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Effect of Herbicides Supplemented with Hand Weeding on Weed Management, Yield, and Yield Components of Tef (*Eragrostis tef*) in Borana, Southern Ethiopia

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Abstract

Tef is one of the major cereal crops widely cultivated in the study area, and it is used both for consumption and as a source of income. However, weeds are among the most challenging factors affecting tef production. Thus, the study was conducted with the objective of identifying the most effective and economically feasible post-emergence herbicides combined with hand weeding on weed management in tef cultivation. The experiment consisted of nine treatments arranged in a randomized complete block design with three replications. Weed density, weed control efficiency, and tef seed yield were recorded and analyzed using SAS software. The analyzed data revealed that the maximum weed control efficiency was observed in the weed-free treatment (90.83%) and in plots treated with Pallas Super 45OD (Pyroxsulam (Triazolopyrimidine) 45 g L^{-1}) at 1L ha^{-1}, supplemented with hand weeding at 15 and 30 days after sowing (DAS) (84 %). The maximum grain yield was obtained from plots treated with Pallas Super 45OD combined with hand weeding at 15 and 30 DAS (1832.3 kg ha^{-1}), followed by the weed-free (1779.1 kg ha^{-1}), while the minimum grain yield was recorded in the unweeded plots (715.30 kg ha^{-1}). Further, the study confirmed that to reduce the yield losses caused by the weeds in tef, the application of Pallas Super 45OD, supplemented with hand weeding at 15 and 30 DAS, is the most effective method for managing weeds.

Keywords

Tef; yield; herbicide; economic analysis; weed

1. Introduction

Tef [*Eragrostis tef* (Zucc.) Trotter] is a small cereal grain crop belonging to the Poaceae family and is cultivated as an annual crop. It is well adapted to a wide range of environmental conditions and performs better under stressful environments compared to other cereals [1]. Due to its tolerance to low moisture conditions, tef can survive and grow even when early sown crops fail as a result of moisture stress.

Tef is one of the major staple cereal crops cultivated and consumed in Ethiopia, and its production has been increasing from year to year [2]. During the 2021/22 production season, it covered about 2932670.03 hectares of land, producing approximately 5614338.801 tons of grain, with an average yield of 1.914 tons ha^{-1} [3].

Similarly, tef is a major crop in the Borana lowlands, where it is produced for both household consumption and as a cash crop. In Borana, out of 6614.01 hectares of land covered by cereal crops, about 1742.32 hectares were allocated to tef. From the total cereal production of 7511.328 tons, approximately 1539.114 tons were achieved from tef [3]. This indicates that tef occupies about 29.33% of the total cereal cultivated area and contributes about 19.31% of the total cereal grain output in Ethiopia. In Borana, it accounts for about 26.34% of the cereal area and contributes around 20.49% of the total cereal yield [3].

Despite its importance, the productivity of tef in the Borana lowlands (0.883 tons ha^{-1}) is significantly lower than the national average yield (1.914 tons ha^{-1}) recorded in the same production year [3]. This low productivity is attributed to several biotic and abiotic factors. Among the biotic factors, weeds are one of the most important constraints, causing significant yield losses in tef production. In moisture stress areas of southern Oromia, the low tef yields may also result from the lack of improved varieties, poor adoption of improved technologies, and the prevalence of diseases and pests [4]. Among these challenges, weed infestation remains a major problem, leading to substantial yield reduction [5]. Yield losses due to weeds in tef production in Ethiopia range from 23-65% [6]. Therefore, effective weed management practices are essential to minimize yield losses. Herbicides such as Pyroxsulam (Triazolopyrimidine) at 45 g L^{-1} can control both grass and broadleaf weeds, while others like 2, 4-D amine, Dicamba, Aim, and Florasu-fluroxy-pyro primarily target broadleaf weeds at varying levels of effectiveness [7].

In the Borana zone, weed infestation is a major constraint to tef production. Although some farmers practice hand weeding, most available commercial herbicides have a narrow spectrum of weed control. Therefore, integrating hand weeding with appropriate herbicides could be more effective for both grass and broadleaf weeds and improve tef productivity.

1.1 Objective

To select the most effective post-emergence herbicides combined with hand weeding for integrated weed management and identify economically feasible options for tef cultivation in the study areas.

