Effects of Chlorsulfuron 75% WDG Herbicide and Varieties on Striga Control and Sorghum Yield in Tigray, Ethiopia

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Authors’ contributions

Both authors designed, analysed, interpreted and prepared the manuscript.

ABSTRACT

Sorghum [Sorghum bicolor (L.)Moench] is widely cultivated but the productivity is very low due to different factors such as Striga hermonthica. Field trials were carried out at Humera location to determine the management of striga to different rates of herbicide application to increase sorghum yield during 2017 cropping season. The trail consisted of eight treatments; 0 (control), 10, 15 and 20 g ha⁻¹ rates of Chlorsulfuron. The herbicide rates were assigned to the main plot while sorghum varieties were assigned to subplots, replicated three times in a split plot design. The data of days to 50% emergence, 50% flowering, plant height at maturity, Panicle length, panicle weight (g), yield per panicle (g), 1000 seed weight (g), grain yield (kg ha⁻¹), above ground dry biomass (kg ha⁻¹) and striga data days to first striga emergence, days to first flowering, number of striga count, branch number per striga plant, striga count per sorghum plant, striga height and biomass (kg/m²) respectively. Partial budget analysis was computed to assess the economic visibility of herbicide application where recorded. Result showed that application of herbicide rates and varieties increased plant height, panicle length, number of heads harvested per plot, panicle weight, yield per panicle, 1000 seed weight and grain yield over the control. Maximum grain yield (3725 kg ha⁻¹) was obtained from application of 15 g ha⁻¹ Chlorsulfuron with variety Deber. Days to first flowering, striga count per sorghum plant, stand counts of striga at 45DAP, 65 DAP and 85DAP M⁻², branch number per plant, plant height and biomass of striga were significantly (P<0.01) affected with the

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application of herbicide rates and varieties. The partial budget showed that an investing of 1.0 birr on application of herbicide with varieties earn 2.34 birr. Generally, application of Chlorsulfuron 75% WDG and use local variety with high yielder could be an advantage to obtain highest yield and profit for the farmers in striga infestation areas.

Keywords: Sorghum bicolor; Striga hermonthica; herbicide; varieties and sorghum yield.

1. INTRODUCTION

Agriculture in Ethiopia is considered as primary activity where about 84% of the country’s population has been engaged in and generates its income for household consumption to sustain its livelihood [1]. Sorghum [Sorghum bicolor (L.) Moench], belongs to the grass family, Gramineae. It is the second most important crop in Africa after maize with 22% of total cereal area coverage, followed by millets (pearl and finger millets) with 19% of total cereal land coverage [2].

Sorghum in Ethiopia has wider geographical adaptation, from lowlands to highlands than any other cereals. This indicates that the country is a center of diversity for the crop [3]. Sorghum in Ethiopia is annually cultivated over 1.83 million hectares contributing to 4.35 million tons to annual grain production in the country [1]. More than 70% of the sorghum in East Africa is cultivated in the dry and hot lowland areas where there is low soil fertility, poor stand establishment, serious water deficit and other biotic and abiotic stresses which constraints production and productivity of the crop.

Striga hermonthica is the most widely distributed and devastating species in Northern Ethiopia and is severely affecting sorghum yield. This weed shows greatest diversity in morphology and behavior attacking exceptionally wide range of crops as compared to other striga spp. found in any other sub-Saharan Africa countries [4].

Striga (witch weed) and drought are the most economically important constraints across regions [5]. More than 80% crop damage due to Striga hermonthica is accomplished before the striga weed starts emerging aboveground soil cover, while most of management practices are undergoing to be applied after the parasitic weed (Striga hermonthica) starts to emerge aboveground cover.

