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Chemical Management of Weeds in Common Bean (*Phaseolus vulgaris*)

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ABSTRACT

Common bean production (*Phaseolus vulgaris*) is severely infested by weeds in Ethiopia. Field experiments were conducted in 2012 and 2013 at Ambo University, Ethiopia, to determine the effect of pre-emergence herbicide s-metalachlor on weed dynamics and yield of common bean (*Phaseolus vulgaris*) in completely randomized block design with three replications. The field experiments were comprised of 5 treatments including s-metolachlor (dual gold) 1.00, 1.50 and 2.00 kg ha^{-1}, weed free and weedy check were used. The common bean in both years were infested with *Amarathus hybridus* L., *Datura stramorium, Erucastrum arabicum* Fisch and May, *Galinsoga parviflora* cav., *Ipomea ariocarpa, Nicandra spps, Oxalis corniculate* L., *Oxalis latifolia* L. *and Polygonum nepalense* Meisn. Among the treatments, hand weeding standard check and s-metolachlor at 2.00 kg ha^{-1} significantly reduced density and dry weight of weeds during 2012 and 2013 years. Moreover, hand weeding and s-metolachlor at 2.00 kg ha^{-1} significantly increased the plant height, number of pods per plant, and seeds per pod as compared to other treatments. The highest grain yield was recorded on hand weeding plot followed by s-metolachlor at the rate of 2.00 kgha^{-1}. However, no significant difference was observed between them, whereas, the lowest grain yield was recorded on untreated plot (weedy check). Weed infestation resulted in a caused–a-yield reduction of 72.5% and 63.5% in 2012 and 2013, respectively. Pre-emergence application of s -metolachlor at the rate of 2 kg ha^{-1} was found to be more effective in controlling weeds and increased the c yield in common bean.

INTRODUCTION

Haricot beans (*Phaseolus vulgaris*) are a grain crop mainly produced in Ethiopia for human consumption and export. It has been raised in most of the agro-ecological zones of low and mid altitude areas of the country. A market demand for the haricot beans both in the domestic & export market has become the main instrument for the growing trends in volume of production (Frehiwot, 2010). Economic significance of common bean in Ethiopia is quite considerable since, it represents one of the major food and cash crops. It is often grown as cash crop by small-scale farmers and used as a major food legume in many parts of the country where it is consumed in different types of traditional dishes (Habtu, 1994; Mohammed *et al.*, 2013).

Despite its potential and importance in the country, the production and productivity of the crop is very low. Soil fertility status, recurrent water stress, insect pests, weeds and diseases are considered as the principal abiotic and biotic constraints of common bean production in Africa (Allen *et al.,* 1989).

Weeds have been a serious constraint in bean production, its competition not only reduces the yield but also the bean quality, affecting seed size, plant height and pod length. Weeds compete with bean plants for water, nutrients, and sunlight and thereby, decrease the crop yield and quality. Heavy weed infestation increased the humidity within the canopy, reducing the airflow and increasing the possibility of disease development. Weeds increased the bean drying time in the field, resulting in yield losses due to shattering (Waters, and Morishita, 2001). Weeds depending on the degree of competition with crops reduced the crop yield by 10 % to 50 % (Karimi, 1998). Research also indicated that weed interference in dry beans can result in yield losses of up to 85% (Pynenburg *et al.,* 2011). Several methods of weed control are practiced in beans; weed fire control and mechanical cultivation are common. Most of these (mechanical) methods are expensive and time consuming. Therefore, the speedy and low cost chemical control measures are acceptable among the farmers. Recent innovations showed that herbicides control of weeds in common bean is getting increased attention. But in Ethiopia, the method has received comparatively little attention. Apparently, the management of weeds through pre-emergence herbicide, particularly , using different rates of metolachlor has not been studied so far in Ethiopia. Therefore, this study was designed with the objective of evaluating the effect of different s- metolachlor rates application on weeds and yield of common bean as well as to assess economics of herbicides at Ambo, Ethiopia.

MATERIALS AND METHODS

Experimental site

The field experiments were conducted at Ambo University, Ethiopia located at latitude of 9° 11' 0" North, 38° 20' 0" East and an altitude of 1980 MSL. The rainy season of the area is bimodal type with an average annual rainfall of 780 mm. The mean minimum and maximum temperatures are 8.25 and 23.4^0 C, respectively.

