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Effect of Hand Weeding Frequency and Pre-emergence Herbicide on Weed Control in Soybean [(*Glycine max* L.) Merrill] at Bako, Western Ethiopia

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Abstract

The experiment was carried out to evaluate the effect of low rate of Dual gold with different hand weeding frequency on weeds, and yield of soybean and to determine the economic feasibility of different weed controls practices in soybean at Bako agricultural Research Center using RCBD design in three replications. The experimental site was predominately susceptible to different weed species belonging to broadleaved and grass weed families. Guizotia scabra, stelliria media and Ageratum conyzoides were the major one from broadleaved group of plants whereas Eluesine indica was predominantly observed from grass weeds in both years. The highest weedy dry matter was recorded for treatment W0 (6.6 g/m^2), and (4.6g/m^2) in 2015 and 2016 respectively. At 30DAS, the lowest weed dry matters of 2.6 g/m^2 and 2.7 g/m^2 were recorded for treatment DG and DG+W1 in 2015 and 2016 respectively. The treatment DG + W2 gave the mean pooled grain yield of 3096 kg ha^{-1}. The lowest yield was obtained from weedy check (1149 kg ha^{-1}). The partial budget analysis showed that pre-emergence herbicide Dual gold @ rate 1 L ha^{-1} + two times weeding was the most economic strategies with marginal rate of return 934.55%. The study gave clues as to how farmers could minimize weed population density and weed dry matter using 1 L ha^{-1} of Dual gold supplemented by one or two times hand weeding which can indirectly min

Keywords: Hand weeding; Pre-emergence herbicide; Weed flora

Introduction

Soybean crop [*Glycine max* (L.) Merrill], family of Fabaceae originated in Eastern Asia, probably in North and Central China [1]. Soybean crop is mainly recognized due to high nutritional value and high seed protein content of about 38 - 42% worldwide [2]. In Ethiopia, soybean crop plays a major role as protein source for resource poor farmers who cannot afford animal products [3]. It is used for preparation of different kinds of soybean foods, animal feed, soy milk, raw material for the processing factories like tasty soya; fafa food factories [4]. Soybean also counter effects depletion of plant nutrients especially nitrogen in the soil resulting from continuous mono cropping of cereals, especially maize and sorghum, thereby contributing to increasing soil fertility (Mekonnen and Kaleb, 2014). Since it is legume crop, soybean used in climate mitigation and adaptation through N2 fixation, as crop diversification and reducing amount inorganic N fertilizer [5]. The ideal grown areas of soybean could be between 1300 and 1800 m altitude with annual rain fall of 900 - 1300 mm, an average annual temperature between 20 - 25oC and soil pH of 5.5 in Ethiopia [6].

According to the evidence of Central statistical Agency, the estimated production and productivity of soybean were 2.1 and 2.2 t ha^{-1} respectively, during 2016 and 2017 cropping season in Ethiopia (CSA, 2020. The average national yield of soybean is below the average potential yield of the crop which is up to 3.5 t ha^{-1} [7], due to several yield-reducing factors such as weed infestation, water logging, lack of necessary inputs and low market prices due to lack of an immediate market Michael GF (2016). The least cultivated and scarcely distributed oil crop in spite of its importance especially in lowland and midland areas of the country is soybean. Likewise, weed infestation affects the crop by competing for light, water and nutrients, serving as hosts for diseases, insects, and nematodes that in turn attack the crop and also severely reduce the harvest efficiency (Norris RF, Buhler DD (1999). As a consequence, weeds cause reduction of soybean crop vigour and yield. Diversities of weed species are affecting the yield by competing with the crop starting from germination to harvest and can causes 27 to 84% soybean yield reduction in soybean producing areas [8].

Hence, to enhance soybean crop yield, weed species control during this period is very important. Mechanical and physical weed species managements approaches are very expensive as labour is usually unavailable during the peak periods of weed removal from the field [9]. Hand weeding required over 50% of the farmers' time leaving them with little or no time for other activities [10]. Dual gold has a tremendous action against annual grass weeds and *Cyperus* species (Getachew and Mekdes, 2016). Research done with Dual gold pre-emergence herbicide in soybean resulted in yields comparable to those receiving the recommended two weeding [8]. Though, the Dual gold herbicide rates may depend upon soil types, rainfall and irrigation patterns, temperature, crops and weeds; nevertheless, 1.5 kg ha^{-1} of Dual gold herbicide has been used in pulse crops in Ethiopia [11]. Use of herbicides may therefore provide a timely and adequate alternative to hand weeding as this not only removes the drudgery associated with it but also lowers the cost of weeding and provides protection for crop against early weed competition when pre-emergence herbicides are used [10].

Currently, soybean has been popularized in western Ethiopia. It is one of the top three soybean producers in Ethiopia [12]. Abundant species of weeds have been serious problems in soybean production and the farmers are reluctant to produce and practices maize monocropping. Generally, weed control are practiced in beans; which are time consuming and expensive. In western Oromia, the use of herbicides in beans for weed control has been received comparatively little attention. However, Dual gold pre-emergence herbicide applications at low rate combined with different hand weeding frequency are not evaluated in western, Oromia. Therefore, this experiment was conducted to evaluate the effect of low rate of Dual gold pre-emergence herbicide combined with different hand weeding frequency on weeds, and yield of soybean and to determine the economic feasibility of different weed management practices in soybean.

