Influence of triclopyr and nitrogen on management of *Striga hermonthica* on sorghum

Suha Hassan Amhed
Department of Biopesticides and Biofertilizers Environment and Natural Resources and Desertification Research Institute, National Centre for Research, Khartoum, Sudan
Rashida Mohamed Ahmed Abusin
Department of Pests and Plant Health, College of Agriculture University of Bahri, Khartoum, Sudan, and
Migdam Elsheikh Abdelgani and Abdel Gabar ELTayeb Babiker
Department of Biopesticides and Biofertilizers Environment and Natural Resources and Desertification Research Institute, National Centre for Research, Khartoum, Sudan

Abstract

Purpose – The purpose of this paper is to study the effects of the herbicide triclopyr, nitrogen and their combinations on *Striga* incidence and sorghum growth.
Design/methodology/approach – A greenhouse study was undertaken in season 2013. Sorghum cv Wad Ahmed, urea and triclopyr were employed. Treatments were arranged in a randomized complete design with four replicates.
Findings – Nitrogen alone suppressed the parasite completely early in the season. Triclopyr at 0.3 and 0.4 kg a.e. ha^{-1} reduced *Striga* emergence by 92.9 and 58.3 per cent early and late in the season, respectively. Triclopyr at 0.3 kg a.e. ha^{-1} applied subsequent to nitrogen at 43.8 kg ha^{-1} effected poor control of the parasite. Unrestricted *Striga* parasitism reduced sorghum height and chlorophyll content by 50.38 and 16.62 per cent, respectively. Triclopyr, nitrogen and their combination improved sorghum growth considerably.
Originality/value – The results suggest that the herbicide when applied subsequent to nitrogen afforded the most consistent performance and resulted in the highest suppression of the parasite.
Keywords Sorghum, Nitrogen, Triclopyr, *Striga*
Paper type Research paper

Introduction

Striga hermonthica, an Orobanchaceae, is a root parasitic flowering plant that attacks sorghum, maize, millet and several grassy weeds in semi-arid tropical Africa. In Sudan, *Striga* is widespread in irrigated and rain-fed areas and is considered to be the main biotic constraint to sorghum production. More than a million hectares under rain-fed cultivation are heavily infested with *Striga*, which commonly results in significant yield

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losses of 70-100 per cent. It has become obvious that there is no simple, fast and inexpensive solution to the problem. The *Striga* life cycle is closely linked with that of its hosts (Haussmann *et al.*, 2000). This complex biology limited the development of successful control methods that can be accepted and practiced by subsistence farmers. Nevertheless, several control measures for *Striga* have been developed including cultural, biological and chemical methods, in addition to the development of resistant and tolerant host varieties (Elzein and Kroschel, 2003; Parker and Riches, 1993). Ogborn (1984) observed that, in Africa and Asia where *Striga* spp. are endemic, re-infestation from wild hosts may make it very difficult to eradicate the weed. The present study was conducted to evaluate the effects of nitrogen fertilizer and the herbicide triclopyr, each alone and in combinations, on *Striga* incidence and sorghum growth and yield.

Literature review

Sorghum

Sorghum (*Sorghum bicolor*) (L.) Moench, a Poaceae, is an important food crop in Africa, South Asia and Central America (FAO, 2006). Sorghum is the second most important cereal crop after maize in sub-Saharan Africa (Haussmann *et al.*, 2000). It is the main staple food for about 300 million people who live in the semi-arid tropics (Chantereau and Nicou, 1994). In Sudan, sorghum is the most important cereal crop in terms of production and consumption (Ibrahim *et al.*, 1995). It is cultivated all over the country, under either rain-fed or supplementary irrigation.

Striga

Striga hermonthica (Del.) Benth. is one of the most important agricultural weeds of cereals in the semi-arid tropics. It is an obligate root hemi-parasite, native to the Savannah ecosystems where wild grasses are hosts. *S. hermonthica* infestation in cereals such as maize (*Zea mays* L.), sorghum (*Sorghum bicolor* (L.) Moench) and pearl millet (*Pennisetum americanum* (L.) Beeke) causes devastating losses in yield and the problem is increasing (Parker, 1991). Sauerborn *et al.* (1991) estimated that 21 million hectares of cereal cultivation in Africa are infected by the weed, and grain production within the 44 million hectares where *S. hermonthica* occurs is potentially endangered.

