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Effects of Organic and Microbial Fertilizers on *Striga hermonthica* in Maize

Osman A. G.[1], Hassan M. M.[1,*], Rugheim A. M. E.[2], Abdelgani M. E.[1], Babiker A. E.[3]

[1]Environment and Natural Resources Research Institute, National Centre for Research, Khartoum, Sudan
[2]Faculty of Agriculture, Omdurman Islamic University, Omdurman Sudan
[3]College of Agricultural Studies, Sudan University of Science and Technology, Khartoum, Sudan
*Corresponding Author: mohkadis@yahoo.com

Abstract A pot experiment was conducted at the Environment and Natural Resources Research Institute, NCR, Sudan to investigate the effect of organic (Elkhairat (T) and Elkhasseb (X)) and microbial (Azospirillin (A) and Phosphobacterin (B)) bio-fertilizers and their combinations on *S. hermonthica* growth and development in Maize. Results showed that all treatments reduced emergence of the parasite, except inoculation with A which enhanced *Striga* emergence compared to control. Treating maize plants with *Striga,* irrespective to treatments reduced maize height as compared with free maize. Plants fertilized with T sustained the highest plant growth at 4 weeks after sowing (WAS). It increased maize height by 79% as compared to infested control. At 6 WAS fertilization with X, B+T and A+B+T were significantly increased plant heights as compared to infested control. Leaf number was affected due to *Striga* infestation. At 6 WAS, all treatments significantly increased leaf numbers except B, A+B and X as compared to infested control. While at 10 WAS, results showed that only A+B+T was significantly increased leaf numbers compared to infested control. Averaged across all fertilization treatments, maize plants infested with *Striga* had smaller leaf areas than did uninfected plants. At 6 and 10 WAS, X sustained the highest leaf area index compared to all other treatments. Maize treated with X and A+B+T sustained the highest shoot dry weight as compared to infested control . Maize fertilized with X, A+T and A+X showed the highest root dry weight as compared to infested control.

Keywords *Striga Hermonthica*, Maize, Organic And Microbial Fertilizers

1. Introduction

Maize (*Zea mays* L.) is widely cultivated throughout the world and greater weight of maize is produced each year than any grain, the United States produced 40% of the world's harvest. Other top producing countries are China, Brazil, Mexico, Indonesia, India, France and Argentina. World wide production was 817 million tones in 2009 – more than rice (678 million tones) or wheat (682 million tones) (1). Maize yield is very low, due to constraints of nutrient depletion, loss of organic matter and poor and erratic rainfall. Maize production also is negatively influenced by the incidence of pests and diseases and increasingly by the parasitic weed *Striga.*

The genus *Striga* (Orobanchaceae, formerly Scrophulariaceae) is one of the most important biotic constraints affecting crop production. Yield losses in staple cereal crops damage by *Striga* varied from a few percentages up to complete crop failure depending on factors such as crop species, level of infestation rainfall pattern and soil degradation (2). *S. hermonthica* (Del.) Benth and *S. asiatica* (L.) kuntze are the two most wide spread and the most economically significant species that parasitize on sorghum (*Sorghum bicolor*), Pearl millet (*Pennisetum glaucum* (L.) R. Br.) Maize (*Zea mays* (L.)) and rice (*Oryza sativa* (L.)), whereas *S. gesnerioides* (Willd.) Vatke attacks crops such as cowpea (*Vigna unguiculata* L. Walp) and peanut (*Arachis hypogaea* L.) (3, 4). *Striga* is most severe in low moisture and low soil fertility.

Manure spreading in the planting furrows has been a known practice by local farmers in order to improve the growth of crop plants and to reduce broomrape infestation (5).

Intensive research is underway in order to achieve better management of witchweed and broomrape, especially with environment-friendly approaches. Many workshops on parasitic weeds in general or specifically on *Striga* discussed various management methods, and claim various levels of success (6). The search for satisfactory control methods of this parasite is a continuous task. The objective of this research was to study the effects of organic and microbial bio-fertilizers on Striga infested maize plants under green house condition.

2. Materials and Methods

The materials used in this experiment included different organic (Elkhairat and Elkhasseb) and microbial fertilizers *(Azospirillum brazilense* (Azospirillin)*; and Bacillus Megatherium var. phosphaticum)*. Maize (*Zea maize* L.) was used as the test plant for *Striga* infestation. *Striga hermonthica* seeds were collected in 2006 from infested sorghum plants at the Gezira Research Station, Sudan.