Materials and Methods

Description of Experimental Site

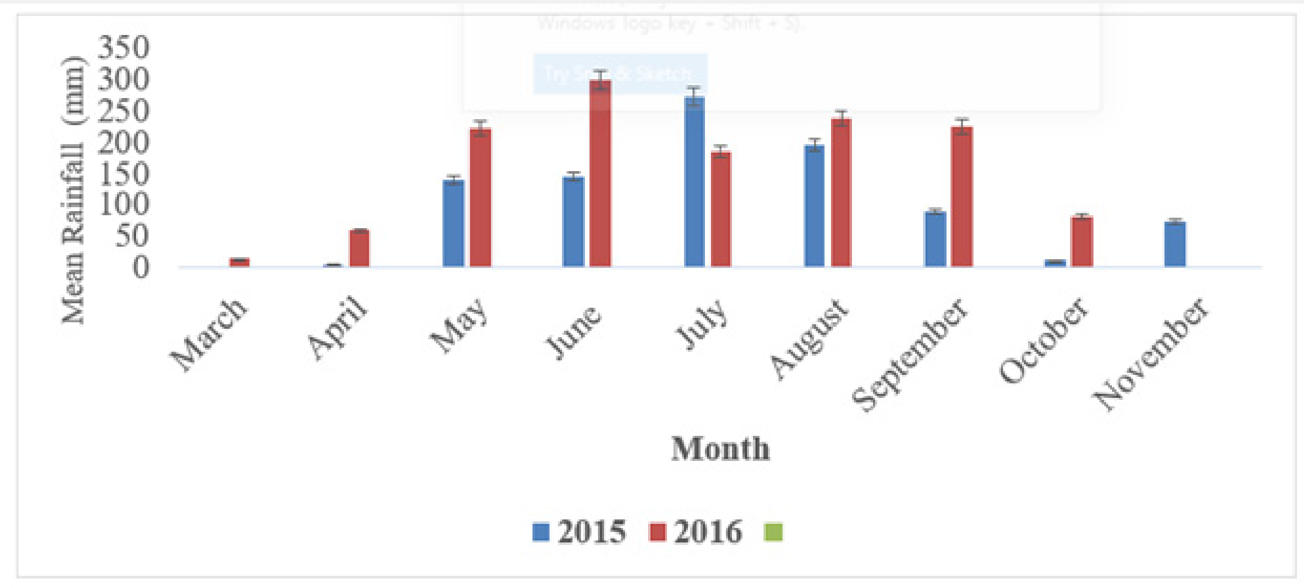

Figure 1: Mean rainfall (mm) during experimental seasons.

A field experiment was carried out at Bako Agricultural Research Center on main station located at latitude of 09o 06' N, longitude of 37° 09'E, altitude of 1650 meter above sea level and annual rain fall of 1239 (mm). The minimum and maximum temperature are 13.9 and 28.6 °C respectively. The soil type of experiment site was reddish nitisol with pH 4.6-5.2.

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Treatments and Experimental Design

Table 1: Time and methods of pre-emergence herbicide spraying.

Common name	Trade name	Chemical name
S-metolachlor	Dual Gold 960EC	[2-chloro-6-ethyl-N-(2-methoxy-1-methylethyl)acet-o toluidide]

A field experiment was carried out in 2015 and 2016 cropping seasons to compare effectiveness of low dose herbicide application with weeding frequency. The field experiment comprised eight treatments; one time weeding (W1), two times weeding (W2), three times weeding (W3) Dual gold(s-metolachlor) @ 1 L ha^{-1} (DG), Dual gold (s-metolachlor) @ 1 L ha^{-1} + one time weeding, Dual gold (s-metolachlor) @ 1 L ha^{-1} + two times weeding, Dual gold (s-metolachlor) @ 1 L ha^{-1} + three times weeding arranged in Randomized Complete Block Design (RCBD) with three replications. The size of each plots were 3mx4m. The spacing between block and plots were 1.5m and 1m respectively. Spacing between row and plant were 40cm and 10cm respectively.

Experimental Procedures

The experimental plots were ploughed twice using tractor to get fine seed bed and the plots were leveled manually before the field layout was made in both years. Soybean variety Boshe was used as a planting material and it was planted manually in late June in both years. Seeds were inoculated by Brady Rhizobium (TAL-379). Recommended Commercial fertilizer NPS @ rate of 50kg/ha was drilled in rows at planting time. Pre-emergence herbicide Dual gold (s-metolachlor) @1L/ha was applied immediately after sowing using back knapsack sprayer of 20 liter content by using 200 L water per hectare.

