



RESEARCH ARTICLE

REVISED Integrated Hand Weeding and Herbicide Application for Corn Marigold (*Glebionis segetum*) in Tef Fields across Western and Southwestern Shewa Zones in Ethiopia

[version 3; peer review: 1 approved, 1 approved with reservations]

Previously titled: Integrated Management of Corn Marigold (*Glebionis segetum*) in Tef Field at Western and Southwestern Shewa Zones in Ethiopia

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V3 First published: 24 Mar 2023, 12:333
<https://doi.org/10.12688/f1000research.131139.1>
 Second version: 16 Jun 2023, 12:333
<https://doi.org/10.12688/f1000research.131139.2>
 Latest published: 20 Sep 2023, 12:333
<https://doi.org/10.12688/f1000research.131139.3>

Abstract

Background: Corn marigold (*Glebionis segetum* (L.) Frourr.) is a serious weed species of agricultural crops in many parts of Ethiopia. However, there is a lack of information on its management in tef fields in the country. Therefore, the current work was designed with the objectives of evaluating integrated management of the weed and determining the most economical integrated weed management options in tef fields.

Methods: The field experiments were conducted in naturally corn marigold infested fields of Cheliya and Woliso districts of West and Southwest Shewa Zones in Ethiopia, respectively, during 2020 to 2021 cropping seasons.

Results: Different corn marigold management practices exhibited different responses to different parameters of the target weed and the test crop differently. Application of Pyroxsulam 45g L⁻¹ at a rate of 0.40 l ha⁻¹ supplemented with once-hand weeding and Halauxifen-methyl 100g kg⁻¹ + Florasulam 100g kg⁻¹ sprayed at a rate of 50 g ha⁻¹ supplemented with once-hand weeding increased grain yield by about 70 and 50%, respectively, over the weedy check. The marginal revenue and benefit-cost ratio obtained from the marketing of goods for the application of Pyroxsulam 45g L⁻¹ with one supplementary hand weeding of corn marigold increased by 110 and 89%, respectively, as compared to the weedy check.

Conclusions: The present study revealed the role of integrated management of corn marigold in improving tef production and productivity by combating the weed. Future research should be

Open Peer Review

Approval Status ? ✓

	1	2
version 3		
(revision)	?	✓
20 Sep 2023	view	view
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version 2		
(revision)	?	?
16 Jun 2023	view	view
version 1		
24 Mar 2023		

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Any reports and responses or comments on the article can be found at the end of the article.

directed towards scaling up and popularizing these technologies among the growers.

Keywords

Benefit-cost ratio, Effective management, *Glebionis segetum*, Pallas, Quelex



This article is included in the **Agriculture, Food and Nutrition** gateway.

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Author roles: **Hundessa N:** Writing – Review & Editing; **Dechassa N:** Conceptualization, Data Curation, Formal Analysis, Investigation, Methodology, Project Administration, Writing – Original Draft Preparation, Writing – Review & Editing; **Bedada S:** Writing – Review & Editing; **Bekele G:** Writing – Review & Editing; **Duguma M:** Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: The author(s) declared that no grants were involved in supporting this work.

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How to cite this article: Hundessa N, Dechassa N, Bedada S *et al.* **Integrated Hand Weeding and Herbicide Application for Corn Marigold (*Glebionis segetum*) in Tef Fields across Western and Southwestern Shewa Zones in Ethiopia [version 3; peer review: 1 approved, 1 approved with reservations]** F1000Research 2023, 12:333 <https://doi.org/10.12688/f1000research.131139.3>

First published: 24 Mar 2023, 12:333 <https://doi.org/10.12688/f1000research.131139.1>

REVISED Amendments from Version 2

Based on the reviewers' suggestions minor revisions are made to the title, abstract, keywords, introduction, materials and methods, result and discussion, conclusion, and references. The title was modified to "Integrated Hand Weeding and Herbicide Application for Corn Marigold (*Glebionis segetum*) Management in Tef Fields across Western and Southwestern Shewa Zones in Ethiopia." It is clearly indicated that the experiment was conducted for two years and at two locations in methodology. Detail information about the variety, type, and rate of fertilizers used, and method of herbicide application is also indicated in the methodology of the revised manuscript. The results of the experiments were analyzed and interpreted per experimental locations. Even though there were very few research works done on the specific weed corn marigold we have tried to discuss based on the result obtained. Revisions are also done in the references.

Any further responses from the reviewers can be found at the end of the article

Introduction

Tef (*Eragrostis tef*) is the most important staple grain for over 60-72% of Ethiopia's population (Gizaw *et al.*, 2018). Its cultivation predates historical records by Ethiopian farmers, and it has a comparative advantage over other cereals in terms of farming and utilization (Minten *et al.*, 2018). It is one of the most widely cultivated and economically important cereal crops in Ethiopia, but one of the lowest in production. Because of its weak root system and short stem with narrow leaves, it is vulnerable to weed competition (Tessema, 2002). Tef-weed competition is a big threat to the crop production and productivity, causing great yield loss.

Particularly, corn marigold (*Glebionis segetum*) is considered as one of the most difficult weed species in many countries of the world in general (Karamaouna *et al.*, 2019) and in Ethiopia particularly (Asres & Das, 2011; Shashitu, 2019). They are specifically harmful in the high land part of Ethiopia and can significantly reduce crops yield (Asres & Das, 2011; Shashitu, 2019). Corn marigold has been reported to cause 56% yield losses in wheat in Ethiopia if appropriate management measures are not implemented (Shashitu *et al.*, 2018).

