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Sequential Application of Herbicide Evaluation for Broad and Grass Weed Management in Tef *(Eragrostis tef(Zucc.) Trotter)*

Shugute Addisu*

Ethiopia Institute of Agricultural Research, Debre Zeit Agricultural Research Center, Debre Zeit, Ethiopia
Department of Crop Protection, Debre Zeit Agricultural Research Center, Debre Zeit, Ethiopia
Email: ashugute@yahoo.com

Abstract

An experiment was carried out to evaluate the efficacy of post-emergence herbicides against major broad and grass weeds of Tef (*Eragrostis tef* (Zucc.) Trotter]. The trial was conducted on-station and on-farm fields of Debre Zeit Agricultural Research Center during 2009 main crop season (Debre Zeit, Akaki and Alem Tena) s during 2012-2014 crop seasons. The treatments were: Flurasulam (75G/L) + Flumelsulam (100 G/L) at ; Flurasulam (75G/L) + Flumelsulam (100G/L). (Derby 175SC) (at 0.06 l ha^{-1}; Pyroxsulam (Pallas45 OD) at 0.45lha^{-1} applied during 35 days after crop emergence (DACE); 2, 4-D at 1.0 lha^{-1}) including sequential application of Derby + Pallas and 2, 4-D + Pallas. Twice hand weeding was applied at 30 and 55 DACE as standard checks for grasses and broadleaved weeds. and weedy check for comparison. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications, The plot size was 3m x 3m. . Weed control efficacy, yield and yield traits were investigated in this experiment. Twice hand weeding significantly decreased weed population over control and maximum grain yield (1822 kg ha-1). All herbicides significantly decreased weed population over control and maximum grain yield (1853 kg ha-1) was obtained where an integration of Pallas*45 OD and 2, 4-D (1 L/ha) was applied @ (0.45L/ha) and (1 L/ha) respectively.

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*Corresponding author.

It was however statistically at same level with the grain yield of 1837 kg ha-1 where an integration of Derby 175Sc and Pallas*45 OD was applied @ (0.45L/ha) and (60ml/ha) respectively. All the herbicidal applications out yielded the control. Single application of herbicide was less effective than integration weed managements. It is thus recommended that Derby + Pallas, 2, 4-D + Pallas and Twice hand weeding for offering control of broad leaf and grassy weeds to increase grain yield of tef.

Keywords: Tef, Herbicide; Broad leaf and Grass weeds; Weed Management.

1. Introduction

Tef (*Eragrostis tef* (Zucc.) Trotter] is the only cultivated cereal in the genus *Eragrostis* under the family Poaceae. Ethiopia is the center of origin of teff and is the only country in the world that uses tef as a cereal crop. Tef occupies 31% of the total farmland area of the country. Its production area is increasing at unprecedented scale due to increased market-demand- both local and foreign. One of the most important characteristics that make teff an efficient crop in arid and semi arid areas is its CO2 assimilation efficiency as a C4 species.

Figure1: Teff (Eragrostis tef (Zucc.) Trotter] photograph which is the only cultivated cereal in the genus Eragrostis under the family Poaceae.

Adaptation to diverse biotic and a biotic stresses has made tef a low risk crop for cultivation. Teff performs well above any other crops under unfavorable circumstances such as drought and water logging. In addition, adaptation of tef to different climatic and soil conditions has exposed it to grow in association with a diverse weed flora [1]. Herbicides are chemicals used to destroy unwanted plants (terrestrial or aquatic) called weeds.

Herbicides fall into two broad categories: inorganic (e.g., copper sulfate, sodium chlorate, and sodium arsenite) and organic (e.g., chlorophenoxy compounds, dinitrophenols, bipyridyl compounds, carbamates, and amide herbicides). Historically, inorganic compounds were the first available and the first used. There has been over a long period a continuous effort to develop herbicide compounds that are more selective that affect weeds, as opposed to desirable plants.

The morphological feature of the teff crop, especially its short and delicate stem, small leaves and shallow fibrous root system, offers low competition ability with weeds. About 48 to 49% yield loss of tef had been reported due to weed competition in the western Amahara region [7]. Farmers around Adet mostly practice twice hand weeding for tef from 30 to 60 days after planting. Hand weeding in tef remained to be one of the most expensive, time and energy consuming practice under all growing conditions [7]. Reference [8] reported that the small size of tef seed poses problem during sowing and indirectly during weeding, and farmers find it difficult to use mechanical weeding implements and are forced to either hand weed or to use chemical herbicides.

