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Pathogenicity of *Fusarium* isolates to *Striga hermonthica* in Burkina Faso

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Abstract: *Striga hermonthica* (Del.) Benth. is an important constraint to cereal crop production in Burkina Faso, of which sorghum (*Sorghum bicolor* L. Moench) is the most important component. Native *Fusarium* species to use as bio-control agents to *S. hermonthica* has been investigated. Fifty one *Fusarium* isolates obtained from diseased plants of *S. hermonthica* were evaluated for their pathogenicity against *Striga* under controlled environmental conditions. Of 51 *Fusarium* isolates, 14 were pathogenic to *S. hermonthica* but their virulence differed. These 14 isolates were evaluated for their effects on *Striga* seed germination in the laboratory and their ability to kill emerged *Striga* plants growing in greenhouse pots. Spores of *Fusarium* sp. isolates 150a-M, 125b-Za, 6-Fa, *Fusarium equiseti* isolates 5-Kou, 31-Kom, 32-Or, 13-Ba and *Fusarium oxysporum* isolate 34-Fo reduced *Striga* germination by 78 to 96% compared to the untreated control. The study showed that at the rate of 33 mg mL^{-1}, metabolites of *Fusarium* sp. isolates 125b-Za, 6-Fa, *F. equiseti* 5-Kou and *F. oxysporum* 34-Fo prevented *Striga* seed germination. In addition to these four isolates, *Fusarium* sp. isolates 141b-O, 150a-M and *F. equiseti* isolate 32-Or were effective at 67 mg mL^{-1}. Percentage of *Striga* mortality ranged from 17-37% between 14 and 28 days after inoculation with spores of *F. oxysporum* 34-Fo and *F. equiseti* 5-Kou. *Striga* dry biomass was reduced by 84 and 78% for the respective isolates compared to the untreated control with *Striga*. Sorghum yield was improved by 84 and 99% with *Fusarium* sp. 6-Fa and *F. oxysporum* 34-Fo, respectively, compared to the control without *Striga*. The use of *Fusarium* spores and metabolites against *Striga* offers different possibilities of bio-herbicides formulation that can be combined with other controls methods in the integrated *Striga* management. Further studies will be carried out under field conditions to assess the efficacy and safety of these *Fusarium* isolates to environment and humans and evaluate low cost strategies for transfer to subsistence farmers.

Key words: *Striga hermonthica*, biocontrol, *Fusarium*, pathogenicity, bioherbicides, Burkina Faso

INTRODUCTION

Among parasitic weeds, *Striga hermonthica* (Del.) Benth. is the most widespread and destructive in sub-Saharan Africa (Haussmann *et al*., 2000). *Striga hermonthica* is virulent on sorghum (*Sorghum bicolor* L. Moench), pearl millet (*Pennisetum glaucum* L. R.Br.) and maize (*Zea mays* L.), the main staple food crops in many parts of the world (Parker and Reid, 1979; Hess *et al*., 1992). *Striga* causes severe losses in crops and more than 75% of its overall damage occurs to the host before parasite emergence from the soil (Parker and Riches, 1993). In sub-saharan Africa, yield losses due to *Striga* in sorghum, pearl millet and maize vary from 8 110 000 to 8 520 000 t, corresponding to 39-45% of total production (Gressel *et al*., 2004). In West Africa, yield losses from damage by *S. hermonthica* range from 24 to 27% (6 555 000 to 6926 000 t) in sorghum and millet whereas, in Burkina Faso they are estimated to 35-40% (710 000-820 000 t) (Gressel *et al*., 2004). Yield losses due to *Striga* are so tremendous that they reach 100% in heavily infested fields (Ejeta and Butler, 1993). Severe *Striga* infestation correlated to poor soil fertility, low rainfall and lack of production inputs contribute to important yield losses and then constitute big issues for subsistence farmers (Vogler *et al*., 1996). *Striga* species are difficult to eradicate because of the unique adaptation of the parasite to its environment and the complexity of the host-parasite-environment relationship (Vogler *et al*., 1996).

