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INFLUENCE OF TRICLOPYR AND NITROGEN ON MANAGEMENT OF *STRIGA HERMONTHICA* ON SORGHUM

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ABSTRACT

Purpose: The investigation was undertaken 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 the 2013 season. Sorghum cv Wad Ahmed, urea and triclopyr were employed. Treatments were arranged in a randomised 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% 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%, respectively. Triclopyr, nitrogen and their combination improved sorghum growth considerably.

Originality: 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*:** triclopyr; nitrogen; *Striga*; sorghum.

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 losses of 70–100%. 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 fertiliser and the herbicide triclopyr, each on their 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 a biotic environment.

Many methods of chemical control are available (e.g. fumigants, germination stimulants, anti-transpirants, 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

(4) 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 10 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 (RCD) 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 1). However, late in the season (75 DAS) only moderate control (57.14%) 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 0.4 kg a.e ha^{-1} reduced *Striga* emergence by 92.8% and 58.3%, 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%, respectively. The corresponding figures for the higher herbicide rate were 92.86% and 71.43%, respectively.

Effects of triclopyr, nitrogen and their combinations

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%, respectively (Table 2). Triclopyr, alone, at 0.3 and 0.4 kg a.e ha^{-1} reduced SDW by 89.7% and 94.1%, 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%, respectively. Triclopyr

Table 1 Effects of triclopyr, nitrogen and their combinations on *Striga emergence*

Triclopyr Kg a.e ha^{-1}	*Striga emergence (plants/pot) (DAS)*								
	45			*60*			*70*		
	0N	*1N*	*2N*	*0N*	*1N*	*2N*	*0N*	*IN*	*2N*
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**			0.50NS				0.96*	
Try	0.090**			2.18**				0.39NS	
N*Try	0.081**			3.37**				0.22**	

Note: ± = Standard errors of means. Means within a column having the same superscript(s) are not significantly different according to LSD test.
* = P ≤ 0.05; ** = P ≤ 0.01; 1N = nitrogen at 43.8; 2N = nitrogen at 87.6 kg ha^{-1}; Try = Triclopyr; NS = Non-significant.

Table 2 Effects of triclopyr, nitrogen and their combinations on SDW

Triclopyr kg a.e ha^{-1}	*Striga dry wt (g)*		
	0N	*1N*	*2N*
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**		

Note: ± = Standard errors of means. Means within a column having the same superscript letter(s) are not significantly different according to LSD test.

* = $P \leq 0.05$; ** = $P \leq 0.01$; 1N = nitrogen at 43.8; 2N = nitrogen at 87.6 kg ha^{-1}; Try = Triclopyr; NS = Non-significant.

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%, 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 3). Early in the season, nitrogen, alone, at 43.8 and 87.6 kg ha^{-1} increased sorghum height by18.11% and 12.72%. The corresponding increments late in the season were 7.75% and 4.92%, respectively. Triclopyr alone, irrespective of rate, increased sorghum height by12.63% and 10.11% early in the season and by 4.78% and 12.55% late in the season. The herbicide, when applied subsequent to nitrogen, increased sorghum height by 16.27% and 14.8% early in the season and by 4.62% and 2.90% late in the season.

Table 3 Effects of triclopyr, nitrogen and their combinations on sorghum height

Triclopyr Kg a.e ha^{-1}	*Sorghum Height (cm) (DAS)*								
	45			*60*			*70*		
	0N	*1N*	*2N*	*0N*	*1N*	*2N*	*0N*	*IN*	*2N*
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 *			0.108^{NS}				0.108^{NS}	
Try	0.71^{NS}			0.297^{NS}				0.297^{NS}	
N*Try	0.87*			0.117^{NS}				0.117^{NS}	

Note: ± Standard errors of means. Means within a column having the same superscript letter(s) are not significantly different according to LSD test.

* = $P \leq 0.05$; 1N = nitrogen at 43.8; 2N = nitrogen at 87.6 kg ha^{-1}; Try = Triclopyr; NS = Non-significant.

Effects of triclopyr, nitrogen and their combinations

Number of leaves: all treatments effected a higher number of leaves in comparison to the *Striga* infested control (Table 4). At 45 DAS nitrogen alone at 43.8 and 87.6 kg ha^{-1} increased the number of leaves by 30.83% and 37%, over the *Striga* infested control. The corresponding increments in number of leaves at 60 DAS were 17.19% and 49.58%, 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% at 45 DAS and by 5.63% and 41.7%, 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%, at 45 DAS and by 47.23% and 42.68%, at 60 DAS. The corresponding figures for the herbicide at the higher rate were 17.38% and 22.5%, at 45 DAS and 50.7% and 52.11%, at 60 DAS.

Table 4 Effects of triclopyr, nitrogen and their combinations on sorghum number of leaves

Triclopyr Kg a.e ha^{-1}	*Number of leaves (DAS)*					
	45			60		
	0N	*1N*	*2N*	*0N*	*1N*	*2N*
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^{**}	

Note: ± Standard errors of means. Means within a column having the same superscript letter(s) are not significantly different according to LSD test.

* = $P \leq 0.05$; ** = $P \leq 0.01$; 1N = nitrogen at 43.8; 2N = nitrogen at 87.6 kg ha^{-1}; Try = Triclopyr; NS = Non-significant.

Effects of triclopyr, nitrogen and their combinations

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% at 45 DAS and by 53.7% and 57.9% at 60 DAS, respectively (Table 5). Triclopyr, alone at 0.3 and 0.4 kg a.e. ha^{-1} increased sorghum leaves chlorophyll content by 47.03% and 39.83% at 45 DAS and by 54.33% and 54.07% 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% at 45 and 53.68% and 49.18% at 60 DAS. The corresponding increments for the higher rate were 51.55% and 45.47% at 45 DAS and 48.36% and 51.59% at 60 DAS, respectively.

DISCUSSION

The results revealed that nitrogen alone completely suppressed *Striga* emergence throughout the experiment (Table 1). 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

Table 5 Effects of triclopyr, nitrogen and their combinations on sorghum Chlorophyll content

Triclopyr Kg a.e ha^{-1}	*Chlorophyll content (DAS)*					
	45			*60*		
	0N	*1N*	*2N*	*0N*	*1N*	*2N*
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**	

Note: ± Standard errors of means. Means within a column having the same superscript letter(s) are not significantly different according to LSD test.

* = $P \leq 0.05$; ** = $P \leq 0.01$; 1N = nitrogen at 43.8; 2N = nitrogen at 87.6 kg ha^{-1}; Try = Triclopyr; NS = Non-significant.

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%, plant height by 21.9–42.7%, and increased sorghum growth as reflected by the increments in number of leaves and by 48.3–27.7% and chlorophyll content by 44.3–57.9% (Tables 2–5 and 6).

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 ($P \leq 0.05$) 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 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 1).

Triclopyr at 0.3 and 0.4 kg a.e ha^{-1} reduced SDW by 89.7–94.1%. The combinations of triclopyr and nitrogen showed inconsistent effects (Table 2). Triclopyr at 0.4 kg a.e ha^{-1} in combinations with nitrogen at 43.8 and 87 kg ha^{-1} effected 82.59% and 88.39% reductions in SDW, respectively. However, a notable increase in SDW (64.19%) was observed when triclopyr at the lower rate was applied to sub-plots previously treated with nitrogen at the lowest rate (Table 2). This finding is consistent with the observed increase in *Striga* emergence caused by the same treatment (Table 1). 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 3).

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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BIOGRAPHICAL NOTES

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