Influence of Nitrogen, Chlorsulfuron and Triclopyr on Management of Striga Hermonthica on Sorghum

Rashida Abusin[#1], Elfatih Ahmed[#2], Amani Hamad Eltayeb[#3] and A. G. T. Babiker[#4]
[#1]*University of Bahri, Pests and Plant Health, College of Agriculture, Khartoum, Sudan*
[#2]*Agricultural Research Corporation (ARC), Sudan*
[#3]*Sudan University of Science and Technology, College of Agricultural Studies,*
[#4]*Environment and Natural Resources and Desertification Research Institute.*

Abstract

*The witchweed, Striga hermonthica (Del.) Benth., is a major constraint to sorghum [*Sorghum bicolor *(L.) Moench] production in sub-Saharan Africa. The present investigation was undertaken at the College of Agricultural Studies, Sudan University of Science and Technology to determine the effects of nitrogen and the herbicides triclopyr, chlorsulfuron and their combinations on Striga incidence and sorghum (cv. Wad-Ahmed) growth and yield. The results showed that all treatments reduced emergence and dry weight of Striga. Chlorsulfuron at 2.38 g a.i ha^{-1} supplemented with nitrogen at 87.6 kg ha^{-1}, combination between triclopyr at 0.49 kg a.e.ha^{-1} and nitrogen at 87.6 kg ha^{-1} and combination between triclopyr at 0.73 kg a.e.ha^{-1} and nitrogen at 43.8 kg ha^{-1}, completely suppressed Striga emergence. Triclopyr, chlorsulfuron and their combinations caused considerable reductions in Striga dry weight (25.3-97.0%). All treatment had no effect on sorghum height. Chlorsulfuron at 2.38 g a.i ha^{-1} supplemented with nitrogen at two rates and triclopyr at 0.49 kg a.e. ha^{-1} in combination with chlorsulfuron and nitrogen at 43.8 kg ha^{-1} increased significantly sorghum head weight by 108.1-113.0%. The combination herbicides and nitrogen, irrespective of rates increased chlorophyll content, head volume and sorghum yield by 40.6-76.1%, 32.5-207.3% and 30.9-382.6%, respectively.*

Keywords - *Striga, nitrogen, triclopyr, chlorsulfuron, sorghum, yield*

I. INTRODUCTION

Sorghum bicolor *(L.) Moench is an important cereal grain for food and animal feed in the tropical, subtropical and temperate regions between latitudes 45°N and 45°S. It is grown in areas where it is too dry or where rainfall is too undependable for maize (Zea mays L.) production [1]. Sorghum is the fifth major cereal crop in the world [2]. It acts as a dietary a staple for millions of people living in 30 countries in the sub tropical and semi-arid regions of Africa and Asia [3].*

Sorghum is the largest crop in Sudan, whereas Sudan is one of the most important countries producing sorghum in the world. Sudan is the fifth country after China, India, USA and Nigeria in sorghum production worldwide. Sorghum is the most important crop and livestock feed [4].

Sorghum production is limited by both biotic and a biotic factors. The most important biotic factors limiting sorghum production are diseases, insect pests and the root parasitic weed *Striga* [5]. However, a biotic factors affecting sorghum production include drought, high temperature, low rainfall, wet weather at harvest, excessive rains and lodging [6].

Striga hermonthica (Del.) Benth, is a parasitic weed that infects cereal crops often causing 30-100% crop losses on farmers' fields [7].The witchweed, *Striga hermonthica* is a major constraint to maize and sorghum production in sub-Saharan Africa [8]. The parasitic weed, *Striga hermonthica* infects millions of hectares of arable land in sub-Saharan Africa, and it threatens production of cereal crops [9; 10]. *Striga hermonthica* problem aggravates in low soil fertility and under mineral nutrient deficiency, the sorghum host secretes large quantities of strigolactones, signalling molecules, into the rhizosphere. These induce *S. hermonthica* seed germination and subsequent infection of the host roots [11]. The parasite, beside its well-known devastating impacts on the most important food cereal crops in Africa, is deemed to be one of the main factors that threaten the food security in this continent [12]. Cereal crops with complete resistance to this pathogen have not been reported [13].

