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RESEARCH ARTICLE

Efficacy of diuron on the management of broad-leaf weeds in sesame (*Sesamum indicum* L.) fields in Tigray, Ethiopia

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ABSTRACT

Sesame (*Sesamum indicum* L.) is a poor competitor with weeds during the first four weeks due to the slow growth of its seedlings. Diuron is a systemic urea herbicide used to control broad-leaf weeds in sesame in different countries. Hence, the objective of this study was to assess the efficacy of diuron and thereby for registration in the country. The study, comprised of 12 treatments of combination of diuron and hand weeding was conducted in 2018 and 2019 cropping season in Western Tigray, Ethiopia. The weed control measures were carried out at 10 and 30 days after seedling emergence (DAE) and the weed counting and weighing of weed biomass were undertaken at 10, 17, 30 and 37 DAE. An average number of 197.03 weeds/m^2 were counted before the control measure while weed count decreased to 20.8 weeds/m^2 after deploying the control measure. The weed biomass was reduced from 889.66 to 166.66 g/m^2 and from 175.33 to 61.33 g/m^2 after first and second application of the control measures, respectively. The highest crop injury (10%) at 10 days after treatment (DAT) was observed from the application of diuron WG 650 g/ha two times as well as diuron WP 650 g/ha two times equally. The highest efficacy (92.2%) against *Commelina foecunda* was obtained from diuron WP 650 g/ha. The ANOVA for sesame grain yield showed significant (P<0.001) difference and the highest yield (669.9 kg/ha) with the application of diuron WP 650 g + hand weeding. Yield losses in sesame ranged between 20- 83% because of weed infestation. The diuron has been registered in Ethiopia to be used as post-emergence herbicide in sesame due to its effective weed control ability. The diuron has been registered in Ethiopia to be used as post-emergence herbicide in sesame due to its effective weed control ability.

Keywords: Diuron, Sesame, Weed biomass, Weed count, Yield loss

INTRODUCTION

Sesame (*Sesamum indicum* L.) is a very important component of semi-tropical and tropical agriculture, providing easily available and highly nutritious human and animal food. Sesame is an industrial crop that grows chiefly for its vital seed that contains about 57.8-59.3% oil, 21.4-23.2% protein (Hassan 2012) and 18.2-20.2% carbohydrates (Adegunwa *et al.* 2012). About 6.4 million tons of sesame seed was produced from 12.5 million hectare worldwide in 2021 (FAOSTAT 2023). Sesame is susceptible to different biotic and abiotic stresses that significantly lower sesame quality and productivity and weed is among the major biotic stresses. Sesame is a poor competitor with weeds during the first four weeks due to the slow growth of its seedlings (Tyagi *et al.* 2013). Sesame yield losses are mainly due to delayed weeding or insufficient weed control (Tepe *et al.* 2011), and therefore, an effective weed control method required to be developed (Bukun 2011). Weed infestation in sesame can cause a significant yield loss up to 74% (Singh *et al.* 1992), 80% (Amare 2011), 30% (Grichar *et al.* 2018) and 70% (Ijlal *et al.* 2011). Hence, studies have been conducted around the world to determine critical period for weed control (CPWC) in sesame, with a range of environmental conditions to avoid the yield losses thereby increasing productivity and quality. Beltrao *et al.* (1997) reported that sesame required weed free period of 60 days after emergence (DAE) in Sousa and 30 to 35 DAE in Monterio of Brazil. However, Venkatakrishnan and Gnanamurthy (1998) reported critical weeding periods in sesame crop as 30-45 DAE in India, 7-35 DAE in Ethiopia (Amare 2011) and 15-45 DAE in West Bengal, India (Duary and Hazra 2013). Variation in CPWC values can be attributed to changes in weed species composition, weed-ground cover and climatic conditions, in which crops and weeds interfere (Knezevic *et al.* 2003).

Weeds are the most severe biological constraint to agricultural production systems that can cause damage in cropped and non-cropped lands; degrade quality of the produce and increase the cost of production besides harboring and serve as alternate

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hosts to several insect pests and diseases (Rao *et al.* 2020, Rao and Nagamani 2010). Broad-leaf weeds are the most important weeds in the sesame producing areas of Tigray (Amare 2011) and these weeds are becoming difficult to eradicate by hand weeding. Langham *et al.* (2007) reported that there are approximately 16 herbicides that are used or have the potential to be used in commercial sesame production in the world based on assessment from 21 sesame producing countries. Alachlor, fluchloralin, fluometuron, linuron, metobromuron plus metolachlor, pendimethalin and trifluralin are among the effective pre-emergence herbicides while linuron, diuron and prometryn are the effective post emergence herbicides in sesame (Grichar *et al.* 2011). Sesame injury is common by most of the herbicides. However, nowadays sesame farmers need to plant extra sesame seeds with the principle "some for the herbicide is, and most for me". Diuron is a systemic urea herbicide which inhibits photosynthesis and this herbicide is used in broad-leaf crops like cotton to control various weeds (Sosnoskie and Culpepper 2014). Grichar *et al.* (2011) reported that minimum crop injury has been reported when diuron was applied in the late juvenile stage. On the other hand, applications of herbicide on the seedling stage severely damage the sesame which cause reduction in yield. However, the rate and formulation of the herbicides, the application method, spray height from ground, and the edaphic and agro-climatic conditions significantly affects the efficacy of the herbicides and crop injury. So far, studies have not been conducted in Ethiopia in sesame crop to control weeds using diuron as post-emergence herbicide. The objective of this experiment was to evaluate the efficacy, and thereby for registration, of WP and WG formulations and different rates of diuron for the management of broad-leaf weeds in sesame (*Sesamum indicum* L.) at Humera, Tigray, Ethiopia.

