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Suicidal Germination of *Striga hermonthica* (Del.) Benth. by Cotton, Cowpea and Groundnut Genotypes in Burkina Faso

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ABSTRACT

This study aimed to evaluate in bio-assays the genetic variability from nine cotton genotypes, 15 cowpea genotypes and six groundnut genotypes with respect to their ability to induce suicidal germination of *S. hermonthica* seeds, using the cut-roots technique. The genotypes of the three non-host trap crops exhibited significant differences for their ability to stimulate the germination of *S. hermonthica*. *S. hermonthica* seeds germination percentages of at least 75% were recorded on nine cotton genotypes. However, seven cotton genotypes (FK290, CS120, FK59M, STAM59A, FK37C, FK59K and FK59) were not statistically different from the control Sorghum Gampéla. *Striga hermonthica* seeds germination percentages recorded on all genotypes of both cowpea and groundnut were statistically lower than that recorded on the control Sorghum Gampéla. Germination percentages of *S. hermonthica* seeds higher than 10% were recorded on three cowpea genotypes (IT81-994, KVX604-6, IT89KD-374-57), while no germination of *S. hermonthica* seeds was recorded on cowpea genotype KVX745-11P. A germination percentage of *S. hermonthica* seeds higher than 1% was recorded on only the groundnut genotype CHICO. Cotton, cowpea and groundnut genotypes showing *S. hermonthica* seeds germination percentages of at least 10% may be recommended for use in cultural systems like rotation or intercropping with cereals, particularly in an integrated management approach against *S. hermonthica*.

Key words: *Striga hermonthica*, control, trap crops, root exudates, genetic variability, weed science, parasitic plants, control

INTRODUCTION

Striga hermonthica (Del.) Benth. (Scrophulariaceae parasite), the most economically important parasitic weed plant in the world (Parker and Riches, 1993), is endemic in the African savanna and the Sahel (Marley *et al.*, 2005; Showemimo, 2007) where, about 20-40 millions ha are infested (Thalouarn and Fer, 1993; Ransom and Odhiambo, 1995). Incidence and severity of *S. hermonthica* are exceptionally high on sorghum, pearl millet and maize, the main staple foods for over 300 million people in sub-Saharan Africa (Scholes and Press, 2008). Cereal yield losses due to *Striga* attack vary from about 10% to complete crop loss and total abandonment of cereal production in severely infested fields (Babiker *et al.*, 2000; Gressel *et al.*, 2004). The annual losses of crop productions in sub-Saharan Africa due to *Striga* amount to 8 million tons (Gressel *et al.*, 2004).

However, if *S. hermonthica* infestation constitutes a major and constant worry for African farmers, their social and economic conditions and their level of technicality do not enable them to apply some control methods designed against *Striga*. In view of some deficiencies and feasibility limits of *Striga* control methods, a single method might not solve effectively the serious agro-economic problems caused by *Striga* infestation (Marley *et al.*, 2005; De Groote *et al.*, 2008). Several methods of *Striga* control including soil preparation, hand pulling, hoe-weeding, the use of herbicides, trap and catch crops, resistant crop varieties, nitrogen fertilizer, biological control, chemical stimulants and the treatment of crop seeds have been developed (Radi, 2007). However, among of them, the use of resistant cultivars is the most effective, cost-effective and practical for small scale farmers of Africa (Anaso, 1990; Haussmann *et al.*, 2001; Omanya *et al.*, 2004). Indeed, the breeding of resistant cultivars would be significantly recommended because the use of these varieties demands no cost and no particular technical qualification from poor resource-farmers (Olivier *et al.*, 1992). The serious problem related to the use of crop resistance is the absence of universal resistance, that is probably due to the existence of various physiological strains of *Striga* (Kim *et al.*, 1994; Freitag *et al.*, 1996).

The exploitation of trap crops also constitutes an effective method and less costly against *Striga*. Indeed, trap crops like cotton, cowpea, groundnut and soybean are those crops that induce germination of *S. hermonthica* seeds but are not parasitized and consequently result in suicidal germination of Striga seeds (Parker and Riches, 1993; Botanga *et al.*, 2003). These crops may be used in cropping systems to deplete *Striga* seedbank in farmers' fields (Parker and Riches, 1993). In a laboratory experiment in Nigeria which consisted to screening 40 cotton genotypes, Botanga *et al.* (2003) recorded *S. hermonthica* germination percentages varying from 13.3 to 50% on cotton roots in comparison with 47.3% with the control sorghum CK60B. Other evaluation tests were also conducted on cowpea, groundnut and soybean genotypes in controlled medium and on-farm conditions in Benin (Gbehounou and Adango, 2003). The results from these studies showed that the efficacy of root exudates of some cultivars to stimulate the germination of *S. hermonthica* was function as the geographical origin of *Striga* seeds as the host crops on which *Striga* seeds have been harvested (Gbehounou and Adango, 2003).