Controlling this weed is a massive assignment considering the seed production capacity of 10,000-100,000 seeds/plant which remains viable in the soil for many years till getting favorable conditions to initiate germination [6] and, their intimate physiological interaction with their host plants [7], the weed causes damage to crop before emergence and its ability to thrive best in poor soil fertility. However, several control methods have been tried and developed for the control of this parasitic weed in the globe which includes; crop rotation, trap and catch cropping, hand-pulling, nitrogen fertilization, intercropping, solarization, chemical (herbicides and or artificial seed germination stimulants, e.g. ethylene, strigol analogue), use of resistant varieties, biological and integrated striga management. Development of herbicide resistant varieties and use of herbicide seed treatments in integrated striga control systems has shown promise for striga management in maize [8]. However data on integrated approach for managment striga in the mandate area is limited. Hence, this study was designed to test the integrated approach of striga management options using herbicide and Varieties. The objective of this study were to i) evaluate the effect of herbicide application rate (chlorsulfuron 75%) for controlling striga and yield improvement, ii) evaluate the interaction effect of herbicide application rate and different varieties on sorghum yield iii) to assess the economic visibility of herbicide application.

2. MATERIALS AND METHODS

2.1 Experimental Location

The experiment was conducted at Humera Agricultural Research Center (HuARC), Tigray, Northern part of Ethiopia during 2017. The center is about 1372 km away from Addis Ababa and 600 km west of Mekelle, which is the capital city of Tigray Regional State. It is located at 14°15’ N latitude and 36°37’ E longitude with an average altitude of 609 meters above sea level. The mean annual rainfall is 443.5 mm. Most of the rainfall is concentrated during summer (June – September).

2.2 Experimental Design and Treatments

The experimental design used was Split plot design with three replications and combination of twelve treatments (four herbicide rates in main plot and three varieties in sub plot). Those
treatments were 0g (control), 10g, 15g, 20g and Brhan resistance, (Deber local) and (wediaker local). The gross plot size was 15m² and the net plot size was 9m². The distance between the plot and block was 1and 2m, respectively. Sorghum seed was sown at row to row and plant to plant distance 75cm and 20cm, respectively. The plots were laid out and leveled manually. One and 1.5 m distances were maintained between each plot and each block respectively. The herbicide was dilutes by the recommended water (200 liter ha⁻¹) and sprayed three weeks after emergence of the crop to the soil. Due to the need to monitor striga emergence without obstruction and quantify the effect of Striga only, plots were kept free of other weeds by repeated hoe and hand weeding at all growth stages.

The experimental plots were thinned to optimum plant density a week after emergence. All the experimental units were receiving all the other management practices equally.

2.3 Measurements

Phonology and Agronomic Trait of Sorghum: phonology data including days to emergence, days to flowering and days to maturity were recorded based on researcher’s observation. Plant height, panicle length; panicle weight and yield per panicle were measured from five plants per plot. Total biomass was measured for all plant parts above ground in each plot. While, thousand seed weight was determined by counting 1000 seeds from each plot after threshing and grain yield of each plot weighed in grams converted to hectare. Finally, striga count at 45, 65, and 85days after planting, and days to striga emergence, days to flowering, number of branch, striga plant height and biomass of striga were recorded.

2.4 Economic Analysis

The partial budget as reported by [9] was analyzed on grain yield of sorghum crop in order to estimate the costs and benefits associated with different treatment. Economic analysis was made using the prevailing inputs at planting and for outputs at the time crop was harvested. All costs and benefits were calculated on hectare basis in Ethiopian Birr (Birr ha⁻¹). Grain yield was adjusted down by 10% to minimize the effect researcher managed small plots as compared to the farmers managed. The following concepts were used in the partial budget analysis [9]. The net benefit ha⁻¹ (NB) for each treatment is the difference between the gross benefit and the total variable costs. For each pair of treatments, a percent marginal rate of return (MRR) was calculated. [9] Reported that the % MRR between any pair of treatments denotes the return per unit of investment in fertilizer and herbicide expressed as a percentage.

MMR was calculated using the following formulas

Gross benefit = yield return x price
Net profit = gross benefit – total cost that vary
MRR = change in net benefit/ total variable costs

2.5 Data Analysis

The data collected from each experimental plot were subjected to analysis using appropriate software (Genstat 19). Treatments that show significant difference were subjected to mean comparison test, Duncan multiple range test (DMRT).

3. RESULTS AND DISCUSSION

3.1 Effect of Herbicide on Phenology and Agronomic Trait of Sorghum

3.1.1 Days to 50% flowering

The current finding showed significant (P<0.001) effect on days to 50% flowering. Chemical herbicide rates (10, 15 and 20g ha⁻¹) and the control (0g) with Birhan variety was flowered 7.59 days earlier than all levels of herbicid (0, 10, 15 and 20 g ha⁻¹ chlorsulfron) application with Deber variety. This indicates that chlorsulfron application had no effect on flowering of sorghum varieties rather the difference was due to the variety difference. Birhan variety needs short time to flowering vis-à-vis the Deber variety.