Elkhairat Compost

It is compost produced commercially in Sudan. It is a mixture of plant residues and animal manure. It was obtained from Elkhairat Company, Khartoum, Sudan. It started in 2007 producing small quantities (1 t/month) applied to nurseries and house gardens. In 2008 the factory was established in an area of 5.5 feddans at Elselate Scheme and the average production was 5 t/month, The average production rate in 2009 reached 150 t/month. It is packaged in two cans 50 Kg or 2Kg sacs and available in the market (7).

Elkhasseb Organic Fertilizer

Elkhasseb organic fertilizer is manufactured locally in El Bagair industrial area, Khartoum, Sudan. It is a mixture of sheep manure, farmyard manure and chicken in 1:2:1 ratio. It is heated up to 70°C for 30 minutes and then belted (2.5, 4 millimeter), it is free from plastic materials, weeds seeds, insects, warms, nematode and pathogenic microorganisms (*Shigella*, *Salmonella* and *E. coli*). The analysis of this fertilizer proved that, heavy metals, micronutrients, sodium, potassium chlorine, total nitrogen, C.N ratio, EC, pH, bulk density, strange materials were within the range compared to finished compost. However, calcium carbonate, phosphorus lignin, cellulose, hemi cellulose and fiber were all over the standard range compared to finished compost. CEC and magnesium were lower than the standard range (Annual Scientific Report of the Environment and Natural Resources Research Institute, 2). It was obtained from Elkhasseb Company.

Table 1. Chemical composition of organic fertilizers

Fertilizers	O.C %	N %	K mmol	Na mmol	Mg %	Ca %	P %
Elkhaseeb	32.5	1.41	6.99	4.44	3.0	5.0	0.7
Elkhairat	11.7	1.02	4.35	1.98	4.5	5.8	0.3

Table 2. Average numbers of emerging *Striga* plants

Treatment	Weeks After Sowing (WAS)							
	6	7	8	9	10	11	12	13
Control 1	0	0	0	0	0	0	0	0
Control 2	2.50	1.00	2.25	2.25	3.25	3.25	3.25	4.75
A	3.00	2.25	3.25	3.25	3.50	3.25	3.25	6.75
B	1.75	2.75	3.25	4.00	4.00	4.00	4.00	11.75
A+B	1.25	1.75	3.00	3.00	1.75	2.00	2.00	12.00
T	0.00	2.50	2.00	2.75	3.25	3.25	3.25	11.75
X	2.50	2.50	1.00	4.25	1.00	1.00	1.00	1.00
A+T	1.25	2.25	1.75	4.25	4.25	4.00	4.00	7.50
A+X	0.00	3.00	3.25	2.00	1.75	1.75	1.75	10.75
B+T	1.00	1.50	2.75	2.25	4.00	4.00	1.75	7.00
B+X	0.00	2.75	1.00	1.00	1.25	1.75	1.75	8.75
A+B+T	2.50	1.00	2.50	1.25	1.25	1.25	1.25	2.00
A+B+X	1.25	2.00	1.00	2.50	3.00	3.00	3.00	9.50
LSD	**2.51**	**2.80**	**2.20**	**2.32**	**2.78**	**2.78**	**6.60**	**2.68**

Control 1 = un-infested Control 2 = infested

A= Azospirillin B = Phosphorin

T= ElKhairat X = ElKhaseeb

Microbial Bio-fertilizers

A broth medium of meat peptone was prepared by adding the following constituents (g) to a liter of distilled water: 7.5 peptone, 5 meat extract and 5 NaCl. The medium was sterilized by autoclaving at 121ºC and 15 ib/in^2 for 15 minutes. The broth was then inoculated by *Azospirillum brazilense* (Azospirillin) and *Bacillus Megatherium var. phosphaticum* (Phosphorin) separately. The inoculated broth was aerated by shaking for 24 hrs. A sample was taken from the broth for the determination of the number of cells/ml using the pour plate method to ensure maturity of inoculant (1x10^9 cell/ml).

Maize Greenhouse Experiment

This study was conducted at the Environment and Natural Resources Research Institute, the National Center for Research, Khartoum- Sudan. In this experiment, soil mix made of Nile silt and sand (2:1 v/v) was used in plastic pots each containing 5 kg soil. Pots were either fertilized with Elkhairat or Elkhasseb organic fertilizer before sowing at a rate of 20 g/pot. *Striga* infestation was accomplished by mixing 10 mg of seeds in the top soil in each pot. Maize seeds were either inoculated with Azospirillin or Phosphobacterin each alone or in combinations with organic fertilizers. *Striga* infested and un-infested maize controls were included in each experiment for comparison. Maize seeds (7/pot) were sown and pots were then irrigated by equal amount of tab water every two days. Aliquots of the respective bacterial suspensions (15 ml each) were injected, within the root zone, in each pot. Subsequent irrigations were repeated every 2 days. Germinated maize was thinned to three plants per pot at 10 days after planting.

