African Crop Science Journal, Vol. 13. No. 1, pp. 41-47, 2005
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ISSN 1021-9730/2005 $ 4.00

BIOLOGICAL CONTROL OF WITCH WEED IN FIELDS OF BURKINA FASO USING ISOLATES OF *Fusarium oxysporum*

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(Received 11 August, 2003; accepted 7 January, 2005)

ABSTRACT

Fifteen *Fusarium oxysporum* isolates from diseased parasitic weeds *(Striga hermonthica* plants) were evaluated over two years (1997-98) to identify the most effective isolates for the control of the parasite in infested sorghum fields in Burkina Faso. In both years the fungus was found to reduce *Striga* infection in sorghum by 50% although no significant differences were found among the 15 isolates in this respect. In 1997, *Striga* emergence was delayed by 10 days and the 47% reduction in *Striga* biomass is attributed to the effects of fungal isolates, whereas in 1998, *Fusarium* reduced emerged *Striga* densities by 45%. However, there is need for improved bioherbicide formulations and delivery systems to enhance the potential role of biological control for integrated management of the parasite in Burkina Faso.

Key Words: Biological control, *Fusarium oxysporum*, *Sorghum bicolor*, *Striga hermonthica*

RÉSUMÉ

Quinze *Fusarium oxysporum* isolés des mauvaises herbes (plante de *Striga hermonthica*) étaient évalués pour une période de plus de deux ans (1997-1998) pour identifier les isolés les plus efficaces pour le contrôle de parasites dans les champs de sorgho infectés au Burkina Faso. Pour les deux ans les champignons avaient significativement réduis les infections dues au *Striga* par 50% même si les quinze isolés n'étaient pas significativement différents. En 1997, l'émergence du striga avait retardé de 10 jours et le 47% réduction de la biomasse du *Striga* était attribuée aux isolés de champignons, alors qu'en 1998, *Fusarium* avait réduit la densité du *Striga* émergeant par 45%. Cependant, il y a nécessité d'améliorer formulation des bio-herbicides et du système de livraison pour augmenter le rôle potentiel du contrôle biologique pour une gestion intégrée de parasites au Burkina Faso.

Mots Clés: Contrôle biologique, *Fusarium oxysporum*, *Sorghum bicolor*, *Striga hermonthica*

INTRODUCTION

Parasitic weeds (witch weeds) of the genus *Striga* constitute a major biotic constraint to cereal production in sub-Saharan Africa (Haussmann *et al.*, 2000). Some 40 million hectares are infested by the parasite, leading to annual yield losses estimated at 4 million tons (M'Boob, 1986; Sauerborn, 1991). *Striga hermonthica* is the most widespread and noxious species for cereal crops

particularly sorghum. Yield losses due *S. hermonthica* in sorghum vary from 41% to 75 % in central Burkina Faso (Zombré and Nikiéma, 1992) and from 28 % to 55 % in the eastern part of the country (Traoré and Yonli, 1999). Although a variety of control methods have been developed, no single methodology is adequate and an integrated approach for *Striga* management is needed (Hess and Haussmann, 1999).

The potential of exploiting natural antagonists (biocontrol) to control *Striga* is receiving increasing attention. In West Africa, fungi of the genus *Fusarium* have been isolated from diseased *Striga* plants and are showing potential for biocontrol of the weed (Zummo, 1977; Ciotola *et al.*, 1995; Abbasher *et al.*, 1998; Marley *et al.*, 1999). Species of *Fusarium* were isolated from more than 90% of diseased *Striga* plants collected in Burkina Faso, Ghana, Mali, and Niger (Abbasher and Sauerborn, 1995; Abbasher *et al.*, 1998). Four species (*F. nygamai*, *F. oxysporum*, *F. semitectum* var. *majus* and *F. solani*) screened in laboratory reduced the germination of *S. hermonthica* seed by 84-96% (Abbasher *et al.*, 1996) and *F. oxysporum* was the predominant species attacking *Striga* spp. in Burkina Faso, Mali and Niger (Abbasher *et al.*, 1998). In Central Burkina Faso, use of 750 g m^{-2} of nere (*Parkia biglobosa* (Jacq.) R.BR. ex G.Don) pods powder at sowing reduced number of emerged plants biomass of *S. hermonthica* by 43- 50% and this resulted in a 40% increase in maize yields (Kambou *et al.*, 1999). So, there is a potential in natural antagonists and natural products that might be exploit for *S. hermonthica* control.

This study was undertaken to evaluate the capacity of fifteen *F. oxysporum* isolates to control *S. hermonthica* under field conditions in Burkina Faso.

