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Integrated Weed Managements Effect on Yield Components, Yield of Common Beans (*Phasoulus vulgaries* L.) and Weed Suppression in Southern Ethiopia

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Abstract

Among the major crops cultivated common bean (Phasoulus vulgaries L.) is a crucial and widely used for home consumption. It is highly preferred by because of its early maturity, and providing producers with food security. However, the yields obtained from farmers' fields remain below those achieved at research stations. Among the factors limiting bean production, weeds are the major constraint. Therefore, this experiment was conducted with the objective of determining appropriate weed management practices in bean production. The experiment consisted of 11 treatments, comprising varying rates of two herbicide types combined with different hand-weeding frequencies. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Among the evaluated treatments, S-metolachlor at 1 kg ha^{-1} supplemented with hand hoeing at 20 and 35 days after sowing (DAS) was the best weed management option, in addition to weed free. This treatment yielded an 81.21% yield advantage beyond the unweeded plots. The weed-free treatment and the S-metolachlor (1 kg ha^{-1}) supplemented with hoeing at 20 and 35 DAS produced the maximum grain yields of 2518.6 kg ha^{-1} and 2320.7 kg ha^{-1}, respectively. The maximum net benefits 59,845.6 ETB ha^{-1} was obtained from the application of S-metolachlor at 1 kg ha^{-1} supplemented with hoeing at 20 and 35 DAS. Therefore, to effectively manage weeds in common bean production within the study area, the using of S-metolachlor at 1 kg ha^{-1} combined with hoeing at 20 and 35 DAS is recommended until other more preferable alternative management options are developed.

Keywords: common bean, herbicide, net return, weed, yield

1. Introduction

The common beans (*Phaseolus vulgaris* L.) are the most important legume crops widely cultivated in Ethiopia. It is an annual crop grown twice yearly (during the Belg and Meher seasons) in areas with bimodal rainfall patterns. The common beans are regarded as an important crops for food security and privileged circumstances establishment [1]. It has also been an important export commodity for the Ethiopian economy for the last 40 years [2]. The common beans provides crucial dietary nutrients, including vitamins, proteins, and minerals [3]. It is primarily cultivated by smallholder farmers for household consumption [4]. Most farmers in Ethiopia prefer growing the common bean because it matures early, allowing it to escape the effects of terminal moisture deficits [5].

The common bean cultivation area and overall production volume have steadily risen over the years due to growing demand [6]. During the 2020/21 production year, common beans were cultivated on 308,025.22 ha, which increased to 339,350.34 ha in 2021/22; the corresponding yields obtained from these areas were

546,898.74 tons and 584,157.957 tons, respectively [7]. However, average yields from smallholder fields remained well below the potential grain yield (~3 tons ha^{-1}) achieved at research stations. This direct yield gap between smallholder farms and research stations spans about 1.26 tons ha^{-1}, falling far short of the crop's genetic potential [8]. The average yields of red common bean cultivation in the Borana and West Guji zones were 1.10 tons ha^{-1} and 0.18 tons ha^{-1}, covering 5,447.35 ha and 5,222.94 ha, respectively [9]. The low productivity of common beans are caused by many biotic and abiotic factors. Among the biotic factors that retard common bean productivity, weeds constitute a major production constraint. Weeds cause significant grain yield declines, primarily by competing with crops for light, space, and nutrients [10].

Weed plants could causes severe yield losses in common bean ranging from 58 to 99%, since common bean is a weak competitor alongside weeds [11]. Because it competes poorly with weeds, it becomes heavily infested and exposed to intense competition, which often causes massive losses [12]. Therefore, identifying consistent, broad-spectrum weed management strategies is essential combat the effect of weeds on common beans. The incapability to manage weeds entirely by hand, labor unavailability, and the high workload of weeding ever more expands the use of herbicides [13]. Chemical weed management serves as an excellent supplementary method in crop production. The use of herbicides offer considerable increases in crop yield through effective weed suppression [14]. Long-term sustainable weed management relies on competitive cropping systems that progressively reduce weed populations over time.

