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Evaluation of Herbicides for the Control of Annual Grass Weeds in Malt Barley

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Abstract
A study was conducted at Bekoji and Kofele farmer's field in 2015/16 and 2016/17 cropping seasons to evaluate effectiveness of two post-emergence herbicides for the control of annual grass weeds in malt barley. Phenoxapropethyl 1 lit/ha, Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l 1 lit/ha, hand weeding twice (30-35 and 55-60 Days After Sowing) as a standard check and a weedy check, respectively were laid out in Randomized Block Design considering sites as a replications. Malt barley, Holker was used as a test variety. Annual grass weeds like *Snowdenia polystachya, Avena fatua, Phalaris paradoxa* and *Setaria pumila* were controlled by Phenoxapropethyl 1 lit/ha a.i and Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l a.i 1 lit/ha with an efficacy rate of 80 to 100%. Fenoxaprop-p-ethyl69 g/l + safener-Mefenpyr-diethyl 75 g/l had a yield advantage over Phenoxapropethyl and weedy check by 21 and 62%, respectively. Application of Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l a.i (23027 Birr) had higher economic benefit than hand weeding twice (22158 Birr), Phenoxapropethyl a.i (17950 Birr) and weedy check (8670 Birr) by 4, 22 and 62%, respectively. It was economically profitable with marginal rate of return of 2538% even if the price of herbicide is increased by 20% as proven by the sensitivity analysis. Hence, Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l a.i at a rate of 1 lit/ha as post-emergence application can be recommended for the control of annual grass weed species in Malt barley for agro-ecologies similar to the study areas.
Keywords: Fenoxaprop-p-ethyl 69 g/lit + safener-Mefenpyr-diethyl 75 g/lit, Grass weeds, Malt barley, Phenoxapropethyl, Post émergence herbicides
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INTRODUCTION

Barley is the most commonly used grain in the production of malt for use in making beer of the world [1]. It is the fifth most important cereal crops after teff, maize, sorghum, and wheat, with yearly estimated harvests of about 1.9 million tons from over 1.02 million hectares of land with an average national yield of 1.85 tons per hectare [2]. The crop is predominantly grown from 2000 to 3500 meters above sea level in Ethiopia [3] and it is an important food grain and malting crop in the Ethiopian highlands, with malting barley a major source of income for smallholder farmers [4]. Malt barley is used for malting for various alcoholic beverages and food as bread, cultural dishes, biscuits, cakes and desserts. Brewers, distiller grains and sprouts from malting barley also have desirable protein content for animal diets [5].

Malt imports has grown tremendously reaching 63 thousand tons in 2015 covering 65% of total annual demand and costing the country about 37 million USD [6]. Although there is a considerable potential for increased production of high quality malting barley, the production of malting barley in Ethiopia has not expanded enough to benefit most barley growers. Among others, limited number of quality malt barley varieties and associated production technologies to farmers; biotic factors (mainly weeds, insect pests and foliar diseases), abiotic factors (low soil fertility, low soil pH, poor soil drainage, drought and poor agronomic practices), weak technology transfer, poor access to markets and unattractive malt barley price are identified as the main constraints responsible for low productivity and limited expansion of malt barley [7].

The low national average yield which is far below the world average, could be partially attributed to poor weed management, which results in high competition from weeds. The crop is very sensitive to weed competition and suffer the greatest yield reduction through competition to its third to sixth leaf stage [8]. She also reported that the average yield loss in barley is about 18% when the crop has received no weed control and weeds caused a yield loss of 17-39% on barley in Ethiopia [9].

Grass weeds are becoming significant production constraints to barely in Ethiopia, due to the high proportion of cereal crops in the rotational systems in highlands and the repeated application of herbicides effective against broad leaf weeds. Among grass weeds, *Avena fatua, Bromus pectinatus, Digitaria scalarum, Lolium temulentum, Phalaris paradoxa, Setaria* spp. and *Snowdenia polystachya* are the most important and problematic weeds. There were no adequate grass weed killer herbicides used in malt barley so far in the study areas. Therefore, the objective of this study was to evaluate effective post-emergence herbicides for the control of annual grass weeds in malt barley.

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MATERIALS AND METHODS

Description of the Study Areas

The activity was conducted at Bekoji and Kofele farmer's field during the main cropping season of 2015/16 and 2016/17. Bekoji (7°32′37"N and 39°15′21" E, 2780 meters above sea level (masl), average rainfall of 1066 mm, mean minimum and maximum temperature is 9.6°C and 24°C, respectively, and soil texture of luvisol) found in Arsi zone. According to FAO, [10] Kofele (07°05′0.2" to 07°13′31.2" N latitude and 038°47′06.8" to 038°56′54.6" E longitude, 2668 to 2682 masl, average rainfall of 1170 mm, mean annual minimum and maximum temperature of 8.51°C and 19.63°C, respectively ,and soil texture of nitosol) found in West Arsi Zone. Bekoji and Kofele are situated 56 km and 170 km away from Assela town and 225 km and 240 km away in South west direction from Addis Ababa, respectively.