3.1.2 Days to 95% maturity

Herbicide rates and sorghum varieties in this study showed highly significance difference (P<0.001) on days to 50% flowering. Chemical herbicide rates (10, 15 and 20 g ha⁻¹) and the control (0g) with Birhan variety was flowered 7.59 days earlier than all levels of herbicid (0, 10, 15 and 20 g ha⁻¹ chlorsulfron) application with Deber varitey. This indicates that chlorsulfron application had no effect on flowering of sorghum varieties rather the difference was due to the variety difference. Birhan varety needs short time to flowering vis-à-vis the Deber variety.

3.1.3 Plant Height (cm) and panicle length (cm)

Herbicide rates and sorghum varieties in this study showed highly significance difference (P<0.001) on days to 95% maturity. The longest period taken for maturity (117days) (Table 2) was recorded from application 10g ha⁻¹ chlorsulfron Deber variety but all rates of chlorsulfron including control on Deber variety delays maturity and statically similar with Wedi-aker variety.

3.1.3 Plant Height (cm) and panicle length (cm)

The interaction of herbicide rates and varieties showed highly significance (P < 0.01) on plant height of sorghum (Table 1). chlorsulfron rates
Table 1. Integration effects of herbicide rate and variety on yield and yield component of sorghum

| Treatments                      | DF        | DM        | PH        | PL        | NH        | PW        | PY        | 1000SW | GY (kg/ha) |
|---------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|--------|------------|
| chlorsulfuron@0g ha⁻¹, Brihan   | 62.58b    | 95.2c     | 82.98e    | 21.47ab   | 54.92cd   | 18.06d    | 11.09f    | 15.43a | 2721def    |
| chlorsulfuron@0g ha⁻¹, Deber    | 70.17a    | 109.5abc  | 109.2abc  | 20.65ab   | 67.5b     | 30.01abc  | 19.06abc  | 13.27a | 2977bc     |
| chlorsulfuron@0g ha⁻¹, Wedi-aker| 65.5ab    | 102.2bc   | 97.8cd    | 15.4c     | 50.42d    | 20.37de   | 12.83de   | 11.17b | 2242g      |
| Chlorsulfuron @10g ha⁻¹, Brihan | 62.5b     | 101.7bc   | 75.78fg   | 22.18ab   | 55.43cd   | 19.81de   | 11.12e    | 15.46a | 2825de     |
| Chlorsulfuron @10g ha⁻¹, Deber  | 70.08a    | 117.6a    | 115.35a   | 20.87ab   | 76.17a    | 30.36ab   | 16.84bc   | 14.18a | 3253b      |
| Chlorsulfuron @10g ha⁻¹, Wedi-aker | 67.33ab | 108.3ab   | 101.02bcd | 20.72ab   | 62.83bc   | 27.52bc   | 15.6cd    | 15.68a | 2492fg     |
| Chlorsulfuron @15g ha⁻¹, Brihan | 62.42b    | 101.7bc   | 72.9g     | 21.15ab   | 59.5bc    | 17.62d    | 12.46a    | 14.43a | 2921cd     |
| Chlorsulfuron @15g ha⁻¹, Deber  | 70.08a    | 114.9a    | 112.07ab  | 20.79ab   | 75.92a    | 34.48a    | 21.29d    | 14.53a | 3725a      |
| Chlorsulfuron @15g ha⁻¹, Wedi-aker | 67.5ab | 109.4ab   | 85.42ef   | 19.93ab   | 58.58a    | 24.64cd   | 15.48cd   | 14.51a | 2575f      |
| Chlorsulfuron @20g ha⁻¹, Brihan | 62.42b    | 101.6bc   | 75.43g    | 21.02ab   | 56.58cd   | 16.28g    | 11.38e    | 14.47a | 2885cde    |
| Chlorsulfuron @20g ha⁻¹, Deber  | 70.17a    | 114.5a    | 91.7de    | 19.28b    | 75.75a    | 27.03bc   | 15.72cd   | 14.97a | 3238b      |
| Chlorsulfuron @20g ha⁻¹, Wedi-aker | 67.42ab | 108.8ab   | 99.92cd   | 21.38ab   | 63.42bc   | 28.62bc   | 16.04c    | 15.15a | 2594def    |
| CV (%)                          | 9.1       | 10.6      | 13.6      | 14.5      | 13.6      | 14.5      | 23.8      | 17.2   | 12.7       |
| LSD(0.05)                       | 4.909     | 9.194     | 10.52     | 2.241     | 7.399     | 4.894     | 2.862     | 2.057  | 295.3      |
| F Pr                            | <.001     | <.001     | <.001     | <.001     | <.001     | <.001     | <.001     | <.016  | <.001      |