Hand weeding usually requires no capital outlay. This is a major advantage when cash is not readily available and labour is provided from the farmer's immediate family or through non-cash exchange. Therefore, to reduce the time and cost of weeding operations, there is a need to reduced hand-weeding dependency and develop herbicide application methods at the correct time. Hence this study is a meant to determine the effective herbicides on broad and grass weeds of tef.

The literature shows that countrywide, Teff yield losses due to weeds (if there is uncontrolled weed growth) range between 23% around the Debrezeit area to 56% in Shewa [7]. As a result, Teff weeding is a laborious task that is critical for productivity. Hand weeding is the most widely used practice to control weeds in Teff production. In addition, the use of 2-4-D herbicide at a recommended rate of 1 liter per hectare can help control broadleaf weeds. However, this herbicide has been banned in almost all countries in the world. In Ethiopia, its continued use has produced a new generation of 2-4-D tolerant broadleaf weeds; thus, new types of herbicides are urgently required [2].

2. Nationwide estimates of the labor required for hand weeding a hectare of teff ranges 40-138 man-days [5]. Moreover, a significant proportion of farmers in Ethiopia have no ox to operate a frequent tillage. Farmers with no ox get a 50% lower yield than those with two oxen [6]. Thus, land preparation and weed control methods in teff production remain to be ones of the most expensive, time and energy consuming and least successful means of increasing yields [9]. Therefore, the study was initiated to increase teff yield by reducing weed infestation level using appropriate weed management options and to find out the most effective herbicide to control these weeds in tef.

The wide range adaptation of tef to different climatic and soil conditions exposes it to grow in association with diverse composition of weed flora. Most surveys report that, in all growing condition, weed control in tef remains to be one of the most expensive, time and energy consuming and least successful means of increasing yields. Grain yields losses in tef due to weed competition have been estimated in various studies conducted in

Ethiopia. Country wide yield losses in tef due to weeds varied from 23 to 65%. Tef weeding is a laborious task that is critical for productivity. Hand-weeding is the most widely used practice to control weeds in Tef production (7).

Over the past two decades, 2,4-D has been the main herbicide available to peasant farmers for the control of broadleaf weeds in small cereals including Tef. However, 2,4-D does not give complete control of some of the major broadleaf weed species for example *Guizotia scabra, Raphanus raphanistrum* and *Galium spurium,* and where applied frequently in Ethiopia, has tended to shift the weed flora towards these more resistant species (3).

Controlling annual and perennial grass and broadleaf weeds from tef fields is of prime importance. Recently one promising wide spectrum herbicide (pyroxsylam) had been already investigated for the control of problematic weeds in tef and wheat. Pyroxsylam was found effective in controlling *Guizotia scabra, Galium spurium, Galinsoga parviflora, Amaranthus spp, Chenopodium spp, Bromus pectinatus* and *Avena spp* with efficacy of 100, 97, 97, 95, 82, 96 and 98%, respectively. Hence, pyroxsylam is recommended for the control of both grass and broad-leaf weeds predominantly grown in tef. However, observation on nation-wide demonstration of pyroxsylam showed that this herbicide is not effective against certain grass and broadleaf weed species such as (*Setaria pumila, Sorghum arundinaceum, Phalaris paradoxa, Convolvulus arvensis and Cichorium intybus,* and *Commelina benghalensis*).

In order to increase weed control spectrum of pyroxsylam a three years integrated weed management on sequential application with either hand weeding or broadleaf herbicides after application of pyroxsylam was studied at Debre Zeit, Alem Tena and Akaki. Results of this follow up activity revealed that: overall weed count means of herbicidal treatments were significantly lower than the untreated weedy check, of which the highest weed suppressions were from Flurasulam (75g/L, Flumelsulam (100g/L) + Pyroxsulam and Pyroxsulam + 2, 4-D followed by Flurasulam(75g, Flumelsulam(100g/l) herbicide; and the highest population was from weedy check and single herbicide treatments either for grass or broad leaf purposes. From the results of the present investigation it was concluded that annual and perennial weed species like: (*Amaranthus hybridus, Bindens pilosa, Commelina benghalensis, Datura stramonium, Galinsoga parviflora, Guizotia scabra Plantago lanceolata, Convolvulus arvensis, Cichorium intybus, Setaria pumila, Cyperus esculentus, Argemone ochroleuca, Sorghum arundinaceum, Eragrostis cilianensis* and *Xanthium strumarium)* were effectively controlled by all sequential applications of the test herbicides.