The control of parasitic weeds has proved to be extraordinarily difficult. Extraordinary seed production, prolonged viability and ease of distribution of the seeds together with the shallow nature of the early stages of parasitism make *Striga* a difficult to control weed [14]. However, several control methods have been researched with positive, but often inconsistent results across seasons and sites. These methods include cultural, biological and chemical methods and they are well reviewed by [5] and summarized by [15; 16; 14; 17 and 18].

II. MATERIALS AND METHODS

A field experiment was undertaken at the College of Agricultural Studies, (CAS), Shambat, University of Science and Technology, Sudan during the season 2011/2012. The experiment was designed to investigate the effects of nitrogen and the herbicides triclopyr, chlorsulfuron and their combinations on *Striga* incidence and sorghum (cv. Wad-Ahmed) growth and yield. Treatments were arranged in Complete Randomized Block Design (CRBD).

The experimental area was disc ploughed, harrowed, leveled, ridged and divided into sub-plots. All sub-plots were artificially infested with Striga hermonthica (Del.) Benth seeds. Striga seeds used in this study were collected from under sorghum in Gezira, Sudan. Inoculums were prepared by thorough mixing of 1g of clean Striga seeds with 1kg of soil. Inoculums were applied to the soil at time of sowing. Sorghum (Wad Ahmed) seeds, supplied by the Arab Seed Production Company, were treated with the fungicide Thiram. Seeds were sown in holes at a within row spacing of 20 cm. In experiments involving fertilization, nitrogen in form of urea was applied as broadcast by hand. Sorghum seedlings were thinned to two per hole, 15 days after emergence. The herbicide triclopyr as Garlon was applied 30 DAS by knapsack sprayer as aqueous spray. Weeds were removed by hand to avoid damaging emerged Striga plants at biweekly intervals for the first six weeks. Irrigation was applied when necessary throughout the duration of the trial.

Treatments effects, were assessed by determining i) Striga emergence ii) Striga dry weight iii) sorghum height 30, 45 and 90 DAS days after sowing (DAS), iv) sorghum head weight in g, v) sorghum head volume in ml, vi) Chlorophyll content and vii) grain yield in kg ha^{-1}.

Effects of nitrogen, triclopyr, chlorsulfuron and their combinations on Striga incidence and sorghum growth and yield

Nitrogen at 43.8 and 87.6 kg ha^{-1} was applied by broadcasting. Triclopyr at 0.49 and 0.73 kg a.e. ha^{-1} implemented alone. Chlorsulfuron 2.38 g a.i ha^{-1} implemented alone. The combinations triclopyr at 0.49 a.e ha^{-1} and nitrogen at 43.8 and 87.6 kg ha^{-1}. The combinations triclopyr at 0.73 kg a.e. ha^{-1}and nitrogen at 43.8 and 87.6 kg ha^{-1}. The combinations triclopyr at 0.49 a.e ha^{-1}, Chlorsulfuron at 1.19 and nitrogen at 43.8 and 87.6 kg ha^{-1} were applied 30 days after sowing.

III. STATISTICAL ANALYSIS

Data collected from the experiment was subjected to statistical analysis using GenStat (PC/Windows 7), VSN International Ltd., UK statistical package (Rothamsted Experimental Station). Means were separated for significance using Least Significant Difference (LSD).