Striga control options

No single method is completely effective in eliminating *Striga* infestation and, accordingly, strategies for *Striga* management are always dependent upon the formulation of packages, the components of which depend on the technical and financial capabilities of farmers as well as the size of the parasite seed bank and the expected returns (Hess and Grard, 1999). Management of the hemi-parasite needs an integrated approach that includes host plant resistance, cultural practices and chemical treatments. With integrated management, it is important to understand the interactions of the host plant with the biotic and abiotic environment.

Many methods of chemical control are available (e.g. fumigants, germination stimulants, antitranspirants, seed treatments and herbicides). However, the relevance of many of these methods to subsistence farmers is limited. Herbicides are considered to have the most potential, however, they have to be appropriate, cost-effective and affordable (Hess and Lenne, 1999). However, the chemical approach poses some difficulties, including a lack of application technology, chemical damage to the host, continuous parasite seed germination throughout the season, marginal crop selectivity, environmental pollution, low persistence and availability. In addition, in developing countries, the income of subsistence farmers is usually too low to afford to purchase inputs including herbicides (Aly, 2007). Triclopyr, a pyridinloxy, is a selective herbicide that mimics the effects of plant hormones. It is currently registered for use on rice, pastures and rangeland, forests and lawns. Triclopyr is used for the control of undesirable woody and herbaceous weeds. The herbicide as Trilina (3, 5, 6-trichloro-2-pyridinyl) oxy] acetic acid), was obtained from Trust Chem China (Barnes and Seefeldt, 2009).

Striga infestation and damage have long been associated with soil fertility (Babiker, 2007). However, reports on the effects of nitrogen on *Striga* infestation are contradictory. Cechin and Press (1993) showed that the successful union of *S. hermonthica* with sorghum is dependent, at least in part, on nitrogen contents of the growth medium. Subsequent attachment of the parasite and early growth of the plant were also lower at higher nitrogen (Cechin and Press, 1993). Nitrogen was reported to reduce the production of germination stimulants and to exert direct suppressive effects on *Striga* growth and development at the post-germination stages (Igbinnosa *et al.*, 1996). On the other hand, however, several reports enunciated no effects for nitrogen, or that nitrogen, especially at low rates, enhanced *Striga* emergence (Osman *et al.*, 1991; Parker and Riches, 1993). The erratic performance of nitrogen is attributable to a multitude of factors including initial soil fertility, *Striga* seed bank size, susceptibility of crop cultivars and timing and rate of application (Ayongwa *et al.*, 2006; Parker and Riches, 1993). Abu-Irmaielh (2008) showed that *Orobanche* infestation tends to be negatively associated with nitrogen levels. Nitrogen, albeit having suppressive effects on parasitism, adversely affects nodulation and nitrogen fixation in faba beans.

Methodology

The experiment was conducted in a greenhouse at the College of Agricultural Studies, Sudan University of Science and Technology at Shambat. Sorghum (cv. Wad Ahmed) was sown in a soil mix, made of soil collected from the college farm and river sand (2:1v/v), placed in pots (11.5 i.d.). *Striga hermonthica* (10 mg) were mixed with soil in each pot. Surface sterilised sorghum seeds (four) were sown in each pot. Nitrogen as urea at 0, 43.8 (1N) and 87.6 (2N) kg ha^{-1} was applied at sowing. Sorghum seedlings were thinned to two plants/pot ten days after sowing (DAS). The urea treatments were overlaid with triclopyr at 0, 0.3 and 0.4 kg a.e. ha^{-1}, applied 21 DAS. *Striga* free fertilised and unfertilised treatments were included as controls for comparison. Treatments were arranged in a Randomised Complete Design with four replicates. Emerged *Striga* plants were counted 45, 60 and 75 DAS, sorghum height was measured 45, 60 and 75 DAS, *Striga* dry weight (SDW) at harvest.

