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Demonstrations of Improved Weed Management Options for Malt Barley in Central Ethiopia Region

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ABSTRACT: Barley (*Hordeum vulgare* L.) production is seriously affected by weed infestation due to the absence of effective management strategies. A field experiment was conducted to demonstrate the effect of post emergence herbicides on the management of malt barley weeds during the main growing season of 2018. The effects of three different herbicides on weed competition and the grain yield of malt barley were evaluated. Untreated controls were included to allow maximum weed infestation for comparison. The trial was laid out in a randomized complete block design with four replications. Based on our weed assessment *Avena fatua and Galinsoga parviflora* were the most common and prevailing weed species of barley. The results of the study revealed that the maximum weed infestation of 84.7% was recorded in the untreated plot, whereas the lowest weed infestation of 16.7% was recorded in the Axial+2.4.D treated plot. The malt barley revealed significant difference ($p \leq 0.05$) for yield related traits due to herbicides treatment. Weed infestation resulted in a high grain yield loss of 71.8% in the unsprayed plot, while the lowest grain yield loss of 7.71% was obtained in the Plass+2.4.D treated plot. The trials clearly determined the appropriate herbicide for the management of malt barley weeds. The combined use of Axial+2.4.D can be recommended as the best option for obtaining higher vegetative growth and yield in barley production. However, future research on the management of major weed species in different agro-ecology is mandatory to develop more conclusive recommendations.

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Barley (*Hordeum vulgare* L.) is a major cereal crop in Ethiopia with a long history of cultivation and a wide range of agro-ecological and cultural practices (Eticha F *et al.*, 2010). It is very important as malt and animal feed. Most importantly, malt barley is used for malting various alcoholic beverages and foods, such as bread, cultural dishes, biscuits, cakes and desserts. Barley is Ethiopia's fifth most important cereal crop in terms of land coverage and annual production (CSA, 2022). This crop is primarily produced by small-scale farmers in many areas of Ethiopia (Getachew *et al.,* 2011). Despite the importance of barley as a food and malting crop, its production under field conditions has remained very low (approximately 2.53 t/ha (CSA, 2022)), which is far below the average productivity worldwide. Barley productivity is low due to multidimensional abiotic and biotic factors EIAR (2019). Biotic factors (weed infestation, foliar diseases and insect pests), abiotic factors (low soil fertility, low soil pH, poor soil drainage) and other factors, such as low-yielding malt barley cultivars, cultivation on marginal lands and poor crop management practices, are responsible for the low average yield in the country (Bayeh and Berhane 2011).

Various weed species affect the production of barley in Ethiopia. Weed infestation significantly reduces the yield and quality of barley (Kanatas *et al*, 2020;

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Wozniak 2020; Watson *et al.,* 2006; Mahajan *et al.,* 2020). Weeds emerge quickly and grow rapidly, competing with crops for nutrients, moisture, sunlight and space during the entire growth of plants. Both broad and grass weed species compete with barley crops. Grass weeds are becoming significant production constraints to barley in Ethiopia due to the high proportion of cereal crops in rotational systems in highlands and the repeated application of herbicides that are effective against broad leaf weeds. Among grassy weeds, *Avena fatua*, *Bromus pectinatus*, *Digitaria scalarum*, *Lolium temulentum*, *Phalaris paradoxa*, *Setaria spp*. and *Snowdenia polystachya* are the most important and prevalent weeds.

Several management options are available to control weeds. These include cultural, physical, chemical and integrated methods. Hand weeding is the most common weed control option for barley. Manual weed control is labour intensive and therefore limits the production area (Verma *et al.,* 2008; Dubey, 2014). Chemical control is the most common, efficient and economical method of control (Dalley *et al.,* 2006; Marwat *et al.,* 2008). In many barley producing areas, barley fields are mostly treated with broadleaf herbicides. However, post emergence and the use of selective grass weed herbicides are also important for reducing the yield loss caused by weed infestation. Based on areal observations, most broadleaf weeds are effectively controlled by hand weeding because they are easier to identify. However, no effective and applicable technology has yet been adopted to control both grass and broad leaf weed species in the study area. The combined application of herbicides is crucial for managing both weed species. Thus, the objective of this study was to demonstrate and develop effective weed management option/s for malt barley weed in the Siltie zone of the central Ethiopia region.

MATERIALS AND METHODS

Description of the experimental areas: Werabe Agricultural Research Center (WARC) conducted the field experiment at the Farmers Training Center (FTC) at Alicho Wuriro during the 2018 main growing season. The experimental sites are located in major barley growing areas of central Ethiopia and are characterized by Dega agro ecologies. Mixed agriculture is the most common economic activity among farmers in these areas. The experimental area is located at 07°56'96"N, 38°09'39"E and 2783 m.a.s.l. The annual rainfall ranges between 750 and 1190 mm, indicating highland agro ecology. The average annual minimum and maximum temperatures are 8.1°C and 16.7°C, respectively. The most common soil type is clay (pellic vertisole). The location represents the weed-infested area of the central Ethiopian region and is characterized by bimodal rainfall, a short rainy season extending from March to May and a main rainy season from June to September.