2. Materials and Methods

2.1 Description of Study Area

The study was conducted for two consecutive main cropping seasons at both Yabello and Teltelle during 2024 and 2025. Yabello is located 570km south of Addis Ababa at an altitude of 1635m above sea level, with coordinates of 04º51'1789"N latitude and 038º06'223"E longitude. It has an annual maximum and minimum temperature of 26.3 °C and 14.5 °C, respectively. Teltelle is located 670km from Addis Ababa at an altitude of 1560m above sea level, with coordinates of 05º3'505"N latitude and 037º22'528"E longitude. It has an annual maximum and minimum temperature of 28.3 °C and 16.7 °C, respectively.

2.2 Experimental Design and Materials

The experiment consisted of nine treatments arranged in a randomized complete block design (RCBD) with three replications. Each plot measured 1.2 m x 2 m, width and length respectively, giving a gross plot area of 2.4 m^2 and a net plot area of 1.6 m^2. The tef variety Dz-cr37 was used for the experiment. The treatments included two different post-emergence herbicides: Pallas supper 45OD (Pyroxsulam (Triazolopyrimidine) 45 g L^{-1}) applied at 1 L ha^{-1} and Power 860 SL applied at 0.3 L ha^{-1}, each supplemented with different hand weeding frequencies. Herbicide concentrations were adjusted according to recommended rates and applied using a 15-L capacity knapsack sprayer.

Hand weeding was carried out according to treatment specifications after crop emergence. The weeding frequency in weed-free plots was based on weed occurrence. The applied hand weeding treatments included weeding at 15 and 30 days after emergence. The treatments were as follows: (1) Power 860 SL, (2) Pallas Super 45OD, (3) Power860SL supplemented with hand weeding at 30 days after sowing (DAS), (4) Pallas Super 45OD combined with hand weeding at 30 DAS, (5) Power 860 SL supplemented with hand weeding at 15 and 30 DAS, (6) Pallas Super 45OD combined with hand weeding at 15 and 30 DAS, (7) two hand weeding at 15 and 30 DAS, (8) weed free treatment and (9) weedy check (unweeded treatment). The experimental fields were prepared to obtain a fine seedbed at both locations. DAP and Urea fertilizers were applied in furrows at the recommended rate of 100 kg ha^{-1} at planting.

3. Data Collection

3.1 Weed Parameters

Weed flora present in the experimental fields were assessed from the weedy check plots in each replication by placing a 0.25 m^2 quadrat randomly at two spots in each plot just before crop flowering. The identified weed species were classified into families using standard flora references.

Weed density (m^{-2}), weed dry weight ($g\ m^{-2}$), and weed control efficiency (WCE) were scored.

Weed density was determined by counting the number of individual weeds per unit area.

$$\text{Weed Density} = \frac{\text{Total number of weed in the quadrat}}{\text{Total area of a quadrat } (m^2)} \times 100$$

For weed dry weight determination, weeds were sampled 15 days before harvest using a 0.25 m^2 quadrat placed randomly at two points per plot. The weeds were cut at ground level, sun-dried for three days, and then oven-dried at 65 °C to constant weight to determine above-ground weed dry biomass. Weed dry weight data were subjected to square root transformation to ensure normality before analysis of variance.

Weed Control Efficiency (WCE) represents the percentage reduction in weed population or dry weight in treated plots compared to the weedy check. It is used to compare the effectiveness of different weed control treatments. Higher WCE values indicate better weed control performance.

$$\text{WCE } (\%) = \frac{\text{WDM in unweeded Treatment} - \text{WDM in Particular Treatment}}{\text{WDM in unweeded treatment}} \times 100$$

Where: WDM- Weed dry matter

3.2 Weed Index

The weed index (WI) measures the efficiency of a treatment compared to the weed-free control. It is expressed as the percentage of yield reduction due to weeds relative to the weed-free yield.

$$WI = \frac{X-Y}{X} \times 100$$

Where:
WI=Weed Index
X=Yield from Weed Free
Y=Yield of Particular Treatment

3.3 Crop Parameters

Days to panicle emergence were recorded as the number of days from planting until 50% of plants showed panicle emergence. Days to physiological maturity were recorded as the number of days from planting until 90% of the plants reached physiological maturity.