Striga infestation was assessed by the number of emerged shoots weekly beginning from the first *Striga* emergence. Maize plant height was recorded at five and nine weeks after sowing (WAS). Leaf area index (LAI) was measured at 6 and 10 WAS. LAI per plant was calculated by dividing the leaf area per plant by the total land area occupied by the plant according to the formula:

LAI=Leaf area per plant (cm2)

Land area occupied by the plant (cm2)

Maize shoot and root dry weights were recorded at the end of the experiment. The experiment was arranged in a Randomized Complete Block Design (RCBD) with four replications. Means of four replications were analyzed for variance and significant differences were determined by LSD test at the 5 % probability level.

3. Results and Discussion

Striga Incidence

At 6 weeks after sowing (WAS), *Striga* was observed in all treatments except A+X treatment. *Striga* emergence was very low as only 2 on un-inoculated control (Table 2). All treatments reduced emergence of the parasite, except inoculation with Azospirillin which increased the numbers of *Striga* emergence as compared to control. Sorghum treated with the T, A+X and B+X displayed no Striga emergence. At 7 WAS, *Striga* emergence increased, substantially. Maize treated with the combinations between A+B showed adverse effects on *Striga* emergence. A+B+T was the most suppressive treatment. It reduced *Striga* infestation by 56%. However, maize fertilized with the combinations between A+X sustained the highest parasite emergence as compared with the control albeit not significantly. At 8 WAS, Fertilization of maize with X, B+X and A+B+X reduced *Striga* infestation by 60% as compared to the control. While maize treated with the A, B or combinations between A+X they increased *Striga* emergence by 30%. At 9 WAS, maize fertilization with the combinations between B, X or A+T increased *Striga* infestation by 45-52 %, while maize treated with the combinations between B+X and A+B+T it reduced *Striga* emergence by 55-64%. At 10 WAS, *Striga* emergence increased, substantially and was highest on the un-inoculated control (4.25 *Striga*/bag). In among all treatments *Striga* emergence began to increased except in the combinations between A+B, A+X, B+X, A+B+T or X alone. At 11, 12 and 13 WAS, *Striga* incidence followed the same trend as at eight WAS. The counts begin to decline in *Striga* incidence with obvious trends. In among all treatments combinations of A+B+T were the inhibitoriest. Manure-free soil had the highest broomrape infestation.

Table 3. Effects of different treatments on plant height (cm)

Treatment	**4 WAS**	**6 WAS**	**8 WAS**
Control (un-infested)	22.5	27.8	28.4
Control (infested)	10.4	20.7	21.3
Azospirillin(A)	27.9	25.2	25.5
Phosphorin(B)	19.2	24.5	24.9
A+B	9.7	12.6	13.1
ElKhairat (T)	72.5	27.7	28.4
ElKhaseeb (X)	15.2	32.5	32.7
A+T	23.2	27.7	28.1
A+X	21.9	28.1	28.7
B+T	22.2	29.3	29.8
B+X	11.7	24.5	24.7
A+B+T	19.5	30.3	30.5
A+B+X	18.1	24.4	24.9
LSD	**5.0**	**7.4**	**8.0**

Leaf Numbers

Leaf number was affected due to *striga* infestation. At 6 WAS, all treatments significantly increased leaf numbers except B, A+B and X as compared to infested control (table 4). While at 10 WAS, results showed that only A+B+T was significantly increased leaf numbers compared to infested control. In contrast to our findings, Gebremedhin *et al*., (12) found that leaf number was unaffected due to *Striga* infestation.