This study aims to screen some improved cotton, cowpea and groundnut genotypes in bio-assays to evaluate the genetic variability with respect to the ability of their root exudates to stimulate the germination of *S. hermonthica* seeds.

MATERIALS AND METHODS

Area of study and plant material: The study was carried out in 2006-2007 at the Kamboinsé research station (01°33' E, 12°28'N and 300 m altitude) of the Environmental and Agricultural Research Institute in Burkina Faso. The Kamboinsé research station is located in North Sudanian climate of Burkina Faso (Guinko, 1984). The annual average of ambient temperature is about 27°C with a minimal of 19°C and a maximal of 35°C.

The genotypes of three trap crops (Table 1) were evaluated in bio-assays for their ability to induce the germination of *S. hermonthica* seeds. The crop species were cotton (*Gossypium barbadense* L.), cowpea (*Vigna unguiculata* L. Walp.) and groundnut (*Arachis hypogaea* L.) and the genotypes, obtained from the national breeding program, were as fallows:

- **Nine cotton genotypes:** FK59, FK59K, FK59M, FK290, FK37C, FK57C, STAM190, STAM59A, CS 120
- **15 cowpea genotypes:** KN-1, KVX404-8-1, Moussa local, KVX396-4-5-2D, KVX604-6, IT89KD-374-57, IAR7/180-4-5-1, IT81D-994, TVX3236, KVX414-22-2, Gorom local, KVX61-1, KVX745-11P, KVX414-22-72, KVX442-3-25

Table 1: Origin and descriptive traits of cotton, cowpea and groundnut genotypes evaluated, Kamboinsé 2006-2007

Crops	Genotypes	Origin	Cycle planting - maturity (days)	Colour of seed
Cotton	FK59	Burkina Faso	120	Gray
	FK290	Burkina Faso	120	Gray
	FK59M	Burkina Faso	120	Gray
	FK37C	Burkina Faso	120	Gray
	FK57C	Burkina Faso	110	Gray
	FK59K	Burkina Faso	120	Gray
	STAM 190	Togo	110	Gray
	STAM 59A	Togo	110	Gray
	CS 120	Australia	110	Gray
Cowpea	KVX61-1	Burkina Faso	70	Mosaic white and brown
	KVX404-8-1	Burkina Faso	70	Brown
	KVX414-22-2	Burkina Faso	70	White
	KVX414-22-72	Burkina Faso	70	White
	TVX3236	Nigeria	65	White
	IAR7/180-4-5-1	Nigeria	75	Mosaic white and brown
	KN-1	Burkina Faso	65-70	Brown
	Gorom local	Burkina Faso	70	White
	Moussa local	Burkina Faso	90	Brown
	IT81D-994	Nigeria	70	Brown
	IT89KD-374-51	Nigeria	70	White
	KVX640-6	Burkina Faso	70	White
	KVX442-3-25	Burkina Faso	70	Brown wrinkled
	KVX745-11P	Burkina Faso	70	White
	KVX396-4-52D	Burkina Faso	70	White
Groundnut	CN94C	Burkina Faso	90	Red clear
	TE3	Burkina Faso	90	Pink salmon
	SH470T	Burkina Faso	90	Pink
	CHICO	Russia	75	Pink
	KH241D	Burkina Faso	90	Red
	QH243C	Burkina Faso	90	Red

- **Six groundnut genotypes:** CHICO, TE3, KH241D, QH243C, CN94C, SH470T

These genotypes of trap crops were compared to a susceptible local cultivar of sorghum (*Sorghum bicolor* L. Moench.) to *S. hermonthica*, used as control. This cultivar was collected in the village of Gampéla (in Central Burkina Faso) and called Sorghum Gampéla.

Striga hermonthica seeds used in the experiments were harvested in 2005 from a sorghum field located at the Kouaré agricultural research station (11°95'03" N and 0°30'58"E) in Eastern Burkina Faso, air dried and stored in the laboratory at ambient temperature (about 30°C).