2. Materials and Methods

The experiment was conducted under on-station and on-farm fields of Debre Zeit Agricultural Research Center : (Debre Ziet, Akaki and Alem Tena during 2014-2015 crop seasons. The treatments were arranged in randomized complete block design (RCBD) with three replications. The experiment comprises a total area of 12m x 22m (264 m^2) with Plot size of 3m x 3m ($9m^2$) and footpaths of 0.5 between plots and 1m between replications were used. The teff variety was DZ-Cr -37 (Tsedey) for Alem tena and Quncho & Cr-37 for Debre Zeit and Akaki at the rate of 25 kg per hectare. Fertilizers rate of 40 kg/ha of Urea and 60 kg/ha DAP were used. The six treatments were consisted of three types of herbicide application and hand weeding. Flurasulam (75g/L,

Flumelsulam (100g/L) i.e. Derby 175Sc herbicides were applied at 35 after crop emergence as post herbicide with rate of (60ml/ha), Pyroxsulam i.e. Pallas*45 OD at 35 day after emergence (0.45L/ha), 2, 4-D at 28 day after emergence ((1 L/ha), with manually pumped Knapsack sprayer. But, two type of herbicides were applied in the form of integrated or sequentially (Derby + Pallas and 2, 4-D + Pallas). Twice hand weeding as standard check were done at 30 and 55 days after crop sowing and weedy check as control. Detail of treatments were cited in the following table.

Data recorded include weed parameters such as individual weed count before spray, after spray, using quadrant size 0.5 x 0.5m; weed biomass weed height and infestation level. Crop parameters such as grain yield, biomass and plant height were recorded and subjected to statistical analysis using SAS statistical soft ware version 9.5 at probability significance level of α=0.05.

Table 1: Detail of post emergence herbicidal treatments used in tef experiment.

Trade name	Common name	Dose ha-1
Derby 175 SC + Pallas 45 OD	Flurasulam(75g, Flumelsulam(100g/l) + Pyroxsulam	0.06L + 0.45L
2, 4-D + Pallas 45 OD	2, 4-D + Pyroxsulam	1L + 0.45L
Pallas 45 OD	Pyroxsulam	0.45L
Derby 175 SC	Flurasulam(75g, Flumelsulam(100g/l)	0.06L
Twice Hand weeding		
Weedy check		

3. Results

The combined analysis of variance over three years indicated that weed count after spray and weed infestation level were significantly ($P<0.05$) suppressed by all sprayed sequential herbicide across locations during the cropping season (Table 1). The other influenced weed parameters by herbicidal treatments in addition to above parameters was the weed height. The overall weed count means of herbicidal treatments were significantly lower than the controls (weedy check), the highest weed suppression were from Pyroxsulam + 2, 4-D followed by Flurasulam (75g/L, Flumelsulam (100g/L) + Pyroxsulam herbicide; and the highest was from weedy check and single herbicide application either for grass or broad leaf purposes.

The overall yield means of in sequential herbicidal treatments were significantly ($P<0.05$) higher than the weedy check yield in all locations. The maximum grain yield were recorded from sequential herbicidal applications of Flurasulam (75g, Flumelsulam (100g/l) + Pyroxsulam followed by 2, 4-D + Pyroxsulam and 1853 kg/ha and 1837.3 kg/ha) respectively. The lowest yield was recorded from single herbicide application as compared to sequential applied (Table-2). The effect may probably due to disturbance of herbicides on the weed plants ability to germinate. This may also be associated to the lower number of branches per plant, number of capsules

per plant, and number of weed seeds weight per capsule, which thus contribute to reduced seed yield and competition of the weeds to the crops.

The crop biomasses not respond significantly to sequentially applied herbicides. This might be due to time of different herbicidal applications. Since the herbicides are new and grouped into broad weed and grass weed herbicides, therefore it was sprayed separately within 7-10 days sequential intervals one from the other herbicide, then during that time some weeds in unsprayed plot aggressively compute the crop specially young tissues of shoot and roots of the crop are very sensitive during this time. This has reduced the uptake of nutrients which ultimately reduced crop growth. Moreover the reduction in leaf number might reduce the amount of photosynthetic productivity which in turn reduced plant height, number of branches that bear flowers and seeds.

3.1 Visual observation

Table 2: The major problematic (infesting) broad leaf and grass weed species observed through the experimental season at study area.