MATERIALS AND METHODS

Experimental design

A field study was conducted in 2018 and 2019 cropping season at Humera, Western Tigray, Ethiopia under rainfed condition to investigate the efficacy of diuron (800 g/kg). The experimental site was situated at 13 °48' N, 36 °30' E in the altitude of 619 meters above sea level (masl) receiving an average annual rainfall of 506 mm and the soil is characterized as vertisol with 56, 26 and 18% of clay, sand and silt, respectively. The herbicide is originated from the manufacturing Company called Jiangsu Golden Chemical Co. Ltd. W3, 16F Huatai Securities Mansion, 90 Zhongshan Road (east), Nanjing, P.R. China, and supplied by the company called Issachor Agro Input Importer and Distributer Plc, principal office at Addis Ababa, Ethiopia. The herbicide was applied in two forms, *viz.* wettable powder (WP) named as "Diuron WP" and wettable granular (WG) named as "Diuron WG" for management of broad-leaf weeds. The weed control measure (both the herbicide application and hand weeding) carried out at 10 and 30 days after seedling emergence (DAE) for the control measures applied once and twice, respectively. The herbicide was diluted in water (1 liter diuron in 200 liter of water) and the hand weeding was done using a local weeding material tool "*mewled*". The experimental design was randomized complete block design with three replications. Each plot had a net harvestable plot sizes of 10 m^2, containing 5 rows with 5 m length and 40 cm row spacing, from which both the yield and weed data were collected. All agronomic practices carried out as per the recommendation for the crop and the area and. Sesame variety '*Setit-2*' was shown in this study. The study consisted of 12 treatments as described in (**Table 1**).

Table 1. Treatment set up and its description

Treatment	Weeding practice	Herbicide rate (g/ha)	Remark
Diuron WP 650 g one time	H	650	Applied once
Diuron WP 650 g two times	H+H	1300	Applied in two splits
Diuron WG 650 g one time	H	650	Applied once
Diuron WG 650 g two times	H+H	1300	Applied in two splits
Diuron WP 650 + hand weeding	H+HW	650	Applied once followed by hand weeding
Diuron WG 650 + hand weeding	H+HW	650	Applied once followed by hand weeding
One hand weeding	HW		Once hand weeding
Two hand weeding	HW+HW		Twice hand weeding
Diuron WP 487.5 g two times	H+H	975	Applied in two splits
Diuron WP 325 g two times	H+H	650	Applied in two splits
No weeding			Season long
Weed free	HW		Season long

H: Herbicide only; HW: Hand weeding

Data collection

Data on weed distribution was assessed before and after control measures were implemented. The weed population and weed biomass from each of the net plot was recorded with quadrate measuring 100 x 100 cm. The weed counting and weed biomass weight were carried out at 10, 17, 30 and 37 days after seedling emergence (DAE). This means during or pre-1st application/weeding and 7 days after 1st application/weeding, during or pre-2nd application and 7 days after 2nd application, respectively. Yield was harvested from the net plot sizes, converted to yield per hectare and analyzed. Yield components data like number of branches per plant, number of pods per plant, plant height, length of pod bearing zone and others were also collected on plot basis from ten selected and representative plants located in the center of the plots. The crop and weed injury because of the herbicide application were recorded in the scale of 0-10 or 1-100% according to (Rao, 2000) where 0% means no weed control or no sesame injury and 100% means complete weed control or complete sesame death. This visual injury was evaluated at 10 days after herbicide treatment (DAT).

Weed distribution: The frequency, abundance and dominance of major weeds in the experiment was assessed before any control measure was taken. Moreover, the frequency, abundance and dominance of the major broad-leaf weed was also estimated after the control measures were applied and computed using excel spread sheet as described by Tesema and Lema (1998) as follows:

- **Frequency (constancy):** is the percentage of sampling plots (vegetation registrations) on which a particular weed species is found. It explains how often a weed species occurs in the survey area. Frequency is calculated for the major weed species as follows:
- **F= 100*X/N**, Where, F= frequency; X = number of occurrences of a weed species; N= sample number
- **Abundance:** population density of weed species expressed as the number of individuals of weed plants per unit area.

  A=ΣW/N; Where, A = abundance; W = number of individual species/sample; N = sample number
- **Dominance:** abundance of an individual weed species in relation to total weed abundance and is computed as:

D = A*100/ΣA Where, D = dominance; A = abundance; ΣA= total abundance

Coefficient of efficacy (KE) and crop injury: The efficacy of herbicides on the major broad-leaf weeds is estimated by comparing herbicide treated plots and the untreated or control plots and this was carried out 10 DAT. The efficacy of herbicides is calculated using the following formula as described by (Šariæ, 1991): $KE\ (\%) = \frac{A}{B} x100$ where KE% is the coefficient of efficacy, A is the number of killed weeds/m^2, and B is the number of weeds/m^2 in the control (untreated) plots. Moreover, the sesame and weed injury is sketched in excel spread sheet to easily visualize the crop and weed injury level of the herbicide formulations and rates. Sesame injury is described and scaled based on the stunting, leaf chlorosis and necrosis status of the plants and leaves.

