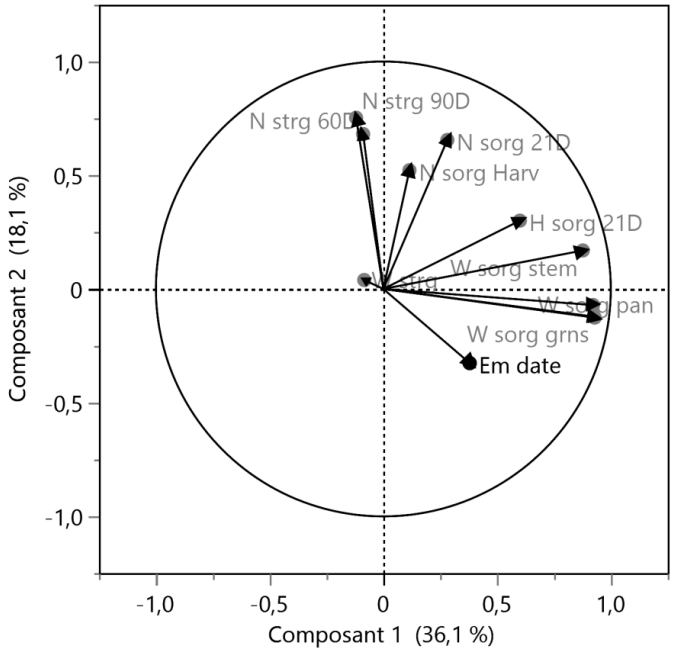

Figure 8: Correlation between the different variables measured in the greenhouse on sorghum and *S. hermonthica*

NB: D.Em = Striga emergence date; H sorg 21D = Height of sorghum plants 21 DAS (Days After Sowing); H sorg harv = Height of sorghum plants at the harvest; N sorg 21J = Number of sorghum plants 21 DAS; N.sorg.rec = Number of sorghum plants at harvest;
N.strg.60DAS = Number of plants of Striga 60 DAS; N.strg.90DAS = Number of Striga plants 90 DAS; W.strg = Dry weight of Striga plants; W.sorg.st = Weight of sorghum stems; W.sorg.pan = Weight of sorghum panicles; W.sorg.gr = weight of sorghum grains

Relationship between *Striga* seed germination in vitro and infestation on sorghum under greenhouse conditions

The two axes PC#1 and PC#2 of the Principal Component Analysis together explained respectively 33.3% and 24.7% of the total variance of the data measured on Striga in vitro and in the greenhouse (Figure 9). These main axes therefore together explain about 58% of the overall inertia. The results showed that the variables GMD, N.strg.60D and N.strg.90D, and GR were interrelated and positively correlated. However, Em date (emergence date) was negatively related to all the other variables. W strg was also negatively correlated with the number of Striga plants at 60 and 90 DAS.

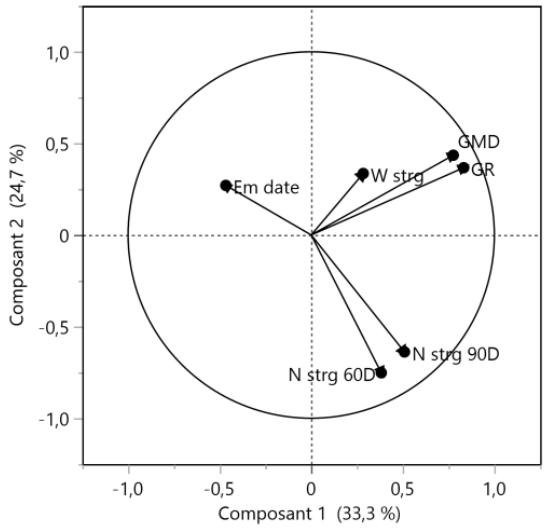

Figure 9: Correlation between the variables of *S. hermonthica* evaluated in vitro and those evaluated in the greenhouse.