Data collected

Weed flora presented in experimental fields were recorded by counting weed species from each plots by placing a quadrant (0.25m x 0.25m) randomly at thrice spots in each plots just at 30 and 60 days after planting which was converted into m-2. Weed species were categorized into their botanical families with aid of weed identification manual and books. Weed at both stages were also cut near ground and after two days of sun drying; the samples were oven dried at 65 °C for a constant weight to determine dry weight of weed species. Other agronomic parameters such as plant height, pod per plant, seed per pod, branch per plant were collected from 5 plants randomly.

Statistical Data Analysis

Weed density and dry weight were subjected to square root transformation (x+0.5)1/2 to have normal data distribution before analysis. Weed and Agronomic data were subjected to analysis of Variance (ANOVA) using the general linear model (GLM) procedure of SAS software program version of 9.3. Mean separation was conducted for significant treatments mean using Least Significance Difference (LSD) at 5% probability level.

Partial Budget Analysis

The partial budget analysis as described by CIMMYT (1988) was done to determine the economic feasibility of the weed management practices. Economic analysis was done using the prevailing market prices for inputs at planting and for the outputs at the time of crop harvest. The concepts used in the partial budget analysis were the mean grain yield of each treatments, the field price of soybean (sale price (ETB 8 kg^{-1}) minus the costs of labors for weeding, harvesting, threshing and winnowing, the gross field benefit (GFB) per hectare (the product of field price and the mean yield for each treatment), the field price of s-metolachlor ETB 417 kg^{-1}, the total costs that varied (TCV) included the sum of field cost of herbicide and its application. The net benefit (NB) was calculated as the difference between the GFB and the TCV. All costs and benefits were calculated on hectare basis in Ethiopian Birr (ETB). Actual yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment.

The price of Soybean was not started on local market and assessed from local farmers cooperatives. The total price of the commodity obtained from each treatment computed on hectare basis. Input costs like biofertilizer, commercial fertilizer, seeds were not taken as variable cost. Cost of daily labors for hand weeding and herbicide costs were converted into hectare basis according to their used. The obtained data analyzed using partial budget analysis method (CIMMYT, 1988). Marginal rate of Return (MRR) was calculated.

$$MRR(\%) = \frac{M\arg inal\, benefit}{M\arg inal\ \cos t} \times 100$$

Results and Discussion

Major Weed Flora Composition in the Experimental Site

The experimental field was infested with different weed species, which belong to different families (Table 2). Thirteen weed species which belong to 8 families were identified in both years (Table 2). This result is in line with Gill et al. [13], Mehmeti et al. [14] and Amare [15] who reported different weed species in a single experimental site. The experimental site was infested by broadleaved and grass weeds in both years. However, the broadleaved weeds were dominant over grass weeds. Guizotia scabra, Stelliria media and Ageratum conyzoides were the major weed species from broadleaved while Eluesine indica was highly observed from grass weeds in both years.

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Weed population Density

The results ANOVA revealed that there were significant ($p<0.05$) differences among the treatment as compared to weedy check in number of weed population densities. At early stage (30 DAS) the largest number of broadleaved weed population densities were recorded in unsprayed plots while the lowest number of broadleaved weeds were recorded from sprayed plots with pre-emergence herbicide (Dual gold) in both years. Similarly, Sajid et al. [16] reported the highest weeds density in weedy check; while, the lowest weeds density was noticed with application of s-metolachlor in pea (*Pisum sativum* L.). On other hand, grass weeds were not recorded in the plots sprayed with pre-emergence herbicide Dual gold (s-metolachlor) @ 1 L ha^{-1} as compared to unsprayed plots in both years (Table 3). This results indicated that Dual gold (s-metolachlor) @ 1 L ha^{-1} were effective for grass weeds but did not total control broadleaved weeds even if it minimized population densities (Table 3). This results in agreement with Gidesa and Kebede [8]. Statistically there were non-significant difference among treatments; weedy check, one hand weeding, and three hand weeding in terms of broadleaved population density in both years (Table 3). However, numerically the highest broadleaved weed population density of 6.94m^{-2} and 6.42m^{-2} recorded in treatments weedy check and one hand weeding in 2015 respectively followed by 6.3m-2 (Table 3). The lowest weed population density was recorded in plots sprayed with Dual gold (s-metolachlor) at 1 L ha^{-1}.

Likewise, in 2016, the highest broad leaved weed were recorded in treatment three hand weeding (5.48m^{-2}), weedy check (5.37 m^{-2}) and followed by one hand weeding (5.26m^{-2}). On other hand, from treated plots the highest weed were recorded in treatment; Dual gold (s-metolachlor) + two hand weeding, Dual gold (s-metolachlor) + one hand weeding (3.99m^{-2}), Dual gold (s-metolachlor) + one hand weeding (3.83 m^{-2}) followed by Dual gold and Dual gold (s-metolachlor) + three hand weeding with value of 3.7m^{-2} (Table 3).The result of both year indicated that application of pre-emergence herbicide Dual gold (s-metolachlor) at rate of 1 L ha^{-1} minimized the weed population per plot as compared to unsprayed plots. These results in agreement Jafari et al. [17] who reported that pre-emergence herbicide, reduced the weed density significantly as compared to weedy check.