Treatments and Experimental Design

The treatments were Phenoxapropethyl at 1 lit/ha, Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l a.i at 1 lit/ha, hand weeding twice (30-35 and 55-60 days after sowing) as a standard check and a weedy check left as a control. A malt barley variety, *Holker* was used as a test variety. The trial was laid out in Randomized Complete Block Design (RCBD) using sites as a replication. Herbicides were applied post-emergence at 30-35 days after sowing (DAS). The seed was sown by broadcasting at a seeding rate of 100 kg/ha. At time of sowing, all plots received a basal application of 100 kg/ha Diammonium Phosphate (DAP) and 50 kg/ha Urea fertilizers in plot size of 10m by 10m.

The required quantity of the herbicide was calculated and measured out into a manual knapsack sprayer with a water volume of 200 lit/ha for each herbicide treatment plots. Broad leaf weeds were controlled by using 2, 4-D herbicide at the rate of 1 lit/ha for herbicide treatments a week after the application of grass weed herbicides. All the necessary agronomic practices were done equally for all treatments.

Data Collection

Agronomic data: The necessary agronomic data of the crop (plant height, number of tillers per plant, spike length, thousand kernel weight (TKW), hectoliter weight (HLW), crop biomass and grain yield) and the weed (weed count before, two and four weeks after herbicide application using 1 m^2 quadrat, weed biomass, general weed control score in 1-5 scale, (where 1= Complete eradication; 2= Effective destruction; 3=Proper reduction in growth and population; 4= Reduced growth and population and 5= no effect on weed control) were collected. The general weed control score was based on Rezene *et al*. [11]. Efficacy of herbicides was calculated using the following formula:

$$\frac{Weed\ count\ before\ herbicide\ application - Weed\ count\ after\ herbicde\ application}{Weed\ count\ before\ herbicide\ application} x100$$

Crop yield and yield components and weed biomass data was collected at time of harvest to supplement field observation.

Economic Analysis: Cost and benefit of each treatment was analyzed and marginal rate of return (MRR) was computed by considering the variable cost of each respective treatments. Yield and economic data were collected to compare the economic advantage of each herbicide in different treatments. Economic data included input cost that vary and costs for chemical and labour during the execution of the experiment. The price and cost items were expressed in Ethiopian Birr (ETB). The price of one liter Phenoxapropethyl and Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l in 2016 was 600 and 800 ETB/lit/ha, respectively. Costs of herbicides were obtained from pesticide companies and local distributing agencies. Labor cost for twice hand weeding was 2500 ETB/ha. Harvesting and threshing was done by manually using daily laborers which needed 20 and 30 man days with a daily laborer cost of 30 ETB/day. Accordingly, the cost of harvesting and threshing of malt barley for Phenoxapropethyl, Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l, twice hand weeding and a weedy check treatments using daily laborers was 1500, 1500, 1500 and 1050 ETB/ha, respectively. Labor cost for three times plowing was uniform for each treatment and costs 2250 ETB/ha. Cost for daily laborer and rent for knapsack sprayer for herbicide application was 110 ETB/ha. Sale price of malt barley in 2016 was 800 ETB/quintal. Cost for land preparation and inputs purchase (seed and fertilizers) were uniform for all treatments. The average yield was adjusted downward by 10%, assuming that farmers could get 10% less yield than the experimental plot [12]. For determining gross returns, the prevailing local market price 800 ETB/100 kg of malt barley at the harvest of malt barley in 2016 was considered. Based on the data obtained from both locations, economic analysis was computed using partial budget analyses, marginal rate of return (MRR) and sensitivity analysis ([a]MRR) even when herbicide cost was increased by 20% [12]. The following formulae were used to compute net field benefits (NBs) and marginal rate of return (MRR), respectively.

Net field benefits (NBs) = Gross field benefits (GB) - Total Variable costs (TVC).

MRR = $\frac{DNI}{DIC}$; where, MRR is the marginal rate of return;

DNI is the difference in net income compared with control;
DIC is the difference in input cost compared with control.

Data Analysis

Data management and statistical analysis: Finally all yield and yield components data were subjected to analysis of variance using the general linear model procedure (Proc GLM) of SAS statistical package version 9.0 [13]. Mean separation was done using least significant difference test at the 5% level of probability.

