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Integration Effects of Herbicide and Hand Weeding on Grain Yield of Soybean (*Glycine max* (L.) Merr.) in Assosa, Western Ethiopia

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Abstract

Soybean (Glycine max (L.) Merr.) is a popular and the miracle crop of the 21st century. A field experiment was conducted for two years (during main cropping season of 2013 and 2015) to examine the effect of integrating hand weeding and post-emergence herbicides on yield and yield components of soybean (*Glycine max* (L.) Merry) at the main experimental farm of Assosa Agricultural Research Center, Assosa Zone, Western Ethiopia. This study incorporated fourteen treatments: pre-emergence spray of Codal-Gold at 1.5 l ha^{-1} and 2.5 l ha^{-1} (with sole and/or supplemented hand weeding), pre-emergence and pre-plant spray of Dual-Gold at 0.5 l ha^{-1} and 1.0 l ha^{-1} (with sole and/or supplemented hand weeding), weed free (control) and weedy check. The result revealed that among treatments pre-emergence spray of Codal-Gold at 1.5 l ha^{-1} supplemented by hand weeding and the pre-plant spray of Dual-Gold at 1.0 l ha^{-1} supplemented by hand weeding were given the highest soybean yield in 2015 cropping season (2541.1 kg ha^{-1} and 2503.1 kg ha^{-1} respectively). However, in 2013 cropping season, pre-emergence spray of Codal-Gold at 2.5 l ha^{-1} supplemented by hand weeding and pre-emergence spray of Dual-Gold at 0.5 l ha^{-1} supplemented by hand weeding were gave higher soybean grain yield (2438.3 kg ha^{-1} and 2343.8 kg ha^{-1} respectively), which is not statistically different from pre-emergence spray of Codal-Gold at 1.5 l ha^{-1} supplemented by hand weeding and pre-plant spray of Dual-Gold at 1.0 l ha^{-1} supplemented by hand weeding. Therefore, weeds can be effectively managed by applying Codal-Gold at 1.5 l ha^{-1} before soybean crop emergence and Dual-Gold at 1.0 l ha^{-1} before planting of soybean crop both supplemented by hand weeding.

Keywords: Codal-gold; Dual-gold; Soybean; Supplemented hand weeding

Introduction

Soybean (*Glycine max* (L.) Merr.) is a popular and the miracle crop of the 21st century. It is economically and nutritionally important crop provides a variety of benefits such as income generation for smallholder producers as being a potentially profitable cash crop, improvement of nutritional diet (for human it can be directly used for food at household levels, or processed for soy-milk, cooking oil and a range of other products including infant weaning food, whereas for animals it plays a great part in feed production for poultry industry), alternative market potentials for product diversification and value addition [1-3]. Additionally, soybean has the potential agronomic benefit of rejuvenating soils by fixing atmospheric nitrogen into the soil (the crop harbors nitrogen-fixing bacteria) and also the decaying root residues improve soil fertility [4]. Therefore, some government-owned sugarcane plantations in Ethiopia used soybean crop as a rotational crop [3].

Currently, the cultivation of soybean in Ethiopia covered 36,635.79 hectares of land with 812,34.659 tons of production and a national average yield of 2.217 tons per hectare (t ha^{-1}) [5]. This national average yield of soybean in Ethiopia is yet below the average potential yield of up to 3.5 t ha^{-1} [6], 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 [3]. Weed infestation affects the crop by competing for light, water and nutrients, serving as hosts for diseases, insects, and nematodes which in turn attack the crop and also severely reduce the harvest efficiency [7]. As a result, weeds cause reduction of plant vigour and yield. For instance, weeds can cause 27 to 84% soybean yield reduction [8,9].

Now a day's weed control is one of the basic production problems faced by soybean producers in the Ethiopia. From a weed management standpoint, chemical factors and coupled with hand weeding that affect the weed population dynamics are of great importance. In order to sustain yields and encourage soybean growers by reducing weed competition, it is important to study weed control management, which include herbicide application practices. Among the various control methods available to farmers for weed management, herbicide used to become widely accepted. Akhtar et al. [10] found that application of grassy and broadleaf herbicides increased grain yield and yield components.

Combination of cultural, mechanical and chemical weed management strategies are the most effective weed management programs in soybeans [11]. Hence, soybean is becoming a popular crop in Assosa zone; which is one of the top three soybean producers in Ethiopia [3]. Soybean producing farmers of Assosa perform a frequent weeding in order to control weeds of soybean (which is more labour intensive) because of the lack of weed management information and technology for the study area. Therefore, the objectives of this study was to provide an option for weed management in soybean fields of the area, to evaluate the effect of integrating hand weeding and pre-emergence herbicides on yield and yield components of soybean at Assosa, Western Ethiopia.