Weed Dry Matter

Weed dry matter was significantly ($p<-0.05$) affected by weed control methods in both years (Table 4). Similar reported also reported by Jafari et al. [17] who stated that pre-emergence herbicides reduced the density and dry weight significantly as compared to weedy check. At 30 DAS, minimum weed dry matter was recorded with pre-emergence herbicides sprayed plots resulted in significant reduction in weed dry matter over weedy check in both years. The highest weedy dry matter was recorded in treatment weedy check (6.2 g/m^2), two hand weeding (5.6 g/m^2) and followed by one and three hand weeding with the same value of 5 g/m^2 (Table 4).

Table 2: Weed flora composition of experimental site at Bako Agricultural Research Center during 2015 and 2016.

2015		2016	
Botanical name	**Family name**	***Botanical name***	**Family name**
Guizotia scabra(Vis)Chiov	Compositae	*Guizotia scabra*	Compositae
Stelliria media	Caryophyllaceae	*Stelliria media*	Caryophyllaceae
Ageratum conyzoides L.	Compositae	*Ageratum conzoide*	Compositae
Biden pilosa L.	Compositae	*Biden pilosa*	Compositae
Galinsoga spp	Compositae	*Galinsoga spp*	Compositae
Nicandra physeolode	Solanaceae	*Nicandra physeolode*	Solanaceae
Celosia tryginata L.	Amaranthaceae	*Celosia tryginata*	Amaranthaceae
Amaranthus spp	Amaranthaceae	*Amaranthus spp*	Amaranthaceae
Commelina benghalensis L	Commelinaceae	*Commelina benghalensis L*	Commelinaceae
Polygonum nepalense Meisn	Polygonaceae	*Polygonum nepalense Meisn*	Polygonaceae
Eleusine indica	Graminaceae	*Elusine indica*	Graminaceae
Digitaria spp	Graminaceae	*Digitaria spp*	Graminaceae
Cyperus rotundus L.	Cyperaceae	*Cyperus rotundus*	Cyperaceae

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Table 3: Effect of different weed control methods on weed density in soybean in 2015 and 2016.

Treatments	Number of weed/m²					
	Broad leaved		Grass		Total	
	2015	2016	2015	2016	2015	2016
W1	6.26^{a}(38.67)	5.26^{a}(28.04)	3.24^{a}(10)	2.27^{a}(5.34)	7^{a}(48.6)	5.7^{a}(33.37)
W2	6.42^{a}(40.67)	4.67^{ab}(23.49)	3.42^{a}(11.6)	1.52^{ab}(2.1)	7.2^{a}(52.24)	4.9^{ab}(25.58)
W3	6.3^{a}(39.33)	5.48^{a}(29.74)	3.14^{a}(9.89)	2.32^{a}(5.1)	7.14^{a}(49.2)	5.9^{a}(34.84)
DG	4.10^{b}(16.33)	3.72^{b}(13.84)	0.78^{c}(0.11)	0.71^{c}(-)	4.1^{b}(16.44)	3.7^{bc}(13.84)
DG+W1	2.92^{c}(8.12)	3.83^{b}(14.50)	0.7^{cd}(-)	0.71^{c}(-)	2.9^{d}(8.12)	3.8^{bc}(14.5)
DG+W2	3.34^{b} (10.67)	3.99^{b}(15.62)	0.7^{cd}(-)	0.71^{c}(-)	3.2^{bc}(10.7)	3.97^{bc}(15.62)
DG+W3	3.24^{b}(10)	3.70^{b}(13.93)	0.7^{cd}(-)	0.71^{c}(-)	3.1^{bc}(10)	3.7^{cb}(13.93)
W0	6.94^{a}(47.67)	5.37^{a}(29.38)	2.69^{b}(7.22)	1.83^{ab}(3.77)	7.37^{a}(54.8)	5.6^{a}(33.12)
LSD(0.05)	1.39	1.28	0.88	0.95	1.55	1.41
CV	16.34	16.24	26	20.2	16.9	17.26

W1= one time hand weeding, W2= two time hand weeding, W3= three time hand weeding, DG= Dual gold herbicide, DG+W1= Dual gold and one time hand weeding, DG+W2= Dual gold+ two time hand weeding, DG+W3= Dual gold+ three time hand weeding W0= Weedy check (Control), LSD=Least Significance difference, CV = coefficient of variance.

Table 4: Effect of different weed control methods on weed dry matter in Soybean in 2015 and 2016.