DF = days to 50% flowering, DM = days to 95% maturity, PH = plant height, PL = panicle length, NH = number of heads harvested per plot, PW = panicle weight, PY = yield per panicle, NH = number of harvested heads, GY = grain yield
Table 2. Interaction effect of herbicide rates and varieties on striga parameters

| Treatments                      | DF  | SC_pl  | 45DAPm² | 65DAPm² | 85DAPm² |
|---------------------------------|-----|--------|---------|---------|---------|
| chlorsulfuron @ 0 g ha⁻¹, Brihan| 74.75⁰ | 2.45(1.70)ᵃᵇ | 1.85(1.48)c | 4.24(2.02)d | 13.35(3.48)de |
| chlorsulfuron @ 0 g ha⁻¹, Deber | 72.58⁰ | 8.6(3)ᵇ | 5.88(2.49)b | 63.84(7.72)b | 95.75(9.61)b |
| chlorsulfuron @ 0 g ha⁻¹, Wedi-aker | 71.83⁰ | 10.33(3.22)ᵃ | 8.25(2.84)a | 85.62(8.97)a | 144.78(11.88)a |
| Chlorsulfuron @ 10 g ha⁻¹, Brihan | 77.25ᵇ⁰ | 1.18(1.29)ᵃ | 0.65(1.07)c | 1.41(1.18)d | 2.47(1.56)e |
| Chlorsulfuron @ 10 g ha⁻¹, Deber | 76.92ᵇ⁰ | 3.26(1.87)ᵈᵉ | 1.28(1.31)c | 8.61(2.84)d | 17.7(4.05)dᵉ |
| Chlorsulfuron @ 10 g ha⁻¹, Wedi-aker | 74.92ᵇ⁰ | 5.51(2.39)ᶜ | 2.17(1.61)c | 25.13(4.6)c | 58.83(7.17)c |
| Chlorsulfuron @ 15 g ha⁻¹, Brihan | 77.75ᵇ⁰ | 1.36(1.35)ᶜ | 0.65(1.07)c | 1.34(1.15)d | 3.98(1.94)e |
| Chlorsulfuron @ 15 g ha⁻¹, Deber | 77.58ᵇ⁰ | 2.73(1.79)ᵉᵗ | 1.12(1.26)c | 5.27(2.22)d | 12.65(3.45)dᵉ |
| Chlorsulfuron @ 15 g ha⁻¹, Wedi-aker | 77.08ᵇ⁰ | 4.46(2.18)ᶜᵈ | 1.18(1.29)c | 10.24(3.17)d | 25.27(4.96)d |
| Chlorsulfuron @ 20 g ha⁻¹, Brihan | 76.92ᵇ⁰ | 0.91(1.17)ᵍ | 0.75(1.11)c | 1.56(1.24)d | 3.26(1.79)e |
| Chlorsulfuron @ 20 g ha⁻¹, Deber | 78.3ᵃ | 1.95(1.55)ᵃᵍ | 1.22(1.22)c | 3.38(1.76)d | 9.06(2.76)dᵉ |
| Chlorsulfuron @ 20 g ha⁻¹, Wedi-aker | 77.08ᵇ⁰ | 1.9(1.54)ᵉᵍ | 1.3(1.33)c | 3.58(1.82)d | 7.97(2.76)dᵉ |
| CV (%)                          | 3.6 | 19.1   | 22.4    | 36.4    | 29.5    |
| LSD(0.05)                       | 2.206 | 1.527  | 1.371   | 13.659  | 17.38   |
| F Pr                            | <.001 | <.001  | <.001   | <.001   | <.001   |