Implementing combined weed control is the most effective option for increasing common bean yields. Using of different chemicals simultaneously with distinct modes of action enhances weed management effectiveness [15]. Currently, due to inadequate information regarding effective weed management technologies, farmers in pastoral and dryland areas highly costed on weed management than on other feature of crop production. Similarly, a combination of graminicides with broadleaf herbicides improves weed control in dry beans [16]. While herbicide-based weed control in common bean cultivation is gaining traction, integrating herbicides with manual weeding has not yet been evaluated in the Borana and West Guji zones. Therefore, the study was done with the objective of determining the most appropriate weed management practices for optimizing the common bean yield and yield components.

2. Materials and Methods

2.1. Description of the Study Areas

The experiment was conducted in Abaya and Yabello districts of southern Oromia. The experimental areas are located between 06°43'52.0'' N, 038°25'42.5'' E and 04°51'17.9'' N, 038°06'22.3'' E latitude and longitude, with elevations of 1442 meter above sea level and 1618 meter above sea level for Abaya and Yabello, respectively.

2.2. Experimental Treatments and Design

To successfully done the work of this study Hawassa Dume (SNNPR-120) common bean variety was used, which is widely cultivated by farmers. The variety was a cultivated crop and adapted at the study areas. It was arranged in a Randomized Complete Block Design (RCBD) with three replications consisted eleven treatments. The treatments comprised varying application rates of two pre-emergence herbicides, namely pendimethalin (Stomp extra 38.7%SC) and S-metolachlor (Dual Gold 960EC), alongside distinct hand-weeding frequencies (one and two hand weedings). The description and arrangement of treatments are explained in table 1. Independent control treatments, including a weed-free check and an unweeded check, were included. Each individual experimental plot measured 3.0 m in length by 2.1 m in width (6.3 m^2 gross area) and consisted of six rows. Inter-row and intra-row spacing were maintained at 0.35 m and 0.15 m, respectively. The data were collected from four central rows of each experimental unit.

Table 1: Treatment descriptions and arrangements

Treatments	
S-metolachlor 1kg ha^{-1}	S-metolachlor 1kg ha^{-1} + HW at 35DAS
Weed free	Pendimethalin 1kg ha^{-1} +HW at 35DAS
Unweeded	Twice Hand Hoeing at 20 and 35DAS
Pendimethalin 1kg ha^{-1}	Pendimethalin 1kg ha^{-1} + HW at 20 and 35DAS
S-metolachlor 1.5 kg ha^{-1}	S-metolachlor 1kg ha^{-1} + HW at 20 and 35DAS
S-metolachlor 2kg ha^{-1}	

Where, HW=Hand weeding, DAS= Days after Sowing

The pre-emergence herbicides were sprayed to the allocated plots two days after sowing. The herbicide concentration levels were adjusted to the required rates and sprayed onto the designated treatment plots using a 15-liter capacity knapsack sprayer.

2.3. Weed Parameter

The weed flora observed in the trial fields were scored from the unweeded treatment by pointing a 0.25 m^2 quadrat at two spots before flowering of the crop. The identified weed species were grouped into respective families by using flora reference books [17], [18]. Weed parameters such as density (no. m^{-2}), weed dry weight (g m^{-2}), weed infestation percentage (WIP), and weed control efficiency were recorded.

The density of weed was calculated by counting the individual plants of each weed species per quadrat used and calculated using the following formula [19].

$$Weed\ Density = \frac{Total\ number\ of\ Weed \in the\ Quadrat\ X\ 100}{Total\ Area\ of\ a\ Quadrat\ (m2)}$$

The relative density was determined using the equations of [20], [21].

$$Relative\ Weed\ Density = \frac{(Number\ of\ Individual\ Weed\ Species\ X\ 100)}{Total\ number\ of\ weed\ species}$$

The weed dry weight, was determined by measuring the weight of dried weed plant collected from each plot by using 0.25 m^2. The weed plants were collected 15 days before harvest. To confirm the normality of the data before the analysis of variance, the weed dry biomass values were subjected to a square root transformation (√x), where (x) represents the original dry weight value.