Experimental design and treatments: An appropriate randomized complete block design (RCBD) with four replications was used for the experiment. Post emergence herbicides included Axial+2,4-D, Pallas+ 2,4-D and 2,4-D were used as a treatment based on company recommendations. The control treatment (untreated) was used for comparison. The malt barley variety Holker was used in experimental plots measuring 4 m × 4 m or 16 m^2, each containing 20 rows spaced 0.2 m apart. The distances between plots and blocks were 1 and 1.5 meters, respectively. The food seeds were barely sown manually in rows at a rate of 100 $kgha^{-1}$ on July 10 during the main growing season. During planting, 100 $kgha^{-1}$ DAP and 100 $kgha^{-1}$ urea fertilizers were applied. The required quantity of the herbicide was calculated and measured in a manual knapsack sprayer with a water volume of 200 lit/ha for each herbicide treatment plot. Broad leaf weeds were controlled by using 2,4-D herbicide at a rate of 1 lit/ha for herbicide treatments one week after the application of grass weed herbicides. All the necessary agronomic practices were performed equally for all the treatments.

Weed assessment: All necessary data were collected from the field experiment. Weed infestation was assessed and scored by throwing quadrats with 50 cm × 50 cm areas three times per plot as per the method described by (Cruz *et al.,* 1986).

Yield parameter assessment: All agronomic data were recorded from 16 central rows on each experimental unit. The details of the agronomic parameters measured are as follows.

Kernels per Spike (KPS): The kernels of the main tillers on each of 10 randomly selected plants were counted, and the average of 10 plants was used for data analysis.

Thousand Kernels Weight (TKW) (g): The weight of one thousand kernels was determined by carefully using a seed counter, adjusting to 12.5% moisture content and weighing them using a sensitive balance.

Grain yield (GY): Grain yield was adjusted to a moisture content of 12.5%, measured from the 16 central rows of each plot and converted to kg/ha-^{1}.

Statistical analysis: Statistical analysis was performed using the general linear model procedure of the SAS software package version 9.3 SAS Institute Inc (2004). The treatment means were compared using the least significant difference (LSD) test at the 5% probability level.

RESULTS AND DISCUSSION

The effects of herbicide application on the vegetative growth of malt barley plants and whether herbicides affect weed infestations and economic yields are shown in Table 2. Based on the field assessment results, grassy weeds appeared to dominate broadleaved weed species in the experiment. The maximum weed infestation (84.7%) was recorded for the untreated group, whereas the lowest weed infestations (16.1%) were recorded for the Axial+2.4-D group (Table 2). Moreover, the application of Axial+2,4-D herbicide significantly increased the percentage of controlling weed species. Malt barley growth was influenced by the type of weed species, time of emergence of the weeds and density of the weeds in the experimental field. The efficacy results indicated that all chemical treatments were effective against major grass weed species, such as *Cyperus* species, *Snowdenia polystachya, Avena fatua, and Setaria pumila,* and broad weed species, such as *Galinsoga parviflora* and *Guizotia scarab*. However, the abundance of weeds, especially wild oat (*Avena fatua*), has increased tremendously in highland areas and rain-fed areas. Based on field observations, this weed competes with barley and wheat crops and causes significant yield losses in the study area. A total of 10 weed species belonging to seven families comprised of four broadleaf and six grasses were observed in the experiment (Table 1). However there was also other weed species like *Solanum nigrum L.*, *Argemone mexicana L. Bides. pilosa L.* in the farmers' field they are not found on the trial. There was an almost equal number of weed families in the experiment. However, the proportion of grass weed species was greater than that of broad leaf weeds. These weed species affect the performance of barley at the early stage of the crop. Farmers' practices include removing the weed at the lateral stage of the crop after infestation. This clearly indicates the need for awareness of the serious negative effects of weeds at early growth stages compared with later growth stages. The lowest weed control efficacy was recorded in the untreated plot. This finding is in line with the findings of (Singh & Ali 2004), who reported that the lowest weed control efficiency was observed under untreated/control plots because of increased weed competition stress.

Table 1: Weed species identified in the experiment.

Scientific name	Family	Life form (Category)
Avena fatua L	*Graminaea*	Annual (Grass)
Commolina latifolia	*Commelinaceae*	Annual (Broadleaved)
Galinsoga parviflora	*Asteraceae*	Annual (Broadleaved)
Guizotia scarba	*Asteraceae*	Annual (Broadleaved)
Setaria pumila	*Graminaea*	Annual (Grass)
Snodonia polystachia	*Graminaea*	Annual (Grass)
Cyperus sp.	*Cyperaceae*	Annual (Grass)
Galium sporium	*Rubiaceae*	Annual (broadleaved)
Cynodon dactylon L.	*Poaceae*	Annual (Grass)
Amaranthus sp.	*Amaranthaceae*	Annual (Grass)