Surface sterilization and conditioning of *Striga* seeds: Discs (6 mm) of glass microfibre filter paper (Whatman GF/A) were placed in Petri dish (9 cm) lined with two Whatman No. 1 filter paper discs. The whole was wrapped in aluminum foil and vapor sterilized at 120°C for 1 h before use in conditioning of *Striga* seeds. *Striga* seeds were firstly surface sterilized in 70% ethanol for 3 min, followed by 5 min in 1% sodium hypochlorite (NaOCl) with Tween 80. Then they were rinsed at least three times with sterile distilled water before their conditioning.

Thirty to 40 sterilized *Striga* seeds were placed on glass microfibre filter paper discs in a sterile Petri dish like previously described. Six milliliter of sterile distilled water were used to condition *Striga* seeds per Petri dish. The Petri dishes were sealed with Parafilm M® barrier film (Pechiney Plastic Packaging, Chicago, IL, 60631) then wrapped in aluminum foil and black polyethylene and incubated in darkness at 28°C for 14 days.

Growth of crop seedlings: The crop genotypes were sown in plastic pots (20×21 cm) in soil medium made up of steam sterilized sand. The density of planting was:

- 20 seeds per pot for cotton and cowpea genotypes
- 30 seeds per pot for sorghum variety
- 15 seeds per pot for groundnut genotype

The pots were regularly watered for 14 days with regard to cowpea and groundnut genotypes and 21 days for cotton genotypes.

Evaluation of suicidal germination of *Striga* by trap crop genotypes: The evaluation of the ability of trap crop genotypes to stimulate the germination of *S. hermonthica* seeds was performed by using the cut-root technique developed by Van Melle *et al.* (1992) with minor modifications. This technique is based on the use of crop root pieces placed in an aluminium foil ring so that cut-roots may exudates stimulant of *Striga* seed germination. Fourteen-day old roots of cowpea and groundnut genotypes and 21-day old roots of cotton genotypes were harvested from pots, washed and then cut up in pieces before use in stimulating of *Striga* seeds.

On the fifteenth day after the conditioning, discs with *Striga* seeds were transferred into new sterile Petri dishes (9 cm) lined with double Whatman No. 1 filter papers. In each Petri dish, discs were arranged in 4 lines (5 discs per radius) around the aluminum foil ring. For each crop genotype, 1 g of crop root pieces was placed in the ring (1.7 cm) to stimulate *Striga* seed germination. The root pieces in the ring were watered with 3 mL of sterile distilled water to help diffuse root exudates. Dishes were again sealed and incubated in the darkness at 30°C for 48 h. After 48 h, the germination of *Striga* seed was determined. Three replications were carried out using a Completely Randomized Block (CRB) design and the experiment was repeated three times.

Statistical analysis: Germination data of *Striga* seeds were arcsine-transformed (Gomez and Gomez, 1984) before performing ANOVA (SAS Institute. Cary. NC) and then back-transformed. Means were separated using Newman Keuls Multiple Range test and differences between treatments were considered significant at $p<0.01$.

RESULTS

Stimulation of *S. hermonthica* seeds germination by cotton genotypes: ANOVA revealed significant variability ($p<0.01$) among cotton genotypes compared to the control Sorghum Gampéla for their ability to stimulate the germination of *S. hermonthica* seed (Table 2). Indeed, the root exudates of all nine cotton genotypes induced *Striga* seed germination percentages of at least 75%. Among the percentages of *Striga* seed germination recorded with cotton genotypes, that obtained with the genotype FK290 was the highest (90.2%). Cotton genotypes could be grouped in two distinct clusters. The first separated cluster was made up of seven genotypes: FK290, CS120,

Table 2: Overall percentages of the germination of *S. hermonthica* consecutive to root exudates from cotton, cowpea and groundnut genotypes, Kamboinsé 2006-2007