Similar to other weeds, corn marigold competes with agricultural crops for water, nutrients, minerals, space and light. Its competitive advantage is enhanced by its extreme fast growth rate, fast spreading ability, rapid multiplication via seeds, and strong competitiveness with crop (Shashitu, 2019). It is a noxious weed which highly adapted to a wide range of nutrient and environmental conditions. Its complicated root system, large number of branches that are difficult to uproot, and cutting worsen its infestation (Shashitu, 2019) Figure 1.

Corn marigold is observed spreading fast and invading grazing and crop lands at an alarming rate at Dabat (Assefa, 2019), Debark districts (Asres & Das, 2011) in Amhara regional state and Cheliya and Woliso districts (Shashitu, 2019) in Oromia regional state in Ethiopia. It is becoming a noxious weed to crop production and causes yield and seed quality reduction in crops at highland parts of the country. As evidenced from Figure 2A-F, it infests grazing land, faba bean, tef, wheat, and linseed fields at Cheliya and Woliso areas in Oromia regional state in Ethiopia.

Hand weeding is the most often utilized weed management approach in tef fields to reduce the detrimental impact of corn marigold. Due to overlapping operations with other crops, farmers' family labor is insufficient during the main cropping season for timely and adequate control of corn marigold in tef fields (Nagassa *et al.*, 2022; Gazoulis *et al.*, 2021). Hand-weeding tef fields takes time and is typically done late in the season, after the weed have reduced crop growth and development. It's especially tough because of the constant rain during the primary cropping season, which inhibits people from getting out into the field and conducting field activities.



Figure 1. Pictures of corn marigold weed with its attractive flower.



Figure 2. Pictures of corn marigold weed in A) Grazing land, B) Faba bean, C) Tef, D) Wheat, E) Barley, F) Linseed fields.

Though the threat of corn marigold in tef production is increasing spatially and temporally in Ethiopia, few studies have been conducted on its management and feasibility of the management option in the country. Therefore, this study was conducted with the objectives of developing effective integrated management of corn marigold, determining the grain yield benefit and yield losses derived from the use of integrated management of the weed, and determining the most economical integrated weed management options tested in tef production in the selected sites of the West and Southwest Shewa Zones of Ethiopia.

Methods

Ethics

This experiment was conducted within an appropriate ethical framework of Ethiopian Institute of Agricultural Research as confirmed by institutional letter with Ref. No.: 9.7/4712/2023 written on 3rd March 2023.

Study area

The study was conducted at Cheliya and Woliso districts in Oromia regional state in farmers' fields for consecutive two years of 2020 and 2021 main cropping season (Figure 3). A naturally corn marigold infested field per district was selected (Table 1 and Figure 3).

Treatments, experimental design and crop husbandry

The experiment consisted of six treatments arranged in randomized complete block design with three replications on the plot size of 4 m × 5 m. Spacing 1.5 m between blocks and 1m between plots were used. The Kuncho variety of tef was drilled in rows in rows 20 cm apart at rate of 10 kg ha⁻¹. NPS (compound fertilizer containing highly uniform granules of three important plant nutrients, nitrogen, phosphate, and sulfur, with a ratio of 19% N, 38% P₂O₅, and 7% S) and urea (CO(NH₂)₂) with 46% N fertilizers (Tufa *et al.*, 2022) were applied at rates of 150 and 100 kg ha⁻¹, respectively (Yared *et al.*, 2020). NPS was applied at sowing time, whereas urea was applied in two split half amounts at sowing time and the remaining amount at the tillering stage of the crop. The herbicide amount required for the treatment was calculated and measured using a sensitive digital balance and measuring cylinder and applied 30 days after sowing (DAS) Table 2. For all herbicide treatments, a uniform spray volume of 200 L ha⁻¹ was used. A knapsack sprayer of 20 L volume with three nozzles was used. Moreover, all experimental plots management activities were executed to the standard level.

Data collected

Both corn marigold weed and tef crop data were recorded. The weed parameters such as the number of corn marigold before and after treatment, biomass and visual scoring scale were recorded using appropriate materials and procedures.