MATERIALS AND METHODS

The study was conducted during two cropping seasons (1997-1998) at the experimental research station in Kouaré (11°95'03" N and 0°30'58" E) in the eastern sudan-savannah region of Burkina Faso.

The trial was sown in a sandy-loam, tropical, Ferruginous soil. A local sorghum landrace (Itchoari) from the village of Kouaré was used. Experimental plots with heavy natural infestation of *S. hermonthica* (at least 30 plants m^{-2} in previous years 1995-1996) were chosen. In normal year, the mean annual rainfall for the region varies from 850 mm to 1,050 mm. Rainfall recorded in 1997 was 816.8 mm in 75 days with 54% (441.07 mm) falling during the crop growth period. Two drought periods (8 days from August 1st to August 8th and 7 days from September 8th to September 14th) occurred during the crop growth period in 1997 and the rain stopped prematurely on October 5th when sorghum was at the booting stage. In 1998, 1,076 mm of rainfall fell in 65 days with 73% (785.48 mm) recorded during the cropping season. Two drought periods (7days from August 28th to September 3rd and 14 days from September 25th to October 9th) were also registered during the cropping season. However, after these drought periods, rain fell regularly until the end of October.

Fifteen *F. oxysporum* isolates collected in 1995 in Burkina Faso (141-B-O, 119-A-Zo, 117-A-Zo, 150-A-M, 123-B-Za, 124-A-Za, 125-B-Za,), Mali (101-A-S, 105-B-S, 111-A-S, 113-C-S, 114-A-S) and Niger (121-N, 4-3-B, P.O.4) were investigated. The growth media were prepared as described by Abbasher and Sauerborn (1992) using sterilized chopped millet straw.

The experimental design was a randomised complete block with 5 replications. The main plot consisted of four rows of 2.4 m length, 0.8 m between rows, and 0.4 m between planting hills (plot size of 7.68 m^2). Treatments consisted of a control without straw, an uninoculated straw and 15 isolates inoculated and cultured on straw (inoculum). The trial was conducted in both years (1997 and 1998) on the same piece of land and the treatments repeated on the same plots.

At sowing, 30 g straw (uninoculated or inoculated with one of the 15 isolates) were incorporated into each hill in the upper 10 cm of soil. A mineral fertiliser of 100 kg ha^{-1} of NPK (12:24:12) was applied to the plots at sowing and 50 kg ha^{-1} of urea (46% N) was applied at the booting growth stage. In 1997, sorghum was sown relatively late on July 18 whereas in 1998, it was sown on June 24. Plants were thinned to two plants per sowing hill about three weeks after emergence. Plots were weeded twice (14 and 28 days after sowing (DAS)) with hand hoes before emergence of *Striga*. Any subsequent weeding

consisted of hand-pulling weeds other than *Striga*. A total area of four sorghum hills (1.28 m^2) was harvested from the center of each plot.

The following data were taken and recorded in both years in 1.28 m^2 including the four sorghum hills in the centre of each plot:

(i) counts of emerged *Striga* plants at weekly interval, beginning one week after the first emergence of *Striga* in the trial;

(ii) weight of *Striga* dry biomass at sorghum harvest;

(iii) weight of sorghum yield (straw and grain);

(iv) reaction of sorghum to 15 *Fusarium* isolates was evaluated using a visual rating scale 0-5 (Linke *et al.*, 1992).

Counts of emerged *Striga* plants during the season were used to calculate area under the *Striga* density progress curve (ASDPC) (Haussmann *et al.*, 2000). Data were checked to determine need for transformation before performing ANOVA (SAS Institute, Cary, NC) on treatment effects. Where significant effects were detected between treatments, the means were separated using the least significant difference test (Steel *et al.*, 1997).

RESULTS

Sorghum plants were not infected by the 15 *Fusarium* isolates used in this study. ANOVA showed that application of inoculated straw (15 *F. oxysporum* isolates) significantly affected *Striga* biomass in 1997 compared to the uninoculated straw (Table 1). There was a significant difference between the uninoculated straw and the inoculated straw for *Striga* biomass. No significant differences were found among the 15 isolates (data not shown) for any of the parameters in 1997. Application of the isolates delayed *Striga* emergence 10 days compared to control (Table 2). *Striga* biomass was greater in the control and uninoculated straw plots than in the plots inoculated with the fungal isolates. *Striga* biomass was reduced in plots inoculated with the isolates by 47% and 42% compared to the control and uninoculated straw, respectively.