Materials and Methods

Description of the study area

The experiment was conducted from 2013 and 2015 cropping seasons on naturally infested fields with common annual broadleaf and grass weed species at the main research farm of Assosa Agricultural Research Center (AsARC), located at 10°03'N and 34°59'E. The site has a Dystric Nitisols soil type. Total rainfall received during crop growing periods in 2013 and 2015 years was 1132.9 mm and 1133.5 mm respectively, with respective ranges of minimum and maximum temperatures 14.54-15.38°C and 27.08-27.72°C.

Experimental design and treatments

The design used for this experiment was Randomized Complete Block Design (RCBD) with three replications which consists 14 treatments (Table 1). Belessa-95 variety of Soybean was sown in 18 m^2 (5 m × 3.60 m) plots at a rate of 60 kg ha^{-1}. The spacing between rows and plants was 60 cm and 5 cm, respectively.

Treatments	Code	Treatment descriptions
T1	PreECodalGold@1.5 l ha^{-1}	Pre-emergence spray of Codal-Gold at 1.5 l ha^{-1}
T2	PreECodalGold@1.5 l ha^{-1}+HW	Pre-emergence spray of Codal-Gold at 1.5 l ha^{-1}+Hand weeding
T3	PreECodalGold@2.5 l ha^{-1}	Pre-emergence spray of Codal-Gold at 2.5 l ha^{-1}
T4	PreECodalGold@2.5 l ha^{-1}+HW	Pre-emergence spray of Codal-Gold at 2.5 l ha^{-1}+Hand weeding
T5	PreEDualGold@0.5 l ha^{-1}	Pre-emergence spray of Dual-Gold at 0.5 l ha^{-1}
T6	PreEDualGold@0.5 l ha^{-1}+HW	Pre-emergence spray of Dual-Gold at 0.5 l ha^{-1}+Hand weeding
T7	PreEDualGold@1.0 l ha^{-1}	Pre-emergence spray of Dual-Gold at 1.0 l ha^{-1}
T8	PreEDualGold@1.0 l ha^{-1}+HW	Pre-emergence spray of Dual-Gold at 1. l ha^{-1}+Hand weeding
T9	PrePDualGold@0.5 l ha^{-1}	Pre-plant spray of Dual-Gold at 0.5 l ha^{-1}
T10	PrePDualGold@0.5 l ha^{-1}+HW	Pre-plant spray of Dual-Gold at 0.5 l ha^{-1}+Hand weeding
T11	PrePDualGold@1.0 l ha^{-1}	Pre-plant spray of Dual-Gold at 1.0 l ha^{-1}
T12	PrePDualGold@1.0 l ha^{-1}+HW	Pre-plant spray of Dual-Gold at 1.0 l ha^{-1}+Hand weeding
T13	Weed-free	Control
T14	Weedy check	Weedy check

Table 1: Treatment descriptions of the study.

Data collections

Five plants were randomly selected per plots to measure yield component parameters included; plant height, number of pods per plant, number of branches per plant, number of seeds per pods. The middle four rows in each plot were harvested for quantification of yield and the seed yields were adjusted to 12.5% moisture. All parameters that can express the weed data was incorporated for analysis and result interpretation.

Data analysis

Combined analysis of variance for the yield and yield component means was performed using PROC GLM of SAS 9.0 software. The level of significance is indicated by the least significant difference between the means (LSD) at 5% probability. The relative yield (percentage yield loss) for each treatment was calculated as the percentage of their corresponding weed-free (control) yields by using the following formula:

$$Yeild\ loss(\%) = \left(\frac{Y_{wf} - Y_i}{Y_{wf}}\right) \times 100$$

Where, Y_{wf} is grain yield from weed-free plots (control), Yi is grain yield from each evaluated treatments.