IV. RESULTS

A. *Effects on Striga*

1) *Striga Emergence*

Statistical analysis showed highly significant differences in number of *Striga* between treatments. Untreated control displayed highest number of *Striga* (19 plants/m^2**)**. All treatments reduced emergence of the *Striga* in comparison to the untreated control (Table1) Chlorsulfuron at 2.38 g a.i ha^{-1} supplemented with nitrogen at 87.6 kg ha^{-1}, combination between triclopyr at 0.49 kg a.e.ha^{-1} and nitrogen at 87.6 kg ha-^{1} and combination between triclopyr at 0.73 kg a.e.ha^{-1} and nitrogen at 43.8 kg ha^{-1}, completely suppressed *Striga* emergence (Table 1). However, chlorsulfuron at 2.38 g a.i ha^{-1}, in combination with nitrogen at 43.8kg ha^{-1}, triclopyr at 0.49 kg a.e. ha^{-1} alone or in combination with nitrogen at 43.8 kg ha^{-1}, triclopyr at 0.49 kg a.e. ha^{-1} tank mixed with chlorsulfuron and nitrogen at 87.6 kg ha^{-1} and triclopyr at 0.73 kg a.e. ha^{-1} alone or in supplementation with nitrogen at 87.6 kg ha^{-1}, reduced significantly *Striga* emergence by 94.7%, as compared to the untreated control (Table 1). Chlorsulfuron alone, triclopyr at 0.49 kg a.e. ha^{-1} tank mixed with chlorsulfuron at 1.19 g a.i ha^{-1} and or supplemented with nitrogen at 87.6 kg ha^{-1} decreased *Striga* emergence by 84.2 and 73.7%, respectively (Table 1).

Table I. Effects of Chlorsulfuron, Nitrogen and Their Combinations on Striga Emergence

Treatments	***Herbicide rate ha^{-1}***	***Striga emergence (plants/m^2)***
Untreated control	-	4(19)^a
Chlor. [i]	2.38	1(3)^b
Chlor.+1N	2.38	1(1)^b
Chlor.+2N	2.38	1(0)^b
Tr. [ii]	0.49	1(1)^b
Tr.+1N	0.49	1(1)^b
Tr.+2N	0.49	1(0)^b
Tr+Chlor.	0.49+1.19	2(5)^b
Tr.+Chlor.+1N	0.49+1.19	2(5)^b
Tr.+Chlor.+2N	0.49+1.19	1(1)^b
Tr.	0.73	1(1)^b
Tr.+1N	0.73	1(0)^b
Tr.+2N	0.73	1(1)^b
P ≤ 0.05	**-**	**0.001*****
CV%	**-**	**46.7**

Note: Means within a column having the same superscript letter(s) are not significantly different according to lsd test. Bracketed data are real. ***= p ⩽ 0.001. [I] = chlorsulfuron/ g a.i. ha^{-1}. [I i] =

triclopyr/kg a.e ha^{-1}, 1n= nitrogen at43.8 kg ha^{-1} 2n= nitrogen at 87.6 kg ha^{-1}.

2) *Striga Dry Weight*:

Untreated control achieved highest *Striga* dry weight (43.1 g). Chlorsulfuron alone, or in combination with nitrogen at 43.8 and 87.6 kg ha^{-1} reduced *Striga* dry weight by 73.1, 85.2 and 97.0%, respectively (Table 2). Triclopyr, alone, at 0.49 and 0.73 a.e. ha^{-1} reduced *Striga* dry weight by 68.9 and 75.6%, respectively, as compared to the untreated control. Triclopyr at 0.49 a.e. ha^{-1} in combination with nitrogen at 43.8 and 87.6 kg ha^{-1} reduced *Striga* dry weight by 96.1 and 93.7%, respectively. The corresponding figures for the higher herbicide rate (0.73 a.e. ha^{-1}) were 77.7% and 74.2%, respectively (Table 2). Triclopyr at 0.49 kg a.e. ha^{-1}, tank mixed with chlorsulfuron at 1.19 g a.i ha^{-1}, reduced *Striga* dry weight and the observed reduction was considerable (74.2%). The combination triclopyr at 0.49 kg a.e. ha^{-1}, chlorsulfuron at 1.19 g a.i ha^{-1} and nitrogen at 43.8 kg ha^{-1} caused slight reduction in *Striga* dry weight (25.3%). However, increasing nitrogen rate to 87.6 kg ha^{-1}, increased the reduction to 76.6% (Table 2).