Plant height was measured from the base to the tip of the main stem at harvest (cm). The number of tillers per plant was counted, and panicle length was measured at harvest (cm). Grain yield (kg) was recorded from each net plot area after threshing.

Relative yield loss (RYL) was calculated using the appropriate formula:

$$\text{RYL } (\%) = \frac{\text{Maximum Yield from Treatment} - \text{Yield from a Particular Treatment}}{\text{Maximum Yield from Treatment}} \times 100$$

Where: RYL = Relative Yield Loss

3.4 Harvest Index

Harvest index (HI) describes the plant's ability to allocate biomass into reproductive parts. It is calculated as the ratio of grain yield to total biomass [8].

$$\text{Harvest Index} = \frac{\text{Grain Weight } (kg\ ha^{-1})}{\text{Total Aboveground Biomass } (kg\ ha^{-1})}$$

3.5 Partial Budget Analysis

Partial budget analysis, as described by [9], was conducted to determine the economic feasibility of the treatments. It considered variable input costs and gross returns from each treatment. Economic analysis was based on market prices for inputs at planting and outputs at harvest.

3.6 Statistical Analysis

The collected data were subjected to analysis of variance (ANOVA) using SAS software version 9.3. Treatment means were separated using the least significant difference (LSD) test at the 5% probability level whenever significant differences were observed. Pearson correlation analysis was performed to assess the relationship between grain yield and weed parameters.

4. Results and Discussion

4.1 Weed Flora

Various weed species were recorded from the experimental fields and grouped into different families. The weed density was categorized into broadleaf and grass weeds. Accordingly, both weed density and dry matter were significantly affected by the evaluated treatments.

Weed density and dry matter were analyzed separately for both broadleaf and grass weeds. Among these two groups, broadleaf weeds showed higher density compared to grass (Table 2).

Furthermore, weed density and dry matter were evaluated across the two experimental locations, Yabello and Teltelle. The highest weed density was recorded at Yabello for both broadleaf (227.45 m^{-2}) and grass (145.67 m^{-2}) weeds.

4.2 Weed Species Composition

A total of 14 weed species were identified across the experimental sites (Table 1). The families with the highest number of species were *Asteraceae* (5 species) and *Poaceae* (4 species).

Table 1. Weed flora composition recorded from tef fields at Yabello and Teltelle

Botanical Name	Family	Life cycle
Amaranthus hybridus	Amaranthaceae	Annual
Bidens pilosa L.	Asteraceae	Annual
Datura stramonium L.	Solanaceae	Annual
Galinsoga parviflora (Cav.)	Asteraceae	Annual
Guizotia scabra	Asteraceae	Annual
Nicandra physalodes L.	Solanaceae	Annual
Parthenium hysterophorus	Asteraceae	Annual
Ageratum conyzoides L.	Asteraceae	Annual
Argemone mexicana	Papaveraceae	Annual
Avena fatua	Poaceae	Annual
*Cynodon dactylon (*L.) *Pers.*	Poaceace	Perennial
Other grass species	Poaceace	Annual
Phalaris paradoxa	Poaceace	Annual
Cyprus esculentus L.	Cyperaceae	Perennial

4.3 Weed Density and Weed Dry Matter

Weed density and dry weight were significantly ($P<0.01$) affected by the interaction of weed management practices. Weed density was one of the major weed parameters measured for each treatment. The highest density of broadleaf weeds was recorded in the weedy check treatment (482.49 m^{-2}), followed by hand weeding at 15 and 30 days after sowing (DAS) (352.42 m^{-2}) (Table 2). Similarly, the maximum total weed density (combined broadleaf and grass weeds) was observed in the weedy check treatment (782.12 m^{-2}). In contrast, the lowest total weed density was recorded in weed-free plots (52.77 m^{-2}), followed by plots treated with Pallas Super 45OD (160.08 m^{-2})

supplemented with two hand weeding at 15 and 30 DAS.

The analysis of weed dry matter indicated that there was a highly significant variation among the evaluated treatments for both broadleaf and grass weeds. The dry biomass of both weed groups was significantly influenced by the application of different herbicides and hand weeding treatments.

