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ORIGINAL ARTICLE

Potential of Bacterial Strains and Nitrogen in Reduction of *Striga Hermonthica* (Del.) Benth. Infesting Sorghum

[1]Hassan, M. M., [1]Abdel gain, M .E. and [2]Babiker, A. G.T.

[1]Environment and Natural Resources Research Institute, National Centre for Research, Khartoum, Sudan.
[2]Sudan University of science and technology faculty of Agriculture.

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ABSTRACT

Two green house experiments were conducted where sorghum was planted in polythene bags filled with soil infested or not infested with *Striga* seeds. In the first experiment, 36 bacterial isolates and strains were employed. The bacterial strain *P. putida* and the bacterial isolates M20, S23, S22, GSL, D8, G11, D20, B2 and D50 reduced *Striga* incidence by 90 to 100% at peak emergence 12 weeks after sowing (WAS) in comparison to the infested untreated control. In the second experiment, sorghum cv. Wad Ahmed was inoculated with two bacterial strains and one isolate. Superimposed on the bacterial treatments was nitrogen as urea fertilizer at 0, 47.6 and 95.2 kg N ha $^{-1}$. *Striga* emergence was earlier and more intense on the uninoculated unfertilized sorghum. Bacterial inoculation alone delayed and reduced *Striga* infestation. At peak emergence (7 WAS) the bacterial isolate D46 and the strains *P. putida* and *A. brasilense* reduced *Striga* emergence by 15 to 30%. Nitrogen as urea curtailed *Striga* emergence by 45 to 68 % at peak emergence. Bacterial inoculation followed by nitrogen was more suppressive to *Striga* emergence than each of the treatments alone. The combination of nitrogen with the bacteria reduced *Striga* emergence by 47 – 70%. The results indicated the possibility of curtailments of *Striga* parasitism on sorghum through the use of bacteria that perturb early developmental stages of the parasite. Moreover, the results, based on prior knowledge that some of the strains used in this study are renown as plant growth promoting bacteria (PGPB) and that *Striga* germination and morphogenesis are modulated by phytohormone, implicate the possibility of involvements of phytohormones in perturbation of *Striga* germination, haustorium initiation, attachment, penetration and parasitism.

Key words: *Striga hermonthica*, bacteria, nitrogen level, suppression.

Introduction

Striga species, obligate root parasites, are prodigious seed producers. *Striga* seed viability in soils may extend for 14 years or more Ayensu *et al.* (4). It is widely believed that *Striga* has become the greatest biological constraint on food production in Africa, a more serious problem than insects, birds and plant diseases [15,27]. The parasite is more damaging and debilitating under drought and low soil fertility conditions [23,24]. The magnitude of the loss in yield due to the parasite is determined by the level of *Striga* infestation, soil fertility, agro-climatic conditions, land use system, the plant species and the host genotype [25]. Soil fertility is important not only for increasing productivity, but also for minimizing *Striga* infestation. Severity of infestation of *Striga* is reported to correlate negatively with soil fertility [21]. Nitrogen proved to be an essential element for reducing *Striga* infestation and mitigation of its

Corresponding Author
Hassan, M. M., Environment and Natural Resources Research Institute, National Centre for Research, Khartoum, Sudan.

adverse effects on crops [27]. The suppressive effects of nitrogen on *Striga* infestation were attributed to delayed germination, reduced radical elongation, reduced stimulants production and reduction of seeds response to the stimulants [29,31]. Obilana and Ramaiah [22] reported that research needs for *Striga* management include biological control involving the survey of organisms parasitic or pathogenic on *Striga* (applied research) and bio-herbicides based on biological enemies of *Striga* and a study of diseases and other pests of *Striga* (basic research). Use of a soil-borne pathogen to control the parasite will reduce both the *Striga* seed bank and emerged *Striga* plants and should contribute to the reduction of the yield losses due to *Striga* [32]. Workable biological control options that meet the target of reducing *S. hermonthica* parasitism and abating crop-yield-loss, within the season of application, is the use of soil-borne antagonists or diseases of *S. hermonthica* seeds, germlings and/or seedlings. Dirar [13] working with *Xanthomonas* sp. reported a significant reduction in germination of S. *hermonthica*. Bacteria of the genus *Azospirillum* are free-living, nitrogen-fixing micro-organisms that are commonly found in soil, but mainly in association with the roots of plants [12]. Bouillant *et al.* [9] reported that two out of four strains of *Azospirillum brasilense* assayed significantly inhibited germination of *S. hermonthica*. Moreover, one of the two strains promoted host growth. *A. brasilense* are, thus, classified as plant growth promoting bacteria [7]. An integrated management approach, if properly designed, using a combination of control measures has the potential to provide a lasting solution to the *Striga* problem [16]. The objective of the present study was to assess the role of bacteria and nitrogen on suppressing, triggering suicidal germination and/or perturbing early developmental stages in *S. hermonthica*.