RESULTS AND DISCUSSION

Efficacy of Herbicides

Efficacy result over locations indicated that all the treatments were effective against *Snowdenia polystachya, Avena fatua, Phalaris paradoxa* and *Setaria pumila* except *Bromus pectinatus.* Phenoxapropethyl, Fenoxaprop-p-ethyl69 g/l + safener-Mefenpyr-diethyl 75 g/l and twice hand weeding controlled *Avena* species by 80, 96 and 100%, respectively (Table 1). Likewise, Phenoxapropethyl, Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l and twice hand weeding controlled *S. polystachya* by 100%, whereas *P. paradoxa* was controlled at efficacy rate of 83, 100 and 100%, respectively. Both herbicides controlled B. *pectinatus* less than 50% efficacy rate, but twice hand weeding gave 90% control of *B. pectinatus* as shown in Table 1. This result is in line with the report of Fasil [14] that the commercial product, Phenoxapro-p-ethyl and Dichlofopmethyl have been noted to give good control of *Snowdenia polystachya, Echinochloa crus-galli, Bromus pectinatus, Avena fatua, Setaria* species and *Phalaris paradoxa* with the exception of another species of *Bromus*. The reports of Belles *et al*. [15], and Michael and Mickelson [16] also proved that Tralkoxydim and fenoxaprop have been shown to control wild oat and other annual grassy weeds effectively in small grains with no effect on broadleaf weeds. Similarly, this result was in line with the works of Singh and Ali [17] who reported that the lowest weed control efficiency (0%) was observed under unweeded control because there is greater weed competition stress.

Table1. Efficacy (%) of Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l as compared to Phenoxapropethyl on major grass weeds 4 weeks after application at two locations in Arsi and West Arsi Zones in 2016/17 cropping seasons

Locations	weed species	Phenoxapropethyl			Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l			Twice hand weeding		
		Weed count/m² Before Application	Weed count/m² After Application	Efficacy (%)	Weed count/m² Before Application	Weed count/m² After Application	Efficacy (%)	Weed count/m² before 1st hand weeding	Weed count/m² After 15 Days of 2nd hand weeding	Results (%)
Bekoji	*Snowdenia polystachya*	6	0	100	8	0	100	0	0	0
	Avena fatua	52	11	80	76	3	96	52	0	100
	Bromus pectinatus	9	6	33	8	5	37.5	0	0	0
	Phalaris paradoxa	18	3	83	27	0	100	15	0	100
Kofele	*Snowdenia polystachya*	13	0	100	11	0	100	8	0	100
	Avena fatua	0	0	0	5	0	100	0	0	0
	Bromus pectinatus	5	3	40	0	0	0	6	0	100
	Phalaris paradoxa	0	0	0	0	0	0	0	0	0

Yield and Yield Components

The combined analysis over locations indicated that there was no significant difference between treatments on plant height, number of tillers/plant, spike length, thousand kernel weight (TKW) and hectoliter weight (HLW). On the other hand, grain yield showed significant (*P<0.05*) difference due to Phenoxapropethyl, Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l and twice hand weeding (standard check) as shown in Table 2. Yield wise, Phenoxapropethyl, Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l and twice hand weeding outperformed in yield than the weedy check by 52, 62 and 63%, respectively (Table 2). The highest grain yield (3633 kg ha^{-1}) was recorded in twice hand weeding followed by Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l (3533 kg ha^{-1}) and Phenoxapropethyl (2800 kg/ha). However, the lowest grain yield of 1350 kg ha^{-1} was recorded in weedy check treatment. Similarly, Fenoxaprop-p-ethyl69 g/l + safener-Mefenpyr-diethyl 75 g/l had a yield advantage over Phenoxapropethyl and weedy check by 21 and 62%, respectively (Table 2). Yield loss due to weeds on barley was widely studied and explained in different countries. In the United States, wild oat density of 170 plants m^{-2} has been reported to reduce barley yield by 40% [18]. Similarly, in Australia, barley yield losses from 100 wild oat plants m^{-2} or more ranged from 30 to 50% [19]. It has also been reported that competition from wild oat reduces worldwide bread wheat and barley production more than 12 million tons annually [20].

Dry weed biomass was significantly (P<0.05) different for applied treatments as shown in Table 2. It was the lowest (33 kg ha^{-1}) in twice hand weeding followed by Fenoxaprop-p-ethyl 69 g/l +safener-Mefenpyr-diethyl 75 g/l (150 kg ha^{-1}) and Phenoxapropethyl (700 kg ha^{-1}), while the highest (1650 kg ha^{-1}) was recorded in untreated weedy check treatment Table 2. These results are correlated with the study of Hossain *et al*. [21] who documented that application of post emergence herbicides reduced the weed dry weight and consequently increased weed control efficiency. These findings are also in agreement with the finding of Amare *et al*. [22] who reported that application of isoproturon @ 1.00kg a.i. ha^{-1} significantly reduced the weed dry biomass, which ultimately increased the weed control efficiency in wheat.