Grain yield, yield components and yield loss

Yield loss (%) was determined for each individual plot and the average yield from the weed free treatment was used to estimate the yield loss and was calculated as follows:

$$Yield\ Loss\ (\%) = \frac{Yield\ from\ the\ weed\ free - Yield\ from\ the\ weedy\ check}{Yield\ from\ the\ weed\ free} X100$$

Both the yield, yield components and yield loss data were subjected to ANOVA and the means were separated using Tukey's test at 5% probability using R statistical software (R Core Team, 2022).

RESULTS AND DISCUSSIONS

Weed distribution

An average number of 197.03 weeds/m^2 (both broad and grass weeds) were counted before any control measure was taken in the experimental field. The major broad-leaf weeds observed in the field were *Commelina foecunda, Corchorus fascicularis, Rahynochosia malacophyla, Convolvulus arvensis, Xanthium strumarium, Traxacum officinale* and the major grass weeds were *Dinebra retroflexa* and *Sorghum halepense,* which were in accordance to the reports of Amare (2011) and Gebregergis *et al.* (2019).

The frequency, abundance and dominance of the weeds in the study site is depicted in **Figure 1**. Generally, 90.8% of the total weeds from the study area were broad-leaves while 8.4% were grassy weeds and the remaining 0.8% were not identified weeds. *C. foecunda* and *D. retroflexa* were the most frequently occurred weeds with 100% frequency followed by *Corchorus fascicularis* with 93.3% frequency. The relative weed density or abundance of the weeds ranged from 1 to 160 where the highest

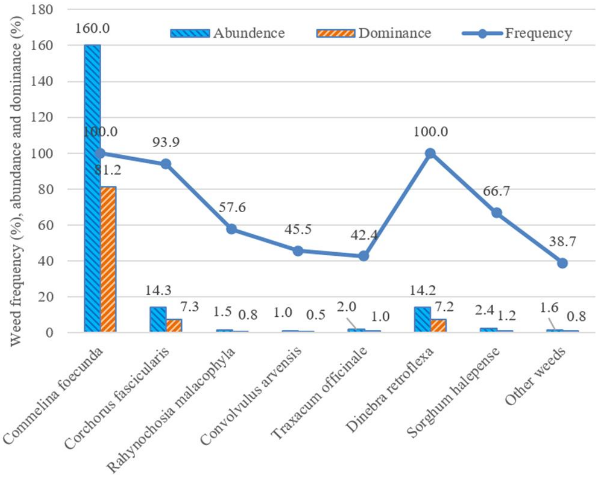

Figure 1. Weed frequency, abundance and dominance in the experimental site

weed abundance (160) was recorded from *C. foecunda* while the lowest was recorded from *Convolvulus arvensis*. *C. foecunda* (81.2%), *C. fascicularis* (14.2%), and *D. retroflexa* (14.2%) were the most dominant weeds in the field, where the first two were broad-leaf weeds while the latter was grassy weed. Zenawi *et al.* (2018) also reported that the frequency, abundance, and density of *C. foecunda* in Western Tigray was found to be 82.9%, 53.7/m², and 859/m², respectively.

Commelina foecunda, the most dominant and frequently occurred weed was the utmost important weed in the sesame growing areas of Western Tigray and it was also the most difficult weed to control using manpower. A survey conducted for five years in the United States revealed *Commelina* weed as troublesome weeds in cotton, maize, and wheat production areas (Webster and Nichols 2012). Therefore, a sesame field once infested with *C. foecunda* can never be free of the weed unless weeded frequently or sprayed herbicides. *Commelina* spp. species are capable of rooting and re-establishing after cultivation or disking from broken vegetative cuttings of stems (Webster *et al.* 2009) and produce areal and subterranean seeds and can regenerate from fragmented stems (Riar *et al.* 2016, Riar *et al.* 2014). From the field observation, the infestation was very high from early vegetative growth stage to reproductive stage (end of flowering) and the weeds became dry during maturity stage of the sesame. Unlike to this weed, *C. fascicularis* and *Ocimum* spp. were among the major late growing weeds in the sesame fields that deteriorated sesame productivity and quality since the infestation started at vegetative growth stage and continues to maturity.

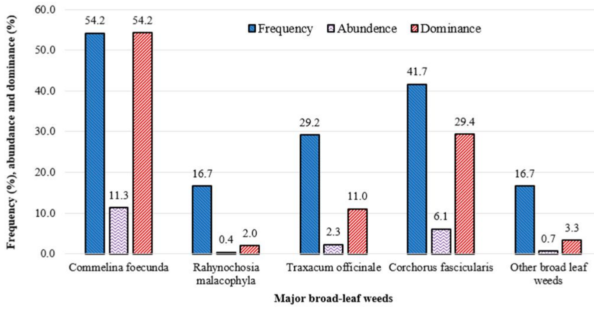

Figure 2. Frequency, abundance and dominance of major broad-leaf weeds after control measure is taken

Weed distribution after hand weeding and herbicide application

The frequency, abundance and dominance of the major broad-leaf weeds in the sesame fields were assessed after the control measures were deployed (after the second application or hand weeding) and depicted in **Figure 2**. An average of 20.8 weeds/m² was recorded, which was very low *vis-à-vis* the weed density prior to weed control measure was taken which was 197.03 weeds/m². This indicated that both the diuron herbicide and the hand weeding were effective in controlling the broad-leaf weeds. *Commelina foecunda* (54.2%) and *C. fascicularis* (41.7%) were the most frequently occurred weeds in the field. Similar to the frequency, *C. foecunda* (54.2%) and *C. fascicularis* (29.4%) were also the most dominant weed species. The abundance for all weeds was decreased except for *C. fascicularis* after the control measure was employed. This was because of the late growing habit of the weed which emerged and grew densely after the weed control measures were implemented and hence, due attention is required in developing weed control measure against this weed.