Results and Discussion

Weeds are hidden enemies of soybean and cause huge losses to crop yields. However, the production of the crop is not without constraints among which includes low soil fertility, lack of fertilizer, climate change and the problem of weed management. The results of analysis of variance showed that there was significant difference for grain yield and yield components (including plant height, number of branches per plant, number of pods per plant and number of seeds per pod) at $p<0.05$ during 2013 and 2015 main cropping season (Table 2). Among the treatments, the highest grain yield of soybean were obtained from the pre-emergence Codal-Gold sprayed at 1.5 l ha^{-1} supplemented by hand weeding and pre-plant Dual-Gold sprayed at 1.0 l ha^{-1} supplemented by hand weeding with soybean grain yield of 2.54 t ha^{-1} and 2.50 l ha^{-1} respectively in 2015 main cropping season, whereas in 2013 main cropping season the highest grain yield of soybean was obtained from pre-emergence Codal-Gold sprayed at 2.5 l ha^{-1} supplemented by hand weeding and pre-emergence Dual-Gold sprayed at 0.5 l ha^{-1} supplemented by hand weeding treatments

respectively having soybean grain yield advantages of 2438.3 kg ha^{-1} (2.438 t ha^{-1}) and 2343.8 kg ha^{-1} (2.344 t ha^{-1}) (Table 2).

The lowest grain yield was recorded under weedy check. Increase in grain yield in the herbicide treated plots was probably due to effective weed control of the broad leaf targeted weeds, which was complemented by hand pulling of non-targeted weeds species on the field. This result agrees with the findings of Hassan et al. there was no significant difference in harvest index between the two tested herbicides. This indicates that controlling weed in the early growth stage has an advantage than late application.

Moreover, this study showed that about four treatments were given a promising result when compared to the current national grain yield of soybean. For instance, pre-emergence Codal-Gold sprayed at 1.5 l ha^{-1} supplemented by hand weeding gave soybean grain yield of 2268.3 kg ha^{-1} (2.268 t ha^{-1}) in 2013 and 2541.1 kg ha^{-1} (2.541 t ha^{-1}) in 2015. Application of pre-emergence Codal-Gold at 2.5 l ha^{-1} supplemented by hand weeding gave a yield of 2438 kg ha^{-1} (2.438 t ha^{-1}) in 2013 and 2541.1 kg ha^{-1} (2.451 t ha^{-1}) in 2015 cropping season. The application of pre-emergence Dual-Gold at 0.5 l ha^{-1} supplemented by hand weeding gave a yield of 2343.8 kg ha^{-1} (2.344 t ha^{-1}) in 2013 and 2376 kg ha^{-1} (2.376 t ha^{-1}) in 2015. Pre-plant Dual-Gold sprayed at 1.0 l ha^{-1} supplemented by hand weeding gave a yield of 2218 kg ha^{-1} (2.218 t ha^{-1}) in 2013 and 2503 kg ha^{-1} (2.503 t ha^{-1}) in 2015 which all were more than the current national average grain yield of soybean (2.217 t ha^{-1}) in Ethiopian [2]. In both 2013 and 2015, the highest numbers of pods per plant (39.93 and 39.00) were obtained from pre-emergence Codal-Gold treated plots at 2.5 l ha^{-1} supplemented by hand weeding than other treatments (Table 2).