Table II. Effects of Chlorsulfuron, Nitrogen and Their Combinations on Striga Dry Weight

Treatments	***Herbicide rate ha^{-1}***	***Striga dry wt/g***
Untreated control	-	6.8(43.1)
Chlor.^{i}	2.38	4.4(11.6)
Chlor.+ 1N	2.38	4.0(6.4)
Chlor.+ 2N	2.38	3.4(1.3)
Tr.^{ii}	0.49	4.7(13.4)
Tr. + 1N	0.49	3.4(1.7)
Tr. + 2N	0.49	3.6(2.7)
Tr. + Chlor.	0.49+1.19	4.5(11.1)
Tr. + Chlor.+1N	0.49+1.19	6.3(32.2)
Tr. + Chlor.+2N	0.49+1.19	4.2(10.1)
Tr.	0.73	4.3(10.5)
Tr. + 1N	0.73	4.1(9.6)
Tr. + 2N	0.73	4.4(11.1)
P ≤ 0.05	-	**NS**
CV%	-	**32.9**

Note: Means within a column having the same superscript letter(s) are not significantly different according to LSD test. Bracketed data are real. NS = Non significant. ***= P ≤ 0.001. ^{i} = Chlorsulfuron/ g a.i. ha^{-1}. ^{ii} = Triclopyr/kg a.e ha^{-1}, 1N= Nitrogen at43.8 kg ha^{-1} 2N= Nitrogen at 87.6 kg ha^{-1}.

3) *Plant Height*

At 90 DAS sorghum height, did not show significant differences between treatments (Table 3). Triclopyr at 0.49 and 0.73 kg a.e ha^{-1} when combined with nitrogen at 87.6 kg ha^{-1}, displayed the highest plant height (124 cm), however, triclopyr at 0.73 kg a.e ha^{-1} supplemented with nitrogen at 43.8 kg ha^{-1} sustained the lowest (106.6 cm). Untreated control and chlorsulfuron at 2.38 g a.i ha^{-1}, alone or in combination with nitrogen at 87.6 kg ha^{-1}, displayed comparable sorghum height (Table 3). Chlorsulfuron at 2.38 g a.i ha^{-1} supplementation with nitrogen at lower rate and the combination between triclopyr at 0.49 kg a.e. ha^{-1}, chlorsulfuron at 1.19 g a.i ha^{-1} and nitrogen at 87.6 kg ha^{-1} displayed slight increase in sorghum height, but not significantly, as compared to the untreated control (Table 3).

Table III. Effects of Chlorsulfuron, Nitrogen and their Combinations on Sorghum Chlorophyll Content

Treatments	***Herbicide rate ha^{-1}***	***Chlorophyll content /plant***
Untreated control	-	21.98^{b}
Chlor.^{i}	2.38	30.88^{a}
Chlor.+ 1N	2.38	33.68^{a}
Chlor.+ 2N	2.38	38.38^{a}
Tr.^{ii}	0.49	33.08^{a}
Tr. + 1N	0.49	34.55^{a}
Tr. + 2N	0.49	33.75^{a}
Tr. + Chlor.	0.49+1.19	32.50^{a}
Tr. + Chlor.+1N	0.49+1.19	35.55^{a}
Tr. + Chlor.+2N	0.49+1.19	38.55^{a}
Tr.	0.73	34.40^{a}
Tr. + 1N	0.73	36.18^{a}
Tr. + 2N	0.73	32.98^{a}
P ≤ 0.05	-	**0.04***
CV%	-	**16.6**

Note: Means within a column having the same superscript letter(s) are not significantly different according to LSD test. *= P ≤ 0.05. ^{i} = Chlorsulfuron/ g a.i. ha^{-1}. ^{ii} = Triclopyr/kg a.e ha^{-1}, 1N= Nitrogen at43.8 kg ha^{-1} 2N= Nitrogen at 87.6 kg ha^{-1}.

4) *Chlorophyll Content*

Untreated control resulted significant the lowest sorghum chlorophyll content per plant (Table 4). However, all Treatments showed significant increment in sorghum chlorophyll content when compared to the untreated control and the observed increment was considerable (40.6-76.1%).