Materials and methods

Two sets of green house experiments were conducted to study the effects of bacterial isolates and strains on *Striga* incidence on sorghum cv. Abu Sabeen, bacterial isolates, strains and nitrogen on *Striga* incidence on sorghum cv. Wad Ahmed.

Soil samples were collected from four locations (Shambat, Gadaref, Abuharaz and Wad Medani). The spread- plate method was used for isolation of 202 bacterial isolates. Seven bacterial strains (*Azotobacter vienlandi, Pseudomonas putida*, *Azomonas* spp., *Bradyrhizobium japonicum*, *Azospirillum brasilense, A. amazonas* and *Bacillus* spp.) were obtained from the Environment and Natural Resources Research Institute (ENRRI), the National Centre for Research and University of Khartoum, Khartoum, Sudan as described by Hassan *et al.* [19].

In all experiments, soil mix made of river silt and sand (2:1 v/v) was sterilized in an oven at 160 °C for 4 h. The sterilized soil was placed in plastic bags (19 cm diameter) with drainage holes at the bottom. *Striga* infestation was accomplished by mixing 10 mg of sterilized *Striga* seeds (*Ca* 1500) in the top 6 cm soil in each bag. Surface sterilized sorghum seeds (7/bag) were planted and immediately irrigated. Aliquots of the respective bacterial suspensions (15 ml each) (10^{-4} dilution) were injected in each bag. Subsequent irrigations were made every 2 days. *Striga* infested and uninfested controls were included in each experiment for comparison. Emergent *Striga* plants were counted weekly starting three weeks after crop emergence. Sorghum height was measured at 7, 11 and 15 weeks after sowing (WAS), while *Striga* height was determined at 7 WAS. In all experiments, treatments were arranged in factorial experiment with randomized complete block design with four replicates.

Effects of bacterial isolates and strains on S. hermonthica incidence on sorghum cv. Abu Sabeen

The experiment was undertaken in the period 7 February to 21 June 2006. A sterilized soil mix was prepared, infested with *Striga* and sown to sorghum cv. Abu Sabeen, as described above. Thirty six bacterial isolates and strains selected on basis of their ability to suppress *S. hermonthica* germination were injected into the soil. Sorghum thinning, *Striga* emergence, sorghum and *Striga* heights were measured as previously described (3.1).

Effects of bacterial isolates, strains and nitrogen on Striga incidence on sorghum cv. Wad Ahmed

The experiment was conducted in the period 5 July to 1 October 2007. Two bacterial strains, *P. putida*, *A. brasilense* and the bacterial isolate D46 were selected based on their ability to suppress *Striga* germination. Soil infested with *S. hermonthica* seeds, placed in plastic bags, was sown to sorghum cv. Wad Ahmed as shown in 3.1. Nitrogen as urea at 0N, ½ N (47.6 kg ha^{-1}) and 1N (95.2 kg ha^{-1}) was applied immediately after sowing. Treatments were irrigated and inoculated with the bacterial strains and isolates as previously described in 3.1. Sorghum thinning, *Striga* incidence, sorghum heights and *Striga* heights were measured as shown above.

Statistical analysis

Data from the greenhouse experiments were transformed to log (x + 0.5) in which x is the number of *Striga* plants/ bag and then subjected to analysis of variance (ANOVA). Means were tested for significance by LSD at 5%. The data was tabulated [17].