Striga species produce a large number of seeds with prolonged viability and special germination requirements (Ejeta and Butler, 1993; Siame *et al*., 1993).

Several control methods have been evaluated against *Striga*. These methods include the use of cultural

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practices, fertilizers, resistant crop varieties (Ejeta and Butler, 1993), herbicides (Carson and Kunjo, 1991; Lagoke *et al*., 1991; Traoré *et al*., 2001). However, it is still difficult to find cultivars with complete resistance (Ejeta and Butler, 1993). The availability and cost of the fertilizers and herbicides are the main constraints to their widespread use in Africa. Moreover, used alone, none of these methods has given satisfactory suppression of the parasite (Ciotola *et al*., 1995). *Striga* management strategies should lead to destruction of both the soil seed bank and emerged *Striga* and before the parasite produces seed (Haussmann *et al*., 2000; Schaub *et al*., 2006).

Spores of some fungi were reported to prevent *Striga* germination (Sauerborn *et al*., 1996; Kroschel *et al*., 1996) and this inhibition can be mechanical and/or chemical. Inhibition of *Striga* seed germination by phytotoxic compounds of some *Fusarium* species was reported by Zonno *et al.* (1996), Sugimoto *et al.* (2002) and Idris *et al.* (2003). In Nigeria, *Striga* infestation was reduced by application of spores of *F. oxysporum* isolates DCP and PSM-197, *F. acuminatum*, *F. equiseti* and *Fusarium* sp. isolate PSM-297 (Marley *et al*., 1999). A bio-control approach should give preference to a biological endogenous agent because of its adaptation to the ecological conditions and in order to reduce the risks associated with introducing organisms from other areas. However, there is need for improved bio-herbicide formulations and delivery systems to enhance the potential role of bio-control in integrated management of *Striga* in the subsistence farmer's level.

The objectives of this study were to: (1) evaluate the pathogenicity of *Fusarium* isolates against *S. hermonthica* and (2) determine methods of application.

MATERIALS AND METHODS

The collecting of plant material started in 1998. Two year (2001-2002) study was conducted at the Kamboinsé Research Station (01°33' E, 12°28' N and 300 m altitude) of Environmental and Agricultural Research Institute in Burkina Faso.

***S. hermonthica* seeds:** *Striga hermonthica* seeds were harvested in 1998 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 (30°C). Seeds were surface sterilized in 70% ethanol for 3 min, followed by 5 min in 3% sodium hypochlorite (NaOCl) with Tween 80, before use in germination tests.

***Fusarium* isolates:** Diseased *S. hermonthica* plants were collected in 1999 from 15 locations in three agro-ecological zones (Sahelian, North-sudanian and South-sudanian) of Burkina Faso. Pieces of *Striga* plants showing disease symptoms were washed with sterile distilled water and surface sterilized with 90% ethanol for 45 sec. They were then rinsed with sterile distilled water, air-dried on sterile Whatman No. 1 filter paper and plated on potato-dextrose agar amended with 0.1 g L^{-1} of streptomycin (PDAS). After incubation at 25-30°C for 3 to 4 days, fungi showing typical morphology of *Fusarium* were transferred to PDAS for purification. From the collection, 42 isolates of fungi with morphological features of the genus *Fusarium* (colour and shape) were obtained. Nine out of these 42 isolates were identified by the laboratory of the Danish Seed Health Centre for Developing Countries (Royal Vet. and Agricultural University, Copenhagen Thorvaldsensvej 40, DK-1871 Frederiksberg C, Denmark): *Fusarium oxysporum* (34-Fo) and *Fusarium equiseti* (5-Kou, 42-Ko, 31-Kom, 13-Ba, 21-Or, 32-Or, 17-Fo, 7-Fo). An additional nine isolates collected by Abbasher *et al.* (1998) were included, giving a total number of 51 isolates evaluated in this study.