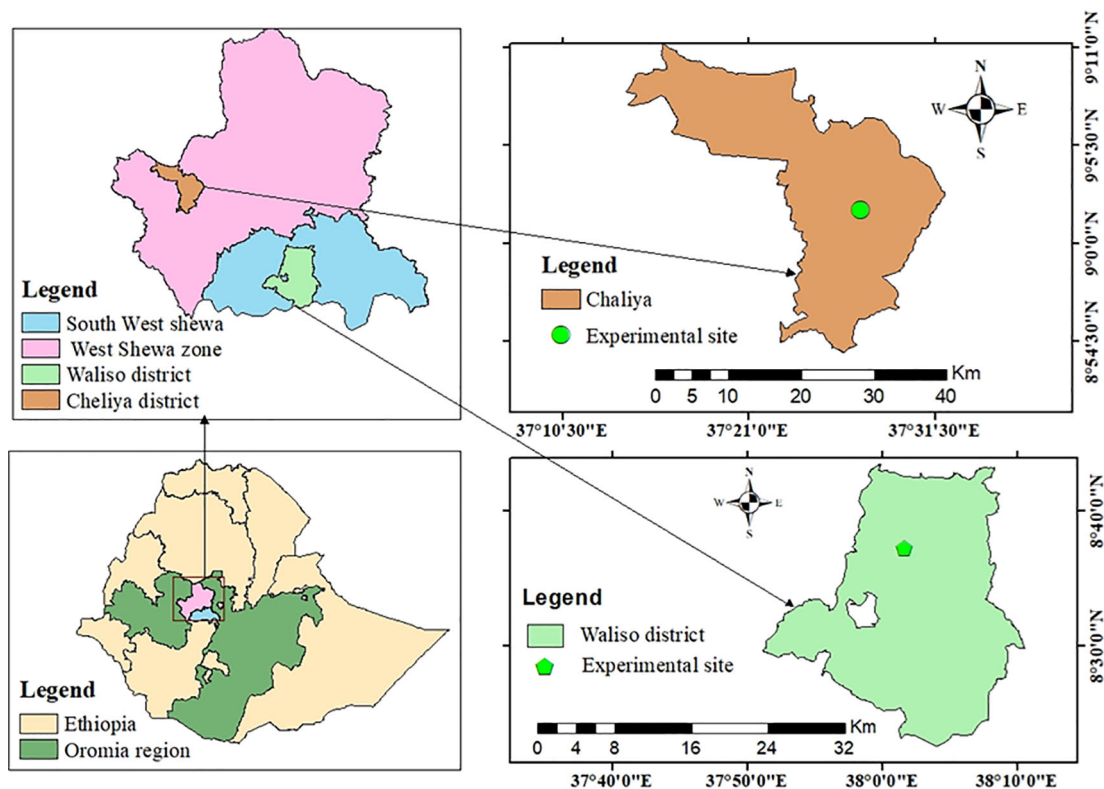


Figure 3. Map of Ethiopia showing regions, zones and districts at which the experiments were conducted.

Table 1. Description of study area.

Zone	District	Peasant association	Altitude	Latitude	Longitude
West Shewa	Cheliya	Chobi Tulu	2488	9.03049	37.45348
Southwest Shewa	Woliso	Adame Gotu	2304	8.62010	38.02782

Table 2. Experimental treatments.

Trade name	Chemical name	Rate	Time (DAS)	Water rate	Frequency of hand weeding	Time (DAS)
Pallas 45 OD	Pyroxsulam 45 g L ⁻¹	0.4 L ha ⁻¹	30	200 L ha ⁻¹	Once	55
Quelex™ 200 WG	Halaxifen-methyl 100 g kg ⁻¹ + Florasulam 100 g kg ⁻¹	50 g ha ⁻¹	30	200 L ha ⁻¹	Once	55
Derby 75 SC	Flurasulam 75 g L ⁻¹ + Flumetsulam 100 g L ⁻¹	80 ml ha ⁻¹	30	200 L ha ⁻¹	Once	55
-	-	-	-	-	Twice	30 and 55
-	-	-	-	-	Weed free	As weed emerged
-	-	-	-	-	Corn marigold unweed	Other weeds weeded twice at 30 and 55

The weed control efficacy percentage was calculated using the appropriate formula. Tef parameters plant height, biomass, and grain yield were recorded, and a harvest index was calculated.

Number of corn marigold: was counted at 30th and 60th days after sowing using 1 m * 1 m quadrat.

Visual scoring: was undertaken using 1-5 scale scoring system at 15th and 30th, days after herbicide application (Taye *et al.*, 2007).

Biomass of corn marigold (kg/plot): the weed shoot biomass at crop physiological maturity from the net plot area was recorded and weed control efficacy was calculated using the following formula (Boutagayout *et al.*, 2023a):

$$\text{Weed control efficiency (WCE)} = \left(\frac{\text{WDC} - \text{WDT}}{\text{WDC}} \right) * 100$$

Where, WDC and WDT are weed dry weight in control and any particular treatment, respectively.

Plant height: was measured from the ground level to the tip of ten randomly selected plants from harvestable rows at physiological maturity.

Grain yield (kg ha⁻¹) was measured by harvesting the crop from the net plot area.

Shoot biomass yield: At physiological maturity, the shoot biomass of ten plants selected randomly from the destructive rows was measured after oven drying the harvested produce till a constant weight (Boutagayout *et al.*, 2023b).

Harvest index: The plants harvested for shoot biomass yield at physiological maturity was used to calculate the harvest index by dividing grain yield by the total shoot dry biomass yield.

$$\text{Harvest index (\%)} = \frac{\text{Seed yield}}{\text{Shoot dry biomass}} * 100$$

Relative tef yield loss due to weed was calculated as follows:

$$\text{Relative yield loss (\%)} = \frac{\text{MY} - \text{YT}}{\text{MY}} * 100$$

Where, MY = maximum yield from a treatment, YT = yield from particular treatment

$$\text{Actual yield loss due to corn marigold} = \frac{(\text{CFy} - \text{FPy})}{\text{CFy}} * 100$$

$$\text{Potential yield loss due to corn marigold} = \frac{(\text{CFy} - \text{CCy})}{\text{CFy}} * 100$$

Where, CFy = crop yield in corn marigold free plots, FPy = crop yield in farmers' practice, and CCy = crop yield in corn marigold un-weeded check plot.

Data on inputs and their costs were collected for each evaluated weed control option/treatment, including the costs of procuring herbicides and planting materials, labor expenses for land preparation, tillage and herbicide application, hand weeding, and tef harvesting.