Data collected from all experiments were subjected to statistical analysis using GenStat (PC, Windows 7), VSN International Ltd UK statistical package (Rothamsted Experimental Station). Data for *Striga* emergence and SDW were subjected to transformation using square root to fulfil ANOVA requirements.

Results

Effects of triclopyr, nitrogen and their combinations on Striga and sorghum

Emergence. Nitrogen at 43.8 kg ha^{-1} completely suppressed *Striga* emergence early in the season (45 and 60 DAS) (Table I). However, late in the season (75 DAS) only moderate control (57.14 per cent) was achieved. Nitrogen at the high rate (87.6 kg ha^{-1}) effected excellent and lasting suppression of the parasite. Triclopyr, alone, at 0.3 and

Triclopyr kg a.e. ha^{-1} (N)	*Striga* emergence (plants/pot) (DAS) 45			60			75		
	0	1	2	0	1	2	0	1	2
Control	3.5 (1)	0.0 (1)	0.0 (1)	3 (2.8)	0.00 (1)	0.00 (1)	4.25 (2)	1.5 (1.54)	0.00 (1)
0.3	2.8 (1.4)	1.5 (1)	0.0 (1)	1.25 (1.36)	0.50 (1.18)	1 (1.40)	1.75 (1.5	1.50 (1.35)	1.25 (1)
0.4	0.25 (1.5)	0.25 (1)	0.25 (1)	1.75 (1.46)	0.25 (1.10)	0.25 (1.10)	1.75 (1.5	0.25 (1.83)	0.00 (1)
CV %		33			37.3			41.6	
2-way ANOVA									
N	0.84**			0.50 ns				0.96*	
Try	0.090**			2.18**				0.39 ns	
N × Try	0.081**			3.37**				0.22**	

Notes: Try, triclopyr; ns, non-significant. ± is standard errors of means. Means within a column having the same superscript(s) are not significantly different according to LSD test. 1N = nitrogen at 43.8 kg ha^{-1}; 2N = nitrogen at 87.6 kg ha^{-1}. $^{*}p \leqslant 0.05$; $^{**}p \leqslant 0.01$

Table I. Effects of triclopyr, nitrogen and their combinations on *Striga* emergence

0.4 kg a.e. ha^{-1} reduced *Striga* emergence by 92.8 and 58.3 per cent, respectively. Triclopyr at 0.3 kg a.e. ha^{-1} applied subsequent to nitrogen at 43.8 and 87.6 kg ha^{-1} reduced *Striga* emergence by 57.14 and 64.29 per cent, respectively. The corresponding figures for the higher herbicide rate were 92.86 and 71.43 per cent, respectively.

Dry weight. In the untreated control SDW was 8.62 g per pot. Nitrogen, alone, at 43.8 and 87.6 kg ha^{-1} reduced SDW by 78.1 and 98.6 per cent, respectively (Table II). Triclopyr, alone, at 0.3 and 0.4 kg a.e. ha^{-1} reduced SDW by 89.7 and 94.1 per cent, respectively. Triclopyr at 0.3 kg a.e. ha^{-1} applied subsequent to nitrogen at 43.8 and 87.6 kg ha^{-1} reduced SDW by 39.09 and 97.09 per cent, respectively. Triclopyr at the higher rate (0.4 kg a.e. ha^{-1}) applied to pots previously receiving nitrogen at 43.8 and 87.6 kg ha^{-1} reduced SDW by 82.59 and 99.18 per cent, respectively.

Effects of triclopyr, nitrogen and their combinations

Sorghum height. All treatments increased sorghum height in comparison to the *Striga* infested control, albeit not significantly (Table III). Early in the season, nitrogen, alone, at 43.8 and 87.6 kg ha^{-1} increased sorghum height by 18.11 and 12.72 per cent.