Table 2: Agronomic and weed infestation result

Treatment	**Weed infestation (%)**	**KPS**	**TKW (g)**	**GY (kgha-1)**	**(GY Loss)**	
					(kgha-1)	**(%)**
Axial+2,4-D	16.1^{d}	21.7^{a}	40.5^{a}	4201.1^{a}	0.00	0.00
Palass+2,4-D	31^{c}	17.2^{ab}	35.4^{b}	3877.2^{b}	323.9	7.71
2,4-D	41.7^{b}	15^{a-c}	31^{c}	2888.3^{c}	1707.1	40.6
Control(untreated)	84.7^{a}	11.7^{d}	18^{d}	1181.2^{d}	3019.9	71.8
LSD	1.74	0.55	1.32	94.8		
CV (%)	5.68	4.93	5.97	4.42		

Note: *$LSD_{0.05}$ = List significant difference at 5%, CV (%) =coefficient of variation (%). Means in the same column followed by the same letters are not significantly different*; *KPS= number of kernels per spike, TKW= thousand kernel weight, GY= grain yield*

The number of kernels per spike is one of the basic parameters used to assess the influence of weeds. The results showed that there was a significant ($p \leq 0.05$) difference among treatments in the number of kernels per spike. All the experimental treatments showed superiority over the un weeded plots. The maximum number of grains per spike (21.7) was obtained from the plots treated with Axial+2,4-D, followed by Pallas+2,4-D, whereas the minimum kernel per spike (15) was obtained from untreated plots (Table 2). The recommended rate of Axial+2,4-D was revealed by the study results at the critical stage of emergence significantly affects the weed population and improves the number of kernels per spike through proper utilization of available nutrients without any competition. Application of 2,4-D provides better results by controlling broad leaf weeds but not grass weeds; however, 2,4-D alone does not yield satisfactory results and must be combined with other herbicides. The results of the present study are similar to those of (Nano *et al.*, 2012), who reported that 2,4-D was ineffective at reducing the population of grassy weeds but effectively controlled broad leaved weed species. More importantly, most grassy weeds such as *Snowdenia polystachya, Avena fatua, Setaria pumila and Cyperus* were controlled by axial one herbicide. The findings of the experiment demonstrated that the impact of herbicides caused a considerable difference in the thousand kernel weight (TKW). The maximum TKW (40.5g) was obtained from Axial+2,4-D, whereas the lowest TKW (18g) was obtained from the untreated plot (Table 2).

Most post emergence herbicides reduce weed infestations and significantly increase the thousand kernel weight. These results are in line with the findings of (Hossain *et al.*, 2009), who reported that the application of post emergence herbicides reduced weed dry weight and consequently increased weed control efficiency. Similarly, (Singh *et al.*, 2002; Singh *et al.*, 2013) reported that weed control efficiency was greatest with weed free treatment because it provided the best control of grass and broad leaf weeds. This is because the combination of herbicides with a broad spectrum achieved effective management for almost all weed species, which in turn led to an increase in the kernel weight and yield of the crop, significantly lowered the weed population and led to a very low dry weight. The grain yield was significantly ($p \leq 0.05$) affected by herbicide treatment.

The maximum grain yield (4201kg ha^{-1}) was obtained from the Axial+2,4-D treatment, whereas the lowest grain yield (1180.2 ha^{-1}) was obtained from the untreated plot (Table 2). The combination of Axial+2,4-D improved the grain yield. This is because the combination of broad-spectrum herbicides has achieved effective management for almost all weed species, which in turn leads to an increase in grain yield. Palls+2,4-D also showed better efficacy on the grain yield potential of food barley than on that of the weedy cheek. Similarly, (Zahara and Shugute, 2016; Sareta *et al*., 2016) reported the maximum amount of biological yield from plots treated with post emergence herbicides across the testing sites, whereas the lowest amount was reported from weedy checks. On the other hand, the lowest grain yield was obtained from the untreated plots. This might be due to severe weed competition between the weeds and crop, which prominently reduced the nutrient mobility towards grains and affected the grain development potential of the barley crop. Crops are very sensitive to weed competition and suffer the greatest yield reduction. Observations from the field showed that grass weed species were more problematic for barley than were broadleaf species. The same information is true for farmers' fields. Intensive monocultures in the area have encouraged the use of the same group of herbicides for weed control. This situation might result in herbicidal resistance during weed management practices. Farmers in the area applied herbicide after the complete emergence/infestation of weeds. Due to late interventions, yield and productivity have significantly decreased. Timing herbicide application is very important, and growers should apply post emergence herbicides at the right time for a better yield advantage. More importantly attention should be given in to account to use low concentration and effective pesticides to control grass and broad weed species.

Conclusion: The results of this concluded that a single method involving these technologies will not yield the desired results for the sustainable management of weeds. Thus, to provide a synergistic effect to address the impact of weeds on the productivity of barley, the integration of all available control methods (preventative, cultural, mechanical, biological and chemical) is vital for achieving optimum results in weed management. The combined use of Axial+2.4.D was quite effective at controlling both grass and broad leaf weed species. However, developing an effective weed management approach must be planned for major weed families and species, especially grassy weeds.

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Data Availability Statement: Data are available upon request from the corresponding author.

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