Treatments	Plant Height (cm)		No. of Pods Per Plant		No. of Seeds Per Pod		No. of Branches Per Plant		Grain Yield (kg ha^{-1})		Grain yield (t ha^{-1})		Grain yield (t ha^{-1})	
	2013	2015	2013	2015	2013	2015	2013	2015	2013	2015	2013	2015	2013	2015
T1	72.07 ± 0.48	70.33 ± 8.34	26.73 ± 4.52	22.80 ± 4.59	2.27 ± 0.13	2.73 ± 0.18	2.87 ± 0.52	2.07 ± 0.53	2248.86 ± 194.20	1354.06 ± 476.78	2.25 ± 0.19	1.35 ± 0.48	2.25	1.35
T2	73.60 ± 2.91	75.33 ± 2.87	33.27 ± 7.27	28.53 ± 0.85	2.13 ± 0.13	2.60 ± 0.12	3.07 ± 0.29	3.20 ± 0.12	2268.26 ± 248.00	2814.03 ± 110.55	2.27 ± 0.25	2.81 ± 0.11	2.27	2.81
T3	68.40 ± 1.74	75.67 ± 2.60	25.33 ± 1.51	23.67 ± 1.19	2.40 ± 0.12	2.67 ± 0.13	2.93 ± 0.67	2.07 ± 0.29	1451.97 ± 316.80	2089.23 ± 123.80	1.45 ± 0.32	2.09 ± 0.12	1.45	2.09
T4	78.80 ± 2.55	84.00 ± 3.20	39.93 ± 11.48	38.07 ± 1.70	2.67 ± 0.33	2.73 ± 0.18	3.40 ± 0.70	3.33 ± 0.24	2438.29 ± 337.45	2463.08 ± 94.87	2.44 ± 0.34	2.46 ± 0.09	2.44	2.46
T5	73.27 ± 3.89	77.20 ± 2.41	35.40 ± 3.93	23.60 ± 1.11	2.33 ± 0.24	2.73 ± 0.07	4.13 ± 0.84	1.73 ± 0.24	1731.71 ± 175.02	1259.30 ± 279.13	1.73 ± 0.18	1.26 ± 0.28	1.73	1.26
T6	69.13 ± 3.19	67.53 ± 5.16	24.13 ± 1.55	32.07 ± 2.33	2.20 ± 0.12	2.93 ± 0.07	2.47 ± 0.41	3.13 ± 0.27	2343.75 ± 265.57	2409.14 ± 394.77	2.34 ± 0.27	2.41 ± 0.39	2.34	2.41
T7	67.73 ± 3.06	74.53 ± 3.94	28.33 ± 5.54	17.60 ± 2.16	2.33 ± 0.07	2.40 ± 0.12	3.00 ± 0.61	0.93 ± 0.27	1352.14 ± 293.02	491.35 ± 195.83	1.35 ± 0.29	0.49 ± 0.20	1.35	0.49
T8	77.73 ± 1.45	66.67 ± 7.63	23.73 ± 3.54	24.87 ± 2.36	2.47 ± 0.13	2.93 ± 0.07	3.07 ± 0.29	2.73 ± 0.29	2156.79 ± 169.66	2520.71 ± 329.55	2.16 ± 0.17	2.52 ± 0.33	2.16	2.52
T9	75.87 ± 5.29	72.13 ± 3.77	32.33 ± 4.71	20.47 ± 5.07	2.13 ± 0.13	2.47 ± 0.18	3.13 ± 0.66	2.07 ± 0.66	2148.32 ± 284.08	1647.90 ± 594.63	2.15 ± 0.28	1.65 ± 0.59	2.15	1.65
T10	70.67 ± 3.15	71.67 ± 4.18	26.07 ± 1.95	26.87 ± 1.75	2.40 ± 0.12	2.80 ± 0.12	3.00 ± 0.61	2.93 ± 0.07	1889.75 ± 46.75	2216.27 ± 417.56	1.89 ± 0.05	2.22 ± 0.42	1.89	2.22
T11	70.47 ± 2.23	70.80 ± 0.87	29.80 ± 4.47	21.73 ± 5.61	2.13 ± 0.07	2.67 ± 0.13	3.73 ± 0.29	2.13 ± 0.66	2252.03 ± 155.49	869.53 ± 120.79	2.25 ± 0.16	0.87 ± 0.12	2.25	0.87
T12	77.47 ± 5.83	74.07 ± 3.93	35.60 ± 10.07	32.73 ± 5.09	2.40 ± 0.12	2.93 ± 0.07	3.00 ± 0.31	3.40 ± 0.46	2217.81 ± 253.10	2788.40 ± 208.87	2.22 ± 0.25	2.79 ± 0.21	2.22	2.79
T13	78.27 ± 2.74	73.33 ± 2.98	33.53 ± 2.86	29.20 ± 2.44	2.73 ± 0.13	2.80 ± 0.12	3.33 ± 0.13	3.27 ± 0.57	2242.51 ± 184.18	2659.64 ± 119.32	2.24 ± 0.18	2.66 ± 0.12	2.24	2.66
T14	69.80 ± 3.10	64.40 ± 5.97	13.80 ± 2.14	21.27 ± 3.96	1.87 ± 0.13	2.47 ± 0.13	1.00 ± 0.32	1.67 ± 0.44	502.33 ± 110.39	551.78 ± 130.55	0.50 ± 0.11	0.55 ± 0.13	0.5	0.62
CV	7.82	9.42	27.24	27.39	10.11	8.88	23.63	28.81	20.8	23.97	20.8	22.66	20.8	22.66
LSD	9.55	7.93	13.33	8.74	0.39	0.26	1.19	0.91	679.35	528.99	0.68	0.74	0.68	0.74

Table 2: Means of grain yield and yield components of soybean in 2013 and 2015 seasons, at Assosa.

The second highest number of pods were produced from plots sprayed with pre-plant Dual-Gold at 1.0 l ha^{-1} in 2013 and pre-emergence Dual-Gold at 0.5 l ha^{-1} in 2015, but it was not statistically different from pre-plant Dual-Gold at 1.0 l ha^{-1} supplemented by hand weeding, pre-emergence Dual-Gold at 0.5 l ha^{-1} and pre-emergence Codal-Gold at 1.5 l ha^{-1} supplemented by hand weeding. These indicated that Dual-Gold at 1.0 l ha^{-1} supplemented by hand weeding; Dual-Gold at 0.5 l ha^{-1} and Codal-Gold at 1.5 l ha^{-1} supplemented by hand weeding had the comparable higher number of pods per plant. However, the lowest number of pods per plant was obtained from the weedy plots (Table 2).