Treatments	Weed dry matter (g/m²)			
	30DAS		60DAS	
	2015	2016	2015	2016
W1	5.0a^{b}(24.67)	4.27^{a}(18.0)	2.86^{cd}(7.67)	4.21^{b}(17.3)
W2	5.6^{a}(31)	4.13^{a}(17.3)	3.34^{c}(10.67)	4.08^{b}(16.3)
W3	5.0b^{a}(24.67)	3.88^{ab}(14.67)	3.48^{c}(11.67)	3.13^{c}(9.3)
DG	4.6^{c}(20.67)	2.66^{b}(6.67)	4.7^{b}(22.0)	5.44^{a}(29.3)
DG+W1	2.68^{d}(6.67)	2.73^{b}(7.0)	0.71^{d}(-)	0.71^{d}(-)
DG+W2	2.7^{d}(7)	2.73^{b}(7.0)	0.71^{d}(-)	0.71^{d}(-)
DG+W3	2.7^{d}(7)	2.94^{b}(8.3)	0.71^{d}(-)	0.71^{d}(-)
W0	6.62^{a}(43.3)	4.56^{a}(20.3)	6.9^{a}(47.67)	5.89^{a}(34.3)
LSD(0.05)	2.43	0.93	2.53	0.53
CV (%)	22.75	15.16	22.68	9.69

W1= one time hand weeding, W2= two time hand weeding, W3= three time hand weeding, DG= Dual gold herbicide, DG+W1= Dual gold and one time hand weeding, DG+W2= Dual gold+ two time hand weeding, DG+W3= Dual gold+ three time hand weeding W0= Weedy check (Control), LSD=Least Significance difference, CV=coefficient of variance, DAS= Days after emergence.

However, the lowest weed dry matter of 2.7 g/m^2 was recorded in plots sprayed Dual gold (s-metolachlor) @rate of 1 L ha^{-1} and supplemented at different time hand weeding (DG, DG+W1, DG+W2 and DG+W3) at 30DAS in 2015. In results indicated that statistically there were non-significant differences among treatments sprayed with Dual gold (s-metolachlor) herbicides at 30 DAS, where as in 2016 the highest weed dry matter of 4.56 g/m^2, 4.27 g/m^2 and 4.13 g/m^2 were recorded in treatment; weedy check, one and two weeding hand respectively (Table 4). At 30DAS the lowest weed dry matter of 2.6 g/m^2, 2.7 and 2.9 g/m^2 were recorded from Dual gold application, Dual gold (s-metolachlor) + one hand weeding, Dual gold (s-metolachlor) + two hand weeding and Dual gold (s-metolachlor) + three hand weeding respectively in 2016 (Table 4). Also, at 60 DAS the highest weed dry matter of 6.9g/m^2 was found in treatment weedy check followed by Dual gold application only which had the value of (4.7g/m^2) while the lowest weed dry matter was found in treatments applied with Dual gold (s-metolachlor) + one hand weeding, Dual gold (s-metolachlor) + two hand weeding and Dual gold (s-metolachlor) + three hand weeding (0g/m2) (Table 4).

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The weedy check had significantly higher dry matter as compared to the other treatments (Table 4). The higher weed dry weight in weedy check might be due to higher weed density that provided an opportunity to the weeds to compete vigorously for nutrients, space, light, water and carbon dioxide resulting in higher biomass production. Likewise, application of Dual gold (s-metolachlor) herbicide @ rate of 1 L ha^{-1} had advantage over weedy check (W0) as well as one, two and three hand weeding at 30DAS. This result indicated that application of pre-emergence herbicides reduced the density of weeds and also suppressed the weed growth bringing about lower dry weight. These results are in agreement with the finding of (Alfonson et al. 2013) who reported maximum weed dry weight in weedy check. Therefore, the farmers could easily manage early competition of weed in soybean by using pre-emergence herbicide Dual gold at 1 L ha^{-1}. However, Dual gold (s-metolachlor) application only had no advantage over one, two and three hand weeding treatments at 60DAS in 2015 (Table 4). Whereas at 60DAS the highest weed dry matter of 5.9g/m^2 was found in treatment weedy check followed by Dual gold application only which had the value of (5.4g/m^2) while the lowest weed dry matter was found in treatment Dual gold (s-metolachlor) + one hand weeding, Dual gold (s-metolachlor) + two hand weeding and Dual gold (s-metolachlor) + three hand weeding in 2016 (Table 4).

The result of analysis of variance revealed that weed density and dry matter were reduced in plots sprayed with Dual gold (s-metolachlor) @ rate of 1 L ha^{-1} + hand weeding than other treatments at 60DAS in both years. The possible reason of weeds reduction at low dose of pre-emergence herbicide supplemented by hand weeding might be due to pre-emergence herbicide reduced amount of weed infestation and hand weeding removed lately emerged weed. This result further clarify that Dual gold (s-metolachlor) herbicide application @ rate of 1 L ha^{-1} supplemented by hand weeding is more effective in minimizing weed density and weed dry matter as compared to weedy check and herbicide application at lower rates alone at 60DAS (Table 4). This result is in agreement with Raize et al. 2006 who stated that herbicide supplemented by hand weeding gave higher efficiency due to complementary effect of both. On the other hand, pre-emergence herbicide, Dual gold (s- metolachlor) at rate of 1 L ha^{-1} failed to control broad leaved weeds like Guizotia scabra, stelliria media, Ageratum conyzoides and Galinsoga parflora in both years under Bako conditions. The failures of pre-emergence herbicide to control broad leaved weed species might be due to low doses of herbicides. These results in agreements with Mekonnen et al. [18]; Peer, [19] who reported that application of s-metolachlor at higher rate reduced the weed density than lower rates.