Spores production: *Fusarium* isolates were grown on PDAS in petri dishes for 14 days. Fifteen milliliter of sterile distilled water was added to mycelium collected from each Petri dish and this mixture was ground with a mixer (Janke and Kunkel, IK labortechnik, Ultra-turrax T25). The suspension was filtered through a 75 μm sieve and adjusted with sterile distilled water to 10^6 spore mL^{-1} using a haemocytometer of Malassez (HERKA®, depth = 0.2 mm, area = 0.0025 m^2).

Metabolites production: Metabolites were extracted from a liquid culture of different *Fusarium* isolates. From a pure culture of each isolate on PDAS, three plugs (4 mm diameter) were placed in a 250 mL glass beaker with 100 mL of Potato Dextrose Broth as growth medium. The glass beaker was stirred on an agitator (Edmund Bühler, 7 400 Tübingen, SM 25) at 120 rpm for 30 days and each solution was then filtered through a Whatman® filter paper. The filtrate was freeze-dried.

Evaluation of the bioherbicidal activity of *Fusarium* isolates

Application of *Fusarium* spores: Spores of 51 *Fusarium* isolates were placed on *Striga* seeds using the technique described by Kroschel *et al.* (1996). Sterilized *Striga* seeds (95% germination rate) were pre-conditioned in a flask with sterile distilled water for 4 days. About 100 preconditioned *Striga* seeds were placed on a 1 cm^2 glass microfibre filter paper disc (Whatman GF/A) in a sterile 9-cm petri dish lined with two Whatman No. 1 filter paper discs.

For each isolate, a suspension of 10 mL (10^6 spore mL^{-1}) was used to condition pre-conditioned *Striga* seeds in the petri dish. Seeds were then sprinkled with 0.05 g of sorghum flour and the Petri dish sealed with Parafilm M® barrier film (Pechiney Plastic Packaging, Chicago, IL, 60631). Dishes were wrapped in aluminum foil and black polyethylene and incubated in darkness at 28°C for 10 days.

After incubation for 10 days, *Striga* seeds were washed with sterile distilled water through two sieves, the first (315 μm) allowing separation of seeds from the mycelium and the second (80 μm) allowing separation of seeds from spores. Stimulation of germination of *Striga* seeds was evaluated in a modification of the technique of Berner and Williams (1998). *Striga* seeds placed on 8 glass microfibre filter discs (1 cm^2) (Whatman GF/A); 20 to 30 seeds $disc^{-1}$. The eight discs were arranged in 4 lines around an aluminum foil ring centered in the Petri dish lined with a double Whatman No. 1 filter paper. Fourteen day-old root pieces (1 g) of sorghum variety S29 (obtained from the national breeding program and susceptible to *S. hermonthica*) were placed in the ring to stimulate *Striga* germination. The root pieces in the ring were watered with 3 mL of sterile distilled water to help diffuse root exudates. Dishes were then wrapped in aluminum foil and black polyethylene and incubated at 30°C for 48 h. The germination rate of *Striga* seeds conditioned in sterile distilled water (control) was then compared to those of seeds conditioned in the spore suspension of the 51 isolates. A Completely Randomized Block design (CRB) was used with three replications. The experiment was repeated three times.

Application of *Fusarium* metabolites: Thirty to Forty sterilized *Striga* seeds were placed on glass microfibre filter paper discs (6 mm diameter) in Petri dishes (7 cm) lined with double Whatman No. 1 filter papers. Six milliliter of solution of each treatment was used to condition *Striga* seeds and treatments were as follows:

- (1) Control (-), seeds conditioned with sterile distilled water
- (2) Control (+), seeds conditioned with 67 mg mL^{-1} of growth medium filtrate freeze-dried
- (3) seeds conditioned with 1 mg mL^{-1} of metabolite of each *Fusarium* isolate
- (4) seeds conditioned with 10 mg mL^{-1} of metabolite of each *Fusarium* isolate
- (5) seeds conditioned with 33 mg mL^{-1} of metabolite of each *Fusarium* isolate
- (6) seeds conditioned with 67 mg mL^{-1} of metabolite of each *Fusarium* isolate

Sealed petri dishes were then incubated in darkness at 27°C for 14 days. On the fifteenth day, seeds were placed on discs and transferred into new 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. Fourteen-day old root pieces (1 g) of sorghum variety S29 were placed in the ring and moistened with 3 mL of sterile distilled water. Dishes were again sealed and incubated in the darkness at 30°C for 48 h. After 48 h, germination of *Striga* seed was determined. Three replications were carried out using a Completely Randomized Block design (CRB) and the experiment was repeated three times.