Weed control efficiency (WCE) is used to compare the efficacy of various weed management methods. A higher weed control efficiency indicates a more effective weed control or herbicidal treatment. WCE was calculated using the following formula [22].

$$Relative\ Weed\ Density = \frac{((Weed\ Dry\ Matter \in Unweeded\ Plots - Weed\ Dry\ Matter \in Treated\ Plots)\ X\ 100)}{Weed\ Dry\ Matter \in Unweeded\ Plots}$$

The weed index (WI) is used to determine the efficiency of each treatment compared to a weed-free treatment. Mostly, it represents the percentage of yield loss caused by weed damage compared to the weed-free plot. A higher weed index indicates a greater yield loss. It was calculated using the following formula:

$$Weed\ Index = \frac{(Yield\ ¿\ Weed\ Free\ Plot - Yield\ ¿\ Treated\ Plots)\ X\ 100}{Y\ ield\ ¿}\ Weed\ Free\ Plot\ ¿$$

2.4. Crop Parameters

The flowering date was scored as the number of days from sowing to the time when 50% of the plants in a plot flowered. The 90% physiological maturity date was scored from planting to when 90% of the plants showed yellow leaves and pods. Plant height (cm) was measured from the ground level to the tip of the main stem on five randomly selected plants per plot. The total number of pods from the five randomly selected plants was counted at harvest and the average of counted pods were used as number of pods per plant. The seeds from these pods were then counted and average number of seeds per pod was determined. The hundred-seed weight was determined by counting one hundred seeds from the bulk harvested seed of each plot and weighed. Grain yield was scored from the net plot area and converted to kg ha^{-1}. The relative yield loss (RYL) was calculated using the following formula:

$$R\,elative\ Yield\ Loss\,(RYL\,\%)=\frac{((Maximum\ yield\ ¿\ treatment-Yield\ ¿\ a\ particular\ treatment)*100)}{Maximum\ yield\ ¿}\ treatment\ ¿$$

2.5. Partial Budget Analysis

A partial budget analysis was done as described by [23] to determine the economic feasibility of the treatments. Common bean price per kilogram was assumed to 40ETB at harvest period.

2.6. Statistical Analysis

The collected data analyzed by using SAS software version 9.3. Least Significant Difference (LSD) test at a 5% probability level was used to separate treatment means.

3. Results and Discussion

3.1. Weed Parameters

3.1.1Weed Flora

The experimental areas were infested with eight broadleaf and four grass weed species, classified into two primary categories (Table 2).

Table 2: The scored weed species from Common bean experiments at Yabello and Abaya

Scientific Name	Family	Category	Life cycle
Amaranths hybrids	Composite	Broadleaf	Annual
Argemon mexicana	Papaveraceae	Grass	Annual
Bidens pilosa L.	Asteraceae	Broadleaf	Annual
Commelina benghalensis L.	Commelinaceae	Broadleaf	Annual
Cynodon dactylon (L.) *Pers.*	Poaceace	Grass	Perennial
Cyprus esculenta L.	Cyperaceae	Grass	Perennial
Datura stramonium L.	Solanaceae	Broadleaf	Annual
Galinsoga parviflora (Cav.)	Asteraceae	Broadleaf	Annual
Guizotia scabra	Asteraceae	Broadleaf	Annual

Nicandra physalodes (L.) *Gaertn.*	Solanaceae	Broadleaf	Annual
Parthnium hysterophus	Asteraceae	Broadleaf	Annual
Phalaris paradoxa	Poaceace	Grass	Annual

3.1.2Weed Density and Weed Dry Matter

The weed density and dry matter were significantly ($P < 0.01$) affected by the applied management practices. Accordingly, weed density was determined by categorizing the weeds into broadleaf and grassy types. Among the two groups, broadleaf weeds exhibited a significantly higher density than grassy weeds (Table 3). The maximum weed density was recorded at Abaya (215.36 plants m^{-2}) than Yabello location and the weeds were dominated by broadleaf.

