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Influence of Sorghum-legume Intercropping on *Striga* Control and Sorghum Performance

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Abstract: *Striga hermonthica* (Del.) Benth is an important parasitic weed on cereals in the semi-arid tropics. Intercropping, particularly of cereals with cowpea (*Vigna unguiculata*), is a common practice in many parts of the semi-arid zone. The main objectives of this study were to determine the influence of sorghum-legume intercropping on striga control in central Sudan, and to assess the effect of such association on crop performance. Field experiments were conducted in striga-infested plots at the Agricultural Research Corporation (ARC) farm at Wad Madani, Sudan, during the 2009/2010 and 2010/2011 seasons. Sorghum cultivars Arfagadamk and Wad Ahmed were intercropped with four legumes. Treatments were arranged in randomized complete block design with 3 replicates. Striga emergence was significantly reduced by 37.7% - 85.6% in sorghum-legume intercropping compared to sole sorghum, irrespective of variety and season. The highest reduction in striga emergence was obtained with the sorghum cv. Arfagadamk-legume intercropping, which reduced striga emergence by 72.5% - 85.6% compared to sole non-fertilized sorghum. Striga dry weight was high in sole sorghum in comparison with sorghum intercropped with legumes. Sorghum cv. Arfagadamk intercropped with lablab bean, brown-seed cowpea, and white-seed cowpea significantly reduced striga dry weight by 95%, 90%, and 73%, respectively. The total biological yield of both sorghum cultivars per unit area was generally higher in the intercropping

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treatments than sole sorghum in the two seasons. The highest total yield was, invariably, obtained on intercropping sorghum with lablab bean which significantly increased the yield by 44.2% compared to sole sorghum. Similarly, Arfagadamk intercropped with lablab bean significantly increased the total biological yield by 41.3% compared to sole sorghum. These results clearly indicate that intercropping sorghum with legumes may be deployed as a component of striga integrated control strategy.

Key words: Sorghum; striga; leguminous crops; intercropping

INTRODUCTION

The parasitic angiosperm *Striga hermonthica* (Del.) Benth (Orobanchaceae) is an important parasitic weed mainly of cereals in the semi-arid tropics. Maize (*Zea mays* L.), sorghum (*Sorghum bicolor* L) and pearl millet (*Pennisetum glaucum* (L.) R.Br.) are the most important hosts. It has been estimated that about 40 to 70 million ha are severely to moderately infested in west Africa (Lagoke *et al*. 1991). Severe striga parasitism is reported to incur 70%–80% crop loss in maize and sorghum and a total crop failure is not uncommon under heavy infestations (Parker and Riches 1993). In Sudan, more than 500,000 hectares in the rainfed areas are heavily infested with striga, resulting in significant yield losses (Babiker 2002). Farmers, sometimes, have to abandon their lands as a result of high infestation by striga (Kroschel 1998). Many factors, including long distance transport of the parasite seeds, continuous monocropping of host plants, cattle grazing, contaminated crop seeds, agricultural equipment, water and wind contribute to heavy striga infestation. The striga problem is further aggravated by the high reproductive capacity of the parasite. A single striga plant can produce over 50,000 seeds, which can remain viable in the soil for 15-20 years (Doggett 1988).

Field infestation with striga is frequently associated with poor soil fertility (Carsky *et al*. 2000). Hence improved soil fertility may lead to reduced infestation (Debra *et al*. 1998). The use of grain legumes contribute to soil nitrogen (Carsky and Iwuafor 1999). Estimates of fertilizer replacement values in a monomodal savanna zone of West Africa were 20 kg N/ha from soybean and 45 kg N/ha from cowpea (Kaleem 1993; Carsky *et al*. 1997).