Table IV. Effects of Chlorsulfuron, Nitrogen and their Combinations on Sorghum Height

Treatments	***Herbicide rate ha-1***	***Sorghum height (cm)***
		90 (DAS)
Untreated control	-	114.8
Chlor.^{i}	2.38	114.3
Chlor.+ 1N	2.38	120.1
Chlor.+ 2N	2.38	114.8
Tr.^{ii}	0.49	118.0
Tr. + 1N	0.49	119.2
Tr. + 2N	0.49	124.3
Tr. + Chlor.	0.49+1.19	116.8
Tr. + Chlor.+1N	0.49+1.19	121.4
Tr. + Chlor.+2N	0.49+1.19	121.2
Tr.	0.73	117.0
Tr. + 1N	0.73	106.6
Tr. + 2N	0.73	123.5
P ≤ 0.05	-	**NS**

CV%	-	**11.0**

Note: Means within a column having the same superscript letter(s) are not significantly different according to LSD test. NS = Non significant. i = Chlorsulfuron/ g a.i. ha-1 . ii = Triclopyr/kg a.e ha-1, 1N= Nitrogen at43.8 kg ha-1 2N= Nitrogen at 87.6 kg ha-1.

B. Sorghum Head Attributes

1) Head weight

Untreated control and the combination between triclopyr at 0.49 kg a.e ha^{-1} with nitrogen at 87.6 kg ha^{-1} displayed the lowest head weight (Table 5). Chlorsulfuron at 2.38 g a.i ha^{-1} supplemented with nitrogen at two rates and triclopyr at 0.49 kg a.e. ha^{-1} in combination with chlorsulfuron and nitrogen at 43.8 kg ha^{-1} increased significantly sorghum head weight by 108.1-113.0%, as compared to the untreated control (Table 5).

Triclopyr at 0.49 kg a.e. ha^{-1}, alone or in supplementation with nitrogen at 43.8 kg ha^{-1}, and triclopyr at 0.73 kg a.e. ha^{-1} combination with nitrogen at 43.8 kg ha^{-1}, increased sorghum head weight by 81.8, 80.8 and 94.9%, albeit not significantly, as compared to the untreated control (Table 5). Other Treatments including chlorsulfuron alone, triclopyr at 0.49 kg a.e. ha^{-1}' when tank mixed with chlorsulfuron at 1.19 g a.i ha^{-1}, triclopyr at 0.49 kg a.e. ha^{-1} in combination with chlorsulfuron at 1.19 g a.i ha^{-1} and nitrogen at 87.6 kg ha^{-1} and triclopyr at 0.73 kg a.e. ha^{-1} alone or in combination with nitrogen at 87.6 kg ha^{-1}, displayed considerable increment in sorghum head weight (30.3- 76.8%).

2) Head volume

Untreated control sustained lowest head volume (8.3/ml). Chlorsulfuron at 2.38 g a.i ha^{-1} in combination with nitrogen at two rates, triclopyr at 0.49 kg a.e. ha^{-1} alone or in combination with chlorsulfuron at 1.19 g a.i ha^{-1} and nitrogen at 43.8 kg ha^{-1} and triclopyr at 0.73 kg a.e. ha^{-1} in combination with nitrogen at 43.8 kg ha^{-1} increased head volume significantly by 173.5, 204.8, 151.8, 192.8 and 207.2%, respectively, over the untreated control (Table 5).

Triclopyr at 0.49 kg a.e. ha^{-1}in combination with nitrogen at 43.8 kg ha^{-1} or tank mixed with chlorsulfuron at 1.19 g a.i ha^{-1}, triclopyr at 0.49 kg a.e. ha^{-1} when tank mixed with chlorsulfuron at 1.19 g a.i ha^{-1} and supplemented with nitrogen at 87.6 kg ha^{-1} and triclopyr at 0.73 kg a.e. ha^{-1} alone or in supplementation with nitrogen at 87.6 kg ha^{-1}, resulted in non-significant increment in sorghum head volume as compared to the untreated control. However, the observed increment was considerable (74.7-113.3%). Chlorsulfuron alone and triclopyr at 0.49 kg a.e. ha^{-1}in combination with nitrogen at 87.6 kg ha^{-1}, increased sorghum head volume by 32.5 and 38.6%, respectively, but not significantly, as compared to the control (Table 5).