The maximum weed dry matter was recorded from the weedy check plot, with values of 712.66 g m^{-2} for broadleaf weeds and 325.78 g m^{-2} for grass weeds. In contrast, the minimum weed dry matter was obtained from the weed-free treatment, with 74.55 g m^{-2} (broadleaf) and 36.08 g m^{-2} (grass weeds). This was followed by plots treated with Pallas Super 45OD combined with hand weeding at 15 and 30 DAS, which recorded 128.51 g m^{-2} (broadleaf) and 59.86 g m^{-2} (grass weeds) (Table 2). Similarly, the total weed dry matter (combined broadleaf and grass weeds) was highest in the weedy check (1038.44 g m^{-2}), while the lowest values were recorded in the weed-free treatment (110.63 g m^{-2}), followed by Pallas Super 45OD combined with two hand weeding at 15 and 30 DAS (188.37 g m^{-2}).

These results clearly demonstrate that the application of post-emergence herbicide integrated with hand weeding significantly reduces the dry weed weight and improves weed control efficiency. These findings are consistent with previous reports [10], which indicated that maximum weed dry weight is observed under unweeded (weedy check) conditions.

Table 2. Weed density, Weed dry matter, and Weed control efficiency

Treatments	Weed density (m^{-2})		Weed dry matter (g m^{-2})		Weed control efficiency (%)		
	Broadleaf	Grass	Broadleaf	Grass	Broadleaf	Grass	TWCE
Power 860 SL	256(16) bc	220.53b	379.28bc	176.28c	47.53e	45.85f	47.15f
Pallas Super 45OD	274.07(16.56) bc	47.48f	330.96cd d	154.78c	56.05d	56.42e	56.00e
Power 860 SL + 1HW@ 30 DAS	276.84(16.58) bc	138.14d	154.15e	72.73ef	80.88b	80.07bc	80.66bc
Pallas Super 45OD + 1HW @ 30 DAS	95.98(9.8) d	122.30d	281.30d	130.30d	63.93c	63.38d	63.80d
Power 860 SL + 2HW @15 and 30 DAS	135.32(11.63) cd	88.61e	186.13e	87.43e	77.21b	76.43c	76.99c
Pallas Super 45OD + 2HW @15 and 30DAS	103.0(10.15) d	57.08f	128.51ef	59.86f	83.69b	83.22b	83.59b
HW @ 15 and 30 DAS	352.42(18.77) ab	158.28c	434.98b	204.22b	39.35f	37.24g	38.84g
Weedy free	31.98(5.66) d	20.79g	74.55f	36.08g	90.78a	90.19a	90.59a
Weedy check	482.49(21.97) a	299.68a	712.66a	325.78a	0.00g	0.00h	0.00h
CV (%)	23.09	16.56	26.08	19.32	14.44	13.14	11.32
LSD (0.05)	2.56	17.22	63.07	21.72	7.02	6.31	5.49
Mean	223.12 (13.68)	128.1	298.06	138.61	59.93	59.2	59.74

Notes. Where: LSD-Least significant differences, HW-Hand weeding, CV (%) - coefficient of variation in percentage, Values in parentheses are square root transformed means used for ANOVA. Means followed by the same letter are not significantly different at $p \leq 0.05$ (LSD).

4.4 Weed Control Efficiency (WCE)

The analysis of weed control efficiency (WCE) revealed highly significant differences among treatments for both broadleaf and grass weeds. Weed management practices significantly influenced the effectiveness of weed control (Table 2).

The highest WCE was recorded in the weed-free treatment, with 90.19% for broadleaf weeds and 90.19% for grass weeds. This was followed by plots treated with Pallas Super 45OD combined with hand weeding at 15 and 30 DAS, which achieved 83.69% (broadleaf) and 83.22% (grass weeds). In contrast, the weedy check treatment showed 0% WCE, indicating no weed control intervention. The total WCE (combined broadleaf and grass weeds) followed a similar trend, with the highest value recorded in weed-free plots (90.59%), followed by integrated treatment (Pallas Super 45OD supplemented with hand weeding at 15 and 30 DAS) (83.59%).