Soybean Yield and Yield Components

Plant height

Analysis of variance showed the data of both years indicated that effect of weed management practices on plant height had highly significant (p<0.01) difference (Table 5). This could be due to availability of enough growth promoting factors in weed free plots that support plants to attain their maximum height, the competition among weeds and crops for sunlight and space in weedy check (unweeded plots) resulted in tall stature soybean plants with lowest seeds per plant. Thus, the tallest plant were recorded at 121.3 and 56.9m in Dual gold (s-metolachlor) @1 L ha^{-1} plots in 2015 and 2016 respectively and followed by plots sprayed by weedy check plot (114.7 and 56.6m) in 2015 and 2016 respectively. This was due to competition of soybean with broadleaved weeds to sunlight for photosynthesis. These results have no in conformity with Imoloame [20] who reported that shortest Soybean plant is produced by the weed check as a result of a greater intensity of weed completion with crop growth resources which lead to poor performance of the crop.

Table 5: Effect of different weed control methods on Plant height, Branch per plant, Pods per plant and Seeds per pod.

Yield components of Soybean								
Treatment	2015				2016			
	PH (cm)	NPP	NSP	NPB	PH (cm)	NPP	NSP	NPB
W0	114.7a	17.7^{e}	2	1.7^{b}	56.6^{a}	33.3^{d}	2	3.7^{b}
W1	93.3b	46.3^{ab}	3	5.7^{a}	50.8^{d}	46.0^{ab}	2	4.7^{a}
W2	94.3b	34.7^{d}	2.7	5.3^{a}	56.3^{abc}	34.0^{cd}	2.7	3.7^{b}
W3	92.3b	40.3^{c}	2.3	5.7^{a}	52.7^{bcd}	52.7^{a}	2.7	4.7a
DG	121.3a	20.3^{e}	2.3	2.3^{b}	56.9^{ab}	41.0^{bc}	2.3	3.7^{b}
DG+W1	97.3b	40.7^{c}	3	5.0^{a}	52.2^{cd}	52.0^{a}	2.3	5.0^{a}
DG+W2	94.3b	49.3^{a}	3	5.7^{a}	56.3^{abc}	46.3^{ab}	2.7	5.0^{a}
DG+W3	91.3b	44.0^{bc}	2.3	4.7^{a}	55.6^{abc}	50.3^{a}	2.3	5.0a
LSD (0.05)	11.32	5.3	ns	1.23	4.59	7.45	ns	0.82
CV (%)	6.5	8.3	20.3	15.6	4.8	9.6	22.5	10.7

W1= one time hand weeding, W2= two time hand weeding, W3= three time hand weeding, DG= Dual gold herbicide, DG+W1= Dual gold and one time hand weeding, DG+W2= Dual gold+ two time hand weeding, DG+W3= Dual gold+ three time hand weeding W0= Weedy check (Control), LSD=Least Significance difference, CV=coefficient of variance.

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Pods per plant

Analysis of variance indicated that number of pods per plant had significant affected by weed management practices ($p<0.01$).The highest number of pods per plant of 49.3 and 46.3) were obtained from the Dual gold + two hand weeding and one hand weeding in 2015 respectively (Table 5). This might be due to reduced weed competition in plots treated with these weed management practices that made growth resources (nutrient, moisture and light) more accessible for individual plant Alemu and Sharma [21]. As a consequence it might result in higher net assimilation rate thus retaining more flowers. Whereas in 2016 the highest number of pods per plant of 52.7 and 52.0) were obtained from three hand weeding and Dual gold + one hand weeding respectively. Similarly, Getachew and Mekdes [22] reported highest number of pods per plant (22.4) obtained with the application of s-metolachlor at 1.0 kg ha^{-1} + one hand weeding at 5 WAE on Cowpea at Haik. The development of more and vigorous leaves under low weed infestation might have also helped to improve the photosynthetic efficiency of the crop and supported large number of pods Hodgson and Blackman [23]. The interaction of two hand weeding at 15 and 30 showed significant difference with each other in 2015, however the use of this treatment in 2016 was failed to demonstrate significantly number of pods per plant compared to three times hand weeding.

The lowest number of pods per plant (17.7 and 33.3) were recorded from weedy check in 2015 and 2016 respectively, which were significantly lower than all other treatments in both year. On other hand, number of pods per plant obtained from weedy check in 2015 was significantly lower than all other treatments including weedy check in 2016. These results are in line with Hadi et al. [24] who observed an increased number of pods per plant where weed population was reduced by management techniques. Similarly, Pereira et al. [25] stated that the number of pods produced per plant or maintained to final harvest depends on a number of environmental and management practices.

Seeds per pods

Number of seeds per pod had not significant affected due to weed management practices ($p<0.001$). The number of seeds per pod did not increased significantly with an increase in weeding frequency (Table 5). Nevertheless, the plants in weedy check gave significantly lower number of seeds per pod (2.0) in 2015 and 2016 respectively.