*DE* = days to striga emergence, *DF* = days to striga flowering, *SC_pl* = striga count per sorghum plant, 45DAP = 45 days after sorghum planting, 65DAP = 65 days after sorghum planting and 85DAP = 85 days after sorghum planting.
10g ha⁻¹ with Deber variety was measured the highest plant height (115.35cm) and it was statistically similar without chlorsulfuron and with 15g ha⁻¹ chlorsulfuron rate, whereas the lowest (72.9cm) was scored on variety Brihan with the application of 15g ha⁻¹ chlorsulfuron rate. Application of chlorsulfuron for Brihan variety stunted its plant height.

The analysis of variance showed significant difference (P < 0.01) of application of chlorsulfuron rates and varieties in panicle length (Table 1). The maximum panicle length (22.18cm) was measured from 10g ha⁻¹ chlorsulfuron rate and variety Brihan whereas the minimum panicle length was obtained from control chlorsulfuron with variety Wedi-aker (15.4cm). This might be due to the variety effect and Wedi-aker was susceptible to striga damage than the other varieties.

3.1.4 Panicle weight (g) and yield per panicle (g)

The result showed highly significant difference (P < 0.01) on panicle weight and yield per panicle (Table 1). The highest panicle weight was obtained from 15g ha⁻¹ application of chlorsulfuron rate and Deber (34.48g) statistically similar with 10g ha⁻¹ with Deber and control with Deber. The lowest panicle weight was recorded from control with Birhan (18.06g) and statistically similar with 15g ha⁻¹ application of herbicide with Birhan and as well as 20g ha⁻¹ application of herbicide with Birhan. These indicates that the variety panicle weight was small in Birhan than Deber, but the expectation was low panicle weight in variety Deber, because in Birhan especially with application of herbicide there were no striga weed but in Deber there were some striga counts when compare with the variety Birhan.

Maximum yield per panicle were measured from 15g ha⁻¹ application of chlorsulfuron with Deber (21.29g) this result was statistically similar with the control herbicide of Deber. Minimum yield per panicle was measured from control, 10g ha⁻¹ and 20g ha⁻¹ application of chlorsulfuron with Birhan.

3.1.5 Number of harvested heads per plot, 1000 seed weight

Herbicide rates with varieties were highly significant (P < 0.01) among the treatments on harvested heads per plot (Table: 1). In the case of chlorsulfuron rates with variety combination higher number of heads per plot was harvested from all rates of herbicide application with Deber (0g ha⁻¹, 10g ha⁻¹, 15g ha⁻¹ and 20g ha⁻¹) (72.5, 78.67, 78.42 and 78.25 harvested heads per plot) while minimum harvested heads was obtained from 0g ha⁻¹ chlorsulfuron with Wedi-aker (50.42 heads per plot) (Table 1). This result was due to the variety sensitivity to the striga weed computation because in the control plot of Wedi-aker there was high number of striga and all Wedi-aker stand count did not produced heads.

Chlorsulfuron rates with varieties were significant difference (P < 0.05) on thousand seed weight. Maximum 1000 seed weight was obtained from 10g ha⁻¹ of chlorsulfuron rate with Wedi-aker (15.68g) but statistically similar with all herbicide rates and varieties except control chlorsulfuron with Wedi-aker which was recorded the lowest 1000 seed weight (11.17g) (Table 1).

3.1.6 Grain yield

The interaction effect of herbicide rates on varieties of sorghum was showed highly significant difference (P < 0.01) on grain yield of sorghum (Table: 1). The highest yield was obtained from 15g ha⁻¹ of chlorsulfuron with Deber (3725 kg ha⁻¹) while lowest yield was recorded from 0g ha⁻¹ of chlorsulfuron with Wedi-aker (2242 kg ha⁻¹). This indicates that variety wedi-aker was sensitive to striga infestation and its grain yield highly reduced. Chlorsulfuron affects the striga attachment negatively to the host and it indicates application of 15g ha⁻¹ of chlorsulfuron with Deber variety it increases the yield by 43.84% over the control chlorsulfuron with Wedi-aker. This result agrees with [10] who reported that treated IR-maize and increasing plant population increases the yield under natural striga infestation. It also agrees with [11] tested chlorsulfuron formulation significantly increased sorghum grain yield.