Intercropping, particularly of cereals with cowpea (*Vigna unguiculata*), is a common practice in many parts of the semi-arid zone. Due to food production diversification, the risk of crop failure is reduced, and resources for crop growth are utilized more efficiently compared to sole cropping (Carsky *et al*. 1994). Intercropping of cereals with legumes has also been proposed as a mean of suppressing striga in cereal crops (Kureh *et al*. 2000). Carson (1989) found that the density of emerged striga plants and soil temperature were both reduced when sorghum was intercropped with groundnut in Gambia. It has been shown in various studies that intercropping cereals with legumes can reduce the number of striga plants that mature in an infested field (Babiker and Hamdoun 1994; Khan *et al.* 2002; Khan *et al.* 2007). The mechanism by which legumes control striga could possibly be due to: i) the benefits derived from increased availability of nitrogen. ii) soil shading and, iii) the possible root exudates with stimulant inducing suicidal striga seed germination; which will enhance in situ reduction of striga seed bank (Parker and Riches 1993).
The main objectives of this study were (i) to determine the influence of intercropping of sorghum with legume crops that are commonly grown in the main sorghum production areas in Sudan on striga parasitism and (ii) to assess the effect of such association on sorghum performance.

MATERIALS AND METHODS

The experiments were conducted in striga-sick plots at the Agricultural Research Corporation (ARC) farm at Wad Madani, Sudan, during the seasons 2009/2010 and 2010/2011 to evaluate the effect of intercropping sorghum with legume crops on striga incidence and sorghum performance. Two high-yielding, striga-tolerant sorghum cultivars (Arfagadamk and Wad Ahmed) were selected. The legume crops used were white-seed cowpea {*Vigna ungicullata var. ungiculata* (L.) Walp}. brown-seed cowpea (*V. ungiculata*) and hyacinth bean (*Lablab purpureus* L). In season 2009/2010 the experiment was sown in the third week of July 2009, while that of season 2010/2011 was sown in the first of August

2010. Two sole sorghum controls, either fertilized with 40 kg /fed urea applied at sowing or unfertilized, were included for comparison. The sorghum cultivars were sown on ridges 80 cm apart and 30 cm between holes. The legumes were planted between the sorghum holes. Both sorghum and legumes were thinned to two plants/hole two weeks after sowing. Subplots of 42 m^2 each were used. Treatments were arranged in Randomized Complete Block Design with three replicates. Cultural practices were done as recommended by ARC. Treatments effects were assessed by counting emerged striga plants 60 days after sowing (DAS) and at harvest by determining sorghum plant height, crop stand, number of heads, and straw yield. Data were analyzed using MSTAT software; mean separation was performed using Duncan Multiple Range Test at $P \leq 0.05$.

RESULTS AND DISCUSSION

Effects on striga

At 60 days after sowing (DAS), striga emergence was generally reduced in sorghum-legumes intercropping compared to sole sorghum, irrespective of cultivar and season. The unfertilized sole sorghum sustained the highest striga emergence on both sorghum cultivars. Intercropping sorghum with legumes in the first season reduced striga emergence by 81% - 99% as compared to unfertilized sole sorghum of both cultivars; and the highest reduction of striga emergence was obtained with the sorghum cv. Arfagadamk-legume intercropping (Table 1). At harvest, intercropping sorghum cv. Arfagadamk with legumes reduced striga emergence by 96%-100% compared to the control. On the other hand, sorghum cv. Wad Ahmed intercropped with legumes reduced striga emergence by 75%-99% compared to the control, with lablab bean being the best in reducing striga emergence. On both counts, differences between cultivars at similar treatments were not statistically significant. In the second season (2010/2011), the performance of sorghum-legume intercropping on reducing striga emergence was lower, and 33%-79% reduction was obtained, with the highest reduction obtained when sorghum cv. Arfagadamk was intercropped with the tested legumes. Combined analysis of the two seasons showed that striga emergence was significantly reduced in sorghum-legumes intercropping compared to sole sorghum irrespective of variety and season by 37.7%-85.6%. The highest reduction of emerged striga was obtained with the sorghum cv. Arfagadamk-legume intercropping, which was found to reduce striga emergence significantly by 72.5%-85.6% compared to sole non-fertilized sorghum at harvest (Table 1).