Results and Discussion

Effects of bacterial strains and isolates on S. hermonthica incidence on sorghum cv. Abu Sabeen

All bacterial strains and isolates, except isolates S9, G14 and *Bacillus* spp.(B3) reduced emergence of the parasite (Table 1). Crop treated with isolates M20, S22, GSL, D8, S23, S19, D20, S25, G11, D50 and *Bacillus* spp. (B2) and *P.putida* strains sustained the lowest *Striga* emergence.

Striga growth, as indicated by height, was differentially affected by the bacteria. Isolates S23, S22, G11, D20, D2, D50, D46, S25, D10, S10, D8, G18x, GSL, M2 and the bacterial strains *Bacillus* spp., *P. putida, Azotobacter* and the combination of *A. amazonas* and *P. putida* reduced *Striga* height significantly. The observed reductions in height ranged between 60 and 96% (Table 1). Isolates M34 and combination between *A. brasilense* and *P. putida*, on the other hand, increased *Striga* height.

The untreated *Striga* free sorghum displayed the tallest plants (154 cm). Unchecked *Striga* infestation reduced crop height by 64%. All bacterial strains and isolates increased sorghum height, significantly, in comparison with the *Striga* infested control. The bacterial isolates M20, S25, S23, S19, S22 and the bacterial strain *Bacillus* spp. and *P. putida* were the most effective. They increased sorghum height by 40 - 50% (Table 1).

Effects of bacteria and nitrogen on Striga incidence on sorghum cv. Wad Ahmed

Effect on Striga

At four weeks after sowing (WAS), *Striga* emergence was only observed on the unfertlized uninoculated sorghum and no emergence occurred on the fertilized and bacteria inoculated plants (Table 2).

At five WAS, *Striga* was observed in all treatments. The unfertilized uninoculated sorghum sustained the highest infestation (10 *Striga* plants/ bag). Nitrogen as urea at 47.6 kg N ha^{-1} and 95.2 kg N ha^{-1} reduced *Striga* emergence to 4 and 1 plant /bag, respectively (Table 3). Sorghum treated with the bacteria, irrespective of nitrogen level, sustained less *Striga* emergence than the respective unfertilized uninoculated control. Combinations of fertilizer and bacterial isolates were, invariably, more suppressive to the parasite emergence than each treatment alone. At six WAS, *Striga* emergence increased, substantially, and was heighest on the unfertilized uninoculated control (24 *Striga* plants/ bag). Unfertilized sorghum, inoculated with bacteria sustained significantly less *Striga* emergence than the respective control. Nitrogen, invariably, suppressed emergence of the parasite. The combinations of fertilizer and bacteria effected more reductions of the parasite emergence than each of the treatments alone, albeit not significantly. Parasite emergence consistently decreased with increasing nitrogen level (Table 4).

At seven WAS, the unfertilized uninoculated control supported the highest *Striga* emergence (40 plants/ bag) (Table 5). Inoculation of sorghum with bacteria reduced *Striga* infestation by 15-30 %. Nitrogen at 47.6 kg N ha^{-1} and 95.2 kg N ha^{-1} reduced *Striga* emergence by 45 and 68%, respectively. Bacteria in combination with nitrogen reduced the parasite emergence by 48 - 70%.

At eight WAS, the number of emergent *Striga* on the unfertilized uninoculated sorghum showed a considerable decrease (Table 6). Sorghum treated with nitrogen sustained less *Striga* emergence than the unfertilized uninoculated control, albeit not significantly. Bacteria alone and in combination with nitrogen showed inconsistent effects on *Striga* emergence. The reduction in parasite incidence displayed a slight decrease and a substantial increase in comparison with the unfertilized uninoculated control. However, because of high variability, differences between treatments were not significant. At nine WAS, *Striga* incidence followed the same trend as at eight WAS (Tables 7).

Count made at ten WAS or later showed a continuous decline in *Striga* incidence with no obvious trends (Tables 8-10).

Striga growth, as indicated by height measured at 7 WAS, was differentially affected by nitrogen fertilization, but not by bacteria (Fig. 1). *Striga* plants on unfertilized uninoculated sorghum showed an average height of 14 cm. Nitrogen at 47.6 kg N ha^{-1} and 95.2 kg N ha^{-1} reduced *Striga* height by about 50%. The bacterial strains and isolates and their combinations with nitrogen reduced *Striga* height, albeit not significantly, in comparison to the respective controls (Fig. 1).