Botanical Name	Family	Local name
Convolvulus arvensis	*Convolvulaceae*	*Tatu*
Cichorium intybus		-
Setaria pumila	*Poaceae*	metene
Cyperus esculentus	*Cyperaceae*	Ingicha
Argemon aurculutes	*Papaverceae*	Abba kore
Sorghum arundinacensis	*Poaceae*	-
Eragrostis cilianensis	*Poaceae*	-
Phalaris paradoxa	*Poaceae*	asendabo
Raninculus arvense	*Asteraceae*	
Amaranthus hybridus	*Amaranthaceae*	
Bindens pilosa	*Asteraceae*	
Commelina benghalensis	*Commelinaceae*	
Datura stramonium	*Solanaceae*	
Galinsoga parviflora	*Asteraceae*	
Guizotia scabra	*Asteraceae*	Tufo
Plantago lanceolata	*Plantaginaceae*	
Xanthium strumarium	*Asteraceae*	Yeset milas

Plots treated by herbicides were infested problematic weed species mentioned above and others however; to some extent *Convolvulus* and *Cichorium were* escaped and lately emerge since these weeds are hard and

perennial characteristics so it needs further study for these individual species.

4. Discussion

The importance of weed species was determined by calculating the frequency and abundance value of particular species. The most frequently distributed species was *Setaria pumila* covering almost 79.9% of the samples followed by *Phalaris paradoxa*, Eragrostis cilianensis, *Cyperus esculentus*, *Cichorium intybus* which scored frequencies ranging from 19.2 to 66.5% (Table 2). In general, there were positive and significant correlations between frequency and abundance values of a particular weed species.

4.1 Number of Weeds Before Spray

The examination of data in Table-2 show that the experiment was infested with several broad leaf and grass weed species. The family *Asteraceae* and Poaceae predominated the other families having 5 and 4 species viz. *Xanthium strumarium, Galinsoga parviflora, Guizotia scabra, Bindens pilosa,* Raninculus arvense *and Setaria pumila*, *Phalaris paradoxa*, Eragrostis cilianensis, Sorghum *arundinacensis respectively*. The rest all families were represented by single species each. Data concerning number of weeds before spray m^2 showed least significant differences among the different treatments (Table-3). Comparative study of the means showed that maximum number of weeds after spray (23.33 m^2) were counted in Pyroxsulam @ 0.45l ha-1 was going to be applied followed by Flurasulam(75g, Flumelsulam(100g/l) @ 1l ha-1 (21.67 m^2), as compared to control where least number of weeds before spraym^2 (14.30) were recorded. There was a arbitrary variability among the remaining treatments (Table-3).

4.2 Weed density (m^2)

Data concerning number of weeds after spray m^2 showed significant differences among the treatments under study (Table -3).As study of the means revealed that minimum number of weeds after spray (4.3m^2) were counted in treatment one were Flurasulam(75g, Flumelsulam(100g/l) + Pyroxsulam was applied, respectively followed by treatment three (6.3 m^2) where 2, 4-D + Pyroxsulam @ 1Land 0.45Lha-1 Pyroxsulam as compared to control (17.3m^2).

4.3 Weed score (0 - 5)

The analysis of variance indicated that weed count after spray and weed infestation level were significantly ($P<0.05$) suppressed by all sprayed combined and alone herbicide applied to all locations during the cropping season (Table 3).

4.4 Crop height (cm)

The analyses of data regarding crop height showed highly significant differences among the treatments (Table-3).The study of the means showed that maximum crop height (92 cm) was achieved in weedy check. There was also least significance among herbicidal treatments.

4.5 Grain yield (kg ha-1)

The analysis of data concerning grain yield revealed significant differences among the different treatments as presented in Table-3.The study of the means showed that maximum grain yield(1853 kg ha-1 and 1837.3 kg ha-1) was achieved in treatment two where Flurasulam (75g, Flumelsulam(100g/l) + Pyroxsulam@1L and 2, 4 D + 0.45L ha-1 was applied, respectively. It was however, statistically comparable with all treatments particularly Pyroxsulam @ 0.45l ha-1 and Flurasulam (75g, Flumelsulam(100g/l) including twice hand weeding with grain yield of 1685.3ab kg, 1668ab kg ha-1 , 1822a kg ha-1, respectively except weedy check. Minimum grain yield of 1194.9kg ha-1 was obtained from weedy check where no herbicide was applied(Table-3).The percentage increment (57.088, 57.88, 54.94, 54.48 and 53.74%) in grain yield was observed in Flurasulam (75g, Flumelsulam(100g/l) + Pyroxsulam, Mesosulfuron methyl + Iodosulfuron methyl, 2,4-D + Pyroxsulam, Twice Hand weeding and Flurasulam (75g, Flumelsulam (100g/l) sodiumtreatments, respectively over control(Table-4).

4.6 Biomass

The other influenced weed parameters by herbicidal treatments in addition to above parameters were the green and dry biomass of the weeds. That means, the overall weed count means of herbicidal treatments were significantly lower than the controls (weedy check), the highest weed suppression were from Pyroxsulam + 2, 4-D and twice hand weeding followed by Flurasulam (75g/L, Flumelsulam (100g/L) + Pyroxsulam herbicide; and the highest was from weedy check and single herbicide application either for grass or broad leaf purposes.