From the Table 3, percent of soybean grain yield loss (or the relative grain yield of soybean) varied from 1.10 to 77.60% in 2013 cropping season and 0.02 to 78.50% in 2015 cropping season depending on the treatments. The negative sign indicates that, the treatments were produced more grain yield of soybean than the reference treatment (weed-free plots) (Table 3). This study revealed that the weedy plots (season-long weed interference) were shown the maximum grain yield reduction; up to 77.60% in 2013 and 78.50% in 2015 (Table 3).

Treatments	Relative yield (%)	
	2013	2015
PreECodalGold@1.5 l ha^{-1}	-0.29	26.5
PreECodalGold@1.5 l ha^{-1}+HW	-1.15	-3.67
PreECodalGold@2.5 l ha^{-1}	35.25	27.76
PreECodalGold@2.5 l ha^{-1}+HW	-8.73	0.02
PreEDualGold@0.5 l ha^{-1}	22.78	38.99
PreEDualGold@0.5 l ha^{-1}+HW	-4.52	3.05
PreEDualGold@1.0 l ha^{-1}	39.71	62.4
PreEDualGold@1.0 l ha^{-1}+HW	3.82	4.59
PrePDualGold@0.5 l ha^{-1}	4.2	22.56
PrePDualGold@0.5 l ha^{-1}+HW	15.73	16.24
PrePDualGold@1.0 l ha^{-1}	-0.42	36.32
PrePDualGold@1.0 l ha^{-1}+HW	1.1	-2.12
Weed-free	0	0
Weedy check	77.6	78.5

Table 3: Relative yield loss of soybean in 2013 and 2015 in cropping seasons at Assosa.

On the other hand, the lowest relative soybean yields were recorded from pre-emergence Codal-Gold treated plots at both 1.5 l ha^{-1} and 2.5 l ha^{-1} supplemented by hand weeding and pre-plant Dual-Gold treated plots at 1.0 l ha^{-1} supplemented by hand weeding (Table 3). This indicates that when Codal-Gold sprayed before crop emergence at 1.5 l ha^{-1} and Dual-Gold sprayed before planting at 1.0 l ha^{-1} were supplemented by hand weeding, there was a significant increase observed in grain yield of soybean than the other treatments (Tables 2 and 3) (Figure 1).

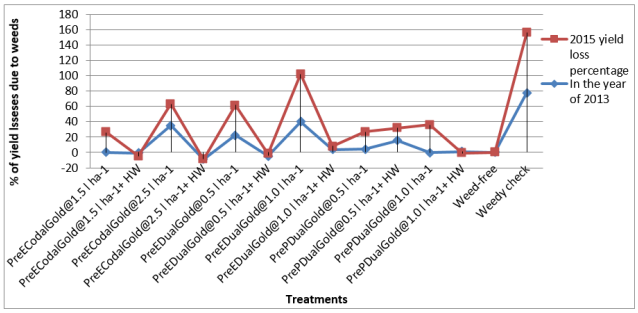

Figure 1: Percentage of soybean yield losses due to weed species in the cropping seasons of 2013 and 2015 at Assosa.

Conclusion

A number of weed species attack soybean in Benishangul Gumuze region. Soybean is very competitive with weeds once the soybean develops a canopy, but early emerging weeds can cause serious yield losses. Weeds growing with soybeans compete with the crop for light, moisture, and nutrients. Thus, early-season weed control is the key to providing the soybeans with a competitive advantage and minimizing the effect of weeds. Fortunately, some level of control appears possible through chemical with hand weeding practices (manipulating cropping systems and time of planting).

Therefore, this study revealed that weedy check plots (season-long weed interference) can cause 77.6% to 78.50% grain yield reduction in soybean. These grain yield reduction (losses) can be reduced by using application of Codal-Gold at 1.5 l ha^{-1} before emergence of soybean crop and Dual-Gold at 1.0 l ha^{-1} before planting of soybean crop both supplemented by hand weeding to effectively manage weeds in soybean field and to obtain 2,217.8-2,541.1 kg ha^{-1} (2.22 to 2.5 t ha^{-1}) of soybean grain yields in Assosa.

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