3.2 Striga Results

3.2.1 Days to striga emergence, flowering and stand count

The result clearly showed that there were highly significant difference between herbicide rates and varieties to striga emergence, flowering, striga count per sorghum plant, stand count at 45DAP, 65DAP and 85DAP (Table 2). As indicated in the table below, the CV% for stand count at 65DAP (36.4) and 85DAP (29.5) seems relatively high, and this is because this data taken was biological count data per a given plot area which tends to inflate the coefficient of variation. This means spray of herbicide affect
the striga count as well as growth of striga. Striga was early emergence in plots both controls of variety Deber and Wedi-aker (42.25 and 42.08 days) as compared with application 20 g ha⁻¹ chlorsulfron with Birhan (56.33) and statistically similar with application of 10 and 15 g ha⁻¹ chlorsulfron with Birhan and application of 20 g ha⁻¹ chlorsulfron with Deber. This might be due to negative effect of chlorsulfron on emergence either by reducing production of stimulatory compounds or their specific leakage from the host root or killing the seed of striga from host roots.

In the case of flowering, plots that was no application of 0 g ha⁻¹ chlorsulfron (control) with Deber and Wedi-aker early flowering than other all combination treatments. This result indicates that application of chlorsulfron delays the flowering time even with the susceptible variety. The result is line with [12] reported coating sorghum seed with herbicide reduced striga infestation, striga flowering and striga seed set, and it is considered as the most effective approach as it does not affect sorghum biomass. Stand count per plant and stand count at 45DAP, 65DAP and 85DAP affected by application of chlorsulfron reduces the number of striga emergence. Greatest number of striga per sorghum was counted from application of 0 g ha⁻¹ chlorsulfron (control) with Wedi-aker (10.33 plants per sorghum) whereas lowest striga was counted from application of 20 g ha⁻¹ chlorsulfron with Birhan. By increasing rate of chlorsulfron it decreases the striga number per sorghum plant.

Striga counted at different time increases dramatically. Maximum number of striga was counted from the control with Wedi-aker (8.25 plants m⁻² at 45 DAP, 85.6225 plants m⁻² at 65 DAP and 144.7825 plants m⁻² at 85DAP striga plants m⁻²) whereas minimum striga was counted from application of 10 g ha⁻¹ chlorsulfron with Birhan (0.65 striga at 45 DAP) and statistically similar with all herbicide rates with all varieties including the control of Birhan except control with Deber, however at 65 DAP minimum striga was counted from application of all rates of chlorsulfron including the control with Birhan (1.34 stiga plants m⁻²) except the control with Deber and 10 g ha⁻¹ chlorsulfron with Wedi-aker. At 85 DAP minimum striga counted was from application of 20 g Cl ha⁻¹ chlorsulfron with Birhan (3.26 striga plants m⁻²) and similar with the application of 10 and 15 g ha⁻¹ chlorsulfron with Birhan. Use of 15 g ha⁻¹ chlorsulfron with variety Deber suppresses striga by 91.26% compared with no chlorsulfron and variety Wedi-aker. The result is in line with [10] application of imazapyr treatments reduced striga emergence at different time. At 69 DAP striga emergence in the untreated was 4.8 plants m⁻² compared to a maximum of 0.9 plants m⁻² in the rest. At 86 DAP emergence in the control was 14.7 plants m⁻² compared to a maximum of 6.6 plants m⁻². In addition, similar results were found by [11] who stated that application of chlorsulfuron at 2.38 and 2.98 g a.i ha⁻¹ suppression of striga (83.3%).

3.2.2 Branch number of striga and striga plant height

The result clearly showed that there were highly significant difference between chlorsulfuron rates and varieties to branch number per plant and plant height (Table 3). Greatest branch number per striga was observed from the control with Wedi-aker (3.41) but not statistically difference with the control with Deber and with application of 10 and 15 g ha⁻¹ chlorsulfron with Wedi-aker whereas lowest striga branch was counted from application of 20 g ha⁻¹ chlorsulfuron with Birhan (1.63 branch number per striga plant) and statistically similar with all rates of chlorsulfuron application with Birhan including the control and application of 10 and 15 g ha⁻¹ chlorsulfuron with Deber and also application of 20 g ha⁻¹ chlorsulfuron with Wedi-aker. Striga plant height was affected by application of chlorsulfuron with varieties by increasing chlorsulfuron rates with resistance variety decrease the height of striga.