Treatments, Experimental Design and managements

Common bean cultivar, Awah-1 currently under production from Melkasa Agricultural Research Center, Ethiopia was used for the study. Based on CIAT's classification, the growth habit of Awash-1 was indeterminate and is navy (small white), which is primarily used for commercial (canning) purpose. Pre-emergence herbicide, s-metolachlor (dual gold) was obtained from Agrishere, Private Limited Company, Ethiopia.

The field experiment comprised of 5 treatments including s-metolachlor (dual gold) 1.0, 1.5, 2.00 $kgha^{-1}$ hand weeding and weedy check were arranged in randomized block design with three replications. Herbicides rates were applied two days after sowing as pre-emergence using Knapsack/ Backpack sprayer. The spray volume will be 600 liters of water per ha. The size of each plot was 1.0 m X 2.0 m. The distance between adjacent replications (blocks) and plots was 1 m and 0.5 m, respectively.

The experimental plot was ploughed twice to get fine seed bed, plots were leveled manually before the field layout was made. The common bean cultivar, Awah-1 was planted manually in the month of May. Two seeds were placed at each hole and thinned to one plant per hill 15 days after sowing. The recommended amount of phosphorus fertilizer was applied. All agronomic practices were kept uniform for all experimental plots. The weed count was taken on 45 days after planting with the help of 0.25 m x 0.25 m quadrate thrown randomly at two places in each plot. Weeds were identified and converted to population/density per m^2. While recording weed population; the biomass was harvested from each quadrate. The harvested weeds were first sun dried and then drying in oven at 650C temperature for 24 hours till constant weight and subsequently the dry weight was recorded and converted in to gm^{-2}.

Weed Control Efficiency (WCE) - It was calculated using the formula

$$WCE = \frac{WDC - WDT}{WDC} X 100$$

; Where, WDC= weed dry matter in weedy check; WDT= weed dry matter in a treatment

Plant height, number of pods per plant and number of seeds per pod were recorded from 8 randomly selected (pre tagged) plants at the middle rows. Hundred kernels from each plot were counted and their weight was recorded in grams and adjusted to 12.5% moisture content. For Grain yield the final produce was recorded from each plot and adjusted to 12.5% moisture content with the help of formula and expressed in kg ha^{-1}.

$$Adjusted\ grain\ yield\ (kg\,ha^{-1}) = \frac{Actual\ yield\ \mathrm{X}100 - M}{100 - D}$$

Where, M is the measured moisture content in grain and D is the designated moisture content.

Crop yield loss due to weeds was calculated based on the maximum yield obtained from a treatment /treatment combination i.e. interaction as follows:

$$\mathrm{Re}lative\ \ yield\ loss = \frac{MY - YT}{MY}\mathrm{X}100$$

, Where, MY= maximum yield from a treatment, YT = yield from a particular treatment. Weed density was subjected to square root transformation $\left(\sqrt{(X+0.5)}\right)$. Data were subjected to analysis of variance. Mean separation was conducted for significant treatment means using Least Significance Differences (LSD) at 5% probability level.

Cost and benefit analysis

The price of common bean seeds (Birr/Kg) was assessed from the local market and the total price of the commodity obtained from each treatment was computed on hectare basis. Input costs like herbicides and labor were converted into hectare basis according to their rates used. Since there were significant differences between mean yields of treatments, the obtained data were analyzed using the partial budget analysis method (CIMMYT, 1988). Marginal rate return was calculated using the formula:

$$\text{Marginal Rate Return}(\%) = \frac{\text{Marginal Benefit x100}}{\text{Marginal Cost}}$$

RESULT AND DISCUSSION

Weed Floral Composition

The experimental site was infested with weed species which belongs to different families. Nine weeds species which belongs to 7 families were identified in both years (Table 1). This result is in agreement with Gill *et al.* (2010) and Mehmeti *et al.* (2012) who found different weeds species in a single experimental site.