The costs of Pyroxsulam 45 g L⁻¹ (2974-birr L⁻¹), Halauxifen-methyl 100 g kg⁻¹ + Florasulam 100 g kg⁻¹ (10913-birr kg⁻¹), and Flurasulam 75 g L⁻¹ + Flumetsulam 100 g L⁻¹ 175 SC (8400-birr kg⁻¹) were obtained from the prevailing local market (53.37 Ethiopian Birr = \$1 United State during merchandising). The shopping unit value of the knapsack sprayer was 1200 birr as information gathered from Addis Ababa (central market), Ethiopia. Around West and Southwest Shewa zones, the labor cost man⁻¹ day⁻¹ was ranges from 50-150 birr. In addition, data on the market price of tef per kilogram were collected at each site. The current market price (as of January 2023) was taken from farmers who sell tef in local markets and district extension workers to compute benefit cost ratio.

Data analysis

Data that included weed dry weight, weed control efficacy, Tef plant height, above ground biomass, grain yield and harvest index were subjected to analysis of variance (ANOVA) using the SAS statistical software version 9.4 packages (Westfall *et al.*, 2011). The assumption of (ANOVA) normality test was executed for all collected parameters before analyzing the data. Mean separation was performed using Least Significance Difference (LSD) test at 5%.

Cost-benefit analysis

The cost-benefit analysis for the proposed management practices, which included herbicidal and cultural (manual weeding) strategies, was determined using the (Program *et al.*, 1988) process. During the cost-benefit analysis, the total input cost of production, gross revenue, marginal revenue and benefit-cost ratio were all taken into account. The total input cost (additional expenses for weed and trial management) was calculated by adding all costs (variable + fixed input costs) incurred during the study. Tillage and fertilizer costs, as well as planting and harvesting wages, were considered fixed production costs. While the knapsack sprayer, herbicides, and manpower for pesticide spraying and manual weeding were considered variable production costs.

The gross revenue was concluded by multiplying of commercialized price and grain yield (Daramola *et al.*, 2019). The marginal revenue was computed as subtracting the total variable costs from the gross revenue (Daramola *et al.*, 2019). In addition, the benefit cost ratio was computed as the proportion of marginal revenue (numerator) and total variable cost (denominator) (Daramola *et al.*, 2019).

Results and discussions

Analysis of variance

The variance analysis revealed statistically significant differences in the evaluated weed management strategies on both the corn marigold and tef characteristics (Tables 3–6). Different corn marigold management approaches produced different results in weed parameters including weed biomass and weed control efficiency, as well as crop factors like plant height, biomass yield, grain yield, and harvest index.

Weeds dry weight

There was statistically significant difference among management strategies in reducing corn marigold dry weight across the study locations (Tables 3 and 4). In the weed-free plots, there was no weed dry weight recorded at the study sites. At Woliso the application of Pyroxsulam 45 g L⁻¹ supplemented with once-hand weeding significantly decreased the weed dry weight by about 41-fold following the weed free plots. Following the application of Pyroxsulam 45 g L⁻¹ supplemented with once-hand weeding, the application of Halauxifen-methyl 100 g kg⁻¹ + Florasulam 100 g kg⁻¹ supplemented with once-hand weeding significantly decreased the weed dry weight by about 29-fold as compared to weedy check plots at Woliso.

Similar trends were found between the two research locations (Woliso and Cheliya). At Cheliya the application of Pyroxsulam 45 g L⁻¹ supplemented with once-hand weeding significantly decreased the weed dry weight by about 28-fold following the weed free plots. Following the application of Pyroxsulam 45 g L⁻¹ supplemented with once-hand weeding, the application of Halauxifen-methyl 100 g kg⁻¹ + Florasulam 100 g kg⁻¹ supplemented with once-hand weeding significantly decreased the weed dry weight by about 26-fold as compared to weedy check plots at Cheliya. Due

Table 3. Effect weed management practices on Corn marigold dry weight and weed control efficiency (WCE) in tef fields at Woliso during 2020 and 2021.

Weed management practices	Dry weight (kg ha ⁻¹)	WCE (%)
Pyroxsulam 45 g L ⁻¹ + once hand weeding	125.00b	98.56a
Halauxifen-methyl 100 g kg ⁻¹ + Florasulam 100 g kg ⁻¹ + once hand weeding	175.00b	96.73a
Flurasulam 75 g L ⁻¹ + Flumetsulam 100 g L ⁻¹ + once hand weeding	283.33b	92.26b
Twice hand weeding	258.33b	92.71b
Weed free	0.00b	100.00a
Weedy check	5191.67a	0.00c
Mean	1005.55	80.04
LSD@0.05	551	3.45
CV (%)	46.25	3.65

Means followed by the same letter(s) within a column are not significantly different from each other at 5%.

Table 4. Effect weed management practices on Corn marigold dry weight and weed control efficiency (WCE) in tef fields at Cheliya during 2020 and 2021.

Weed management practices	Dry weight (kg ha ⁻¹)	WCE (%)
Pyroxsulam 45 g L ⁻¹ + once hand weeding	183.33b	97.63a
Halauxifen-methyl 100 g kg ⁻¹ + Florasulam 100 g kg ⁻¹ + once hand weeding	200.00b	96.26a
Flurasulam 75 g L ⁻¹ + Flumetsulam 100 g L ⁻¹ + once hand weeding	208.33b	90.26b
Twice hand weeding	241.67b	90.13b
Weed free	0b	100a
Weedy check	5383.33a	0c
Mean	1036.11	79.05
LSD@0.05	324.89	5.26
CV (%)	26.47	5.62

Table 5. Effect of weed management practices on tef plant height, biomass yield, grain yield and harvest index at Cheliya mean of 2020 and 2021 cropping seasons.