The higher WCE observed in herbicide-treated and weed-free plots is attributed to reduced weed biomass and minimized competition. These results agree with findings reported by [10], who observed maximum weed control efficiency under herbicide application and no efficiency in untreated plots.

4.5 Weed Index (WI)

The weed index varied significantly among treatments. The highest weed index (56.61%) was observed in the weedy check, followed by hand weeding at 15 and 30 DAS (53.23%), indicating substantial yield reduction due to weed competition. Conversely, the lowest weed index (-2.99) was recorded in plots treated with Pallas Super 45OD combined with hand weeding at 15 and 30 DAS, suggesting a yield advantage over the control. This indicates that integrated weed management practices effectively minimize yield loss and enhance productivity.

5. Crop Growth Parameters

5.1 Panicle Emergence and Physiological Maturity

The analysis of variance indicated that panicle emergence (flowering date) and physiological maturity were not significantly affected by the evaluated treatments. However, numerically, the maximum flowering date (37.25days) was recorded from plots treated with hand weeding at 15 and 30 DAS, whereas the minimum (36.75 days) was observed from plots treated with Power 860 SL supplemented with hand weeding at 15 and 30 DAS and from weed-free plots.

Similarly, the maximum maturity period (77.33days) was recorded in the weedy check, while the minimum (75.83) was obtained from the weed-free treatment. The delayed flowering and maturity in the weedy check may be attributed to higher weed density and shading effects, which reduce light interception and prolong vegetative growth [11].

5.2 Plant Height and Panicle Length

Plant height was highly significantly ($p<0.001$) influenced by the applied treatments. The plant height ranged from 82.04 cm to 104.21 cm, with the highest value (104.21 cm) recorded from plots treated with Pallas Super supplemented with hand weeding at 30 DAS. The lowest plant height was recorded in the weedy check. The overall mean plant height was 90.56 cm. Plant height is one of the important factors that positively affect the yield of Tef [12]. This variation indicates that effective weed management enhances crop growth by reducing competition for nutrients, moisture, and light. However, similar findings by [11] reported no significant difference in plant height among treatments despite variations in weed density.

Panicle length was also significantly ($P<0.001$) affected by the treatments. The maximum panicle length (35.63 cm) was obtained from plots treated with Pallas Super 45OD combined with hand weeding at 15 and 30 DAS, whereas the minimum (24.46 cm) was recorded from the weedy check. This improvement can be attributed to reduced weed competition, which enhances resource availability for crop development. These findings are consistent with [13], who reported longer panicles under improved weed management practices.

5.3 Tiller Number

The number of tillers was significantly affected by the applied treatments. The highest tiller numbers were recorded from plots treated with Pallas Super 45OD supplemented with hand weeding at 15 and 30 days after sowing (DAS), Power 860 SL supplemented with hand weeding at 15 and 30 DAS, and Pallas Super 45OD supplemented with hand weeding at 30 DAS, while the lowest tiller number was recorded from the weedy check (Table 5). This increase in tillering under weed-free conditions is likely due to reduced competition, allowing better access to water, nutrients, and light, thereby promoting the development of tillers from basal nodes. Similar results were reported by [14].

5.4 Biomass and Grain Yield of Tef

Above-ground biomass yield was highly significantly ($P<.001$) affected by the treatments. The highest biomass yield (7315.7 kg ha^{-1}) was recorded from the weed-free treatment, followed by Pallas Super 45OD supplemented with hand weeding at 15 and 30 DAS (7276.8 kg ha^{-1}). The lowest biomass yield (3057.3 kg ha^{-1}) was recorded from the weedy check.

The increase in biomass reflects improved crop performance due to effective weed suppression. These findings are consistent with [4], who reported high biomass yield under improved management practices.

Grain yield was also highly significantly ($P<.001$) influenced by the treatments. The highest grain yield (1832.3

kg ha^{-1}) was obtained from Pallas Super 45OD supplemented with hand weeding at 15 and 30 DAS, followed by weed-free treatment (1779.1 kg ha^{-1}). The lowest grain yield (715.30 kg ha^{-1}) was recorded from the weedy check. The higher yield in treated plots is associated with improved tillering, plant height, and biomass accumulation, resulting from reduced weed competition.