Number of branches per plant

The results of ANOVA revealed that number of branches per plant were significantly different among treatments in both years as compared to weedy check. The highest number of branches per plant was recorded at one and three hand weeding, and Dual gold + two hand weeding with the same value of (5.7) followed by Dual gold + three hand weeding mean of value of (4.7) in 2015. However, in 2016 the highest number of branches per pod was recorded at Dual gold +one, two and three hand weeding with the same mean value of (5) branches per plant and followed by one and three hand weeding (4.7) which is statistically parity with Dual gold + one, two and three hand weeding (Table 5).

Grain yield (kg/ha)

Table 6: Effect of different weed control methods on grain yield.

Treatment	2015	2016
	Yield (kg/ha)	Yield (kg/ha)
W0	540^{f}	1757^{e}
W1	2679^{d}	2382^{d}
W2	3081^{ab}	2668^{c}
W3	3107^{a}	2851^{b}
DG	749^{e}	2124^{e}
DG+W1	2982^{bc}	2882^{b}
DG+W2	3112^{a}	3013^{a}
DG+W3	2879^{c}	3019^{a}
LSD (0.05)	103.04	66.78
CV (%)	10.5	8.5

W1= one time hand weeding, W2= two time hand weeding, W3= three time hand weeding, DG= Dual gold herbicide, DG+W1= Dual gold and one time hand weeding, DG+W2= Dual gold+ two time hand weeding, DG+W3= Dual gold+ three time hand weeding W0= Weedy check (Control), LSD=Least Significance difference, CV=coefficient of variance.

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Table 7: Mean pooled of soybean yield and yield components over year.

	Growth and yield parameters				
Treatment	PH (cm)	NPP	NSP	NPB	Yield (kg/ha)
W0	87.1ᵃ	25.5ᶜ	2	2.5ᶜ	1149ᶠ
W1	72.1ᵇ	46.2ᵃ	2.5	5.2ᵃᵇ	2530ᵈ
W2	75.3ᵇ	34.5ᵇ	2.6	4.5ᵇ	2874ᶜ
W3	72.5ᵇ	46.5ᵃ	2.5	5.2ᵃᵇ	2979ᵇ
DG	89.1ᵃ	30.7ᵇ	2.3	3.0ᶜ	1436ᵉ
DG+W1	74.8ᵇ	46.3ᵃ	2.7	5.0ᵃᵇ	2932ᵇ
DG+W2	75.4ᵇ	47.8ᵃ	2.8	5.3ᵃ	3062ᵃ
DG+W3	73.5ᵇ	47.2ᵃ	2.3	4.8ᵃᵇ	294⁹ᵇ
LSD (0.05)	8.04	6.34	ns	1.01	81.47
CV (%)	6.2	9.4	21.3	13.6	2.5

W1= one time hand weeding, W2= two time hand weeding, W3= three time hand weeding, DG= Dual gold herbicide, DG+W1= Dual gold and one time hand weeding, DG+W2= Dual gold+ two time hand weeding, DG+W3= Dual gold+ three time hand weeding W0= Weedy check (Control), LSD=Least Significance difference, CV=coefficient of variance.

Soybean grain yield was significantly (P<0.01) influenced by year, weed management practices and their interaction. The highest grain yield (3112 kg ha^{-1}) was obtained from Dual gold + two hand weeding (Table 6) in 2015 while the lowest yield (540kg ha^{-1}) obtained from the weed control treatment (W0), as comparing it with herbicide treated, the highest grain yield was recorded with Dual gold (s-metolachlor) @1 L ha^{-1}. Furthermore, in 2016 the effect of weed management practices revealed that significant difference was existed among the grain yield obtained. The highest grain yield (3019 kg ha^{-1}) was obtained from Dual gold + three hand weeding (Table 6) in 2015 which is parity with treatment Dual gold + two hand weeding (3013 kg ha^{-1}). This can be ascribed to fact that the effective control of weeds led to the favorable environment for growth and photosynthetic activity of the crop. Likewise, the lowest yield (1757kg ha^{-1}) obtained from the weed control treatment (W0) (Table 6). Generally, the highest mean grain yield (3062 kg ha^{-1}) was obtained from Dual gold + two hand weeding in both year while the lowest yield (1149 kg ha^{-1}) was obtained from weedy check (W0). The increased grain yield in these treatments might be due to the proper utilization of moisture, nutrients, light and space by the Soybean in the lesser of weed competition. The results are corroborating with those reported by Mekonnen et al. [18]; Mengesha et al. [26]. Moreover, the yield obtained in 2016 was significantly higher than the yield obtained in 2015 from different treatment this might have been partially due the differences that existed in the amount of rainfall (Figure 1).

Partial Budget Analysis

Table 8: Partial budget analysis for different hand weeding frequency and pre-emergence for weed control in Soybean at Bako 2015.