3.2.3 Striga biomass

The result clearly showed that there was highly significant difference between chlorsulfuron rates and varieties to biomass of striga (Table 3). Chlorsulfuron and variety also affected the biomass of striga; maximum biomass was recorded from the control with Wedi-aker (0.258 kg m⁻³) whereas minimum biomass of striga was measured from 20 g ha⁻¹ chlorsulfuron application with Birhan and similar with 10 and 15 g ha⁻¹ chlorsulfuron application with Birhan variety. This result might be due to the resistance of the variety and the herbicide application that suppressed the striga emergence and growth due to the reduction in number of striga and growth while decreasing biomass of striga. This result agree with the study of [13] using granular mycoherbicides (Foxy 2 and PSM197) with susceptible and resistance maize and sorghum cultivars, it reduces the striga count per plot by 75.3%, dry weight of striga by 74.4%, striga flowers by 83.6% and crop plant infested by 64.8% compared to the control.
3.3 Economic Analysis

Among the 12 treatment combination tested, 8 treatments were dominated and eliminate from the marginal analysis (Table 4). The 8 treatments were dominated because of their non-profitability to the farmers. Application of 10 and 15 g ha\(^{-1}\) chlorsulfuron and Deber offered 88.71% and 234.381% marginal rate return (Table 5). This indicates that farmer can obtain 2.34 birr by investing 1 birr on application of 15 g ha\(^{-1}\) chlorsulfuron with Deber variety. On striga infestation its own advantage because striga weed is very dangerous weed to control and it damages sorghum growth and yield of sorghum.

Table 3. Interaction effect of herbicide rates and varieties on striga parameters

| Treatments         | Br_no/plant | PH (cm)       | Biomass kg m\(^{-2}\) |
|--------------------|-------------|---------------|-----------------------|
| Chlorsulfuron @0gha\(^{-1}\), Brihan | 2.19(1.63)\(^{cd}\) | 28.48(5.25)\(^{cd}\) | 0.037(0.73)\(^{d}\) |
| chlorsulfuron@0gha\(^{-1}\), Deber     | 2.97(1.85)\(^{ab}\) | 51.42(7.15)\(^{a}\) | 0.155(0.87)\(^{a}\) |
| chlorsulfuron@0gha\(^{-1}\), Wedi-aker | 3.41(1.97)\(^{a}\) | 53.15(7.28)\(^{a}\) | 0.258(0.87)\(^{a}\) |
| Chlorsulfuron @10g ha\(^{-1}\), Brihan | 2.3(1.65)\(^{cd}\) | 15.07(3.81)\(^{g}\) | 0.002(0.7)\(^{g}\) |
| Chlorsulfuron @10g ha\(^{-1}\), Deber     | 2.41(1.7)\(^{bc}\) | 31.17(5.48)\(^{cd}\) | 0.037(0.73)\(^{ef}\) |
| Chlorsulfuron @10g ha\(^{-1}\), Wedi-aker | 3.16(1.9)\(^{bc}\) | 43.7(6.54)\(^{b}\) | 0.108(0.77)\(^{c}\) |
| Chlorsulfuron @15g ha\(^{-1}\), Brihan | 1.63(1.45)\(^{d}\) | 10.38(3.19)\(^{g}\) | 0.002(0.7)\(^{g}\) |
| Chlorsulfuron @15g ha\(^{-1}\), Deber     | 2.77(1.78)\(^{c}\) | 29.32(5.4)\(^{cd}\) | 0.04(0.73)\(^{f}\) |
| Chlorsulfuron @15g ha\(^{-1}\), Wedi-aker | 2.91(1.79)\(^{bc}\) | 33.1(5.74)\(^{f}\) | 0.074(0.75)\(^{d}\) |
| Chlorsulfuron @20g ha\(^{-1}\), Brihan | 1.63(1.42)\(^{f}\) | 11.43(3.32)\(^{g}\) | 0.002(0.7)\(^{g}\) |
| Chlorsulfuron @20g ha\(^{-1}\), Deber     | 1.86(1.51)\(^{d}\) | 19.93(4.41)\(^{ef}\) | 0.015(0.78)\(^{e-g}\) |
| Chlorsulfuron @20g ha\(^{-1}\), Wedi-aker | 2.3(1.66)\(^{cd}\) | 25.4(5.03)\(^{cd}\) | 0.007(0.71)\(^{g}\) |