Weed management practices	PH	ABM	GY	HI
Pyroxsulam 45 g L ⁻¹ + once hand weeding	105.10a	6075.00a	1709.00a	29.11b
Halauxifen-methyl 100 g kg ⁻¹ + Florasulam 100 g kg ⁻¹ + once hand weeding	90.89b	4416.67ab	1430.86ab	32.94b
Flurasulam 75 g L ⁻¹ + Flumetsulam 100 g L ⁻¹ + once hand weeding	89.97b	4083.33bc	1161.67bc	29.01b
Twice hand weeding	87.68b	3225bc	904.33cd	28.05b
Weed free	86.90b	3750bc	1709.08a	46.67a
Weedy check	86.47b	2333.33c	633.5d	28.07b
Mean	91.17	3980.56	1258.07	32.31
LSD@0.05	9.54	1788.4	521.66	6.77
CV (%)	8.83	37.92	35.00	17.68

PH = plant height (cm), ABM = biomass yield (kg ha⁻¹), GY = grain yield (kg ha⁻¹), HI = harvest index, and means followed by the same letter(s) within a column are not significantly different from each other at 5%.

Table 6. Effect of weed management practices on tef plant height, biomass yield, grain yield and harvest index at Woliso mean of 2020 and 2021 cropping seasons.

Weed management practices	PH	ABM	GY	HI
Pyroxsulam 45 g L ⁻¹ + once hand weeding	118.02a	8491.67a	2053.25a	24.18b
Halauxifen-methyl 100 g kg ⁻¹ + Florasulam 100 g kg ⁻¹ + once hand weeding	116.45a	7825.00ab	1862.99ab	23.70b
Flurasulam 75 g L ⁻¹ + Flumetsulam 100 g L ⁻¹ + once hand weeding	117.48a	7575.00ab	1662.83bc	21.75b
Twice hand weeding	120.13a	7875.00ab	1797.25abc	22.77b
Weed free	121.3a	7125.00b	2069.83a	29.67a
Weedy check	120.18a	7625.00ab	1578.17ac	20.55b
Mean	118.93	7752.78	1837.39	23.77
LSD@0.05	5.02	1027.30	273.15	3.91
CV (%)	3.56	11.19	12.55	13.90

to the higher density of the weed at Cheliya than at Woliso, the reduction in dry weight of the weed there was less than that of at Woliso.

Weed control efficiency

There was statistically significant difference among management strategies in corn marigold control efficiency across the study locations (Tables 3 and 4). Continuous hand weeding of corn marigold as it appeared in the field resulted in complete eradication, whereas Pyroxsulam 45 g L⁻¹ supplemented with once hand weeding followed by Halauxifen-methyl 100 g kg⁻¹ + Florasulam 100 g kg⁻¹ supplemented with once hand weeding resulted in effective corn marigold destruction across the location in similar trend. However, frequent hand-weeding of the weed in tef field is one of the most difficult tasks faced by farmers, especially during the main cropping season. It requires 3–4 rounds of continued weed removal per season to make the field weed-free. Uprooting the weed is difficult due to its complex root system, and cutting it worsens its infestation. Additionally, Tef seedlings are also uprooted and the crop population reduced during frequent hand weeding.

Yield and yields attributes

The effects of weed management practices on Tef plant height, biomass yield, grain yield, and harvest index were significantly different among the management practices across the study locations (5 and 6). However, in terms of plant

Table 7. Effect of corn marigold weed on yield of tef crop under different weed management practices.

Weed management practices	Relative yield loss (%)	
	Cheliya	Woliso
Weed free	-	-
Pyroxsulam 45 g L ⁻¹ + once hand weeding	0.00	0.80
Halauxifen-methyl 100 g kg ⁻¹ + Florasulam 100 g kg ⁻¹ + once hand weeding	16.28	9.99
Flurasulam 75 g L ⁻¹ + Flumetsulam 100 g L ⁻¹ + once hand weeding	32.03	19.66
Twice hand weeding	47.09	13.17
Weedy check	62.93	23.75

Table 8. Tef potential and actual yield losses due to corn marigold at West and Southwest Shewa Zones in Ethiopia.

Districts	Actual yield loss (%)	Potential yield loss (%)
Cheliya	47.09	62.93
Woliso	13.67	23.75
Mean	41.47	41.47

Table 9. Economic feasibility analysis for corn marigold management through the integration of herbicide application and hand weeding in the two locations, Western and Southwestern Shewa Zones in Ethiopia, during the 2020 and 2021 main cropping season.

	Activity	Price per Ps	Variable costs/ha	Treatments					
				1. Pyroxsulam + hand weeding	2. Halauxifen-methyl + Florasulam + hand weeding	3. Flurasulam + Flumetsulam + hand weeding	4. Twice hand weeding	5. Weed free	6. Weedy check
Input cost	NPS Fertilizer purchase	41	5330	5330	5330	5330	5330	5330	5330
	UREA Fertilizer purchase	40	3480	3480	3480	3480	3480	3480	3480
	Seed purchase	86	860	860	860	860	860	860	860
	Pyroxsulam purchase	2974	1190	1190					
	Halauxifen-methyl + Florasulam purchase	10913	546		546				
	Flurasulam + Flumetsulam	8400	672			672			
Labor cost of operation	1st oxen plough	400	2000	2000	2000	1600	2000	2000	2000
	2nd oxen plough	400	1600	1600	1600	1600	1600	1600	1600
	3rd oxen plough	400	1600	1600	1600	1600	1600	1600	1600
	Planting	250	3000	3000	3000	3000	3000	3000	3000
	Herbicide application	250	500	500	500	500			
	1st hand weeding	100	2600					2600	
Harvest cost	2nd hand weeding	100	800	800	800	800	800	800	
	3rd hand weeding	100	800					800	
	Harvesting	250	5000	5000	5000	5000	5000	5000	5000
	Total variable cost (TVC)			25360	24715.65	24442	23670	27070	22870
	Revenue A. Tef price/t	52000		52000	52000	52000	52000	52000	52000
	B. Tons of Tef harvested per Ha			1.88	1.66	1.41	1.35	1.34	1.11
Gross Revenue (GR)				97819	86361	73437	70241	98280	57503
Marginal Revenue (MR) = GR – TVC				72459	61645	48995	46571	71210	34633
Benefit-cost ratio (BCR) = (Marginal revenue/Total variable cost)				2.86	2.49	2.00	1.97	2.63	1.51