Triclopyr kg a.e. ha^{-1} (N)	*Striga* dry wt (g) 0	1	2
Control	8.62 (3)	1.88 (1.5)	0.12 (1)
0.3	0.88 (0.8)	5.25 (2.8)	0.25 (0.3)
0.4	0.5 (0.3)	1.50 (1.2)	0.0 (0.1)
CV %		47.1	
2-way ANOVA			
N	0.012**		
Try	0.897*		
N×Try	0.068**		

Notes: Try, triclopyr. ± is standard errors of means. Means within a column having the same superscript letter(s) are not significantly different according to LSD test. 1N = nitrogen at 43.8 kg ha^{-1}; 2N = nitrogen at 87.6 kg ha^{-1}. $^{*}p \leqslant 0.05$; $^{**}p \leqslant 0.01$

Table II. Effects of triclopyr, nitrogen and their combinations on *Striga* dry weight

	Sorghum height (cm) (DAS)								
	45			60			75		
Triclopyr kg a.e. ha^{-1} (N)	0	1	2	0	1	2	0	1	2
Control	78.2	95.5	89.6	88.4	97.7	106.6	123.8	134.2	130
0.3	89.5	93.4	91.7	104.9	91.9	105	130	126.2	129.8
0.4	87	89.3	91.8	94	112.4	99.4	110	128.2	127.5
CV %	15.9				14.7			26.7	
2-way ANOVA									
N	0.47*				1.08 ns			0.108 ns	
Try	0.71ns				0.297 ns			0.297 ns	
N × Try	0.87*				0.117 ns			0.027 ns	

Notes: Try, triclopyr; ns, non-significant. ± is standard errors of means. Means within a column having the same superscript letter(s) are not significantly different according to LSD test. 1N = nitrogen at 43.8 kg ha^{-1}; 2N = nitrogen at 87.6 kg ha^{-1}. *$p \leqslant 0.05$

Table III.
Effects of triclopyr, nitrogen and their combinations on sorghum height

The corresponding increments late in the season were 7.75 and 4.92 per cent, respectively. Triclopyr alone, irrespective of rate, increased sorghum height by12.63 and 10.11 per cent early in the season and by 4.78 and 12.55 per cent late in the season. The herbicide, when applied subsequent to nitrogen, increased sorghum height by 16.27 and 14.8 per cent early in the season and by 4.62 and 2.90 per cent late in the season.

Number of leaves. All treatments effected a higher number of leaves in comparison to the *Striga* infested control (Table IV). At 45 DAS nitrogen alone at 43.8 and 87.6 kg ha^{-1} increased the number of leaves by 30.83 and 37 per cent, over the *Striga* infested control. The corresponding increments in number of leaves at 60 DAS were 17.19 and 49.58 per cent, respectively. Triclopyr, alone, at 0.3 and 0.4 kg a.e. ha^{-1} increased the number of leaves by 20.5 and 25.33 per cent at 45 DAS and by 5.63 and 41.7 per cent, at 60 DAS, respectively. Triclopyr at 0.3 applied subsequent to nitrogen at 43.6 and 87.6 kg ha^{-1} increased the number of leaves by 13.88 and 21.56 per cent, at 45 DAS and by 47.23 and 42.68 per cent, at 60 DAS. The corresponding figures for the herbicide at the higher rate were 17.38 and 22.5 per cent, at 45 DAS and 50.7 and 52.11 per cent, at 60 DAS.

	Number of leaves (DAS)					
	45			60		
Triclopyr kg a.e. ha^{-1} (N)	0	1	2	0	1	2
Control	7.75	11.12	11.25	8.38	10.12	16.62
0.3	9.75	9	9.88	8.88	15.88	14.62
0.4	10.38	9.38	10	14.38	17	17.50
CV %		24			33.8	
2-way ANOVA						
N		0.97**			0.063*	
Try		0.34*			0.092*	
N × Try		0.86*			0.008**	

Notes: Try, triclopyr. ± is standard errors of means. Means within a column having the same superscript letter(s) are not significantly different according to LSD test. 1N = nitrogen at 43.8 kg ha^{-1}; 2N = nitrogen at 87.6 kg ha^{-1}. *$p \leqslant 0.05$; **$p \leqslant 0.01$

Table IV.
Effects of triclopyr, nitrogen and their combinations on sorghum number of leaves

Chlorophyll content. All treatments, invariably, increased chlorophyll content of sorghum leaves in comparison to the infested control. Nitrogen, alone at 43.8 and 87.6 kg ha^{-1}, increased chlorophyll content by 44.26 and 46.9 per cent at 45 DAS and by 53.7 and 57.9 per cent at 60 DAS, respectively (Table V).