CV (%)          15.5 13 3.1
LSD(0.05)       0.714 5.7 0.029
F Pr       <.001 <.001 <.001

Table 4. Dominance analysis of herbicide rates and varieties effect on sorghum

| Treatments         | TCV (Birr) | Gross benefit (Birr) | Net benefit (Birr) | Dominance (D) |
|--------------------|-----------|----------------------|-------------------|---------------|
| Chlorsulfuron @0g ha\(^{-1}\), Brihan | 0         | 3757.97              | 3757.97           | D             |
| Chlorsulfuron @0g ha\(^{-1}\), Deber     | 0         | 4721.33              | 4721.33           | D             |
| Chlorsulfuron @0g ha\(^{-1}\), Wedi-aker | 0         | 3062.23              | 3062.23           | D             |
| Chlorsulfuron @10g ha\(^{-1}\), Brihan | 300       | 3560.17              | 3260.167          | D             |
| Chlorsulfuron @10g ha\(^{-1}\), Deber     | 300       | 5331.83              | 5031.83           | D             |
| Chlorsulfuron @10g ha\(^{-1}\), Wedi-aker | 300       | 3403.9               | 3103.9            | D             |
| Chlorsulfuron @15g ha\(^{-1}\), Brihan | 350       | 3456.8               | 3106.8            | D             |
| Chlorsulfuron @15g ha\(^{-1}\), Deber     | 350       | 6202.17              | 5852.17           | D             |
| Chlorsulfuron @15g ha\(^{-1}\), Wedi-aker | 350       | 3608.33              | 3258.33           | D             |
| Chlorsulfuron @20g ha\(^{-1}\), Brihan | 400       | 3513.5               | 3113.5            | D             |
| Chlorsulfuron @20g ha\(^{-1}\), Deber     | 400       | 5093.67              | 4693.67           | D             |
| Chlorsulfuron @20g ha\(^{-1}\), Wedi-aker | 400       | 3797.97              | 3397.97           | D             |

Table 5. Marginal rate of return and residual analysis of herbicide rates and varieties

| Treatments         | TCV (Birr) | NB (Birr) | MRR (%) |
|--------------------|-----------|-----------|---------|
| Chlorsulfuron @0g ha\(^{-1}\), Brihan | 0         | 3757.97   | 88.71   |
| Chlorsulfuron @0g ha\(^{-1}\), Deber     | 0         | 4721.33   | 234.381 |
| Chlorsulfuron @10g ha\(^{-1}\), Deber     | 300       | 5031.83   | 88.71   |
| Chlorsulfuron @15g ha\(^{-1}\), Deber     | 350       | 5852.17   | 234.381 |

3.3 Economic Analysis

Among the 12 treatment combination tested, 8 treatments were dominated and eliminate from the marginal analysis (Table 4). The 8 treatments were dominated because of their non-profitability to the farmers. Application of 10 and 15 g ha\(^{-1}\) chlorsulfuron and Deber offered 88.71% and 234.381% marginal rate return (Table 5). This indicates that farmer can obtain 2.34 birr by investing 1 birr on application of 15 g ha\(^{-1}\) chlorsulfuron with Deber variety. On striga infestation its own advantage because striga weed is very dangerous weed to control and it damages sorghum growth and yield of sorghum.

4. CONCLUSIONS

The result of this investigation indicated that herbicide application has influence on striga management and yield of sorghum as the yield increased with application of 15 g ha\(^{-1}\) chlorsulfuron with Deber compared to all chlorsulfuron control with all variety. The highest yield was obtained from 15 g ha\(^{-1}\) chlorsulfuron with Deber variety (3725 kg ha\(^{-1}\)) which is 43.84% yield advantage over control (no chlorsulfuron) chlorsulfuron with Wedi-aker and striga reduction 91.26% at 85 DAP striga counted.
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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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