Table 1. Effects of sorghum –legume intercropping on striga control

Sorghum cultivar	Legume intercrop				
	Cowpea White-seed	Cowpea Brown-seed	Lablab Bean	Sorghum + Urea	Sole Sorghum
	Striga emergence/m² 60 DAS				
Season 2009/2010					
Wad Ahmed	0.70b	0.94b	0.47b	1.80b	5.23a
Arfagadamk	0.08b	0.31b	0.24b	0.94b	6.48a
Season 2010/2011					
Wad Ahmed	14.38ab	18.75ab	9.29ab	29.14ab	28.05ab
Arfagadamk	7.91ab	9.9ab	6.64b	22.73ab	31.48a
	Combined analysis				
Wad Ahmed	7.54cd	9.84bcd	4.88cd	15.47ab	16.64ab
Arfagadamk	3.98cd	5.12cd	3.44d	11.84abc	18.98a
	Striga emergence/m² at harvest				
Season 2009/2010					
Wad Ahmed	2.50c	1.25c	0.08c	5.23abc	10.00a
Arfagadamk	0.31c	0.24c	0.00c	4.22bc	7.73ab
Season 2010/2011					
Wad Ahmed	11.30b	20.0ab	7.6b	36.6a	24.2ab
Arfagadamk	4.60 b	9.3b	5.0b	21.0 ab	27.0 ab
	Combine analysis				
Wad Ahmed	6.88cd	10.63bcd	3.83d	20.90a	17.07a
Arfagadamk	2.50d	4.77cd	2.50d	12.62bc	17.34a
	***Striga* dry weight g/m²**				
Season 2010/2011					
Wad Ahmed	31.25abc	35.42abc	17.71abc	33.33abc	42.71ab
Arfagadamk	11.46cd	4.17d	2.08d	45.83a	42.71ab

In each parameter, in the season, values followed by the same letter(s) are not significantly different at $p \geq 0.05$ according to Duncan's Multiple Range Test

This study indicated that sorghum cv. Arfagadamk intercropped with legumes was more effective in reducing striga emergence than Wad Ahmed cultivar. Sorghum intercropped with lablab bean sustained the lowest striga emergence. These results are in line with those previously reported by Carson (1989), Babiker and Hamdoun (1994), Khan *et al*. (2002), Tenebe and Kamara (2002) and Khan *et al*. (2007). Carsky *et al*. (1994) reported that the number of mature striga plants was low when the cowpea ground cover was high in a sorghum-cowpea intercrop. This suggests that any spatial arrangement that increases cowpea ground cover at the base of sorghum reduces the density of mature striga. However, Carson (1989) found that striga density was reduced by 60%-70% in sorghum-groundnut intercropping. Similarly, Khan *et al*. (2007) reported that intercropping sorghum with cowpea (*Vigna unguiculata*), greengram (*Vigna radiata* (L.) Wilczek) and crotalaria (*Crotalaria ochroleuca* G. Don.) and maize with crotalaria significantly reduced striga populations.

Striga dry weight was high in sole sorghum in comparison with sorghum intercropped with legume. Sorghum cv. Arfagadamk intercropped with lablab bean, brown-seed cowpea, and white-seed cowpea significantly reduced striga dry weight by 95%, 90%, and 73%, respectively. However, intercropping sorghum cv. Wad Ahmed with the same legumes reduced striga dry weight by 27%, 17%, and 59%, respectively.

Several mechanisms could be suggested to explain the reduction of striga infestation when sorghum is intercropped with legumes. In addition to the smothering effect resulting from an increased ground cover at the base of sorghum plants produced by the legume crops, namely lablab bean and cowpea brown-seed, it has been found that the root exudates of the legumes tested, namely cowpea white-seed, cowpea brown-seed and lablab bean, stimulated *S. hermonthica* seeds germination by 52.5%, 40%, and 43.9%, respectively (Abbasher *et al*. 2012). This provides a novel means of *in situ* reduction of striga seed bank through efficient suicidal germination. Similar reports indicated that some varieties of cowpea, soybean, and groundnut have also been shown to control striga through a combination of mechanisms ranging from induction of suicidal germination of striga seeds in the rhizosphere due to the stimulants exuded by the legume crops, N_2 fixation, and smothering effect resulting from canopy cover (Oswald *et al*. 2002; Emechebe and Ahonsi 2003; Kuchinda *et al*. 2003).

Effects on sorghum

Intercropping sorghum with legumes had no significant effect on crop stand (Table 2) a month after sowing or at harvest for both cultivars. However, in the first season intercropping sorghum cv. Arfagadamk with white-seed cowpea and brown-seed cowpea resulted in significantly lower sorghum stand than sole unfertilized crop by 42%, and 36%, respectively (Table 2). The imposed treatments had no significant effects on sorghum height. Nevertheless, the effect was only significant when sorghum cv. Arfagadamk was intercropped with lablab bean, where it gave 50% increase in plant height compared to sole sorghum.