Effects on Sorghum height

At 7 WAS, *Striga* free sorghum, irrespective of nitrogen level or bacterial inoculation displayed 51 to 75 cm height and the *Striga* infested unfertilized uninoculated sorghum displayed 68 cm in height. Nitrogen, at all rates, had no effect on crop growth, irrespective of *Striga* infestation (Fig.2). The bacteria had no adverse effects on sorghum growth and partially mitigated the depressive effects of *Striga* on plant growth. The bacteria in combination with nitrogen showed variable effects on sorghum growth. *Striga* infested sorghum treated with nitrogen at 47.6 kg N ha^{-1} and inoculated with *P. putida* displayed a significant increase in height, in comparison to the corresponding uninoculated fertilized crop. In presence of nitrogen as urea at 95.2 kg ha^{-1} *P. putida* had no effect on infested sorghum growth in comparison to the corresponding nitrogen treated control. The combination of *A. brasilense* and nitrogen as urea at 47.6 kg ha^{-1} and 95.2 kg ha^{-1} increased sorghum height in comparison to nitrogen alone. The combination of the bacterium with the nitrogen at 95.2 kg ha^{-1} affected the heighest increment (18 %) in sorghum growth (Fig. 2).

At 11 WAS, the *Striga* free sorghum, irrespective of nitrogen level or bacterial inoculation, showed no significant differences in height (103, 94 and 82 cm). Unrestricted *Striga* growth, irrespective of nitrogen rate or bacterium inoculum, reduced sorghum height significantly (Fig. 3).

At 15 WAS, unrestricted *Striga* growth reduced sorghum height by 76-100%. The unfertilized uninoculated crop was the most affected. The bacterial strains and isolates, partially, mitigated the adverse effect of the parasite on sorghum. Reduction of the adverse effect of *Striga* on sorghum growth by *A. brasilense* increased with increasing nitrogen level. Unfertilized sorghum inoculated with *A. brasilense* displayed 85% reduction in height in comparison to the corresponding *Striga* free control. Sorghum treated with combinations of *A. brasilense* and nitrogen at 47.6 kg N ha^{-1} and 95.2 kg N ha^{-1} displayed 67 and 41% reduction in height in comparison to the corresponding *Striga* free control, respectively. The partial mitigation of the adverse effects of *Striga* on sorghum by *P. putida* and isolate D46 did not show consistent trends with nitrogen level (Fig. 4)

Discussion

Root parasitic weeds generally damage their hosts plant even before they emerge above ground. Germination, radicle elongation, haustorium initiation, attachment and penetration are the earliest developmental stages of *Striga*. These stages are especially fragile, can be modulated by phytohormones and are very likely targets for control methods [30,5]. The study focused on inhibition and/or perturbation of early growth stages of the parasite in an endeavour to develop an integrated control strategy.

The results revealed that some of the bacteria reduced and delayed *Striga* emergence on sorghum, others reduced *Striga* infestation and growth while some had enhancing effects, some bacterial strains and isolates increased sorghum growth in comparison to the *Striga* infested untreated control combinations of bacterial strains and isolates with nitrogen were often more suppressive to *Striga* growth, but promoting to sorghum growth, albeit often not significantly.

Inoculation of *Striga* infested soil with bacterial strains, isolate and treatment with nitrogen as urea reduced and delayed *Striga* emergence on sorghum. Treatments comprising combination of bacterial inoculation and nitrogen were more suppressive to the parasite emergence than each treatment alone (Tables 1-7).

The observed reduction and delay in *Striga* emergence caused by bacterial strains and isolates may be attributed to reduced germination, reduced haustorium initiation and attachment. However, the decline in the suppressive effects of bacteria with time may be due to competition with soil micro-flora, disintegration of inoculated bacteria and/or to utilization of precursors of compounds initially present at low concentrations in soil.