NB: The cost, gross revenue, Marginal revenue was in Ethiopian birr. The tef market price was estimated in January 2023.

height, above-ground biomass, and grain yield, there was a statistically insignificant difference among weed-free plot, Pyroxsulam 45 g L⁻¹ spray supplemented with one hand weeding, and Halauxifen-methyl 100 g kg⁻¹ + Florasulam 100 g kg⁻¹ spray supplemented with one hand weeding (5 and 6) across the study locations.

At Cheliya weed-free plots, Pyroxsulam 45 g L⁻¹ spray supplemented with one hand weeding and Halauxifen-methyl 100 g kg⁻¹ + Florasulam 100 g kg⁻¹ spray supplemented with one hand weeding increased tef grain yield by 170, 170, and 126%, respectively. Whereas at Woliso weed-free plots, Pyroxsulam 45 g L⁻¹ spray supplemented with one hand weeding and Halauxifen-methyl 100 g kg⁻¹ + Florasulam 100 g kg⁻¹ spray supplemented with one hand weeding increased Tef grain yield by 31, 30, and 18%, respectively. Overall, the results showed good agreement in the trends of all yield-related parameters across the study locations.

Effect of corn marigold weed on yield loss in tef

The highest yield was obtained from weed free plots, followed by the application of Pyroxsulam 45 g L⁻¹ at 0.40 L ha⁻¹ with supplementary hand weeding. The minimal relative yield loss 0.00% at Cheliya and 0.80% at Woliso due to corn marigold was obtained from application of Pyroxsulam 45 g L⁻¹ at 0.40 L ha⁻¹ with supplementary hand weeding, followed by application of Halauxifen-methyl 100 g kg⁻¹ + Florasulam 100 g kg⁻¹ at 50 g ha⁻¹ with one supplementary hand weeding with intermediate relative yield loss of 16.28% at Cheliya and 9.99% at Woliso (Table 7).

Based on corn marigold density per area, the potential tef yield loss by the weed ranged from 23.75 to 62.93%, whereas the actual tef yield loss was 13.67 to 47.09% (Table 8). Both actual and potential yield losses due to the weed were highest at Cheliya District, whereas yield losses due to the weed were lowest at Woliso District. This might be due to the fact that the weed density in Cheliya District was higher than that in Woliso District.

Cost-benefit analysis

For the integrated use of herbicide application and supplementary hand weeding for corn marigold management, the marginal revenue (MR) and benefit-cost ratio (BCR) were computed for treatment combinations. The cost-benefit analysis showed that significant variation in MR and BCR was observed among the evaluated experimental treatments (Table 9). Comparing the management practices, the most prominent MR 72459- and 71210-birr ha⁻¹) and BCR (2.86 and 2.63) were calculated from application of Pyroxsulam 45 g L⁻¹ supplemented with hand weeding and weed free plots, respectively. Conversely, the lowest MR (34633- and 46571-birr ha⁻¹) and BCR (1.51 and 1.97) were computed from weedy check and application of Flurasulam 75 g L⁻¹ + Flumetsulam 100 g L⁻¹ supplemented with hand weeding, respectively, whereas the intermediate MR and BCR were obtained from the application of Halauxifen-methyl 100 g kg⁻¹ + Florasulam 100 g kg⁻¹ with supplementary hand weeding. The MR and BCR obtained from the marketing of goods for application of Pyroxsulam 45 g L⁻¹ supplemented with hand weeding of corn marigold increased by 110 and 89% as compared to corn marigold weedy check (control plot) (Table 9).

Cost-benefit analysis indicated that integration of Pyroxsulam 45 g L⁻¹ with supplementary hand weeding exhibited the topmost MR 72459 Birr ha⁻¹) and BCR (2.86), followed by the weed free plots correspondingly with the MR of 71210-birr ha⁻¹ and BCR of 2.63. Overall, integrated use of broad leaf killer herbicides with supplementary hand weeding provides a better MR and BCR than single weed management practices (Table 9).

Summary and conclusion

Corn marigold is one of the aliens weed species that has seriously infested cereal and pulse crops in many parts of Ethiopia since its introduction. It is a noxious weed that is difficult to manage due to its: prolific seed production, fastest growth and spread, adaptation to a wide range of environmental conditions, and strong competitiveness with crops. Integrated effects of herbicide application and hand weeding significantly lowered the weed infestation in the study locations.

The current study revealed that application of Pyroxsulam 45 g L⁻¹ at a rate of 0.40 l ha⁻¹ supplemented with once-hand weeding and Halauxifen-methyl 100 g kg⁻¹ + Florasulam 100 g kg⁻¹ at a rate of 50 g ha⁻¹ supplemented with once-hand weeding effectively manage the weed and increased tef grain yield. The marginal revenue and benefit cost ratio obtained from the marketing of goods for application of Pyroxsulam 45 g L⁻¹ at a rate of 0.40 l ha⁻¹ supplemented with hand weeding of corn marigold increased by about 110 and 89% as compared to a weedy check.