Table 1: Weed floral composition of experimental at Ambo during 2012 and 2013

2012		***2013***	
Botanical name	**Family name**	**Botanical name**	**Family name**
Amarathus hybridus L.	Amaranthaceae	*Amarathus hybridus* L.	Amaranthaceae
Datura stramorium	Solanaceae	*Datura stramorium*	Solanaceae
Erucastrum arabicum Fisch and May	Brassicaceae	*Erucastrum arabicum* Fisch and May	Brassicaceae
Galinsoga parviflora cav.	Asteraceae	*Galinsoga parviflora* cav.	Asteraceae
Ipomea ariocarpa	Convolvulaceae	*Ipomea ariocarpa*	Convolvulaceae
Nicandra spps		*Nicandra spps*	
Oxalis corniculate L.	Oxalidaceae	*Oxalis corniculate* L.	Oxalidaceae
Oxalis latifolia L.	Oxalidaceae	*Oxalis latifolia L.*	Oxalidaceae
Polygonum nepalense Meisn	Polygonaceae	*Polygonum nepalense* Meisn	Polygonaceae

Density and Dry Weight of weeds

Weed density and dry weight were significantly affected by weed control methods in both years. During both years, minimum weed density was observed in hand weeding followed by s-matachlor at 2.0 kg ha^{-1}(4.90 m^{-2} and 5.92 m^{-2}) and the highest weed density was observed in weedy check (16.80 m^{-2} and 18.40 m^{-2}).

Table 2: Effect of different rates of metolachlor herbicide on weed density (m^{-2}) and dry weight (gm^{-2}) of weeds in 2012 and 2013

Treatments	2012		2013	
	Density (m^{-2})	Dry weight (gm^{-2})	Density (m^{-2})	Dry weight(gm^{-2})
s-metolachlor at 2.0 $kgha^{-1}$	4.90(24.01)^{d}	17.87^{c}	5.92 (34.67)^{c}	28.00^{d}
s-metolachlor at 1.50 $kgha^{-1}$	6.76(45.33)^{c}	24.80^{c}	8.35 (69.33)^{b}	57.20^{c}
s-metolachlor at 1.0 $kgha^{-1}$	8.19(66.67)^{b}	61.87^{b}	9.95(98.67)^{b}	79.33^{b}
Hand weeding	0.71(0.0)^{e}	0.00^{d}	0.71(0.0)^{d}	0.00^{e}
Weedy check	16.80(282.67)a	155.47^{a}	18.40 (338.67)^{a}	140.93^{a}
LSD (0.05)	1.15	9.94	1.61	13.95
CV (%)	8.19	10.15	9.59	12.13

Figures or numbers in the parenthesis are original values, CV= coefficient of variation, means within a column followed by the same letter are not significantly different at the 0.05 probability level using Fisher's protected LDS test

Different rates of metolachlor herbicide also significantly affected the dry weight of weeds in both years. In 2012, the highest weed dry weight (155.47 gm^{-2}) was scored from weedy check whereas, the lowest was recorded in hand weeding (0.0 gm^{-2}) plot followed by a plot treated with s-metolachlor at 2.0 $kgha^{-1}$ (17.87 gm^{-2}), Similarly in 2013 also, hand weeding recorded the lowest dry weight (0.0 gm^{-2}) followed by s-metolachlor at 2.0 $kgha^{-1}$ (28.0 gm^{-2}) whereas, the highest was recorded (140 gm^{-2}) in weedy check. As the application rate of s-metolachlor increased there was decrement of weed density and dry weight in both years. Similar report also reported by Jafari *et al.* (2013) who stated that pre-emergent herbicides reduced the weed density and dry weight significantly as compared to weedy check.

Weed Control Efficiency

As stated in Table (3), weed control efficiency (%) was affected significantly by different rates of metolachlor herbicide in both years. In 2012, the maximum weed control efficiency was recorded in hand weeding plot (100.0) followed by s-metolachlor at 2.0 $kgha^{-1}$ (88.4) and s-metolachlor at 1.50 $kgha^{-1}$ (83.9%). While, the lowest weed control efficiency was recorded in weedy check (0). Similarly in 2013, plot treated with hand weeding gave highest weed control efficiency (100.0). However, the minimum weed control efficiency was observed in control plot. In this trial, as the application rate of s- metolachlor increased, the weed control efficiency was also increased in both years. A similar trend is also reported by Jafari *et al.* (2013) who stated that pre-emergent herbicides gave higher weed control efficiency by reducing the weed density and dry weight significantly as compared to weedy check.