5.5 Relative Yield Loss (RYL)

Relative yield loss was highest (60.96%) in the weedy check, indicating severe yield reduction due to weed competition. In contrast, minimum yield loss was observed in treatments involving Pallas Super 45OD combined with hand weeding at 15 and 30 DAS and in weed-free plots.

Table 3. Mean values of tef yield and yield components

Treatments	FD	MD	PHT	TLN	SPL	Biomass (kg ha^{-1})	GY (kg ha^{-1})	RYL (%)	WI (%)
Power 860 SL	37.17	76.83	83.21cd	2.67^{ab}	25.79cd	5554.9^{b}	1130.3c	38.31	36.468
Pallas Super 45OD	37.08	76.92	83.04cd	3.00^{a}	28.13cd	4297.1^{c}	1108.2c	39.52	37.710
Power 860 SL + HW@ 30 DAS	37.00	76.50	92.21bc	2.25^{b}	25.63cd	5576.6^{b}	1289.6bc	29.62	27.514
Pallas Super 45OD + HW @ 30 DAS	37.00	76.25	104.21a	3.25^{a}	32.79ab	6789.5^{a}	1287.4bc	23.37	27.638
Power 860 SL + HW @15 and 30 DAS	36.75	76.58	92.88b	3.25^{a}	28.79c	**6371.8^{ab}**	1514.3b	17.36	14.884
Pallas Super 45OD + HW @15 and 30 DAS	37.00	76.67	102.21a	3.25^{a}	35.63a	**7276.8^{a}**	1832.3a	0.00	-2.990
HW @ 15 and 30 DAS	37.25	76.67	82.38d	2.33^{b}	26.13cd	3753.7^{cd}	832.0d	38.22	53.235
Weedy free	36.75	75.83	92.88b	3.00^{a}	29.29bc	**7315.7^{a}**	1779.1a	2.90	0.000
Weedy check	37.17	77.33	82.04d	2.17^{b}	24.46d	3057.3^{d}	772.0d	60.96	56.607
CV (%)	3.31	4.41	12.66	27.99	16.63	25.09	23.03		
LSD (0.05)	1.02	2.74	9.31	1.99	3.85	1131.1	239.97		
Mean		37.02	76.62	90.56	2.8	28.51	5554.82		

Notes. Where: FD-Flowering date, MD-Maturity date, PHT-Plant height, TLN-Tiller number, SPL-Spike length, GY-Grain Yield, RYL-Relative yield loss, DAS-Days after sowing, HW-Hand weeding, WI-Weed Index, CV (%) - coefficient of variation in percentage, Means followed by the same letter are not significantly different at $p \leq 0.05$ (LSD).

5.6 Harvest Index (HI)

Harvest index was significantly affected by the treatments. The highest HI values were recorded in treatments including Power 860 SL combined with hand weeding at 15 and 30 DAS (26.16%), Pallas Super 45OD (26.04%), and Pallas Super 45OD combined with hand weeding at 15 and 30DAS (25.45%). A higher harvest index indicates efficient partitioning of biomass into grain yield [15].

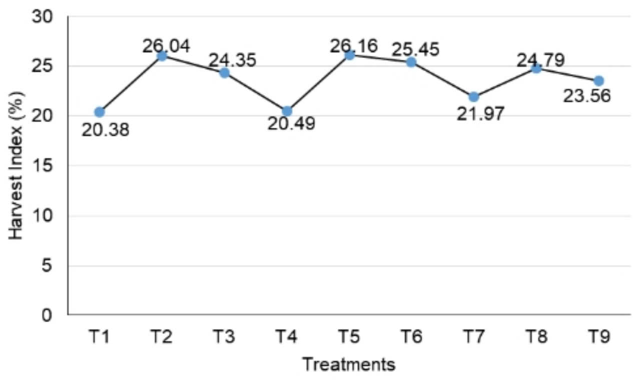

Figure 1. Harvest Index of the evaluated treatments on tef.