In conclusion integrated management of corn marigold by integrating broad spectrum and/or broad-leaf killer herbicides with hand weeding practices played a crucial role in improving tef production and productivity by contesting the weed. Forthcoming studies should focus on scaling up and popularizing these technologies in corn marigold weed-infested tef fields in Ethiopia.

Data availability

All data supporting the results are included in the article, and no extra source data are necessary.

Acknowledgement

We would like to express our gratitude to Ethiopian Institute of Agricultural Research (EIAR) for financially sponsoring the research. A special appreciation also goes to Ambo Agricultural Research Centre (AmARC) for providing logistical help during the research periods. We also thank our colleagues at AmARC, particularly Mr. Tadele Gudeta, for his valuable technical assistance during the project.

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Version 3

Reviewer Report 12 September 2025

<https://doi.org/10.5256/f1000research.154300.r208128>

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Ioannis Gazoulis 

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Since issues are addressed it can be endorsed.

Competing Interests: No competing interests were disclosed.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 28 September 2023

<https://doi.org/10.5256/f1000research.154300.r208129>

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Abdellatif Boutagayout 

The Environment and Soil Microbiology Unit, Faculty of Sciences, Moulay Ismail University, Meknes, Morocco

Herbicide Application for Corn Marigold (*Glebionis segetum*) in Tef Fields across Western and Southwestern Shewa Zones in Ethiopia"

Dear Authors,

I trust that this letter finds you in good health. I have had the privilege of conducting a thorough review of the revised version of your manuscript titled "Integrated Hand Weeding and Herbicide Application for Corn Marigold (*Glebionis segetum*) in Tef Fields across Western and Southwestern Shewa Zones in Ethiopia." I am pleased to acknowledge that substantial improvements have been

made compared with the previous version. Your meticulous revisions and responses to the reviewers' comments have significantly improved the manuscript's overall quality and clarity.

I wish to express my appreciation for your commitment to address the reviewers' comments and suggestions. Below, I provide feedback on your responses to each comment.

1. Title: The revision of the title to "Integrated Hand Weeding and Herbicide Application for Corn Marigold (*Glebionis segetum*) Management in Tef Fields across Western and Southwestern Shewa Zones in Ethiopia" effectively aligns it with the manuscript's content, enhancing its focus and clarity.
2. Introduction: Your expansion of the Introduction to briefly touch upon potential environmental and sustainability concerns arising from herbicide usage, as well as how the integrated approach could address these concerns, enhances the context of the study.
3. Material and Methods: The forthcoming inclusion of details on weather conditions during the growing season, encompassing parameters such as precipitation and temperature, will provide valuable insights into potential climatic influences on the study outcomes, further enriching the methodology section.
4. Results - Presentation: While the suggestion to segregate the results for each district (Cheliya and Woliso) has not been implemented, I encourage you to reconsider this change. Providing separate values for each district within the results section would allow readers to better comprehend potential differences due to geographical nuances.
5. Discussion: The previous comments linked to the Discussion section have not been fully explored in the revised manuscript. We recommend revisiting and addressing these comments in future versions of the manuscript.
6. Conclusion: I appreciate your willingness to consider revising the Conclusion section to concisely summarize the primary findings and their implications for corn marigold management in tef fields. Additionally, your comment regarding the statement about potential avenues for future research in integrated weed management remains open for your consideration.

In summary, your diligence in revising the manuscript has been commendable and resulted in significant improvements. I recommend addressing the outstanding comments, especially those related to segregating results by district, and reconsidering the comment about discussion and future research avenues in the conclusion section, to further enhance the quality of the manuscript. Once these remaining issues are addressed, the manuscript will be prepared for the final publication.

Thank you for your unwavering commitment to refining your work. I eagerly anticipate receiving the final version of your manuscript accompanied by a letter including the authors' responses to each specific comment.

Best regards,

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Agroecology and Agroecological weed management

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Version 2

Reviewer Report 29 August 2023

<https://doi.org/10.5256/f1000research.151466.r196661>

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Ioannis Gazoulis

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Keywords should include herbicide active ingredients onstad of trade names.

Use species full scientific names when species are mentioned for the first time in the text.

Introduction is precise and without generalities. Good work here.

Materials and methods

- Fertilizer trade names and company name should be cited. Crop rotation history should be added. Something more about your tef genotype should be added.
- Herbicide application pressure and sprayer trade name should be added. Number and type of nozzles should be also mentioned.
- For statistical analysis, did you include year's effects in the ANOVA as fixed? Did you pool data over growing seasons and why was that possible?

I do not see any reference cited in the Discussion section. Please include references when trying to explain why phenomena occurred.

Do not forget to mention that except for herbicides, non-chemical cultural practices should be considered to build Integrated Weed Management (IWM) systems in this "novel" crop as also in other crops where herbicide options are still limited¹.

The Conclusion section should summarize your key findings highlight research gaps and state your future research objectives on the topic.

References

1. Gazoulis I, Kanatas P, Papastylianou P, Tataridas A, et al.: Weed Management Practices to Improve Establishment of Selected Lignocellulosic Crops. *Energies*. 2021; **14** (9). [Publisher Full Text](#)

Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

Yes

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: WEED MANAGEMENT/WEED CONTROL

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Reviewer Report 14 August 2023

<https://doi.org/10.5256/f1000research.151466.r196230>

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Review Report, August 13, 2023

Comments to the author(s):

Below are both general and specific comments that I hope the authors will find helpful in revising the manuscript.