Triclopyr, alone at 0.3 and 0.4 kg a.e. ha^{-1} increased sorghum leaves chlorophyll content by 47.03 and 39.83 per cent at 45 DAS and by 54.33 and 54.07 per cent at 60 DAS, respectively. Triclopyr at 0.3 kg a.e. ha^{-1} applied subsequent to nitrogen at 43.8 and 87.6 kg a.e. ha^{-1} increased chlorophyll content by 55.23 and 52.17 per cent at 45 and 53.68 and 49.18 per cent at 60 DAS. The corresponding increments for the higher rate were 51.55 and 45.47 per cent at 45 DAS and 48.36 and 51.59 per cent at 60 DAS, respectively.

Discussion

The results revealed that nitrogen alone completely suppressed *Striga* emergence throughout the experiment (Table I). Suppression of *Striga* emergence by nitrogen is consistent with several reports (Abusin, 2014; Adam, 2007; Ahonsi *et al.*, 2002; Dawoud *et al.*, 2007; Babiker, 2002; Hassan *et al.*, 2009; Hamad Elneel, 2011; Showemimo *et al.*, 2002) and may be attributed to a decrease in stimulant production (Cechin and Press, 1993; Hassan *et al.*, 2009) and/or to direct toxicity to the parasite at early developmental stages (Parker and Riches, 1993). Nitrogen alone at 43.8 and 87.6 kg ha^{-1} reduced SDW by 78.1-98.6 per cent, plant height by 21.9-42.7 per cent, and increased sorghum growth as reflected by the increments in number of leaves and by 48.3-27.7 per cent and chlorophyll content by 44.3-57.9 per cent (Tables II-IV and VI). Triclopyr is reported as a selective herbicide that acts as an auxin-like herbicide. Triclopyr alone at 0.4 kg a.e. ha^{-1} reduced *Striga* emergence significantly ($p \leqslant 0.05$) early and late in the season.

These findings are consistent with those obtained by Abusin (2014), and these reductions could be attributed to the direct toxicity of the herbicide. However, Triclopyr is an auxin-like herbicide, and auxin-like herbicides are renowned for high potency on dicotyledonous plants. The possibility of indirect effects through influence on early developmental stages of the parasite cannot be ruled out. The closely related herbicide, 2, 4-D is reported to reduce *Striga* germination, radical extension and haustorium initiation (Abusin, 2014). However, triclopyr at its lowest rate when applied to pots

Table V. Effects of triclopyr, nitrogen and their combinations on sorghum chlorophyll content

	Chlorophyll content (DAS)					
		45			60	
Triclopyr kg a.e. ha^{-1} (N)	0	1	2	0	1	2
Control	16.62	29.82	31.32	15.88	34.33	37.75
0.3	31.38	37.12	34.75	34.77	34.28	31.25
0.4	27.65	34.30	30.48	34.58	30.75	32.80
CV %		19.9			31.2	
2-way ANOVA						
N	0.72**				0.50**	
Try	0.573**				0.59**	
N × Try	0.001**				0.658**	

Notes: Try, triclopyr. ± is standard errors of means. Means within a column having the same superscript letter(s) are not significantly different according to LSD test. 1N = nitrogen at 43.8 kg ha^{-1}; 2N = nitrogen at 87.6 kg ha^{-1}. ** $p \leqslant 0.01$

previously treated with nitrogen, as urea, resulted in an increase in *Striga* emergence. Such performance is akin to reports on increased *Striga* emergence following treatments with nitrogen at low rates (43.8). Such performance may be attributed to intense competition between the parasite plants and inability of the host to sustain emergence of the parasite under heavy infestation. A decrease in infestation lessens the competition and allows for the emergence of the parasite. This shows a significant drop in *Striga* emergence (Table I).