Table V. Effects of Chlorsulfuron, Triclopyr, Nitrogen and Their Combinations on Sorghum Head Attributes

Treatments	***Herbicide rate ha-1***	***Head Attributes***	
		Weight/g	***Volume/ml***
Untreated control	-	9.9	8.3
Chlor. [i]	2.38	15.3	11.0
Chlor.+ 1N	2.38	20.6	22.7
Chlor.+ 2N	2.38	20.7	25.3
Tr. [ii]	0.49	18.0	20.9
Tr. + 1N	0.49	17.9	15.0
Tr. + 2N	0.49	9.7	11.5
Tr. + Chlor.	0.49+1.19	15.7	14.5
Tr. + Chlor.+1N	0.49+1.19	21.1	24.3
Tr. + Chlor.+2N	0.49+1.19	17.5	17.7
Tr.	0.73	12.9	14.5
Tr. + 1N	0.73	19.3	25.5
Tr. + 2N	0.73	15.4	17.3
$P \leq 0.05$	-	**NS**	**NS**
CV%	-	**44.5**	**47.5**

Note: Means within a column having the same superscript letter(s) are not significantly different according to LSD test.. NS = Non significant [i] = Chlorsulfuron/ g a.i. ha^{-1} . [ii] = Triclopyr/kg a.e ha^{-1}, 1N= Nitrogen at43.8 kg ha^{-1} 2N= Nitrogen at 87.6 kg ha^{-1}.

3) Sorghum Yield

As general, all treatments increased sorghum yield in comparison to the untreated control (Table 6). Triclopyr at 0.49 kg a.e. ha^{-1}, tank mixed with chlorsulfuron and supplementation with nitrogen at 87.6 kg ha^{-1}displayed highest sorghum yield (892.8 kg /ha^{-1}). Chlorsulfuron at 2.38 g a.i ha $^{-1}$ in combination with nitrogen at 87.6 kg ha^{-1}, and triclopyr at 0.73 kg a.e. ha^{-1} in combination with nitrogen at 43.8 kg ha^{-1} increased sorghum yield significantly by 184.2 and 168.3%, respectively, as compared to untreated control (Table 6). Sorghum yield increased by 70.3-132.1%, when applied with chlorsulfuron at 2.38 g a.i ha^{-1} in combination with nitrogen at 43.8 kg ha^{-1}, triclopyr at 0.49 kg a.e. ha^{-1}, alone or in combination with nitrogen at two rates or tank mixed with chlorsulfuron at 1.19 g a.i ha^{-1}. However, the observed increment was not significant (Table 6). Chlorsulfuron alone and triclopyr at 0.73 kg a.e. ha^{-1} caused considerable increment in sorghum yield. Triclopyr at 0.49 kg a.e. ha^{-1} in combination with chlorsulfuron at 1.19 g a.i ha^{-1} and nitrogen at 43.8 kg ha-1 and triclopyr at 0.73 kg a.e. ha^{-1} combination with nitrogen at 87.6 kg ha^{-1}, increased sorghum yield by 32.3 and 30.3%, respectively, albeit not significantly (Table 6).

Table VI. Effects of Chlorsulfuron, Nitrogen and Their Combinations on Sorghum Yield

Treatments	***Herbicide rate ha-1***	***Yield kg /ha-1***
Untreated control	-	185.0^{d}
Chlor. ^{i}	2.38	292.1 ^{bcd}
Chlor.+ 1N	2.38	429.3^{bcd}
Chlor.+ 2N	2.38	525.7^{b}
Tr. ^{ii}	0.49	315.0 ^{bcd}
Tr. + 1N	0.49	341.9 ^{bcd}
Tr. + 2N	0.49	408.6^{bcd}
Tr. + Chlor.	0.49+1.19	332.1 ^{bcd}
Tr. + Chlor.+1N	0.49+1.19	244.8^{cd}
Tr. + Chlor.+2N	0.49+1.19	892.8^{a}
Tr.	0.73	290.5 ^{bcd}
Tr. + 1N	0.73	496.4^{bc}
Tr. + 2N	0.73	242.1^{cd}
$P \leq 0.05$	-	**0.001*** **
CV%	-	**50.3**