The maximum weed density was observed for broadleaf in the weedy check treatment (576 plants m^{-2}). The lowest weed densities for grassy weeds were scored in the weed-free plots and the treatment of S-metolachlor at (1 kg ha^{-1}) supplemented with hoeing at 20 and 35 days after sowing (DAS), (0.50 plants m^{-2}) and (4.92 plants m^{-2}), respectively. Similarly, the lowest weed densities for broadleaf were obtained in the weed-free and the S-metolachlor (1 kg ha^{-1}) combined with hoeing at 20 and 35 DAS, with values of (0.92 plants m^{-2}) and (8.42 plants m^{-2}), respectively (Table 3).

Table 3: The scored weeds density (WD), and weed dry matter (WDM)

Treatments	BL WD (m^{-2})	Grass WD (m^{-2})	BL WDM (g m^{-2})	Grass WDM (g m^{-2})
S-metolachlor 1kgha^{-1}	325.92^{b}(18.05)	200.67^{ab}(14.17)	458.25^{b}(21.41)	210.67^{b}(14.51)
Weed free	0.92^{e}(0.96)	0.5^{e}(0.71)	37.08^{f}(6.09)	17^{f}(4.12)
Unweeded	576^{a}(24)	245.75^{a}(15.67)	289.75^{a} (17.02)	289.75^{a}(17.02)
Pendimenthalin 1kgha^{-1}	278.08^{b}(16.67)	151^{bc}(12.29)	373.25^{bc}(19.32)	171.67^{bc}(13.1)
S-metolachlor 1.5 kgha^{-1}	261.75^{b}(16.18)	140.42^{c}(11.85)	322.67^{c}(17.96)	148.5c(12.19)
S-metolachlor 2kgha^{-1}	188.75^{c}(13.74)	132.33^{c}(11.5)	275.5^{cd}(16.59)	126.58^{dc}(11.25)
Pendimenthalin 1kgha^{-1} + HW at 35DAS	98.75^{d}(9.94)	61.25^{d}(7.83)	192.67^{de}(13.88)	88.75^{de}(9.42)
S-metolachlor 1kgha^{-1} + HW at 35DAS	54.58^{de}(7.39)	29.83^{de}(5.46)	157.08^{e}(12.53)	72.17^{e}(8.49)
Two Hand hoeing at 20 and 35DAS	45.08^{de}(6.71)	29.58^{de}(5.44)	139.83^{ef}(11.82)	64.17^{ef}(8.01)
Pendimenthalin 1kgha^{-1} + HW at 20 and 35DAS	25.17^{e}(5.02)	13.17^{de}(3.63)	101.58^{ef}(10.08)	46.75^{ef}(6.84)
S-metolachlor 1kgha^{-1} + HW at 20 and 35DAS	8.42^{e}(2.9)	4.92^{de}(2.22)	39^{f}(6.25)	18^{f}(4.24)
Error	5.69	5.69	16.32	7.30
LSD (0.05)	2.40	1.93	3.26	2.1879
CV (%)	26.18	25.79	29.02	28.65

Where: Means with the same letter are not significantly different, Data in parenthesis are transformed values with square root method. BL = Broadleaf weeds, CV = Coefficient of Variation, LSD = least significant difference