Leaf inoculation with *Fusarium* spores: Sorghum variety S29 was sown in plastic pots (26×28 cm) in soil medium made up of two parts unsterilized soil and one part of steam sterilized sand. Pots had been artificially infested with *Striga* seeds as described by Marley *et al.* (1999) in order to have an infestation rate of 5×10^3 viable *Striga* seeds per pot. Seventy Days after Sowing (DAS), emerged *Striga* plants were inoculated by spraying a spore suspension (1×10^6 spore mL^{-1}) of *Fusarium*. *Striga* plants were inoculated in a growth chamber at 25-28°C and 100% HR and incubated there for 24 h; they were then transferred into a greenhouse.

The experimental design was a randomized complete block with three replications and the following treatments: (1) non-infested soil + sorghum, (2) soil infested with *Striga* seeds + sorghum ; 3 to 16) soil infested with *Striga* seeds + sorghum + 10 mL suspension (1×10^6 spore mL^{-1}) of each isolate spread on *Striga* plants 70 DAS.

The following observations were made

- Percentage of dead *Striga* plants 14, 21 and 28 Days after Inoculation (DAI) of spores
- Counts of emerged *Striga* plants flowering or bearing seed capsules
- A visual estimation of *Striga* vigor recorded 14, 21 and 28 DAI using a rating scale of 0 to 9 (Haussmann *et al*., 2000), where 0= No emerged *Striga* plant, 9 = Mean height of *Striga* plants > 40 cm, with more than 10 branches
- Weight of *Striga* dry biomass at sorghum harvest
- Weight of sorghum dry biomass (stalks and roots) and grain yield

Statistical analysis Percent germination of *Striga* and percentage of dead *Striga* were arc sine transformed (Gomez and Gomez, 1984) before performing ANOVA (SAS Institute. Cary. NC) followed by separation of means using the LSD's test. Number of flowering *Striga*, vigor of

Striga plants, *Striga* dry biomass and sorghum yields were subjected to an Analysis of Variance (ANOVA) and to separation of means using LSD's test.

RESULTS

Effect of *Fusarium* spores on *Striga* germination: Of the 51 isolates evaluated, 14 were found to reduce significantly *Striga* germination in comparison to the control. Indeed, the 14 isolates led to a reduction by more than 50% of potential germination rate of *Striga* (Fig. 1). The spores of *F. oxysporum* (34-Fo), *F. equiseti* (5-Kou, 32-Or, 31-Kom, 13-Ba) and *Fusarium* sp. (6-Fa, 125b-Za, 150a-M) were more effective reducing *Striga* germination by 78 to 96%.

Effect of *Fusarium* metabolites: ANOVA revealed that the 4 doses (1, 10, 33 and 67 mg mL^{-1}) of metabolites of the 14 isolates significantly reduced *Striga* germination. The dose of 1 mg metabolites mL^{-1} of the 14 isolates slightly influenced *Striga* germination. A reduction by more than 50 % was recorded with 10 mg metabolites mL^{-1} of the isolates *F. oxysporum* 34-Fo, *F. equiseti* (5-Kou, 6-Fa) and *Fusarium* sp. 125b-Za. *Striga* germination rate was 0% with four isolates at the dose of 33 mg metabolite mL^{-1} whereas at the dose of 67 mg mL^{-1}, *Striga* germination was inhibited with seven isolates (Fig. 2).

The results showed a highly significant positive correlation (r = 0.88) between *Striga* germination rates for seeds treated with *Fusarium* spores and *Striga* germination rates when seeds were treated with *Fusarium* metabolites.