Weed biomass at pre-first and post-first treatment: The average weed biomass (g/m²) of the broad-leaf weeds was weighed four times at different time intervals (pre- and post- 1st application, pre- and post- 2nd application). The weed biomass was measured at 10 DAE (pre- 1st application) and 17 DAE (post 1st application) to evaluate the efficacy of the hand weeding and diuron application on weed biomass reduction. The weed biomass was decreased after the 1st application of the herbicide and after the 1st hand weeding. The highest weed biomass reduction (about 96%) was observed from the hand weeding indicating that hand weeding is preferable over one time spray of diuron. The weed biomass was decreased more or less similarly in the treatments where 650 g diuron in both formulations were applied (**Figure 3**). However, the weed biomass was

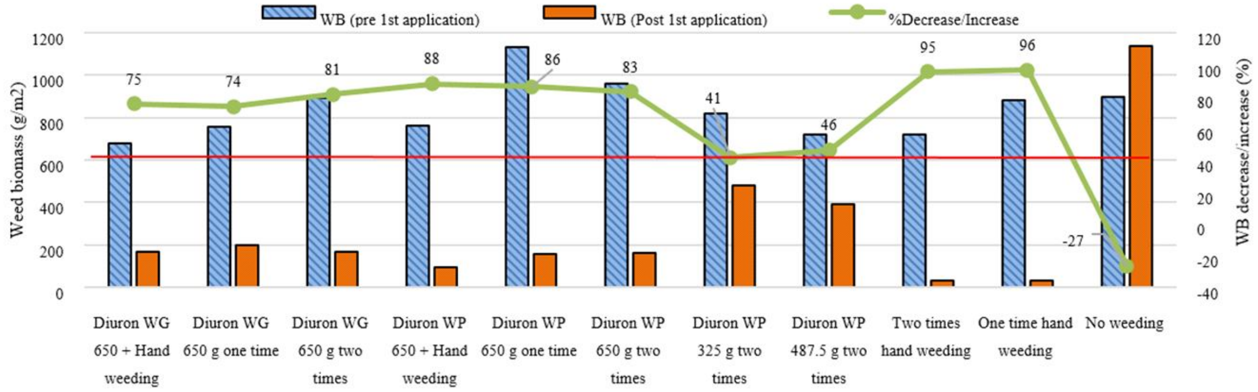

Figure 3. Weed biomass of major broad-leaf weeds at pre-and post-1st treatment

recorded lower in the treatments which received reduced rate of diuron (325 and 487.5 g/ha with 41 and 46% weed biomass decrease, respectively). On the other hand, the weed biomass was increased by 27% in the weedy check, where no control measure was applied and which is obviously expected.

Weed biomass at pre-second and post-second treatment: After the 2nd weeding practice (both the herbicide application and hand weeding) was executed, the weed biomass was decreased significantly for the treatments received twice weed control practice. On the other hand, weed biomass was significantly increased for the treatments, which received only once weed control practice (for both the herbicide application and hand weeding practices) and which is expected. The highest weed biomass reduction (94%) was observed from the treatment iuron WG 650 g + hand weeding" which was the application of diuron WP 650 g/ha in the 1st weeding and hand weeding in the 2nd weeding followed by the application of diuron WP 650 g + hand weeding with weed biomass decrease of 88% (**Figure 4**). The lowest weed biomass decrease was observed from two times application of diuron 325 g indicating lowering the rate of diuron decreased the weed control potential of the herbicide.

Weed biomass at pre-first and post-second treatment: The average weed biomass from all experimental plots was 837 g/m^2 at 10 DAE and the biomass in the weedy check treatment was reached 1901 g/m^2 at 37 DAE. The weed biomass increased by more than 100% which indicated that weed was among the most important constraints in sesame production. Sesame yield can be highly influenced by the relative leaf area or the biomass of the weeds that in turn affects the weed completion for different resources (Kropff and Spitters 1991). The highest weed biomass reduction (97.9%) was observed from the treatment diuron WG 650 g + hand weeding followed by diuron WP 650 g + hand weeding (96.6%) (**Figure 5**). This means the weed biomass decreased from 675 g/m^2 to 14 g/m^2 and from 759 g/m^2 to 26 g/m^2 from the former and the latter treatments correspondingly. This indicated that combining the herbicide and hand weeding (diuron at the 1st weeding time and hand weeding at the 2nd weeding time) is very important to control broad-leaf weeds in sesame fields. Exceptionally, the weed biomass was increased by 50.8% in the one-time hand weeding where the weed biomass was increased from 881 g/m^2 to 1328 g/m^2 indicating one-time hand weeding could not significantly reduce