The findings revealed that the broadleaf weed dry matter at Abaya was (300.65 g m^{-2}), which was significantly higher than the (195.12 g m^{-2}) scored at Yabello. The highest total weed dry matter was obtained from the unweeded (919.67 g m^{-2}) plot. Conversely, the lowest weed dry matter was recorded in the weed-free treatment (54.08 g m^{-2}) and the S-metolachlor (1 kg ha^{-1}) combined with hoeing at 20 and 35 DAS (57.00 g m^{-2}). The considerable lower weed dry matter scored from the integration of herbicides with hand hoeing is attributed to the early-season chemical suppression of weeds followed by subsequent manual weedings. The result is supported with [15], who found that applying of S-metolachlor at (1 kg ha^{-1}) combined with hand weeding for four weeks after the emergence of the crop could effectively suppresses weeds (Table 3).

Among the evaluated treatments, the maximum weed index was observed in the unweeded plots (82.68%). Conversely, the minimum weed index was scored in the treatment applied with S-metolachlor at 1 kg ha^{-1} supplemented with hoeing at 20 and 35 DAS (7.86%), followed by pendimethalin at 1 kg ha^{-1} supplemented with hoeing at 20 and 35 DAS (14.07%). The results demonstrate that S-metolachlor at 1 kg ha^{-1} combined with hand hoeing at 20 and 35 DAS was the most effective weed management strategy, since the weed index indicates the loss of yield in specific treatment relative to a weed-free. Consequently, the integrated measures successfully reduced the crop yield losses due to weed competition, while the maximum yield loss was occurred in the unweeded plots (Table 4).

Table 4: Weed control efficiency (%) and Weed index (%)

Treatment	Broadleaf WCE	Grass WCE	Weed Index (%)
S- metolachlor 1kg ha^{-1}	27.083^{f}	27^{f}	51.94
Weed free	95.08^{a}	95.08^{a}	0.00
Unweeded	0^{g}	0^{g}	82.68
Pendimethalin 1kg ha^{-1}	41.25^{e}	41.25^{e}	56.54
S- metolachlor 1.5kg ha^{-1}	50.42^{d}	50.42^{d}	49.86
S- metolachlor 2kg ha^{-1}	57.83^{d}	57.83^{d}	30.66
S- metolachlor 1kg ha^{-1} + 1HW at 35DAS	69.92^{c}	69.92^{c}	32.81
Pendimethalin 1kg ha^{-1} + 1HW at 35DAS	75.58^{bc}	75.58^{bc}	29.98
Two Hand hoeing at 20 and 35DAS	77.67^{bc}	77.67^{bc}	21.11
Pendimethalin 1kg ha^{-1} + 2HW at 20 and 35DAS	81.42^{b}	82.08^{b}	14.07
S- metolachlor 1kg ha^{-1} +2HW at 20 and 35DAS	93.92^{a}	93.92^{a}	7.86

3.2. Crop Flowering Date and Physiological Maturity

The results revealed that both site and weed management practices had a significant ($P < 0.001$) effect on the flowering and physiological maturity days of common beans. The effect of weed management practices on common bean flowering and maturity dates was highly significant; the maximum average days to flowering (47.33 days) was scored in the unweeded plot, while the minimum days to flowering (42.67 days) was observed in the S-metolachlor at (1 kg ha^{-1}) supplemented with hand hoeing at 20 and 35 DAS. The result is supported with the findings of [24], who reported that weed management methods are significantly affect the days to flowering and physiological maturity of common beans. Correspondingly, the maximum average days to physiological maturity (79.83 days) was scored in the unweeded plot, while the minimum days to maturity (74.00 days) was obtained in the weed-free plots. In the unweeded plots, the shading of crop plants by high weed densities could reduce sunlight interception, and prolonging vegetative growth and delaying both flowering and maturity [24].

3.2.1. Plant Height

The plant height of common beans were significantly influenced by applied weed management practices ($P < 0.001$) and environmental conditions. The maximum average common bean height was scored from Yabello (80.98 cm) location as compare to the Abaya location (61.17 cm). Similarly, the tallest plants (90.08 cm) were observed in the weed-free treatment, while the shortest (54.17 cm) were scored in the unweeded plot. The result is in contrasts with [24], who reported there is no significant variations in plant height among weed management practices.