Triclopyr at 0.3 and 0.4 kg a.e. ha^{-1} reduced SDW by 89.7-94.1 per cent. The combinations of triclopyr and nitrogen showed inconsistent effects (Table II). Triclopyr at 0.4 kg a.e. ha^{-1} in combinations with nitrogen at 43.8 and 87 kg ha^{-1} affected 82.59 and 88.39 per cent reductions in SDW, respectively.

However, a notable increase in SDW (64.19 per cent) was observed when triclopyr at the lower rate was applied to sub-plots previously treated with nitrogen at the lowest rate (Table II). This finding is consistent with the observed increase in *Striga* emergence caused by the same treatment (Table I). However, the combination of the lower herbicide rate and nitrogen at the highest rate effected a considerable reduction in SDW. As revealed by crop height, number of leaves and chlorophyll content, all treatments improved crop growth. Triclopyr alone, irrespective of rate, resulted in a crop height comparable to the control; however, it had no significant effect on chlorophyll content (Table III).

In conclusion, the results clearly showed the adverse effects of *Striga* on its host and the need for an integrated approach for *Striga* management. However, these results need to be verified in field experiments and the cost effectiveness of the treatments needs to be considered.

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About the authors

Dr Suha Hassan Amhed, PhD Student, is a Researcher at the Environment and Natural Resources and Desertification Research Institute-National Centre for Research. She has worked at the Department of Biopesticides and Biofertilizers for ten years as a Teaching Assistant at the Khartoum University. The language of teaching is English; she speaks and writes both Arabic and English. She has taken part in many training courses including a training course on applications on biological control, Egypt and a training course on waste management, at the Tongi University Chine, Shanghi. She has participated in nine conferences and many seminars, and has published two papers. Dr Suha Hassan Amhed is the corresponding author and can be contacted at: hashimsuha@yahoo.com

Dr Rashida Mohamed Ahmed Abusin, Assistant Professor of Weed Science, currently works as a Lecturer and a Researcher of Weed Science and Plant Pathology, College of Agriculture, University of Bahri (formerly University of Juba), Department of Pests and Plant Health. The language of teaching is English so she speaks and writes both Arabic and English. She has supervised and marked dissertations, and supervised scientific trips and practicals. She has taken part in many training courses, including Neuro Linguistic Programming (NLP), EndNote Program, writing and publishing a scientific paper, English language intermediate course one, two and upper intermediate. She has participated in five conferences and many seminars.

Professor Migdam Elsheikh Abdelgani is a Soil Microbiologist. He worked as a Researcher at the Environment and Natural Resources and Desertification Research Institute-National Centre for Research from 1992 to 2007, and as the Deputy General Director of the National Centre for Research from 2007 to 2013. Currently, he is the General Director of the National Centre for Research (NCR). He graduated from the Faculty of Agriculture University of Khartoum in 1981, obtained his MSc in Environmental studies in 1990 at the Institute of Environmental Studies, University of Khartoum. His PhD was awarded by the Faculty of Agriculture, University of Khartoum in 1997 in Soil Microbiology. His current research is in the use of soil microorganism in the production of bio-fertilisers and pesticides.

Abdel Gabar ELTayeb Babikeris a Professor of Weed Science Sudan, University of Science and Technology. He has supervised 33 PhD and MSc students. He was a Regional Co-ordinator of Striga Research East Africa 1986-1991, a Co-ordinator of INTSORMIL (International Sorghum and Millet Research) funded by USAID (1996-1998), a Visiting Professor, Department of Agronomy, Purdue University, USA, 1992-1993 (12 months conducting research on Striga), and a Visiting Professor at the Arid Land Research Centre, Tottori University, 1994-1996. He spent 15 months in Japan conducting research on Striga, and was a Visiting Professor at the Arid Land Research Center, Tottori University, 1997-1998. He spent a further 12 months in Japan conducting further research on Striga, and was a Visiting Professor at the University of Hohenheim, Germany, 2000-2001. He has produced hundreds of publications.