Effect of *Fusarium* spores on *Striga* infestation: *Striga* infestation of sorghum was significantly reduced 14, 21 and 28 Days after Inoculation (DAI) of the emerged parasite with *Fusarium* spores (Table 1). *Striga* death rates greater than 11% were recorded with four isolates 14 DAI and isolate 34-Fo was the most effective with a 22% kill rate. A *Striga* death rate greater than 11% was recorded with 8 isolates 21 and 28 DAI; isolates of *F. oxysporum* 34-Fo, *F. equiseti* (5-Kou, 32-Or) and *Fusarium* sp. (6-Fa, 150a-M) were the most effective for both dates (*Striga* death rate varying from 17 to 37%). Number of flowering *Striga* and *Striga* bearing seed capsules were significantly reduced 21 and 28 DAI with *Fusarium* spores (Table 2). Seven and 10 isolates

Table 1: Effect of inoculation with *Fusarium* spores on *Striga* death rate in greenhouse

Isolates	14 DAI§	21 DAI	28 DAI
F. oxysporum (34-Fo)	21.6a†*	32.4a	37.2a
Fusarium sp. (6-Fa)	15.5abc	24.5ab	26.4bc
F. equiseti (5-Kou)	17.8ab	27.6a	30.5ab
Fusarium sp. (125b-Za)	10.4cde	15.4cd	16.4def
Fusarium sp. (150a-M)	11.9bcd	19.1bc	23.4bcd
F. equiseti (32-Or)	9.4cde	17.4bc	21.4cde
Fusarium sp. (141b-O)	4.5fgh	10.4de	7.3gh
F. equiseti (31-Kom)	6.7def	13.5cde	15.3ef
F. equiseti (13-Ba)	4.5fgh	8.5ef	8.4gh
F. equiseti (21-Or)	5.5efg	12.6cde	12.4fg
Fusarium sp. (12-Ba)	4.5fgh	8.4ef	7.4gh
F. equiseti (17-Fo)	3.5fgh	5.4fg	4.4hi
F. equiseti (7-Fo)	2.1ghi	3.4g	2.3i
F. equiseti (42-Ko)	1.7hi	3.6g	1.8ij
Control (+)	0.5i	0.3h	0.2j
Means	8	13.5	14.3

§: Days after inoculation, †: Means are back-transformations of percentage of dead *Striga*, *: Means within a column followed by the same letter are not significantly different (p = 0.01) according to LSD's test

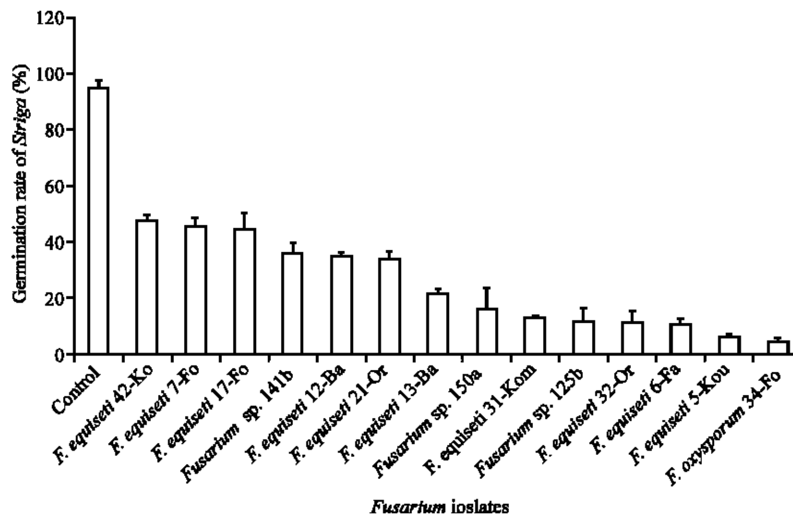

Fig. 1: Effect of spores of *Fusarium* isolates on *Striga hermonthica* seeds germination. Vertical lines indicate standard errors of the means. Control: *Striga* seeds conditioned in sterile distilled water

significantly reduced number of flowering *Striga* and *Striga* bearing fruits, respectively, 21 and 28 DAI.