NB: GMD= Germination Maximum Distance; GR= Germination Rate, N strg 60D = Number of Striga plants 60 DAS; N strg 90D = Number of Striga plants at 90 DAS, W Strg (g): Weight of Striga Plants in gram

Discussion

Stimulation of *Striga* germination in vitro

The results showed a low production of *S. hermonthica* seed germination stimulant with 5 sorghum varieties and 8 mutant lines *in vitro*. This should confer resistance to these genotypes against the parasitic plant. Indeed, the gel-Agar test is sorghum varieties method selection for their low stimulation of *Striga* seed germination, an important component of resistance [16]. The SbEMS3609-1 mutant was identified in vitro to be a major producer of germination stimulant with the highest germination rate. This mutant could thus be considered as a reference control for the sensitivity of sorghum to *S. hermonthica.* In addition, the *Striga* seeds non-germination in vitro with the seedlings of the varieties ICSV 1049, Framida and SRN39 confirms the results of the work from [17] that Framida and SRN39 were low stimulant-producing genotypes. These authors have shown that it is the formation of a mechanical barrier against the penetration of the *Striga's* haustorium which justifies the resistance of these varieties. [18] was also able to observe a late accumulation of polyphenolic compounds in the tissues surrounding the *Striga's* haustorium on the Framida variety. Furthermore, through an EAGA method (Extended Agar Gel Assay) which is a modification of that of [10], [19] showed that the root of SRN39 prevents the differentiation of *Striga* radicles close to sorghum into haustoria. [20] before also reported that SRN39 root exudates contain two types of sorgolactones: 5-deoxystrigol in low amounts and orobanchol in large amounts The amount of orobanchol and the number of emerged *Striga* plants were negatively correlated.

Interaction between the variables *in vitro*

The linear relationship between the germination maximum distance (GMD) and the germination rate (GR) of *Striga* seeds and their positive correlation means that the greater the GMD, the higher the number of germinated seeds and vice versa. This would mean that the lines shown to be strong producers of stimulants would be able to make the seeds germinate over a long distance and in high numbers. The linear relationship between GMD and GR (y = 4.8427x - 0.6391) indicates that for each unit increase

in GMD, the value of GR increases by 4.84% According to [21] the low production of stimulants is linked to a single nuclear recessive gene, the expression of which depends on several other genes. A strong positive correlation (r = 0.93) was also observed between the GMD and the percentage of Striga seeds germinated in an agar medium in a screening of sorghum genotypes for their resistance [10]. Similarly, [22] before reported a positive (r = 0.88) and significant (P < 0.001) correlation between the *S. asiatica* seeds germination percentage and GMD on sorghum cultivars after an incubation of 72 hours [16]. According to GMD is much easier to measure than the percentage of germination. Indeed, this measurement takes much less time than counting germinated and ungerminated *Striga* seeds to deduce the GR [8]. According to [10], GMD is much easier to measure than the percentage of germination. Indeed, this measurement takes much less time than counting germinated and ungerminated Striga seeds to deduce the GR.

Striga Infestation and Its Effect on Sorghum under Greenhouse Conditions

The emergence of *S. hermonthica* that was more or less early in greenhouse conditions could be due to the regular watering of the pots which favored a rapid lifting of the dormancy of seeds *Striga*. Absolute resistance was not observed as *Striga* emerged on all sorghum lines and varieties. In addition, a greenhouse evaluation of several performance parameters of two sorghum genotypes, Tiémarifing and E36-1, showed similar responses with increased *Striga* seed densities in the soil [23]. These authors reported that the two genotypes showed differences in tolerance but not resistance. Also, according to [24] none of the 6 sorghum cultivars they evaluated in the greenhouse in Sudan, showed a true resistance". mechanism. However, a weak emergence of Striga without significant reduction in the sorghum biomass was observed with the cultivar S3 in Sudan, showed a true resistance mechanism. However, a weak emergence of *Striga* without significant reduction in the sorghum biomass was observed with the cultivar S3 [23]. The effect of *Striga* was severe on BTx623 variety, the susceptible control, to the point that the aerial parts of the plants were completely desiccated at 50 DAS. SbEMS2311-1 which recorded the lowest number of *Striga* 90 DAS plants would be the mutant line most likely to resist in greenhouse conditions. The high weight of the panicles, as well as that of the grains of the varieties ICSV 1049, Framida, SRN39, and Sariaso 14, could be explained by the fact that they are already adapted to the environment's climatic conditions. In addition, previous studies had shown that these varieties are resistant to *S. hermonthica* [25, 26, 19]. Mortality of *Striga* seedlings in the Framida variety between 60 DAS and 90 DAS could be due to necrosis of *Striga* attached to sorghum plants. The necrosis of 71.4% of *Striga* seedlings that emerged on Framida in vitro was also reported by [27]. Moreover, this variety could be considered tolerant to *Striga* in this trial because of its high grain yield despite the heavy infestation at 60 DAS. A similar tolerance ....as a resistance control" and replace it by "A similar tolerance had been observed by [20] with the Mogud and Wadbaco sorghumgenotypes which, despite a high density of S hermonthica, gave higher grain yields than those of the SRN39 variety used as a resistance had been observed by with the Mogud and Wadbaco sorghum genotypes which, despite a high density of S [14]. *hermonthica*, gave higher grain yields than those of the SRN39 variety used as a resistance control. The low weights of the panicles and grains of the mutant lines would be due to the effect of *Striga* which led to the drying up of the main stem of many lines followed by the development of the tillers whose fruiting gave small panicles provided with mature grains. As regards [28], tillering in sorghum is a yield adjustment variable that contributes to production stability.