Table 2. Effects of sorghum–legume intercropping on sorghum height and sorghum stand

Sorghum cultivar	Legume intercrop				
	Cowpea White seed	Cowpea Brown seed	Lablab Bean	Sorghum + Urea	Sole Sorghum
		Sorghum plant height (cm)			
Season 2009/2010					
Wad Ahmed	90.3	92.0	85.2	87.5	77.3
Arfagadamk	69.8	77.8	84.0	75.3	71.8
Season 2010/2011					
Wad Ahmed	65.3b	63.0b	80.7ab	75.0ab	75.0ab
Arfagadamk	86.0ab	64.7b	92.0a	77.0ab	63.3b
		Combined analysis			
Wad Ahmed	77.75abc	77.50abc	83.13ab	81.25ab	74.13bc
Arfagadamk	77.88abc	71.25bc	88.00a	76.25abc	67.50c
		Sorghum stand (1000/fed.) at harvest			
Season 2009/2010					
Wad Ahmed	26.91	31.17abc	34.78a	29.86abc	30.19abc
Arfagadamk	20.67c	22.97c	23.30bc	34.13b	35.77a
Season 2010/2011					
Wad Ahmed	37.6	38.9	38.5	48.1	36.8
Arfagadamk	39.4	36.8	33.3	40.3	42.9
		Combined analysis			
Wad Ahmed	32.32abc	35.11abc	36.59abc	39.05a	33.47abc
Arfagadamk	30.02bc	29.86bc	28.22c	37.24ab	39.38a

In each parameter, in the season, values followed by the same letter(s) are not significantly different at $p \geq 0.05$ according to Duncan's Multiple Range Test

The total biological yield per unit area was generally higher in the intercropping treatments than sole sorghum (Table 3). The highest total biological yield was obtained on intercropping sorghum with lablab bean which was significantly higher than sole sorghum irrespective of season or cultivar (Table 3). Sorghum cv. Wad Ahmed intercropped with white-seed cowpea, brown-seed cowpea and lablab bean increased the total biological yield by 82%, 98%, and 142% in the first season, respectively. Also sorghum cv. Arfagadamk intercropped with lablab bean significantly increased the total biological yield in the second season as compared to sole sorghum. Combined analysis of the two seasons indicated that the highest total biological yield was obtained on intercropping sorghum cv. Wad Ahmed with lablab bean which significantly increased the yield by 44.2% compared to sole sorghum. Similarly, Arfagadamk intercropped with lablab bean significantly increased the total biological yield by 41.3% compared to sole sorghum.

In the first season, intercropping sorghum cv. Arfagadamk with brown-seed cowpea resulted in significantly higher sorghum straw yield compared to sole sorghum and similar to fertilized sorghum, whereas in the second season sorghum straw yield was lower when sorghum was intercropped with legumes than sole sorghum. However, the differences were not statistically significant (Table 3). Similar results were reported by Carsky *et al*. (1994) who found no significant reduction in sorghum yield by intercropping sorghum with cowpea. In contrast, Kureh *et al*. (2006) reported that intercropping cowpea with maize reduced maize yield by 47% despite the reduction in the number of emerged striga which may be due to competition between cowpea and maize. Despite the considerable reduction in sorghum yield when intercropped with legumes in the second season, this could be compensated for by the higher cash value of the legumes of both straw and grains products. It could be concluded that intercropping sorghum with legumes is one of the options for striga control. Moreover, the study showed that the three legumes could be used in intercropping with sorghum to control striga and to increase farmer income in striga infested fields. Choice of the legume to be used depends on farmer interest, farming system and the expected returns of each legume crop.