Genotypes	Percentage of germination of *Striga hermonthica* seed[§]
Cotton	
Sorghum Gampéla (control)	1,19abc! (86,17)
FK290	1,30a (90,22)
CS120	1,23ab (88,00)
FK59M	1,17bc (83,45)
STAM59A	1,14bcd (81,43)
FK37C	1,12cd (80,06)
FK59K	1,10cd (78,19)
FK59	1,08cd (75,50)
STAM190	1,06d (75,24)
FK57C	1,06d (75,04)
Cowpea	
Sorghum Gampéla (control)	1,19a (86,17)
IT81D-994	0,42b (19,17)
KVX640-6	0,39b (16,64)
IT89KD-374-57	0,35bc (14,50)
KVX404-8-1	0,29cd (9,36)
IAR7/180-4-5-1	0,27cd (9,60)
KN-1	0,23def (6,78)
KVX396-4-5-2D	0,18def (7,85)
Moussalocal	0,18efg (4,63)
KVX442-3-25	0,14efg (4,75)
TVX3236	0,11gh (2,20)
KVX414-22-72	0,07hi (1,85)
KVX61-1	0,06hi (1,52)
Goromlocal	0,04hi (0,90)
KVX414-22-2	0,04hi (0,89)
KVX745-11P	0,00i (0,00)
Groundnut	
Sorghum Gampéla (control)	1,19a (86,17)
CHICO	0,23b (6,74)
TE3	0,03c (0,79)
KH241D	0,02c (0,55)
QH243C	0,01c (0,18)
CN94C	0,01c (0,04)
SH470T	0,00c (0,00)

[§]The means are back-transformation Arc sin (x), x being the percentage of germination of Striga seed in brackets. [!]The means followed by the same letter are not significantly different according to Newman Keuls test at 1%

FK59M, STAM59A, FK37C, FK59K and FK59 which significantly induced *S. hermonthica* seed germination percentages of more than 75%; these seven cotton genotypes were not significantly different from the control sorghum Gampéla (86.2%). The second separated cluster comprised STAM190 and FK57C genotypes with *Striga* germination rates of 75.2 and 75.0%, respectively.

Stimulation of *S. hermonthica* seeds germination by cowpea genotypes: ANOVA showed a highly significant difference ($p<0.01$) between cowpea genotypes and the control (Sorghum Gampéla) for the germination rate of *Striga* seed (Table 2). *Striga* seeds germination rate induced by the control (86.2%) was greater than that of the 15 cowpea genotypes. On the basis of the ability of root exudates to stimulate *Striga* seeds germination, cowpea genotypes were ranked into five distinct clusters. The first separated cluster was made up of IT81-994, KVX604-6, IT89KD-374-57 genotypes with percent germination of *Striga* seed varying from 14.5 to 19.6%; the second consisted of KVX404-8-1, IAR7/180-4-5-1, KN-1 and KVX396-4-5-2D genotypes inducing percent germination of *Striga* seed ranging from 7.8 to 9.6%; the third made up of Moussa local, KVX442-3-25, TVX3236, KVX414-22-72 and KVX61-1 genotypes inducing percent germination of *Striga* seed ranging from 1.5 to 4.6%; the fourth consisted of Gorom local and KVX414-22-2 genotypes inducing percent germination of *Striga* seed less than 1% and KVX745-11P genotype constituted the fifth separated cluster which induced no *S. hermonthica* seed germination.

Stimulation of *S. hermonthica* seed germination by groundnut genotypes: ANOVA showed that the root exudates of Sorghum Gampéla significantly stimulated ($p<0.01$) the germination of *S. hermonthica* seed (86.2%) compared to groundnut genotypes (Table 2). Regarding the *Striga* seed germination rates of groundnut roots, the genotypes evaluated may be divided in two distinct clusters. TE3, KH241D, QH243C, CN94C and SH470T genotypes can make a cluster within which the percent germination of *S. hermonthica* seed was less than 1% and significantly different from that recorded on CHICO genotype which induced 6.7% of *S. hermonthica* seed germination. The groundnut genotype SH470T induced no S. hermonthica seed germination.

DISCUSSION

Striga seeds were conditioned for 14 days before being stimulated by crop root exsudates. This conditioning duration did not affect the potential germination of *Striga* seed. Indeed, Dzomeku and Murdoch (2007) showed in a study on the modelling effects of prolonged conditioning on dormancy and germination of *S. hermonthica* for up to 133 days that there is non-linear relationship between *Striga* seed germination and the period of conditioning. These authors reported that the results of their experiment suggest the release of *Striga* seed from dormancy during the initial period and later on dormancy induction.

Cotton genotypes induced *Striga* seed germination by more than 75%; two genotypes obtained higher percent germination of *Striga* seed than that of the control Sorghum Gampéla (86.2%). Present results confirmed the observations of Botanga *et al.* (2003), who reported some cotton genotypes producing highly active germination stimulants in large amounts. The germination rates of *Striga* seed stimulated by cotton genotypes in this experiment were higher than that recorded on forty Nigerian cotton genotypes also evaluated in a similar test where *Striga* germination rates varied from 13.3 to 50% (Botanga *et al.*, 2003). In addition, Cook *et al.* (1972) extracted from roots of cotton an organic compound called strigol which is active in stimulation of *S. hermonthica* seed germination. This result suggested the possible use of cotton as a non-host trap crop.