General Comments:

This article delves into a significant issue within Ethiopian agriculture, shedding light on an integrated approach involving hand weeding and herbicide application for the management of corn marigold. Nonetheless, there are aspects that require further elucidation and enhancement. These encompass the reference list, trial duration, lack of citations in the Methods section, and the method of presenting results for distinct districts. While the findings gleaned from this study hold great value, it is imperative to incorporate a comprehensive discussion section that can holistically interpret the results, establish context, and address potential ramifications.

Specific Comments and Recommendations**Title:**

The current title does not align with the article's content, as it lacks consistency with the concept of "Integrated Management." It is suggested to revise the title to "Integrated Hand Weeding and Herbicide Application for Corn Marigold (*Glebionis segetum*) Management in Tef Fields across Western and Southwestern Shewa Zones in Ethiopia."

Abstract and Keywords:

The abstract provides a succinct overview of the study's design, results, and implications, accentuating the integrated approach adopted for corn marigold management across the Western and Southwestern Shewa Zones in Ethiopia.

Introduction:

The introduction effectively outlines the issue of corn marigold infestation and underscores the importance of effective weed management in tef fields. To fortify the introduction, briefly touch upon potential environmental and sustainability concerns arising from herbicide usage and elaborate on how the integrated approach could serve to address these concerns.

Methods:

Ethical Considerations: If the study involved human subjects, it provided pertinent details regarding ethical considerations. This would facilitate readers' comprehension of the ethical framework underpinning this research.

Material and methods:

- Elucidate whether the trial was conducted over two discrete years (2020 and 2021) or confined within a single growing season (2020-21).
- Information concerning weather conditions during the growing season encompasses parameters such as precipitation and temperature. This provides insights into the potential climatic influences on the outcomes. Additionally, please state clearly whether the collected data were subjected to normality checks.
- Offer a rationale for the selected statistical methods to enhance readers' grasp of the appropriateness of the approach. Furthermore, the Methods section should feature

citations, particularly for calculations related to biomass, weed control efficiency, and corn marigold density. Recent studies, such as those by Boutagayout *et al.* (2023a)¹ and Boutagayout *et al.* (2023b)², can be referenced to comprehensively detail the methodologies employed.

Results:

- Ensure that the data presentation is lucid and succinct, and that suitable tables or figures are incorporated to illustrate noteworthy trends and findings.
- The study encompassed two districts: Cheliya and Woliso. However, the Results section provides only a single value for each assessed parameter. To accurately encapsulate the scope and findings of the study, we segregated the results for each district. This would facilitate an understanding of potential divergences in outcomes due to geographical nuances.

Discussion:

- Given the absence of a discussion section, it is imperative to incorporate this section in the revised article. The discussion should be pivotal, encompassing the interpretation of results, comparisons with prior research, and contextualization of the study's implications.
- Addressing plausible environmental concerns stemming from herbicide application and expounding on how the integrated approach of hand weeding and herbicide usage could potentially ameliorate these effects.
- The findings are analyzed within the context of agricultural sustainability. The integrated approach aligns with sustainable weed management practices and explores trade-offs between weed control efficacy and potential ecological repercussions.
- Synthesize the findings with the extant literature. Draw parallels between your results and studies investigating analogous weed-management approaches. Illuminate the contribution of your findings to the existing knowledge base.
- Delving into the limitations of the study, knowledge of any constraints or obstacles encountered during the research process may impinge on the generalizability of the findings.
- Provide insights into the pragmatic implications of the results for farmers, policymakers, and researchers. How can an integrated approach be scaled and adopted? Are there any policy recommendations based on your findings?

Conclusion:

- Concisely encapsulate the primary findings of this study and their implications for corn marigold management in tef fields.
- Potential avenues for future research in the domain of integrated weed management include factoring in efficacy and sustainability.

Formatting and References

- The reference list should encompass no more than 12 sources and should be enriched with references that are more recent. Eliminate older references (1988, 2002, 2007, etc.)
- Harmonize reference formatting with a specific citation style mandated by the target

journal.

Overall Impression:

This study has the potential to contribute significantly to the realm of integrated hand weeding and herbicide application for weed management in tef fields. By addressing the suggestions of the review, including clarifying trial duration, bolstering method citations, segmenting results for each district, and delving into environmental considerations, the article aims to gain robustness, impact, and informativeness.

Finally, while cost-benefit analysis remains crucial for farmers, burgeoning environmental costs demand attention. It is our role as scientists to explore ecologically sound alternatives to herbicides, ensuring the sustenance of African agro-ecosystems and food security for future generations.

References

1. Boutagayout A, Bouiamrine E, Nassiri L, Rhioui W, et al.: Integrated agroecological practices for sustaining weed management and improving faba bean (*Vicia faba* var. *minor*) productivity under low-input farming. *International Journal of Pest Management*. 2023. 1-13 [Publisher Full Text](#)
2. Boutagayout A, Bouiamrine El H, Adiba A, Yahbi M, et al.: Reduced Corum herbicide dose with allelopathic crop water extract for weed control in faba bean. *Journal of Plant Protection Research*. 2023; **63** (2): 219-232 [Publisher Full Text](#) | [Reference Source](#)

Is the work clearly and accurately presented and does it cite the current literature?

Partly

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Partly

Are all the source data underlying the results available to ensure full reproducibility?

Partly

Are the conclusions drawn adequately supported by the results?

Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Agroecology and Agroecological weed management

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

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