Table 3: Main effect of herbicides on weeds and crop growth parameters in tef crop (2014-2015) at Debre Zeit, Akaki and Alem Tena Districts, Ethiopia

Treatments	Wa	wi	wg	wd	wh	cb	Ph	gy
Flurasulam(75g, Flumelsulam(100 g/l) + Pyroxsulam	4.3c	1.56c	999.9d	1036.9b	50c	12161b	75ab	1837.3a
2, 4-D + Pyroxsulam	6.3bc	1.66c	1123.3d	1320.9b	54.33c	13025ab	81ab	1853a
Pyroxsulam	11b	4b	12160.7b	6172.7a	81.67ab	12839ab	79ab	1685.3ab
Flurasulam(75g, Flumelsulam(100 g/l)	7.7bc	1.56c	1666.5cd	753b	45.00c	9420b	60.6b	1668ab
Twice Hand weeding	9.1bc	2.2c	3648c	1851.7b	63.67bc	14012a	67b	1822a
Weedy check	17.3a	5a	14259.3a	4821a	103a	11481ab	92b	1194.9a
Mean	9.29	2.66	5642	2659	66.38	12156	75.77	1686.7
CV (%)	29.36	15.17	19.48	34.3	19.32	17.2	16.35	17.37

LSD .05	4.96	0.736	1999.9	1660.6	23.35	3804.8	22.5	533.2
MSE	7.5	0.16	1208401.4	833189.2	164.7	4373927.4	153.6	85898.3

Means within columns not sharing the same letter show significance difference at $p < 0.05$.

wh = weed height cb = crop biomass

was = weed after spray wg = weed green biomass ch = crop height

wi = weed infestation wd = weed dry biomass gy = grain yield

Table 4: %Increase in grain yield of five different treatments over control.

Treatments	Rate L/ha	Yield (kg/ha)	Additional yield (kg/ha)	% increase
Flurasulam(75g, Flumelsulam(100g/l) + Pyroxsulam	1 + 0.45	1837.3a	1649.5	54.94
2, 4-D + Pyroxsulam	1 + 0.45	1853a	1463.4	57.88
Pyroxsulam	1	1685.3ab	1596.1	57.088
Flurasulam(75g, Flumelsulam(100g/l)	1	1668ab	1617.9	54.48
Twice Hand weeding		1882.a	1394.5	53.74
Weedy check		1194.9a	-	-

5. Conclusion

The data were collected on weed dynamics and growth and yield parameters of teff like weed before spray (number/m^2),weed after spray (number/m^2), weed height (cm),crop height (cm), crop biomass(kg ha-1), weed green biomass (kg ha-1),weed infestation (scale 0- 5),weed dry biomass(kg ha-1), grain yield(kg ha-1). The study demonstrates that the overall weed count means of herbicidal treatments were significantly lower than the controls (weedy check), the highest weed suppression were from Flurasulam (75g/L, Flumelsulam (100g/L) + Pyroxsulam and Pyroxsulam + 2, 4-D followed by Flurasulam(75g, Flumelsulam(100g/l) herbicide; and the highest population was from weedy check and single herbicide application either for grass or broad leaf purposes. From the results of the present investigations we conclude that: annual weed species like (*Amaranthus hybridus, Bindens pilosa, commelina benghalensis, Datura stramonium, Galinsoga parviflora, Guizotia scabra Plantago lanceolata, Convolvulus arvensis, Cichorium intybus, Setaria pumila, Cyperus esculentus, Argemon aurculutes,* Sorghum *arundinacensis,* Eragrostis cilianensis and *Xanthium strumarium)* were highly managed by these sequential herbicides.

6. Recommendation

Generally, the finding demonstrated that combined herbicide weed management practices are essential for future if further research is done. The emphasis has been given on the management of both broad and grass weeds with sequential herbicidal management options because of the labour and time limitation in hand weeding. An integrated strategy consisting of crop rotation and reduction of weed seed bank benefited for small holder farmers not only as control of weed but also increase soil fertility should be involved for the sustainable management of the crop system. In addition more studies should be undertaken on perennial weed species. These suggest that there is a need to encourage the research on perennial weed species like, *Convolvulus* and *Cichorium*, evaluate the efficacy of research findings at farmer's field with individual weed based, emphasize on the advanced research on these unique species and establish infrastructure to develop advanced but farmer's friendly simple and effective management methods.

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