Cowpea and groundnut genotypes induced weaker percent germination of *S. hermonthica* seed than that of the control Sorghum Gampéla. Only three cowpea genotypes obtained percent germination of *Striga* seed more than 10%: IT81-994, KVX604-6, IT89KD-374-57 and one groundnut genotype CHICO led to a percentage more than 1%. So, the root exusdates of cowpea genotypes are more skilful to stimulate *Striga* germination than that of groundnut genotypes. The high potential efficacy of cowpea to induce *Striga* germination than groundnut was also reported by Gbehounou and Adango (2003) from field experiment. Indeed, a study carried out in Benin revealed that the percent germination of *Striga* seeds collected in sorghum fields from eight locations varied from 0 to 53% when the root exsudates of three cowpea genotypes (Vita 5, IT90K-56, TVX1850-01F) were used as a stimulant whereas the percent germination of *Striga* seeds collected from the same locations varied from 0% to 37.9% when *Striga* seeds were stimulated by the root exsudates of three groundnut genotypes (69-101, RMP91, RMP12) (Gbehounou and Adango, 2003).

Among the genotypes of the different crops used in this study, that of cotton proved to be more apt to stimulate the germination of *S. hermonthica* seed. However, a large variation in the ability of root exsudates to induce abortive germination of *S. hermonthica* seed was observed among the three trap crops tested and among the genotypes from the same crop. Indeed, in addition of cotton genotypes, three cowpea genotypes and one groundnut genotype significantly stimulated the germination of *Striga* seed. On the other hand, three other cowpea genotypes and five other groundnut genotypes induced *Striga* germination at rates less than 1%. These results prove that genotypes of trap crops have no similar ability to stimulate the germination of *S. hermonthica* seed. Despite of the weak percent germination of *Striga* seed recorded with cowpea and groundnut genotypes compared with cotton genotypes, these two crops remain well-paid trap crops in controlling *Striga hermonthica* on-farm. Indeed, the intercropping of pearl millet or sorghum with groundnut led to a reduction by 50 to 60% of the number of emerged *S. hermonthica* plants in fields experiments conducted in Mali (Dembele *et al.*, 1994). Sorghum variety (SAMSOR 14) intercropped with cowpea variety in alternate ridges significantly reduced density and dry matter production of *S. hermonthica* during 2002-2003 crop seasons in Nigeria (Udom *et al.*, 2007). The use of trap crop genotypes in cropping systems like crops rotation or intercropping including cereals should be recommended in the frame of biological control against *S. hermonthica*. This approach of bio-control consists to reduce *S. hermonthica* seedbank by causing suicidal germination of *Striga* seeds, which may be effective and practical in farmers' fields because it does not request a high technical level. In this perspective, the combination in the same plot of the effects of trap crop genotypes selected for heavy production of germination stimulant of *Striga* seed with pathogen agents, particularly Fusarium oxysporum (Yonli *et al.*, 2004, 2006) should achieve to performing an integrated management of *Striga*. Indeed, since there is no single effective and economically feasible *Striga* control available, it would be opportune to consider an integrated management approach.

This study allowed identifying in bio-assays some local genotypes of cotton and cowpea which significantly induced the germination of *S. hermonthica* seed. The high production of the stimulant of *S. hermonthica* germination is a dominant genetic trait related to one gene that is qualitatively inherent (Hess and Ejeta, 1992; Botanga *et al.*, 2003). Thus, this trait might be easily incorporated in genotypes having good agronomic attributes. The microsatellites, particularly SSR markers, should be powerful tools for elucidating genetic diversity in inducing suicidal germination of *Striga* seed and characterization of germplasm collections.

CONCLUSION

This study highlighted the influence of crop species and the genotype within the same crop species on the ability of root exudates to stimulate *Striga* seed germination. The trap crop genotypes with high potential to induce the germination of *S. hermonthica* seed might be used in integrated *Striga* management including cereals resistant/tolerant genotypes. The choice of components of integrated management should be done according to the economic standard and the degree of intensification of the farming. In this respect, the use of cotton in crops rotation or cowpea in intercropping with cereal crops could be advised in agricultural subsistence zones.

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