Suppression of *Striga* by nitrogen is consistent with several reports. Nitrogen curtails production of germination stimulants by host root exudates [10]. Furthermore, nitrogen in form of urea and ammoniated compounds including $(NH_4)_2$ SO_4 and NH_4^+ H_2PO_4 suppressed *S. hermonthica* shoot development [6]. Inhibition of *S. hermonthica* development by ammoniated compounds and urea was attributed to possible accumulation and toxicity of ammonium ions [20]. This is consistent with the reported low glutamine synthase activity in *S. hermonthica* [26].

The observation that bacterial inoculation, nitrogen and their combination decreased growth vigour of emergent *Striga* (Fig. 1) and that the combinations were more suppressive than each alone may be due to their combined effects and is in line with the report of [1,2,3]. The authors reported that nitrogen was more effective in controlling the parasite on suppressive soil. Microbial activity in suppressive soils was claimed to curtail *Striga* infestation [8]. The beneficial effects of bacteria on sorghum growth as indicated by height (Fig. 2-3) may be attributed to production of phytohormones. *Striga* is reported to perturb the hormonal balance of its host. Sharp reductions in Indol Acetic Acid (IAA), cytokinins and gibberellins were reported in *Striga* infested sorghum [28].

Striga damage is attributed to perturbations of the hormonal balance of its hosts which sets in at the very early stages of infestation. The parasite decreases the levels of auxins (IAA), Cytokinins (CKS) and Gibberellins (GAs) and increases that of abscisic acid (ABA) [14]. The decrease in GAs leads to dwarfing of the shoot, which lessen the ground covered by the crop and decreases humidity. Low humidity increases transpiration in *Striga*, enhances transfer of nutrients from the host to the parasite and increases the debilitating effects of the parasite [18]. High ABA levels lower photosynthesis and increase root growth. An increase in root growth results in more contacts with *Striga* seeds and increases infestation [18]. The parasite is less of a problem in fertile soil and where crop rotation is practiced.

Table 1: Effects of bacteria on *Striga* incidence on sorghum (cv. Abu Sabeen), at 12 WAS

Bacteria	No. of emerging *Striga*	Height	
		Striga	sorghum
Azomonas	1	7.68	98.6
D46	1.5	3.75	98.2
M20	0	0	110
Azotobacter	*2.25*	9.37	97.88
D50	0.25	1.25	95.3
S25	0.25	4.25	101.27
D49	1.5	9.87	97.9
D10	0.5	5.5	78.55
A. brasilense+P. putida	*5*	24.62	87
S10	1.25	4.87	73.52
S23	0	1.25	94.75
D2	0.75	0.75	93.5
G14	5.25	20.37	90.67
Bacillus spp. (B3)	5.25	4.5	83.72
Bacillus spp. (B2)	0	4.75	109.47
D8	0	5.37	76.67
G18x	1.75	5	89.95
D25	0.75	16.62	71.05
A. amazonas	1.5	7.87	91.05
Bradyrhizobium	4	4.87	87.3
G4c	0.5	8.87	83.35
GSL	0	3.12	85.4
G11	0.5	6.37	96.15
M7	3.25	17.87	62.27
P. putida+A.amazonas	1.5	5	88.92
A.brasilense	3.75	17.75	75.4
S9	5	7.37	69.7
M34	1.75	30.12	72
G18	2	14.37	77.3
P. putida	0.5	7.06	91.8
G6c	2	11.25	69.95
M2	0.5	5.37	89.2
Bacillus spp. (B1)	1.25	17.25	94.85
S19	0.25	0	154.15
S22	0	19	55
D20	0.25	4.87	93.12
infested control	5.25	8.75	95.75
LSD	± 3.51	± 5.87	± 10.88

Table 2: Effects of bacterial strains, isolates and nitrogen level on *Striga* incidence on sorghum cv. Wad Ahmed (4 WAS)

	Striga incidence (plants/bag)				
	Bacterial isolate				
Treatment (kg N $ha^{-1)}$	b1	b3	b2	b0	mean
0	(0.70) 0	(0.70) 0	(0.70) 0	(0.83) 0.3	(0.73) 0.07
47.6	(0.70) 0	(0.70) 0	(0.70) 0	(0.70) 0	(0.71) 0
95.2	(0.70) 0	(0.70) 0	(0.70) 0	(0.70) 0	(0.71) 0
Mean	(0.71) 0	(0.71) 0	(0.71) 0	(0.75) 0.1	

LSD bacteria n.s. =non significant
LSD urea n.s
( ) indicates square root transformed data (√x+0.5 x: variable).
b1=*P. Putida,* b2= *A. brasilense*, b3= D46 isolate, b0= control.