Effect of *Fusarium* spores on *Striga* growth: *Fusarium* isolates significantly reduced *Striga* vigor 21 and 28 DAI (Table 2). *Striga* vigor was highly reduced 21 DAI with three isolates whereas at 28 DAI, all the isolates (except *F. equiseti* 42-Ko) reduced *Striga* vigor. The most effective were isolates of *F. oxysporum* 34-Fo and *Fusarium* sp. 6-Fa. The fourteen *Fusarium* isolates significantly reduced *Striga* biomass compared to the control and thirteen led a reduction by more than 48%. *F. oxysporum* 34-Fo was the most efficient at reducing *Striga* growth (84% biomass reduction) followed by *Fusarium* sp 6-Fa (78% biomass reduction).

Effect of *Fusarium* spores on *Striga* infestation and sorghum yield: Application of *Fusarium* spores significantly reduced number of emerged *Striga* plants in pots. As a result, the dry biomass of sorghum stalks and roots and sorghum grain yield were improved. *Striga* infestation only reduced sorghum root biomass on the control. Seven fungal isolates (*F. oxysporum* 34-Fo, *F. equiseti* (5-Kou, 31-Kom, 32-Or) and *Fusarium* sp. (150a-M, 6-Fa, 125b-Za)) all alleviated *Striga* effect with respect to stalk biomass (Fig. 3). *Striga* depressive effect

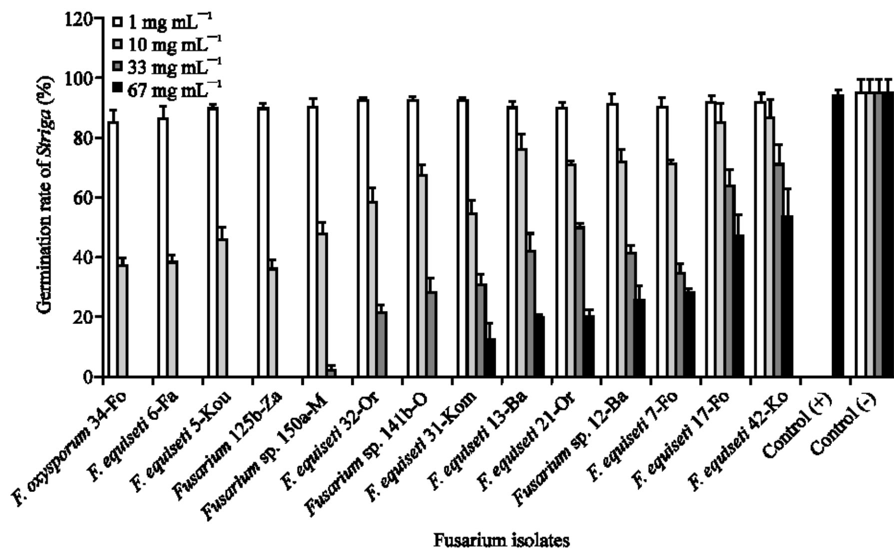

Fig. 2: Effect of metabolites of *Fusarium* isolates on *Striga hermonthica* seeds germination. Vertical lines indicate standard errors of the means. Control (-): Striga seeds conditioned with sterile distilled water; Control (+): seeds conditioned with 67 mg mL^{-1} of growth medium filtrate freeze-dried

Table 2: Effect of Fusarium spores on number of flowering *Striga*, *Striga* vigor and dry biomass in greenhouse