V. CONCLUSIONS

The herbicides chlorsulfuron and triclopyr, irrespective of rates, effected considerable significant reductions in *Striga hermonthica* infestation. Nitrogen as urea, at 43.8 (1N) and 87.6 (2N) kg ha^{-1}, when combined with chlorsulfuron, triclopyr or combined with their tank mixtures, showed excellent performance (Table1). Chlorsulfuron at 2.38g a.i ha^{-1} supplemented with nitrogen at 87.6 kg ha^{-1}, combination between triclopyr at 0.49 kg a.e.ha^{-1} and nitrogen at 87.6 kg ha^{-1} and combination between triclopyr at 0.73 kg a.e.ha^{-1} and nitrogen at 43.8 kg ha^{-1}, completely suppressed *Striga* emergence (Table1). However, chlorsulfuron at 2.38 g a.i ha^{-1}, in combination with nitrogen at 43.8.8 kg ha^{-1}, triclopyr at 0.49 kg a.e. ha^{-1} alone or in combination with nitrogen at 43.8 kg ha^{-1}, triclopyr at 0.49 kg a.e. ha^{-1} tank mixed with chlorsulfuron and nitrogen at 87.6 kg ha $^{-1}$ and triclopyr at 0.73 kg a.e. ha^{-1} alone or in supplementation with nitrogen at 87.6 kg ha^{-1}, effected excellent suppression of the parasite (94.7%). Triclopyr at 0.49kg a.e. ha^{-1} tank mixed with chlorsulfuron 1.19 g a.i ha^{-1} and or supplemented with nitrogen at 87.6 kg ha^{-1} tended to be less suppressive to the parasite than chlorsulfuron alone (Table 1). Triclopyr, chlorsulfuron and their combinations caused considerable reductions in *Striga* dry weight by 25.3-97.0%.

Chlorsulfuron is acetolactate synthase (ALS) inhibitor [19; 20]. The herbicide inhibits synthesis of the branched amino acids L-leucine, L- isoleucine and L-valine, and thus may interfere with protein synthesis and cell division [21]. These findings indicate clearly that chlorsulfuron, triclopyr, nitrogen and their combinations reduced *Striga* emergence. These findings are in agreement with those previously reported by 22; 23; 24; 25; 26 and 27. Triclopyr, as a pyridinloxy, is a selective herbicide that mimics the effects of plant hormones. It is used for the control of undesirable woody and herbaceous weeds.

Nitrogen is reported to decrease stimulant production by sorghum [27; 28] and this is consistent with the recently emerging knowledge that *Striga* germination stimulants (strigolactones) are the mycorrhizal branching factor and that their production is enhanced by low soil fertility. Mycorrhizal infestation is reported to down regulate strigolactones production [29]. Furthermore, nitrogen is reported to have direct toxic effects on Striga at the early stages of parasitism [5]. The parasite at early developmental stages is reported to display low activity of both NO-3 and NO-2 reductases and accordingly accumulation of both NO-3 and NO-2 and possibly ammonia may contribute to the observed reduction in Striga emergence early in the season [5].

All treatments had no effect on sorghum height. Chlorsulfuron at 2.38g a.i ha^{-1} supplemented with nitrogen at two rates and triclopyr at 0.49 kg a.e. ha^{-1} in combination with chlorsulfuron and nitrogen at 43.8 kg ha^{-1} increased significantly sorghum head weight by 108.1-113.0%. The combination herbicides and nitrogen, irrespective of rates, increased chlorophyll content, head volume and sorghum yield by 40.6-76.1%, 32.5-207.3% and 30.9-382.6%, respectively.

This could be attributed to the effect of nitrogen, chlorsulfuron, triclopyr and their combinations that all treatments had a negative effect on striga emergence which positively affects sorghum growth and yield, and that means the crop benefited from the reduction in the parasite infection. Nevertheless, the possibility of interplay of multiple effects due to repression of Striga germination stimulant production by nitrogen, a direct toxic effect of nitrogen on the parasite and/or improvement of crop growth may account, at least in part, for the observed increase in grain yield.

These results, which are in line with those obtained with chlorsulfuron and those previously reported by Last [30] and Last [31] for nitrogen, indicate clearly the consistency in performance of the combinations of the herbicides and nitrogen.

ACKNOWLEDGEMENT

The authors are indebted to the JST/JICA SATREPS (Japan Science and Technology Agency, Tokyo Japan and International Cooperation Agency, Tokyo, Japan) for financial support.

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