Table 4. Effects of different treatments on leaf numbers

Treatment	6 WAS	10 WAS
Control (un-infested)	25.3	21.3
Control (infested)	18.8	18.3
Azospirillin(A)	21.5	18.8
Phosphorin(B)	20.0	16.0
A+B	20.3	19.0
ElKhairat (T)	23.3	16.0
ElKhaseeb (X)	18.8	15.8
A+T	22.3	18.5
A+X	21.8	18.3
B+T	21.3	17.3
B+X	22.5	19.5
A+B+T	22.8	20.0
A+B+X	24.3	18.5
LSD	**1.7**	**1.6**

Table 5. Effects of different treatments on leaf area index

Treatment	6 WAS	10 WAS
Control (un-infested)	20.58	27.14
Control (infested)	12.50	14.12
Azospirillin(A)	26.80	30.59
Phosphorin(B)	21.19	25.54
A+B	5.00	8.12
ElKhairat (T)	26.42	28.92
ElKhaseeb (X)	35.15	37.90
A+T	29.61	32.65
A+X	27.56	28.75
B+T	25.86	28.53
B+X	17.43	20.76
A+B+T	27.21	28.53
A+B+X	31.77	21.06
LSD	**11.60**	**12.480**

Leaf Area Index

Averaged across all fertilization treatments, maize plants infected with *Striga* had smaller leaf areas than did uninfected plants. The leaf area of infected and uninfected plants increased asymptotically from emergence to 10 WAS. At both sampling times X sustained the highest leaf area index compared to all other treatments (Table5).

Infection with *S. hermonthica* reduced the leaf area of the maize host from emergence to harvest. This result confirms those reported for the sorghum- *S. hermonthica* association obtained by Press and Stewart (13), Cechin and Press (14), Frost *et al*. (15), and for the millet-*S. hermonthica* association obtained by Graves et al (16). In this study, leaf area for both infected and uninfected maize plants increased asymptotically from the first to the last sampling date but the differences in leaf area between infected and uninfected maize increased with time, demonstrating the progressively deleterious effect of *Striga* on its host.

Dry Matter

At 13 WAS maize free shoot dry weight displayed the highest weight as compared with maize infested, irrespective to treatments. Maize treated with A+B, A+X, A+T and X sustained the highest shoot dry weight albeit not significantly as compared to infested control (Table 6).

With respect to root dry weight, results displayed that maize inoculated with A+B+T, X, and B+T showed the highest dry weight as compared to infested control (Table 6).

Table 6. Effects of different treatments on shoot dry weight (13 WAS)

Treatment	Root dry weight (g)	Shoot dry weight (g)
Control (un-infested)	2.38	3.42
Control (infested)	3.81	3.08
Azospirillin(A)	3.14	3.14
Phosphorin(B)	1.87	3.58
A+B	5.42	2.35
ElKhairat (T)	3.12	2.89
ElKhaseeb (X)	5.16	4.98
A+T	5.17	3.41
A+X	5.34	3.75
B+T	2.48	4.04
B+X	4.06	3.35
A+B+T	4.54	5.02
A+B+X	2.20	3.54
LSD	**5.00**	**2.41**

Infection of maize by *S. hermonthica* did not affect root biomass but led to smaller shoot biomass; the differences in shoot biomass between uninfected and infected plants increased with time. However, the proportion of total biomass per plant partitioned to roots differed between infected and uninfected plants in both experiments. The results from this study contrast with those of Graves *et al.* (16) and Taylor *et al.* (18) but are similar to those of Graves *et al.* (17) Cechin and Press (14). Graves *et al.* (16) reported that leaf and root biomasses in *Striga*-infected millet were increased by 41 and 86% respectively while grain yield was reduced by 80% and stem dry weight by 53%. Similarly, Taylor *et al.* (18) found higher root biomass in infected maize than in uninfected maize, Press *et al.* (16) reported a marked shift in allocation of dry matter to roots in two sorghum cultivars, CSH-1 and Ochuti, infected with *S. hermonthica*. Frost *et al.* (15) showed that although the biomass of *Striga*-infected sorghum (CSH-1 and Ochuti) was lower than that in uninfected plants, shoot biomass was affected more than was root biomass. In sorghum, Graves *et al.* (17) reported a reduction in grain and stem dry weights while leaf and root dry weights remained similar for infected and uninfected plants. The physiological basis for these differences in response is unknown. It is possible that variations in genetic composition of different host crops and cultivars of the same species to different strains of the parasite may play a part. Changes in the balance of plant growth hormones may be responsible for some of the differences in lometry (20, 15, 18). Another possible reason for the observed differences in lometry may be the time of emergence of parasites above ground. The data from this study showed that differences in leaf area and shoot biomass between infected and uninfected plants increased with time and the development of the *Striga* shoots. These results, however, did not support the hypothesis that higher applications of N would reduce biomass of infected maize relatively more than un- infected maize.

Reference (21) reported that if managed properly, manure composting in planting furrows contributes to the reduction of environmental pollution. Composting manure would offer a new environmentally safe procedure to manage broomrape using farm resources at the minimum cost.

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