	No. of flowering *Striga* and/or *Striga* bearing fruits		Vigor of *Striga* plants		
Isolates	21 DAI[§]	28 DAI	21 DAI	28 DAI	*Striga* dry biomass (g pot^{-1})
F. oxysporum (34-Fo)	2.67c[¹]	5.67e	1.67c	2.00e	4.76h
Fusarium sp. (6-Fa)	4.33c	8.00e	2.00c	2.33e	6.48gh
F. equiseti (5-Kou)	7.00c	9.00de	2.00c	2.67de	8.56fgh
Fusarium sp. (125b-Za)	9.67bc	15.67bcde	2.67bc	3.33cde	11.74cdef
Fusarium sp. (150a-M)	7.00c	10.33cde	2.33bc	3.00cde	9.00fg
F. equiseti (32-Or)	5.0 c	9.33de	2.33bc	3.33cde	11.11cdef
Fusarium sp. (141b-O)	12.33abc	17.33bcde	2.33bc	3.00cde	10.73ef
F. equiseti (31-Kom)	7.33c	9.00de	2.33bc	2.67de	11.81cdef
F. equiseti (13-Ba)	12.33abc	22.33abc	2.33bc	2.67de	14.71cd
F. equiseti (21-Or)	11.00abc	12.00cde	2.67ab	3.33cde	10.93def
Fusarium sp. (12-Ba)	12.67abc	15.00bcde	2.67bc	3.33cde	11.20cdef
F. equiseti (17-Fo)	10.67abc	21.00abcd	3.33ab	4.33bc	14.99c
F. equiseti (7-Fo)	18.0ab	25.3ab	3.3ab	4.0bcd	13.90cde
F. equiseti (42-Ko)	19.3ab	25.0ab	3.3ab	5.0ab	20.86b
Control (+)	20.67a	1.67a	4.33a	6.33a	29.00a
Means	10.69	15.78	2.64	3.42	12.65

[§]: Days after inoculation. [¹]: Means within a column followed by the same letter are not significantly different (p = 0.05) according to LSD's

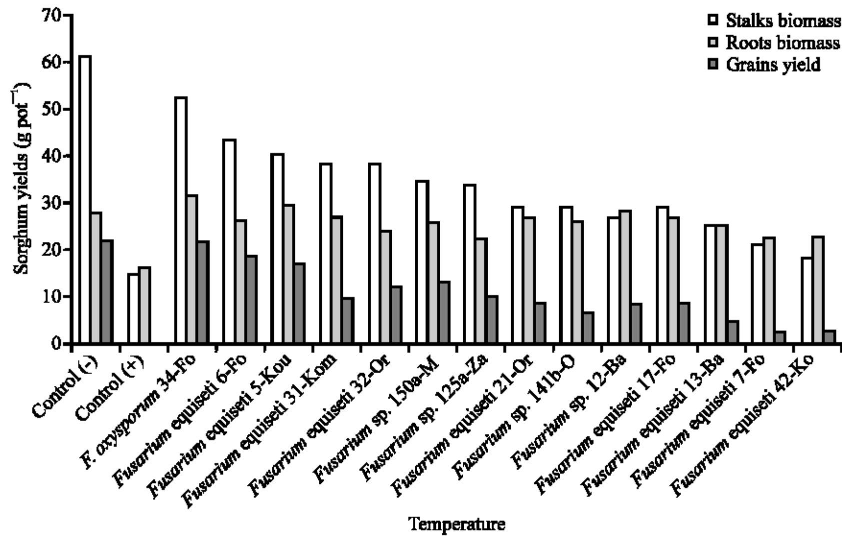

Fig. 3: *Sorghum* stalks, roots dry biomass, *Sorghum* grains yield following upon application of *Fusarium* spores on *Striga hermonthica* plants. Vertical lines indicate standard errors of the means. Control (+): *Sorghum* with *Striga*, Control (-): *Sorghum* without *Striga*

on sorghum grain yield was alleviated by three isolates (*F. oxysporum* 34-Fo, *F. equiseti* 5-Kou and *Fusarium* sp. 6-Fa), for which we recorded, respectively, 78, 84% and 99% of yield of the control without *Striga*. Sorghum grain yield recorded with the other isolates were between 12% and 60% of that of the control (Fig. 3).