Table 3: Effects of bacterial strains, isolates and nitrogen level on *Striga* incidence on sorghum cv. Wad Ahmed (5 WAS)

	Striga incidence (plants/bag)				
	Bacterial isolate				
Treatment (kg N $ha^{-1)}$	b1	b3	b2	b0	Mean
0	(1.98) 4	(1.83) 5	(2.15) 4	(3.17)10	(2.23) 6
47.6	(1.69) 3	(1.30) 2	(1.55) 3	(1.87) 4	(1.61) 3
95.2	(1.21) 1	(0.83) 0.0	(0.92) 1	(1.21)1	(1.05) 1
mean	(1.63) 3	(1.32) 2	(1.54) 3	(2.08) 5	

LSD interaction	(±1.239)
LSD urea	(±0.619)
LSD bacteria	n.s

( ) indicates square root transformed data (√x+0.5 x: variable).
b1=*P. Putida,* b2= *A. brasilense*, b3= D46 isolate, b0= control.

Table 4: Effects of bacterial strains, isolates and nitrogen level on *Striga* incidence on sorghum cv. Wad Ahmed (6 WAS)

	Striga incidence (plants/bag)				
	Bacterial isolate				
Treatment (kg N $ha^{-1)}$	b1	b3	b2	b0	mean
0	(3.83)15	(4.0)17	(4.49)21	(4.88)24	(4.31)19
47.6	(3.16)12	(2.62)11	(2.45)6	(3.48)13	(2.93)10
95.2	(2.59)7	(2.36)7	(2.86)9	(2.95) 9	(2.69) 8
mean	(3.19)11	(2.99)12	(3.27)12	(3.77)15	

LSD urea (±1.004)
LSD bacteria n.s
( ) indicates square root transformed data (√x+0.5 x: variable).
b1=*P. Putida,* b2= *A. brasilense*, b3= D46 isolate, b0= control.

Table 5: Effects of bacterial strains, isolates and nitrogen level on *Striga* incidence on sorghum cv. Wad Ahmed (7 WAS)

	Striga incidence (plants/bag)				
	Bacterial isolate				
Treatment (kg N $ha^{-1)}$	b1	b3	b2	B0	mean
0	(5.3)28	(5.48)32	(5.82)34	(6.25)40	(5.71)33
47.6	(4.1)19	(4.001)21	(3.97)16	(4.65)22	(4.18)19
95.2	(3.8)15	(3.30)12	3.67)16	(3.50)13	(3.57)14
Mean	(4.39)21	(4.26)21	(4.49)22	(4.8)25	

LSD urea (±1.043)
LSD bacteria n.s
( ) indicates square root transformed data (√x+0.5 x: variable).
b1=*P. Putida,* b2= *A. brasilense*, b3= D46 isolate, b0= control.

Table 6: Effects of bacterial isolates and nitrogen level on *Striga* incidence on sorghum cv. Wad Ahmed (8 WAS)

	Striga incidence (plants/bag)				
	Bacterial isolate				
Treatment (kg N $ha^{-1)}$	b1	b3	b2	b0	mean
0	(5.43)29	(3.99)17	(5.52)30	(4.48)20	(4.85)24
47.6	(3.72)21	(3.76)25	(4.10)19	(4.70)22	(4.07)22
95.2	(3.53)15	(5.38)34	(3.83)18	(3.92)16	(4.16)21
mean	(4.23)22	(4.37)25	(4.48)22	(4.37)19	

LSD urea n.s
LSD bacteria n.s
n.s. =non significant
( ) indicates square root transformed data (√x+0.5 x: variable).
b1=*P. Putida*, b2= *A. brasilense*, b3= D46 isolate, b0= control.