The mutants SbEMS0937-1, SbEMS3105-2, and SbEMS2311-1 would have a higher level of resistance compared to the others. The male sterility of a mutant (ms8) from the BTx623 variety has already been characterized by [29]. This property would allow hybridizations with other varieties to increase the resistance of sorghum genotypes to *S. hermonthica.* The most resistant NERICA rice cultivars reported by [30] were the ones least damaged by Striga, even though low numbers of Striga caused a reduction in host biomass. The identification of interesting mutants requires the examination of a large number of plants [31, 32]. The greenhouse experiment was conducted during a dry and hot period in Burkina Faso. The low panicle and grain weights of the mutants could therefore be due to adaptation issues and the effect of probable photoperiodism because these mutants were created in a temperate climate.

The Influence of Some Parameters on Others

Principal component analysis (PCA) showed that there was no reduction in the number of emerged *Striga* plants between 60 DAS and 90 DAS. The negative correlation between sorghum grain weight and the number of *Striga* at 90 DAS would mean the high *Striga* count caused a decrease in sorghum grain weight. [33] Furthermore, noted reduced sorghum growth and stunted growth as the dominant symptoms due to *Striga* infestation.

The PCA also emphasizes that the weight of sorghum grains is proportional to that of the panicles and stems and to the plant's height. Thus, the lines whose stems were taller were also the most productive in terms of grain yield and stem biomass that could be used as fodder. A strong correlation between the height of sorghum plants, the weight of their panicles, and their grains under *Striga* infestation, has already been reported by [34]. The dry weight of *Striga* plants and their number were not related to the parasite emergence date. Although the number of *Striga* plants is high, their biomass is low. The weak correlation between the level of germination stimulants production in vitro and the number of *Striga* plants that emerged in greenhouse conditions shows that the measured GMD has little influence on the emergence of the parasite in semi-controlled conditions. This is confirmed with the Framida variety which induced on average the emergence of 92 *Striga* /pot at 60 DAS under greenhouse conditions, whereas, in vitro, no *Striga* germination was recorded. On the other hand, [20] showed a significant positive correlation of root exudate

5-deoxystrigol concentration with *Striga* germination rate in vitro and also with *Striga* infestation under field conditions. *Striga* emergence time is negatively correlated with *Striga* density. This result corroborates that of except that this correlation was strong [35]. It follows that the earlier *Striga* plants emerge, the higher the density of *Striga* plants.

Conclusion

The evaluation of the sorghum mutant lines, in controlled conditions, made it possible to identify mutants such as SbEMS2250-1, SbEMS0937-1, SbEMS3963-1, and SbEMS1557-1 with potential resistance to *S. hermonthica* through low production of germination stimulant. The SbEMS0937-1 and SbEMS3105-2 mutants would be elite lines for their low production of *Striga* seed germination stimulant in vitro and low induced germination rates. The sorghum production variables of which plant height and the weights of the stem, panicle, and grain were positively correlated. Also, the mutant lines with a high germination rate of *Striga* seeds in vitro showed a strong emergence of *Striga* plants in the greenhouse. But other tests are needed to better confirm these results in order to lead to the popularization of resistant mutants among farmers for efficient and sustainable production of sorghum. Thus, tests under natural conditions will make it possible to verify the resistance and adaptability of sorghum mutants [29-35].

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