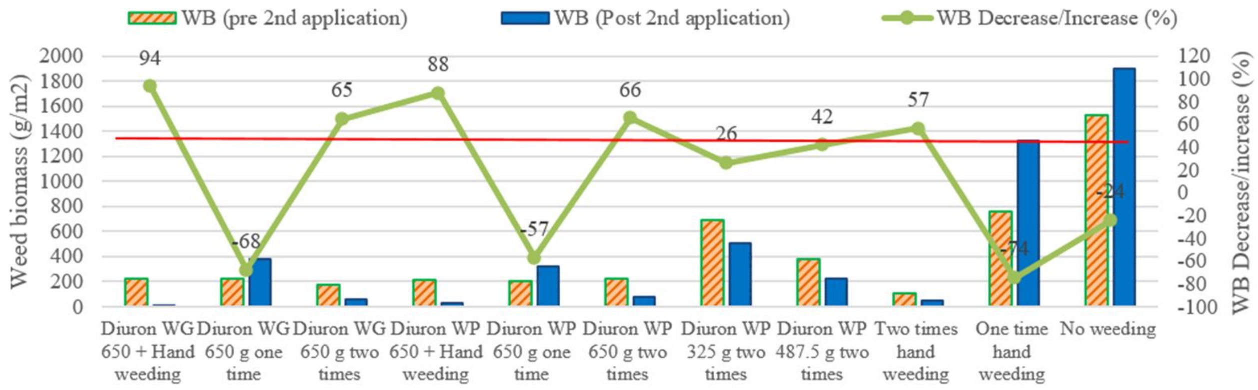

Figure 4. Weed biomass of broad-leaf weeds at pre-and post-2nd treatment

weed infestation. Moreover, the weed biomass was increased by 112% (from 896 g/m^2 to 1901 g/m^2) in the weedy check which indicated that the weed can significantly dominate the sesame crop if no control measure is taken. Generally, diuron is effective to minimize the weed biomass of broad-leaf weeds in the sesame field and this could result in an increase of the sesame biomass and thereby sesame productivity. This is in line with the findings of Bukun (2011) who reported that as the weed density and biomass decreased, the total biomass of the crop and productivity increased and vice versa. Furthermore, Bennett (1998) reported 1.3 times increased biomass of weeds that of sesame 42 days after planting while Eagleton *et al.* (1987) recorded 6 times increase in weed biomass that of sesame 48 days after planting.

Weed count of major broad-leaf weeds: Weed count of *C. foecunda* decreased in all treatments after a control measure was deployed (**Figure 6**). Weed count decreased from 180 to 2, 263 to 3 and 241 to 3 weeds/m^2 in the treatments of diuron WP 650 g + hand weeding, diuron WG 650 g + hand weeding and diuron WP 650 g two times, respectively. This was about 99% reduction indicating the application of diuron twice and application of diuron followed by hand weeding could be effective in controlling the *C. foecunda*. Grichar *et al.* (2014) and Ibrahim *et al.* (1988) also reported that integration of this herbicide with other control measures is crucial to increase synergy. Reduced rate of diuron (325 and 487.5 g/ha) decreased the efficacy of the herbicide in controlling *Commelina* spp. This study suggests the application of diuron 650 g/ha twice could be better than twice hand weeding. Hence, herbicide can be considered as best option to control this weed since this weed is very difficult to control effectively by hand weeding because of its reproduction capabilities.

The application of diuron was also effective to control *C. fascicularis*. The application of diuron 650 twice or diuron 650 combined with hand weeding during the second weeding reduced the *C. fascicularis* infestation from 21 to 2 weeds/m^2 (90% weed decrease). The weed count for this weed increased by 267 and 404% for the one- time hand

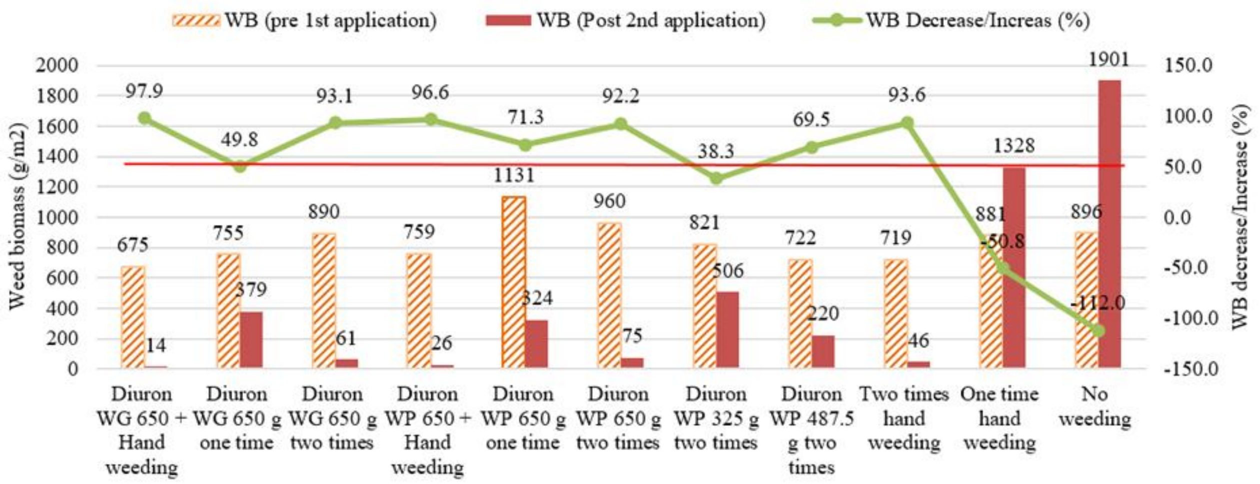

Figure 5. Weed biomass of major broad-leaf weeds at Pre-1st and post 2nd treatment