Table 2. Mean grain yield (kg ha^{-1}) of Malt barley after Phenoxapropethyl and Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l herbicides application at two locations in 2016/17 cropping seasons

No	Treatments	Number of tillers	Plant height (cm)	Spike length (cm)	TKW (gms)	Hectoliter weight	Crop biomass (kg/ha)	Grain Yield (kg/ha)	Total Dry weight of weeds(kg/ha)	**GWCVS (1-5 scale)	
										2***WAA	At Maturity
1	Phenoxapropethyl	5.2	104	6	46.70	61.4	6917	2800b	700b	2	3
2	Fenoxaprop-p-ethyl 69 g/lit + safener-Mefenpyr-diethyl 75 g/lit	4.4	103	6.4	46.90	61.8	9583	3533a	150c	1	2
3	Two hand weeding	4.0	101	6.2	48.10	63.6	7667	3633a	33d	1	2.5
4	Weedy check	3.2	108	6.6	46.64	63.4	6333	1350c	1650a	4	4.5
	Mean	4.2	104	6.3	47.08			2829	633		
	LSD<0.05							100			
	CV%		4.45		3.66			12.15			

** General weed control visual score
***Weeks After herbicide Application

Economic Analysis

The results of partial budget analysis of the different treatments were presented in Table 3. Farmers earned the highest net field benefit of 23027 ETB/ha from malt barley production through the application of Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l herbicide with an economic advantage over twice hand weeding (22157 ETB/ha), Phenoxapropethyl (17950 ETB/ha) and weedy check (8670 ETB/ha) by 4, 22 and 62%, respectively. Moreover, the result of marginal rate of return (MRR) showed that Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l found to be profitable for farmers with a MRR of 2538%. Similarly, the sensitivity analysis ([a]MRR) result depicted that Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l remained the most profitable weed treatment even when the cost of herbicide is increased by 20% as shown in Table 4. Demelash *et al*. [23] reported economical profitability with 844% MRR owing to integration of compost with mineral fertilizers in wheat production. Otinga *et al.* [24] also reported an increased net benefit of over 33% in response to combined application of FYM and mineral fertilizer in maize production.

Table 3. Partial budget analyses for weed control with herbicides and two times hand weeding in 2016/17

Adjusted mean yield and different costs	Treatments			
	Weedy Check	Phenoxapropethyl	Fenoxaprop-p-ethyl 69 g/lit + safener-Mefenpyr-diethyl 75 g/lit	Two hand weeding
Adjusted mean yield (kg/ha)	1215	2520	3179.7	3269.7
Gross field benefit	9720	20160	25437	26157.6
Cost of herbicide (birr)	-	600	800	-
Herbicide application labor cost & rent of knapsack (birr)	-	110	110	-
Labor cost for weeding (birr)	-	-	-	2500
Harvesting cost (birr)	450	600	600	600
Threshing cost (birr)	600	900	900	900
Total variable cost (birr)	1050	2210	2410	4000
Net field benefit (birr)	8670	17950	23027	22157

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Table 4. Marginal rate of return analysis for weed control with herbicides and two times hand weeding in 2016/17

Treatments	Rate (lt/ha)	Net field benefit (birr)	Total variable costs (birr)	MRR	MRR[a]
Weedy check	-	8670	1050		
Phenoxapropethyl	1.0	17950	2210	800	715
Fenoxaprop-p-ethyl 69 g/lit + safener-Mefenpyr-diethyl 75 g/lit	1.0	23027	2410	2538	2098
Farmers' practice with 2 hand weeding	-	22157	4000	D	D

Note: [a]MRR calculated for cost of herbicides increased by 20%
D: treatments with MRR<50% considered as dominated.

CONCLUSION AND RECOMMENDATION

Most of the grass weeds like *Snowdenia polystachya, Avena fatua, Phalaris paradoxa* and *Setaria pumila* were effectively controlled by Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l. It has better weed control efficacy and yield advantage than Phenoxapropethyl herbicide. Moreover, this herbicide was found to be profitable for farmers with MRR of 2538%. Besides, it was the most profitable weed treatment even if the cost of herbicide is increased by 20% as depicted by sensitivity analysis ([a]MRR). Hence, the herbicide Fenoxaprop-p-ethyl 69 g/l + safener-Mefenpyr-diethyl 75 g/l a.i at a rate of 1 lit/ha post-emergence application can be recommended for the control of annual grass weeds in Malt barley for agro-ecologies similar to the study areas.

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