Table 3: Effect of different rates of metolachlor herbicide on weed control efficiency in 2012 and 2013

Treatments	Weed Control Efficiency (%)	
	2012	**2013**
s-metolachlor at 2.0 $kgha^{-1}$	88.4^{b}	80.0^{b}
s-metolachlor at 1.50 $kgha^{-1}$	83.9^{c}	59.3^{c}
s-metolachlor at 1.0 $kgha^{-1}$	60.1^{d}	43.2^{d}
Hand weeding	100.0^{a}	100.00
Weedy check	0.0^{e}	0.0^{e}
LSD (0.05)	3.02	8.56
CV (%)	6.79	8.05

Figures or numbers in the parenthesis are original value, CV= coefficient of variation, means within a column followed by the same letter are not significantly different at the 0.05 probability level using Fisher's protected LDS test

Yield and Yield Components

Data on yield parameters of both years showed significant difference (P<0.01) among the treatments. In 2013, the tallest plant was recorded in hand weeded plot followed by s-metolachlor rate at 2.0 kg ha^{-1}. Whereas, the shortest plant height was observed in weedy check plot. This might be due to the fact that plants growing with effective weed control could attain higher heights because, there is no competition for nutrients. Hand weeded plot and s-metolachlor at 2.0$kgha^{-1}$ gave the highest number of pods per plant. The untreated control gave the least number of seeds per pod. Current results are also in agreement with Jafari *et al.* (2013) who stated that pre-emergent herbicides increase the plant height, pods per plant and seed number per pod significantly as compared to weedy check. Morad (2013) also observed that increase in yield component of bean may be due to effective weed management through herbicides.

Table 4. Effect of different rates of metolachlor herbicide on plant height, pods number per plant, and seeds number per pod in 2012 and 2013

Treatments	2012			2013		
	PH(cm)	Pods/ plant	Seeds/po d	PH(cm)	Pods/plant	Seeds/pod
s-metolachlor at 2.0 $kgha^{-1}$	36.1^{ab}	11.5^{a}	5.7^{b}	33.5^{b}	11.4^{a}	6.7^{b}
s-metolachlor at 1.50 $kgha^{-1}$	33.2^{bc}	8.4^{b}	4.7^{bc}	31.2^{b}	7.6^{b}	5.7^{bc}
s-metolachlor at 1.0 $kgha^{-1}$	29.5^{cd}	5.4^{bc}	4.3^{cd}	28.9^{bc}	4.3^{c}	5.3^{cd}
Hand weeding	39.7^{a}	11.7^{a}	7.4^{a}	39.7^{a}	12^{a}	8.3^{a}
Weedy check	24.9^{d}	3.5^{c}	3.4^{d}	24.3^{c}	2.8^{c}	2.1^{e}
LSD (0.05)	5.02	2.73	0.99	4.85	2.73	1.2
CV (%)	8.15	17.98	10.29	8.18	17.99	10.29

CV= coefficient of variation, Means within a column followed by the same letter are not significantly different at the 0.05 probability level using Fisher's protected LDS test

Hundred seed weight was also significantly affected by different rates of metolachlor herbicide. In 2012, the maximum 100 seed weight was recorded in hand weeded plot followed by s-metolachlor at 2.0$kgha^{-1}$. However, the lowest 100 seed weight was recorded in weedy check. The seed yield data also showed significant differences among treatments in both years. The maximum seed yield was obtained from hand weeding and plot treated with s-metolachlor at 2.0$kgha^{-1}$; however, S the lowest was recorded in weedy check. This might be due to uniform and complete coverage of herbicides across the rows and inter-row weeds helped in reducing the weed density below the economic threshold level next to hand weeding which might result in highest yield. These results are in agreement with Morad (2013) who observed that yield of bean increased in plot treated with herbicides due higher pods per plant, seed number per pod and kernel weight are due to effective weed management through herbicides.