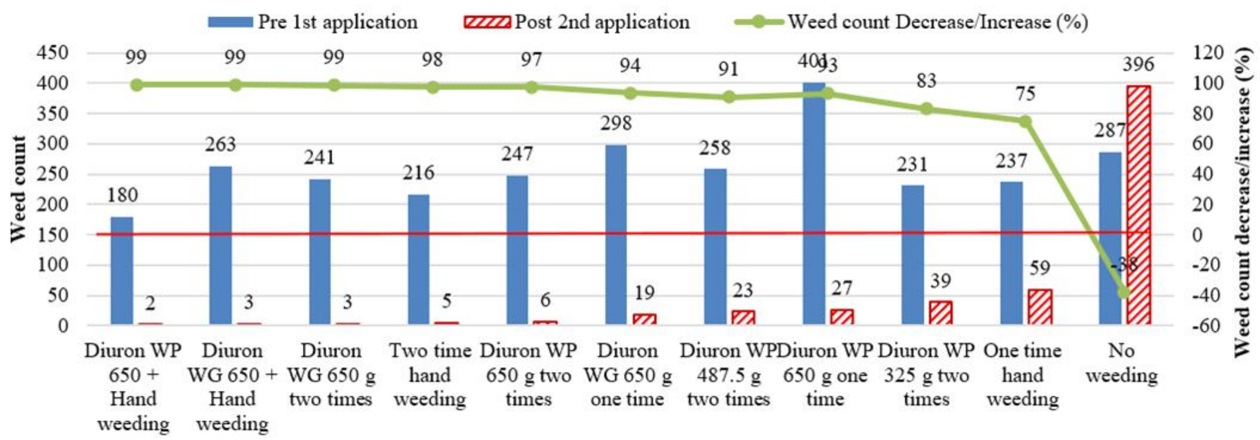

Figure 6. Weed count of *Commelina foecunda* at pre-1st and post 2nd treatment

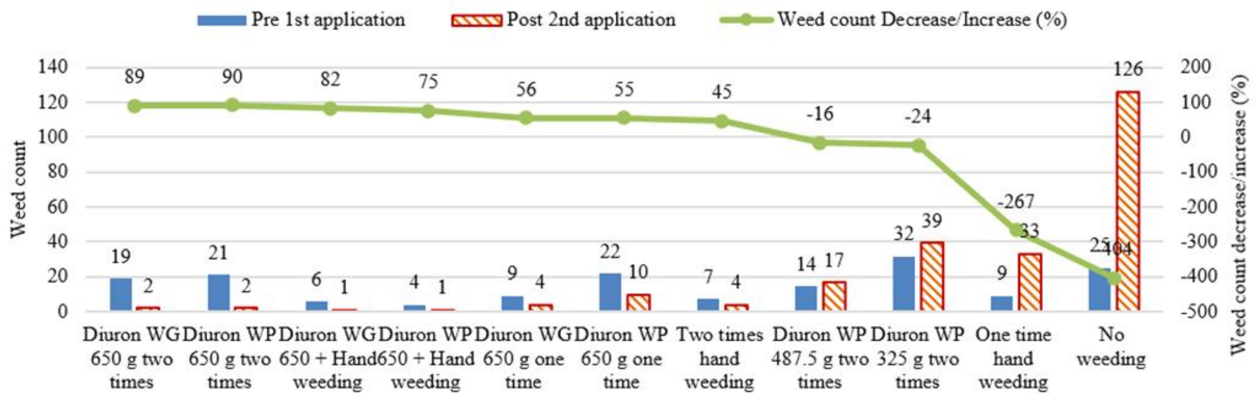

Figure 7. Weed count of *Corchorus fascicularis* at pre-1st and post 2nd treatment

weeding and no weeding, respectively. Diuron was found more effective in controlling *C. foecunda* than *C. fascicularis* (**Figure 6 and 7**). However, this might be because of inappropriate time of application against the latter weed since this is a late growing weed and hence an investigation on the time of application is crucial. Generally, the application of diuron is effective to control major broad-leaf weeds like *Convolvulus arvensis, Xanthium strumarium* and other broad-leaf weeds in addition to the above-mentioned weeds. Similar to this investigation, Grichar *et al.* (2014) and Langham *et al.* (2007) also reported that this herbicide as very effective in controlling broad leaf weeds in sesame fields.

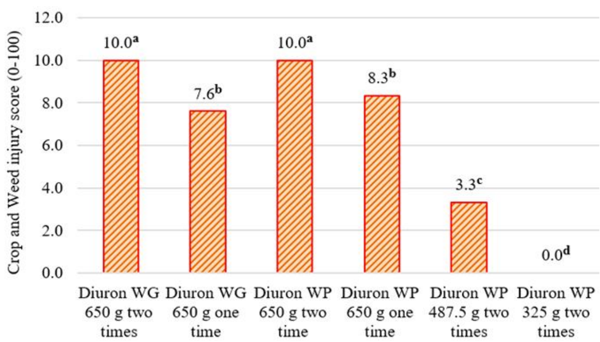

Figure 8. Crop injury score/damage score/ (0-100) as affected by the herbicide rate and formulation