Trt	Yield (kg/ha)	SC/(birr/kg)	SR	ILC(Birr/ha)	MC (Birr/ha	NB(Birr/ha)	MB (Birr/ha)	MRR%
W0	486	8	3888	1280.5	0	2607.5	0	-
W1	2411.1	8	19288.8	3800.5	2520	15488.3	D	D
W2	2772.9	8	22183.2	3870.5	2590	18312.7	D	D
W3	2796.3	8	22370.4	3730.5	2450	18639.9	D	D
DG	674.1	8	5392.8	1880.5	600	3512.3	904.8	150.8
DG+W1	2683.8	8	21470.4	2965.5	1685	18504.9	D	D
DG+W2	2800.8	8	22406.4	3070.5	1790	19335.9	16728.4	934.55
DG+W3	2591.8	8	20734.4	3035.5	1755	17698.9	D	D

Trt: Treatment, W1: one time hand weeding, W2: two time hand weeding, W3: three time hand weeding, DG: Dual gold herbicide, DG+W1: Dual gold and one time hand weeding, DG+W2: Dual gold+ two time hand weeding, DG+W3: Dual gold+ three time hand weeding W0: Weedy check (Control), LSD: Least Significance difference, CV: coefficient of variance, SC: Sale cost, Incurred labor cost, MC: Marginal cost, NB: Net benefit, MB: Marginal benefit, MRR: Marginal of rate of return.

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Table 9: Partial budget analysis for different hand weeding frequency and pre-emergence for weed control in Soybean at Bako 2016.

Trt	Yield (kg/ha)	SC/(birr/kg)	SR	ILC (Birr/ha)	MC (Birr/ha)	NB (Birr/ha)	MB (Birr/ha)	MRR%
W0	1581.3	8	12650.4	1280.5	0	11369.9	0	-
W1	2143.8	8	17150.4	4010.5	2730	13139.9	1770	64.84
W2	2401.2	8	19209.6	5515.5	4235	13694.1	D	D
W3	2565.9	8	20527.2	5130.5	3850	15396.7	D	D
DG	1911.6	8	15292.8	1880.5	600	13412.3	D	D
DG+W1	2593.8	8	20750.4	3175.5	1895	17574.9	6205	327
DG+W2	2711.7	8	21693.6	4435.5	3155	17258.1	D	D
DG+W3	2717.1	8	21736.8	4750.5	3470	16986.3	D	D

Trt: Treatment, W1: one time hand weeding, W2: two time hand weeding, W3: three time hand weeding, DG: Dual gold herbicide, DG+W1: Dual gold and one time hand weeding, DG+W2: Dual gold+ two time hand weeding, DG+W3: Dual gold+ three time hand weeding W0: Weedy check (Control), LSD: Least Significance difference, CV: coefficient of variance, SC: Sale cost, Incurred labor cost, MC: Marginal cost, NB: Net benefit, MB: Marginal benefit, MRR: Marginal of rate of return.

Partial economic analysis was done to select the most economically feasible weed control strategies in soybean under Bako conditions. The partial budget for 2015 showed that pre-emergence herbicide Dual gold (s-metolachlor) @ rate 1 L ha^{-1}+ two weeding (DG + W2) was the most economic strategies with marginal rate of return 934.55% over other treatment. This was not due to yield but, it was minimized amount of labor cost (Table 7). Moreover, in 2016 pre-emergence herbicide Dual gold (s-metolachlor) @ rate 1 L ha^{-1} + one weeding (W1 + DG) was showed marginal rate of return of 327% (Table 8). In agreement with the result, most studies showed that, applying herbicide or herbicide plus manual weeding was more economical than manual or hand weeding alone Ismaila et al. [27].

Otherwise, in both years, the cost of hand weeding without application of Dual gold were greater than Dual gold @ rate 1 L ha^{-1} application and Dual gold (s-metolachlor) @ rate 1 L ha^{-1} + one weeding (DG+W1) because, hand weeded plots were weeded 1 to 2 times and consumed high numbers of daily labor due to high number of weed population density. This findings in agreement with Suria et al. [28]; Amare et al. [15] who reported that weed control efficiency cannot considered as the only criteria to determine the suitability of chemical weed control strategy rather, than economic of weed control should be also be taken into consideration while making any decision [39-32].

Conclusion and Recommendation

The results of this stydy have demonstrated that the experimental site was infested by broadleaved and grass weeds in both years. The broadleaved weeds were dominant over grass weeds. Guizotia scabra, stelliria media and Ageratum conyzoides were the major one from broadleaved while Eluesine indica was highly observed from grass weeds in both years. Weed dry matter and density was reduced in plots sprayed with Dual gold pre-emergence herbicide @rate of 1 L ha^{-1} supplemented by hand weeding. The partial budget analysis for effect of hand weeding and pre-emergence herbicide was different in both years based of weeds population density and number of labor used for weeding. About 934.55% and 327% marginal rate of return recorded from Dual gold + two hand weeding and Dual gold + one hand weeding in 2015 and 2016 respectively. Generally, the study gave clues how farmer could minimized weed population density and weed dry matter using low dose of Dual gold supplemented by one and/or two hand weeding which indirectly minimize labor cost as compared to unsprayed plots at 30DAS in both years. However, testing the herbicide at current dose/rate @1 L ha^{-1} may not be enough to recommend as a full control package of weeds in Soybean, but this information may lead to start further research directions under Bako conditions.

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