In 1998, the uninoculated straw significantly reduced *Striga* emergence, number of emerged *Striga* at 100 DAS and ASDPC compared to control (Table 3). There was highly significant difference between the control and the uninoculated straw for *Striga* emergence whereas significant differences were revealed between the control and the uninoculated straw for number of emerged *Striga* at 100 DAS and ASDPC. There were significant differences between the

TABLE 1. ANOVA of effect of treatments on *Striga* emergence, emerged *Striga* density, biomass of *Striga* and sorghum straw, Kouaré, Burkina Faso, 1997

Source of variance		F values				
	df	*Striga* emergence	*Striga* emergence at 86 DAS[a]	ASDPC[b]	*Striga* biomass	Sorghum straw
Block	4	0.3876	0.0001**[c]	0.0002**	0.0308	0.0097**
Treatment	16	0.1900	0.3319	0.1286	0.0156*	0.3581
Control vs Uninoculated straw	1	0.1773	0.7523	0.7977	0.7532	0.8562
Uninoculated straw vs Inoculated straw	1	0.33	0.3883	0.2230	0.9161 *	0.8427

a: Days after sowing
b: Area under *Striga* Density Progress Curve (Haussmann *et al.*, 2000)
c: *, ** Asterisks indicate level of significance such that * indicates $P \leq 0.05$ and ** indicates $P \leq 0.01$

uninoculated straw and the inoculated straw (with 15 *F. oxysporum* isolates) for *Striga* emergence and sorghum straw (Table 3). Also in 1998, ANOVA did not show significant differences among the 15 isolates (data not presented) for any of the parameters. Use of uninoculated straw delayed *Striga* emergence by 17 days and reduced number of emerged *Striga* (at 100 DAS) and ASDPC, respectively, by 75% and 76% compared to control (Table 4). Application of the isolates reduced number of emerged *Striga* (at 100 DAS) and ASDPC by 45% compared to the control. There were no significant differences between the uninoculated straw and the inoculated straw (with 15 *F. oxysporum* isolates) for number of emerged *Striga* at 100 DAS, ASDPC and *Striga* biomass. On the contrary, sorghum yield was improved by 51% in plots treated by *Fusarium*.

DISCUSSION

The isolates used in this study were non-pathogenic to sorghum, confirming published results from the region (Ciotola *et al.*, 1995; Abbasher *et al.*, 1998).

As compared to previous studies (Kroschel *et al.*, 1996; Abbasher *et al.*, 1998), results of this study reveal that the performance of *F. oxysporum* as a biological control agent against *Striga* in the field is more variable than that obtained in laboratory and pot experiments. Interactions between environmental factors and the morphological, ecological and physiological variability of the fungi can influence the ability of *F. oxysporum* isolates to parasitize *Striga* (Booth, 1971). Amount and timing of rainfall influence emerged *Striga* numbers (Hess *et al.*, 2001;

TABLE 2. Effect of treatments on *Striga* emergence, emerged *Striga* density, biomass of *Striga* and sorghum straw, Kouaré, Burkina Faso, 1997

	Striga emergence	*Striga* emergence at 86 DAS[a]	ASDPC[b]	*Striga* biomass	Sorghum straw	
					log_{10}	back transformed
Control	46.80	108.80	4 879.70	32.00	2.42	262.79
Uninoculated straw	53.40	98.60	4 596.90	29.00	2.40	251.09
Inoculated straw	56.47	81.43	3 567.29	16.81	2.38	240.00
LSD	7.04	35.45	1 669.50	10.90	0.21	
Uninoculated straw vs inoculated straw	NS	NS	NS	*[c]	NS	

a: Days after sowing
b: Area under *Striga* Density Progress Curve (Haussmann *et al.*, 2000)
c* Asterisk indicates level of signficance such that * indicates P≤0.05

TABLE 3. ANOVA of effect of treatments on *Striga* emergence, emerged *Striga* density, biomass of *Striga*, sorghum straw and grain, Kouaré, Burkina Faso, 1998

Source of variance		F values					
	df	*Striga* emergence	*Striga* emergence at 100 DAS[a]	ASDPC[b]	*Striga* biomass	Sorghum straw	Sorghum grain
Block	4	0.3630	0.8058	0.9904	0.1373	0.0097**	0.0018**
Treatment	16	0.1134	0.1189	0.1354	0.6663	0.7750	0.6546
Control vs Uninoculated straw	1	0.0095**[c]	0.0144*	0.0230*	0.1005	0.2809	0.7953
Uninoculated straw vs Inoculated straw	1	0.0419*	0.0730	0.0693	0.2383	0.0262*	0.1222

a: Days after sowing
b: Area under *Striga* Density Progress Curve (Haussmann *et al.*, 2000)
c: *, ** Asterisks indicate level of significance such that * indicates P ≤ 0.05 and ** indicates P ≤ 0.01

Ogborn, 1972) and rainfall variability probably contributed significantly to the recorded differences in the isolates' ability to suppress emerged *Striga* plants in the two years. Conditions of irregular rainfall can favour *Striga* infection when crop growth is not compromised and may have contributed to the high infections observed in 1997.