Sesame and weed injury

All post-emergence herbicides that control broad-leaf weeds in sesame production have caused sesame injury, reduced plant stand or reduced sesame production (Grichar *et al.* 2009, Grichar *et al.* 2001). Crop injury consisted of leaf chlorosis, stunting growth, leaf necrosis, brooming effect and complete death of plants that results in decreased plant population and thereby reduced crop yield. In some cases, crop injury can also be expressed as absence of branching and no flower formation even from the available branches (Langham *et al.* 2010). The crop injury because of the herbicides rate and formulation was statistically significant ($P<0.001$) and depicted in **Figure 8**. The highest crop injury (10%) at 10 days after treatment (DAT) observed from the application of diuron WG 650g two times as well as diuron WP 650g two times equally. The lowest crop injury (3.3%) was recorded from the application of 487.5 g/ha two times while no crop injury was observed from the application of 325 g/ha twice. This indicates that the sesame injury depends on the rate of the herbicide and the formulation difference has no effect on crop injury. Grichar *et al.* (2018) reported that diuron applied at 1.12 kg/ha active ingredient on sesame after seedling emergence (post) caused leaf necrosis and chlorosis at Texas locations reaching up to 50% sesame injury but little to no injury was observed at the Lane location when rated early season, while late-season injury was 4% or less. This indicated that sesame injury from diuron is reversible and the plants can slowly recover. Furthermore, the authors also reported that the diuron applied 2 WAE can cause more injury (48% plant injury) than that of applied 4 WAE (23% plant injury). Grichar *et al.* (2011) also reported that diuron injury with post applications to sesame is temporary, and by late-season, only slight leaf chlorosis may be occurred on lower leaves. Furthermore, Grichar *et al.* (2014), Langham *et al.* (2007) and Grichar *et al.* (2011) also reported that diuron is effective in controlling broad-leaf weeds with minimum damage on the crop although the chemical resulted a crop damage at above 1.7 l/ha (Culp and Mcwhorter 1959). However, no adverse effects with diuron were seen in two-year study in south Texas. Hence, herbicide rate, time of application other agro-climatic and edaphic factors can significantly affect the sesame injury. Similar to the cop injury score, weed injury score is also depicted in **Figure 9**. The highest weed injury score (80%) was recorded from diuron WG 650 g two times followed by diuron WP 650g two times (77%) and diuron WG 650 g one time (77%) indicating the WG formulation is more effective to control broad-

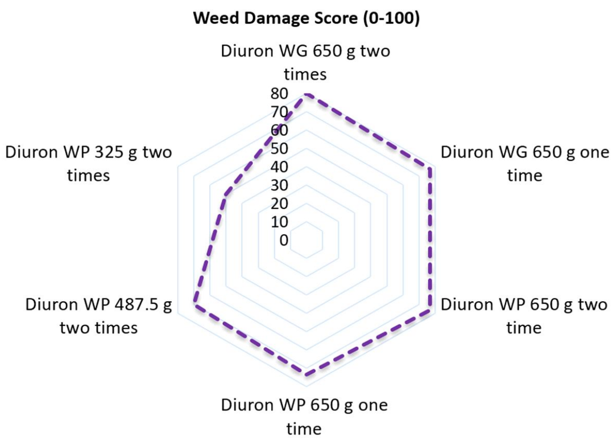

Figure 9. Weed injury score/damage score/ (0-100) score as affected by the herbicide rate and formulation

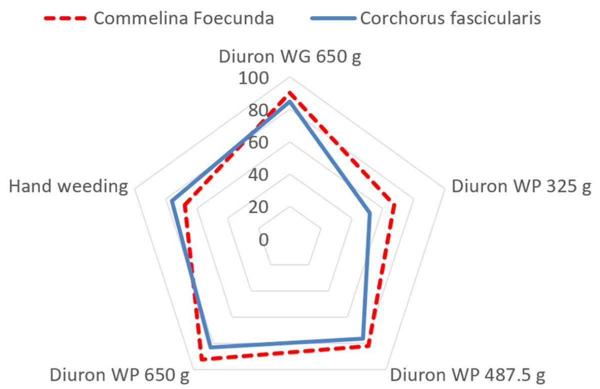

Figure 10. Coefficient of Efficacy (KE) of diuron on *Commelina foecunda* and *Corchorus fascicularis*

leaf weeds although it needs further detailed investigation. The lowest weed injury (50%) was recorded from the application of 325 g/ha two times indicating the rate of diuron matters in reflecting the efficacy of the herbicide.

Mehmeti *et al.* (2012) used the coefficient of efficacy (KE) to evaluate the efficacy of herbicides and the authors reported that this KE is vital in herbicide trials. The efficacy of the different rates and formulations of diuron on the major broad-leaf weeds was evaluated and depicted in Figure 10. The highest efficacy (92.2%) of the major broad-leaf weed *C. foecunda* was obtained from the application of diuron WP 650 g followed by the application of diuron WG 650 g. The lowest rate of the herbicide (325 g diuron WP) resulted into less efficacy (67%) against this weed. On the other hand, diuron WG 650 g was more effective (85%) followed by diuron WP 650 g (83%) against *Corchorus fascicularis*. Similar to that of *Commelina foecunda*, the lowest rate of diuron at 325 g showed lowest efficacy to control *C. fascicularis*. Generally, diuron at different rates is more effective to control *C. foecunda* vis-à-vis *C.fascicularis*. Moreover, as the rate of the herbicide decreased, the efficacy also decreased indicating the need for further investigation to optimize the rate of application.

Yield, yield loss and yield components of sesame

The ANOVA for grain yield showed significant (p=0.001) difference for grain yield, yield loss, number of branches per plant, number of pods per plant and plant height while non-significant (P<0.01) for length of pod bearing zone. The highest yield (837.5 kg/ha) was obtained from plots which were frequently hand weeded (weed free treatment) while the lowest yield was obtained from the weedy check 145.9 kg/ha (**Table 2**). Diuron WP 650 g/ha + hand weeding (669.9 kg/ha), diuron WG 650 g/ha + hand weeding (666.7 kg/ha), diuron WG 650 g/ha two times (621.1 kg/ha), diuron WP 650 g/ha two times (611.5 kg/ha), two times hand weeding (606.4 kg/ha) produced better sesame yield following to the weed free and these treatments were statistically non-significant to each other and hence, these management practices could be best options to control the major broad-leaf weeds in sesame production in the study areas and other similar production areas. This was in accordance with the findings of different workers (Audu *et al.* 2021, Joshi *et al.* 2022, Neetu *et al.* 2023) who reported the application of herbicide increased sesame yield and yield components.