Table 7: Effects of bacterial isolates and nitrogen level on *Striga* incidence on sorghum cv. Wad Ahmed (9 WAS)

	Striga incidence (plants/bag)				
	Bacterial isolate				
Treatment (kg N $ha^{-1)}$	b1	b3	b2	b0	mean
0	(5.40) 29	(3.99) 17	(6.04) 37	(4.3) 20	(4.96) 25
47.6	(3.72) 21	(5.32) 40	(4.60) 25	(3.97)18	(4.41) 26
95.2	(4.87) 23	(5.3) 34	(4.08) 20	(3.92)16	(4.56) 23
mean	(4.67) 24	(4.9) 30	(4.91) 27	(4.09)18	

LSD urea n.s
LSD bacteria n.s
n.s. =non significant
( ) indicates square root transformed data (√x+0.5 x: variable).
b1=*P. Putida,* b2= *A. brasilense*, b3= D46 isolate, b0= control.

Table 8: Effects of bacterial isolates and nitrogen level on *Striga* incidence on sorghum cv. Wad Ahmed (10 WAS)

	Striga incidence (plants/bag)				
	Bacterial isolate				
Treatment (kg N $ha^{-1)}$	b1	b3	b2	b0	mean
0	(2.36) 9	(2.28) 6	(2.22) 7	(2.25) 7	(2.28) 7
47.6	(2.28) 6	(2.88) 10	(2.44) 9	(2.88) 10	(2.63) 9
95.2	(2.21) 5	(3.15) 10	(1.86) 7	(2.72) 9	(2.49) 8
mean	(2.28) 7	(2.77) 9	(2.17) 8	(2.62) 8	

LSD urea n.s
LSD bacteria n.s
n.s. =non significant
( ) indicates square root transformed data (√x+0.5 x: variable).
b1=*P. Putida,* b2= *A. brasilense*, b3= D46 isolate, b0= control.

Table 9: Effects of bacterial isolates and nitrogen level on *Striga* incidence on sorghum cv. Wad Ahmed (11 WAS)

	Striga incidence (plants/bag)				
	Bacterial isolate				
Treatment (kg N ha^{-1})	b1	b3	b2	b0	Mean
0	(1.11)1	(1.83)3	(1.65)3	(1.76)3	(1.59)3.
47.6	(1.54)2	(1.84)3	(1.38)2	(1.52)2	(1.57)2
95.2	(1.63)3	(2.757)8	(0.70)0	(1.62)3	(1.68)3
mean	(1.43)2	(2.14)5	(1.25)2	(1.63)3	

LSD urea n.s
LSD bacteria n.s
n.s. =non significant
( ) indicates square root transformed data (√x+0.5 x: variable).
b1=*P. Putida,* b2= *A. brasilense*, b3= D46 isolate, b0= control.

Table 10: Effects of bacterial isolates and nitrogen level on *Striga* incidence on sorghum cv. Wad Ahmed (12 WAS)

	Striga incidence (plants/bag)				
	Bacterial isolate				
Treatment (kg N ha^{-1})	b1	b3	b2	b0	mean
0	(0.70)0	(1.27)2	(1.14)1	(1.38)2	(1.13)1
47.6	(1.46)2	(0.92)1	(0.96)1	(0.70)0	(1.01)1
95.2	(1.27)2	(1.09)1	(0.70)0	(1.59)3	(1.16)1
mean	(1.15)1	(1.1)1	(0.94)1	(1.23)2	

LSD urea n.s
LSD bacteria n.s
n.s. =non significant
( ) indicates square root transformed data (√x+0.5 x: variable).
b1=*P. Putida,* b2= *A. brasilense*, b3= D46 isolate, b0= control.

Table 11: Effects of bacterial isolates and nitrogen level on *Striga* incidence on sorghum cv. Wad Ahmed (13 WAS)

	Striga incidence (plants/bag)				
	Bacterial isolate				
Treatment (kg N ha^{-1})	b1	b3	b2	b0	mean
0	(0.70)0	(1.33)2	(1.05)1	(1.19)1	(1.07)1
47.6	(1.21)1	(0.92)1	(0.70)0	(0.99)1	(0.88)1
95.2	(0.92)1	(1.09)1	(0.70)0	(1.98)4	(1.05)1
mean	(0.94)1	(1.11)1	(0.82)1	(1.13)1	

LSD urea n.s
LSD bacteria n.s
n.s. =non significant
( ) indicates square root transformed data (√x+0.5 x: variable).
b1=*P. Putida,* b2= *A. brasilense*, b3= D46 isolate, b0= control.