Where: T1-Power 860 SL, T2-Pallas Super 45OD, T3-Power 860 SL with hand weeding at 30 DAS, T4-Pallas Super 45OD with hand weeding at 30 DAS, T5-Power 860 SL with hand weeding 15 and 30 DAS, T6-Pallas Super 45OD with hand weeding 15 and 30DAS, T7- hand weeding 15 and 30 DAS, T8-Weedy free and T9-Weedy check

5.7 Association of Weed Infestation and Grain Yield

The correlation analysis indicated a very significant difference and a strong positive relation (r=0.883, r=0.728, r=0.717, r=0.728) between grain yield and plant height, tillers, spike, and biomass yield, respectively. However, it was revealed that weed parameters (total weed density and dry matter) showed a negative association and very significant variation with tef grain yield. The relation between tef grain yield with total weed density and dry matter was (r=-0.889 and r= -0.888) respectively (Table 4). These results confirm that weed infestation significantly reduces crop productivity, while effective weed control enhances yield performance.

Table 4. Grain yield correlates with yield components and weed parameters

Variables	WD	WDM	PHT	TLN	SPL	Biomass (kg ha^{-1})	GY (kg ha^{-1})
WDM	0.907						
PHT	-0.700	-0.649					
TLN	-0.836	-0.605	0.669				
SPL	-0.745	-0.574	0.860	0.828			
Biomass (kg ha^{-1})	-0.890	-0.869	0.831	0.751	0.745		
GY (kg ha^{-1})	-0.889	-0.888	0.728	0.717	0.728	0.929	
RYL (%)	0.928	0.910	-0.754	-0.718	-0.771	-0.925	-0.958

Notes. Where: WDM-Weed dry matter, WD-Weed density, PHT-Plant height, TLN-Tiller number, SPL-Spike length, GY-Grain yield, RYL-Relative yield loss.

5.8 Economic Analysis

Partial budget analysis showed that all treatments provided higher net benefits compared to the weedy check. The highest net benefit (128061.7 ETB ha^{-1}) was obtained from Pallas Super 45OD combined with hand weeding at 15 and 30 DAS, followed by the weed-free treatment (125513.1 ETB ha^{-1}). The lowest net benefit (52658.15 ETB ha^{-1}) was recorded from the weedy check. The marginal rate of return further confirmed that integrated weed management practices are economically viable and profitable.

Table 5. The Economic analysis of different weed management methods in tef production

Treatments	GY (kg ha^{-1})	Ad. GY (kg ha^{-1})	TGB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR %
Weedy check	715.3	643.77	61158.15	8500	52658.15	-
Power 860 SL	1130.3	1017.27	96640.65	14800	81840.65	463.21
Pallas Super 45OD	1108.2	997.38	94751.1	17600	77151.1	D
HW @ 15 and 30 DAS	832	748.8	71136	18500	52636	D
Power 860 SL + 1HW@ 30 DAS	1289.6	1160.64	110260.8	19800	90460.8	2909.6
Pallas Super 45OD + 1HW @ 30 DAS	1404	1263.6	120042	22600	97442	249.33
Weedy free	1779.1	1601.19	152113.1	26600	125513.1	701.78
Power 860 SL + 2HW @15 & 30 DAS	1514.3	1362.87	129472.7	27800	101672.7	D
Pallas Super 45OD + 2HW @15 & 30 DAS	1832.3	1649.07	156661.7	28600	128061.7	3298.63

Notes. Where: HW = Hand weeding, DAS = Days after sowing, GY = Grain yield, Ad.GY=Adjusted grain yield, TGB= Total gross income, TVC=Total variable cost, NB= Net benefit, MRR=Marginal rate of return, D= Dominated treatments, ETB=Ethiopian birr.

6. Conclusion

Tef is a major staple crop in Ethiopia, particularly in the Borana lowlands, where it is cultivated for both consumption and income. However, weed infestation remains a major constraint to its productivity. The study demonstrated that integrated weed management, particularly the use of Pallas Super 45OD (Pyroxsulam (Triazolopyrimidine) 45 g L^{-1}) at 1L ha^{-1} combined with hand weeding at 15 and 30 DAS, was the most effective and economically profitable. The approach resulted in the highest grain yield, maximum net benefit, and reduced yield loss. Therefore, it is recommended that farmers adopt integrated weed management practices combining chemical and manual control methods to achieve sustainable tef production and improved profitability.

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