Grichar *et al.* (2009) and Grichar *et al.* (2014) also reported higher sesame yield after post-emergence application with diuron. The lowest yield was obtained from one-time hand weeding, one-time diuron application and from the application of reduced rate of diuron (diuron WP 325 g/ha two times). Moreover, some of late growing weeds like *Ocimum* spp. and *Corchorus fascicularis*, which are other most important weeds in the study area, can significantly deteriorate the sesame quality in addition to the productivity. Although, hand weeding is effective and environmental friendly but it is time-

Table 2. Treatment set up and its description

Treatment	Weeding practice	Herbicide rate (g/ha)	Remark
Diuron WP 650 g one time	H	650	Applied once
Diuron WP 650 g two times	H+H	1300	Applied in two splits
Diuron WG 650 g one time	H	650	Applied once
Diuron WG 650 g two times	H+H	1300	Applied in two splits
Diuron WP 650 + HW	H+HW	650	Applied once *fb* HW
Diuron WG 650 + HW	H+HW	650	Applied once *fb* HW
One hand weeding	HW		Once hand weeding
Two hand weeding	HW+HW		Twice hand weeding
Diuron WP 487.5 g two times	H+H	975	Applied in two splits
Diuron WP 325 g two times	H+H	650	Applied in two splits
No weeding			Season long
Weed free	HW		Season long

H: Herbicide only; HW: Hand weeding

Table 3. Effect of weed management on grain yield and yield traits of sesame

Treatment	Yield (kg/ha)	Yield loss (%)	BPP	PPP	PH	LPBZ
Diuron WG 650 g + hand weeding	666.7^{b}	20.4^{d}	3.3^{bc}	38.2^{abc}	149.6^{b}	67.4
Diuron WG 650 g one time	432.9^{d}	48.3^{b}	1.9^{de}	25.2^{cd}	147.7^{b}	70.2
Diuron WG 650 g two times	621.1^{bc}	25.8^{cd}	3.8^{ab}	38.4^{ab}	149.5^{b}	67.2
Diuron WP 325 g two times	410.0^{d}	51.0^{b}	1.8^{de}	12.8^{d}	122.7^{bc}	61.7
Diuron WP 487.5 g two times	497.2^{cd}	40.6^{bc}	2.7^{cd}	25.3^{bcd}	128.5^{bc}	69
Diuron WP 650 + hand weeding	669.9^{b}	20^{d}	3.8^{ab}	41.4^{a}	144.4^{b}	70
Diuron WP 650 g one time	407.7^{d}	51.3^{b}	2.4^{cd}	23.8^{d}	146.5^{b}	74.3
Diuron WP 650 g two times	611.5^{bc}	26.97^{cd}	3.3^{bc}	41.8^{a}	142.6^{b}	72.2
One time hand weeding	437.3^{d}	47.8^{b}	1.9^{de}	20.0^{d}	129.8^{bc}	70
Two times hand weeding	606.4^{bc}	27.6^{cd}	3.2^{bc}	39.8^{a}	144.5^{b}	67.4
Weedy check	145.9^{e}	82.6^{a}	1.2^{e}	17.7^{d}	98.9^{c}	66
Weed free	837.5^{a}		4.3^{a}	45.7^{a}	182.2^{a}	74
Mean	528.7	40.2	2.8	30.8	140.6	69.1
CV (%)	163.8	19.9	1.0	13.2	30.9	10.8
LSD (<5%)	14.4	16.8	11.7	14.5	7.4	NS

BPP=Branches per plant; **PPP**=Pods per Plant; **PH**= Plant Height (cm)**; LPBZ**=Length of Pod Bearing Zone (cm); NS: non-significant

consuming and hence, it is important to use herbicides since they are effective as they are quick in action and selective (Jain and Badkul 2013).

Sesame yield loss ranging from 20-82.6% was because of weed infestation. This was in accordance to the findings of Amare (2011). However, the yield loss can reach up to complete failure (100% yield loss) if the production system is conventional like poor pest management and land preparation in addition to weed infestation. The highest number of branches per plant (3.8 branches/plant) was obtained from diuron WP 650 g/ha + Hand weeding and diuron WG 650 g/ha two times following the weed free treatment (4.3 branches/plant). Similar to the number of branches per plant, the trend of number of pods per plant was also obtained from these treatments, this is because of the reduced competition from weeds, and the plants become vigor.

Conclusions

The highest grain yield (669.9 kg/ha) followed by weed free (837.5 kg/ha) was obtained from the application of diuron WP 650 kg/ha + hand weeding, which was statistically at par with the application of diuron WG 650 kg/ha + hand weeding, diuron WP 650 g/ha two times, diuron WG 650 g/ha two times and two times hand weeding. Sesame yield loss of 82.6% was found in the weedy check.

Combining the herbicide and hand weeding (diuron at the 1st weeding time and hand weeding at the 2nd weeding time) is very important to control broad-leaf weeds in sesame fields. This study, therefore, recommends the application of diuron WG or WP at the rate of 650 g/ha applied twice at 10 and 30 DAE for the control of annual broad-leaf weeds in sesame in the sesame producing areas of Western Tigray and North Western Ethiopia. Ethiopian Ministry of agriculture reviewed the report on the efficacy of diuron to evaluate at the testing site and accepted and registered the herbicide to be used as post-emergence sesame herbicide in the country. However, further investigations on the optimum rate, time and method of application, integration with other cultural and chemical weed control measures should be carried out.

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