For both years, the ANOVA test did not show any significant difference among the 15 *F. oxysporum* isolates for their ability to control *Striga*. In the irregular rainfall conditions of 1997, no significant differences were found between the uninoculated straw and the control for the parameters examined, whereas in 1998, use of an uninoculated straw delayed *Striga* emergence by 17 days and reduced number of emerged *Striga* (at 100 DAS) and ASDPC by at least 75%.

In 1997, *Striga* emergence was delayed 10 days and *Striga* biomass reduced 47% by the inoculated straw, whereas in 1998, both *Striga* number (at 100 DAS) and ASDPC were reduced 45% by the isolates compared to control. So, the results of both years clearly demonstrated the ability of the *F. oxysporum* isolates to reduce *Striga* emergence and the field densities.

In 1997, inoculated straw reduced *Striga* biomass and ASDPC, respectively by 42% and 22% compared to the uninoculated straw. On the contrary, in 1998, uninoculated straw was as effective as the inoculated straw in the control of the parasitic weeds. The regular rainfall amounts received in 1998 could have contributed to a better colonisation of the uninoculated straw by the soil indigenous fungi which affected *Striga* emergence and densities.

In this study the reduction of *Striga* infestation was relatively low (≤ 50%) compared to previous results in pot experimentation studies which demonstrated that six out of nine *Fusarium* isolates used on sorghum reduced *Striga* emergence by 75-95% (Abbasher *et al.*, 1998). It was noted in 1998 that emerged *Striga* densities were remarkably low on uninoculated straw and this treatment did not differ from the isolates (inoculated straw) for their effect on *Striga* density and biomass. No isolations from the soil were made, and probably the indigenous soil microflora colonised the straw and controlled emerged *Striga*. This lends support to earlier studies and observations that soil-borne pathogens may play an important role in "*Striga* suppressive soils" and some sites where *Striga* has declined due to soil-borne pathogens were located in West Africa (Abbasher *et al.*, 1998).

Improvement of sorghum yield in plots treated by *Fusarium* in 1998 was probably due to mycorrhization between sorghum plants and *Fusarium* isolates. Lendzemo and Kuyper (2001) reported that arbuscular mycorrhizal fungi can increase sorghum biomass under *S. hermonthica* infestation.

Since reduction of *Striga* infestation in the field by the isolates under study was relatively low (≤ 50%), there is scope for additional work in bio-herbicide formulation to enhance spore

TABLE 4. Effect of treatments on *Striga* emergence, emerged *Striga* density, biomass of *Striga*, sorghum straw and grain, Kouaré, Burkina Faso, 1998

	Striga emergence	Number of *Striga* 100 DAS[a]	ASDPC[b]	*Striga* biomass	Sorghum straw		Sorghum grain
					log_{10}	back-transformed	
Control	52.60	71.40	2 890.30	48.00	2.81	639.46	80.00
Uninoculated straw	69.60	17.80	699.30	30.00	2.49	311.33	67.00
Inoculated straw	56.11	39.28	1 598.80	41.07	2.80	633.26	118.40
LSD	14.43	27.67	1 170.20	20.40	0.29		68.07
Uninoculated straw vs Inoculated straw	*[c]	NS	NS	NS	*		NS

a: Days after sowing
b: Area under *Striga* Density Progress Curve (Haussmann *et al.*, 2000)
c: * Asterisk indicates level of significance such that * indicate P ≤ 0.05

germination, stability and virulence of pathogen isolates. If these constraints are overcome, it is anticipated that biological control could be a new component of integrated *Striga* management in Burkina Faso, in addition to host plant resistance, organic and/or mineral manure, weeding, and cereal-legume intercropping.

ACKNOWLEDGMENTS

We are grateful to the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) for financial support channelled through the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). We also thank Mrs Judy Santini, Statistical Consultant, Agronomy Department, Purdue University, for her assistance in data analysis. Finally, we thank the Institut de l'Environnement et de Recherches Agricoles (INERA) for allowing us to use the infrastructure of the Kouaré Experimental Research Station.

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