Table 5. Effect of different rates of metolachlor herbicide on hundred seed weight (g), grain yield (kg ha^{-1}) and relative yield losses (%) in 2012 and 2013

Treatments	*2012*			*2013*		
	HSW (g)	GY ($kgha^{-1}$)	RYL (%)	HSW(g)	G Y ($kgha^{-1}$)	RYL (%)
s-metolachlor at 2.0 $kgha^{-1}$	32.9b	3271.7a	9.8d	30.9a	2283.3a	10.8c
s-metolachlor at 1.50 $kgha^{-1}$	27.3c	2400.0b	33.5c	25.3b	1600.0b	38.4b
s-metolachlor at 1.0 $kgha^{-1}$	20.9d	1950.0b	46.6b	18.3c	1133.3c	56.4a
Hand weeding	39.3a	3650.0a	0.0d	36.0a	2600a	0.00c
Weedy check	20.3d	1000.0	72.5a	16.7c	933.3	63.5a
LSD (0.05)	9.09	459.16	11.69	4.77	462.64	17.6
CV (%)	9.09	9.94	19.12	9.21	14.37	27.6

HSW=hundred seed weight; GY=grain yield; RYL=relative yield loss, means within a column followed by the same letter are not significantly different at the 0.05 probability level using Fisher's protected LDS test

Cost Benefit

Partial economic analysis was done to select the most economically feasible weed control strategy. The partial budget for 2012 (Table 6) showed that the hand weeding and s -metolachlor at rate 2.0 $kgha^{-1}$ were the most economic strategies with a marginal rate of return of 3786.67% and 2279.8% , respectively over s-metolachlor at rate 1.5 and 1$kgha^{-1}$. Moreover in 2013, hand weeding and s-metolachlor at rate 2.0 $kgha^{-1}$

showed marginal rate of return of 2344.5% and 1314.3%, respectively (Table 7). In both years, the cost of hand weeding was greater than herbicide used because, hand weeded plots were weeded three times instead of two times. The result is in agreement with the findings of Jaya Suria *et al*. (2011) who reported that weed control efficiency cannot be considered as the only criterion to determine the suitability of a chemical weed control strategy, rather, economics of weed control should also be taken into consideration while making any decision.

Table 6: Partial budget analysis for the effect of different rates of metolachlor herbicide for management of weeds in Common Bean at Ambo, Ethiopia in 2012

Treatments	Bean yield (Kg/ha)	Bean sale (Birr/kg)	Sale revenue	Inputs & labor cost (Birr/ha)	Marginal cost (Birr/ha)	Net profit (Birr/ha)	Marginal benefit (Birr/ha)	MRR (%)
M (2.0 $kgha^{-1}$)	3271.7	22	71977.4	3700	2100	68277.4	47877.4	2279.88
M (1.50 $kgha^{-1}$)	2400.0	22	52800	3550	1950	49250	28850	1479.49
M (1.0 $kgha^{-1}$)	1950.0	22	42900	3400	1800	39500	19100	1061.11
HW	3650.0	22	80300	3100	1500	77200	56800	3786.67
Weedy check	1000.0	22	22000	1600	0	20400	0	-

M= Metolachlor, HW =Hand Weeding

Table 7: Partial budget analysis for the effect of different rates of metolachlor herbicide for Management of Weeds in Common Bean at Ambo, Ethiopia in 2013

Treatments	Bean yield (Kg/ha)	Bean sale (Birr/kg)	Sale revenue	Inputs & labor cost (Birr/ha)	Marginal cost (Birr/ha)	Net profit (Birr/ha)	Marginal benefit (Birr/ha)	MRR (%)
M (2.0 $kgha^{-1}$)	2283.3	22	50232.6	3700	2100	46532.6	27600	1314.3
M (1.50 $kgha^{-1}$)	1600	22	35200	3550	1950	31650	12717.4	652.2
M (1.0 $kgha^{-1}$)	1133.3	22	24932.6	3400	1800	21532.6	2600	144.4
HW	2600	22	57200	3100	1500	54100	35167.4	2344.5
Weedy check	933.3	22	20532.6	1600	0	18932.6	0	-

M= Metolachlor, HW =Hand Weeding

COMPETING INTEREST

The authors have not declared any conflict of interests.

AUTHOR'S CONTRIBUTION

- Substantial contribution to conception and design; or acquisition of data; or analysis and interpretation of data.
- Drafting the article or revising it critically for important intellectual content.
- Final approval of the version to be published.

CONCLUSIONS

From the field experiment it could be concluded that s-metolachlor at 2.0$kgha^{-1}$ significantly reduced the weed density and dry weight. The treatment also significantly increased the yield and yield components of common bean. Weed infestation resulted in a relative yield reduction of 72.5% and 63.5% in 2012 and 2013, respectively.

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