DISCUSSION

The results of these investigations confirm the potential pathogenicity of *Fusarium* sp. on *S. hermonthica* as reported by Kroschel *et al.* (1996), Abbasher *et al.* (1998), Elzein and Kroschel (2004) and Elzein *et al.* (2009). However, the pathogenicity varied significantly between *Fusarium* isolates collected in the same location. In addition, bioherbicidal activity of *Fusarium* isolates from different locations should be influenced by the method of inoculation with *Fusarium* (Kroschel *et al.*, 1996; Marley *et al.*, 1999).

Spores of 51 fungi isolates were evaluated for inhibition of *Striga* seed germination. Of these 51 isolates, 14 were found to reduce *Striga* germination by more than 50%. Isolates of *F. equiseti* (13-Ba, 150a-M, 31-Kom, 32-Or, 5-Kou), *Fusarium* sp. (125b-Za, 6-Fa) and *F. oxysporum* 34-Fo were the most effective with a reduction of *Striga* germination by more than 78%. Kroschel *et al.* (1996) also demonstrated that spores of two *F. oxysporum* isolates (Fo1, Fo2) and one *F. solani* isolate (Fs1) used to condition *Striga* seeds reduced *Striga* germination by more than 90%. A suspension of 10 mL *F. nygamai* at a rate of 4×10^6 spore mL^{-1} used to inoculate *Striga* seeds in roots chamber reduced germination rate by 88% (Abbasher and Sauerborn, 1992). Reduction of *Striga* germination by spores of *Fusarium* isolates is probably the result of penetration of mycelium into *Striga* seeds which are then killed (Sauerborn *et al.*, 1996).

Application of fungal metabolites to parasite seed reduced or inhibited *Striga* germination. In this study, no germination of *Striga* was observed with 33 mg mL^{-1} metabolites of isolates *Fusarium* sp. (125b-Za, 6-Fa), *F. equiseti* 5-Kou and *F. oxysporum* 34-Fo. Three other isolates (*Fusarium* sp. (141b-O, 150a-M) and *F. equiseti* 32-Or) showed a complete inhibition of *Striga* germination with 67 mg mL^{-1} metabolites. The bio-herbicide effect of these seven isolates is probably due to metabolites of the filtrates. Four toxic metabolites (fusaric acid, 9,10-acid dehydrofusaric, 2 ester-methyl) produced *in vitro* by *F. nygamai* and completely inhibiting *Striga* germination were identified (Zonno *et al.*, 1996; Idris *et al.*, 2003). Four other metabolites of tricothecene group (acuminatin, neosolaniol, 8-acetylneosolaniol and tetraacetoxy T-2 tetraol (neosolaniol diacetate)) produced by *F. solani* (Sud 96) lead to inhibition of *S. hermonthica* seed germination (Sugimoto *et al.*, 2002). The high positive correlation between *Striga* germination rates with *Fusarium* spores and metabolites indicates that when evaluating *Striga* germination rate with *Fusarium* spores,

it appears unnecessary to determine *Striga* germination rates with *Fusarium* metabolites.

Application of *Fusarium* spores led to a *Striga* death rate more than 20% with five isolates. In this study, the highest *Striga* death rate due to application of *Fusarium* spores was lower than 40% whereas *Striga* death rates of 44 to 89% were reported with local isolates from Nigeria (Marley *et al*., 1999). *Fusarium* isolates affected *Striga* vigor and consequently *Striga* biomass was reduced by more than 48% with all isolates except *F. equiseti* 42-Ko. The great reduction of number of flowering and fruiting *Striga* recorded with 10 *Fusarium* isolates 28 DAI, may lead to reduce *Striga* seeds production. Thus, the application of *Fusarium* spores on *Striga* in the field could limit the increase of the soil seed bank. The increase of sorghum dry biomass and yield was the result of effectiveness of *Fusarium* isolates to protect the host plants.

We are currently investigating the metabolites/toxins responsible for *Striga* death. A potential use of *Fusarium* isolates by farmers to control *Striga* infestations in the field could be through crop seed coating with fungal spores before sowing. So, use of *Fusarium* isolates could be a biological component in the integrated *Striga* management in West Africa.

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