Table 3. Effects of sorghum –legume intercropping on sorghum straw and total biological yields

Sorghum cultivar	Legume intercrop: Cowpea White-seed	Cowpea Brown-seed	Lablab Bean	Sorghum + Urea	Sole Sorghum
	Sorghum straw yield (t/fed)				
Season 2009/2010					
Wad Ahmed	2.98abc	3.58ab	3.81a	3.81a	2.28abcd
Arfagadamk	1.44d	1.67cd	1.81cd	2.89bcd	2.72abcd
Season 2010/2011					
Wad Ahmed	1.88bc	1.9bc	2.38abc	2.55abc	3.54a
Arfagadamk	2.08abc	1.51c	2.0abc	3.4ab	2.1abc
	Combined analysis				
Wad Ahmed	2.42abc	2.74ab	3.10a	3.18a	2.910a
Arfagadamk	1.77c	1.59c	1.90bc	3.14a	2.41abc
	Total biological yield (t/fed)				
Season 2009/2010					
Wad Ahmed	4.15b	4.51ab	5.52a	3.81bc	2.28d
Arfagadamk	3.18bcd	3.77bc	3.74bc	2.89d	2.72cd
Season 2010/2011					
Wad Ahmed	3.92abc	2.8bcd	4.99a	2.55cd	3.54abc
Arfagadamk	3.38abc	3.13bdc	4.43ab	3.4abcd	2.10d
	Combined analysis				
Wad Ahmed	4.04bc	3.66bcd	5.26a	3.18cde	2.91de
Arfagadamk	3.51bcd	3.45bcd	4.09b	3.14cde	2.41e

In each parameter, in the season, values followed by the same letter(s) are not significantly different at $p \geq 0.05$ according to Duncan's Multiple Range Test.

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تأثير تحميل الذرة الرفيعة مع البقوليات علي مكافحة البودا (*Striga hermonthica* (Del.) Benth) ونمو الذرة الرفيعة

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المستخلص: تعتبر البودا من أهم الحشائش المتطفلة على محاصيل الحبوب في المناطق المدارية شبه الجافة . زراعة الحبوب مع اللوبيا من الطرق المتبعة عادة في المناطق المدارية شبه الجافة . هدفت الدراسة إلى معرفة تأثير تحميل الذرة الرفيعة مع البقوليات على مكافحة البودا ونمو الذرة الرفيعة في وسط السودان . أجريت التجاربة الحقلية في حقل مصاب بالبودا في مزرعة هئية البحوث الزراعية ، ود مدني ، السودان ، خلال الموسمين 2010/2009 و 2011/2010 . تم إختيار صنفي الذرة الرفيعة أرفع قدمك وود أحمد للزراعة بالتحميل مع أربعة محاصيل بقولية . وزعت المعاملات في تصميم القطاعات العشوائية الكاملة في ثلاث مكررات . إنبثاق نباتات البودا إنخفض في معاملة الزراعة بالتحميل مع البقوليات مقارنة بمحصول الذرة الرفيعة منفرداً بغض النظر عن صنف الذرة الرفيعة المزروع أو الموسم بنسبة 37.7%-85.6% . تحميل البقوليات مع الذرة من الصنف أرفع قدمك أدى إلى أعلى إنخفاض في إنبثاق بذور البودا حيث إنخفض إنبثاق نباتات البودا معنوياً وبلغت نسبته حوالي 72.5%-86.5% مقارنة بالشاهد عند الحصاد . كان الوزن الجاف للبودا في الشاهد عالياً مقارنة بالمعاملات التي تشتمل على الزراعة بالتحميل (ذرة رفيعة + بقول) .

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أدى تحميل صنف الذرة الرفيعة أرفع قدمك مع لوبيا عفن أو لوبيا حلو ذات البذرة البنية (حنيطير) أو لوبيا حلو ذات البذرة البيضاء إلى خفض معنوي في الوزن الجاف للبودا بنسبة 95% و 90% و 73% على التوالي . كان الانتاج الحيوي الكلي للمحصولين في وحدة المساحة عالياً في معاملات التحميل بالبقول .

مقارنةً بالذرة الرفيعة منفرداً للصنفين في الموسمين . أعطى تحميل الذرة الرفيعة مع لوبيا عفن أعلى قيمة للإنتاج الحيوي الكلي مما أدى إلى زيادة الإنتاجية بنسبة 42.2% مقارنة بالشاهد . أدى تحميل الصنف أرفع قدمك مع لوبيا عفن إلى زيادة معنوية في الإنتاج الحيوي الكلي بنسبة 41.3% مقارنة بالشاهد . أوضحت الدراسة أن تحميل الذرة الرفيعة مع محاصيل البقول يمكن أن يُدرج في إستراتيجية المكافحة المتكاملة للبودا خاصة في الحيازات الصغيرة .