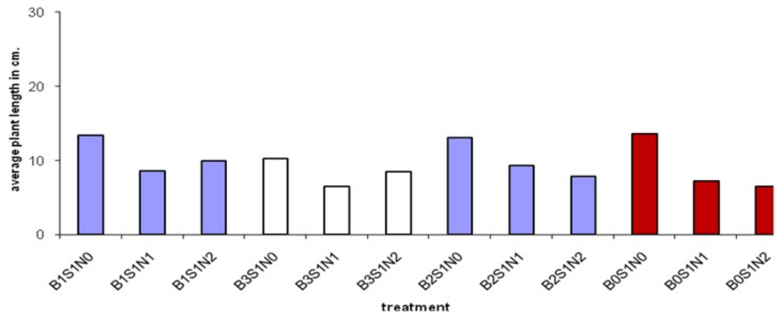

Fig. 1: Effects of bacterial strains, isolates and nitrogen level on Striga height at 7 WAS

N0: without nitrogen, N1: 47.6 kg N ha-1, N2: 95.2 kg N ha-1. B1: P. putida, B2: A. brasilense, B3: D46 isolate B0: control. S1: with Striga. Vertical bar indicates LSD

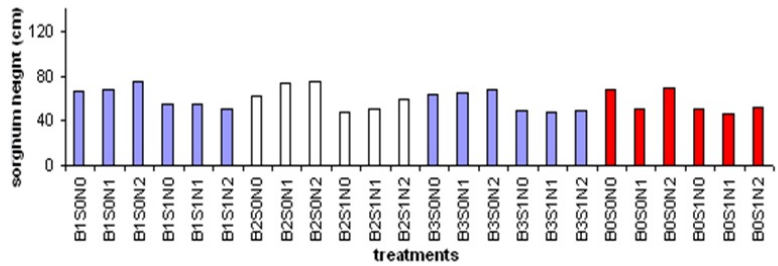

Fig. 2: Effects of bacterial strains, isolates, S. hermonthica and nitrogen level on sorghum height, at 7 WAS

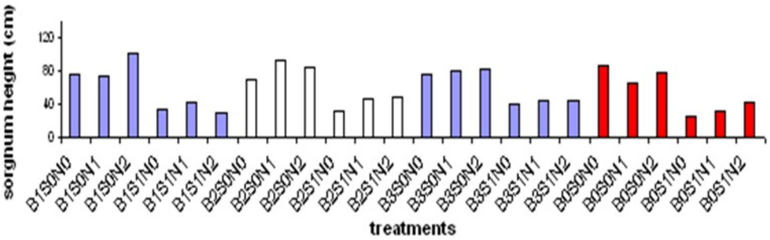

Fig. 3: Effects of bacterial strains, isolates, S. hermonthica and nitrogen level on sorghum height, at 11 WAS

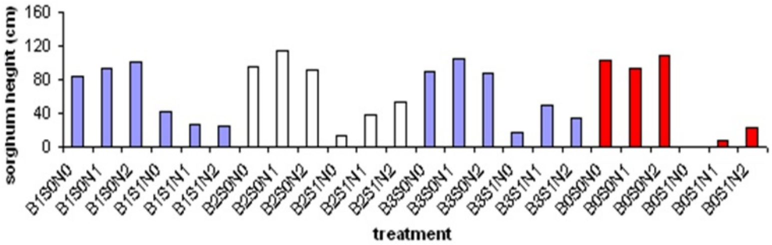

Fig. 4: Effects of bacterial strains, isolates, S. hermonthica and nitrogen level on sorghum height, at 15 WAS

N0: without nitrogen, N1: 47.6 kg N ha-1, N2: 95.2 kg N ha-1. B1: P. putida, B2: A. brasilense, B3: D46 isolate B0: control. S1: with Striga. Vertical bar indicates LSD

Some soils are suppressive to the parasite and their suppressiveness was attributed to microbial population [11]. Currently there is no universally accepted and adopted control method for *Striga*. The present study indicated the possibility that good control of the parasite may be achieved by manipulation of the host – rhizosphere microorganism in combination with nitrogen.

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