3.2.2. Number of Pods and Seeds per Plant

The numbers of pods and seeds per plant were significantly ($P < 0.001$) influenced by both site and weed management practices. The maximum number of pods per plant (20.82) was scored from the weed-free plot, followed by S-metolachlor at (1 kg ha^{-1}) supplemented with hand hoeing at 20 and 35 DAS (20.50), while the minimum (8.17) pod per plant was scored in the unweeded plot. The result is agrees with [15], who reported that plants in weed-free throughout the season produced the maximum pods per plant (25.30) as a result of weed competition absence. The management practices, causes to minimize weed competition and leads to increased number of pods per plant. Thus, the findings revealed that applying of S-metolachlor herbicide at (1 kg ha^{-1}) combined with hand hoeing at 20 and 35 DAS could increase the number of pods per plant by 59.19% compare to unweeded plot. Hence, integrating pre-emergence herbicides with hand hoeing yields more pods in common bean than applying herbicides alone.

The plots with weed free throughout the season had the maximum number of seeds per plant, followed by the S-metolachlor at (1 kg ha^{-1}) supplemented with hand hoeing at 20 and 35 DAS. The common bean plants in unweeded plots produced the minimum number of seeds per plant (67.58) among all treatments (Table 5).

3.2.3. Hundred-Seed Weight (HSW)

The analysis of variance revealed that location and the applied management practices significantly ($P < 0.001$) affected hundred-seed weight. The maximum HSW was determined from the weed-free plots (32.58 g), followed by S-metolachlor at (1 kg ha^{-1}) supplemented with hand hoeing at 20 and 35 DAS (31.83 g). The minimum HSW was scored in the unweeded plot (18.75). The result is supported by [26], who reported that the maximum HSW was achieved in lower weed densities. The maximum HSW scored in the treatments as a result of the availability of more space for optimal light interception, and causes better utilization of growth resources during grain development [15].

Table 5:

Means values of nine traits of common influenced by the main effects of sites and weed management practices

Treatments	FD	MD	SC	Pht(cm)	PPP	SPP	HSW	Gy(1kg ha^{-1})	RYL(%)
S- metolachlor 1kgha^{-1}	45.67^{b}	74.83^{bc}	40.08^{fg}	54.75^{e}	9.50^{e}	83.08^{fg}	20.92^{de}	1094.7^{f}	56.00^{b}
Weed free	45.67^{b}	74.00^{c}	93.50^{a}	90.08^{a}	20.83^{a}	181.5^{a}	32.58^{a}	2518.6^{a}	3.58^{g}
Unweeded	47.33^{a}	79.83^{a}	29.75^{g}	54.17^{e}	8.17^{e}	67.58^{g}	18.75^{e}	436.1^{g}	83.33^{a}
Pendimenthalin 1kgha^{-1}	45.33^{b}	75.00^{bc}	44.00^{f}	64.67^{de}	12.33^{d}	79.33^{g}	21.33^{de}	1210.5^{f}	51.83^{b}
S- metolachlor 1.5kgha^{-1}	45.33^{b}	75.00^{bc}	50.00^{ef}	68.17^{d}	12.83^{d}	97.67^{efg}	22.17^{de}	1262.8^{ef}	50.92^{b}
S- metolachlor 2kgha^{-1}	44.67^{c}	74.67^{bc}	62.75^{de}	68.58^{cd}	14.50^{bcd}	112.92^{efg}	24.33^{be}	1746.4^{cd}	30.58^{cd}
S- metolachlor 1kgha^{-1} + HW at 35DAS	44.67^{c}	75.17^{b}	72.83^{cd}	71.08^{cd}	14.42^{cd}	133.17^{bcd}	24.08^{cde}	1692.3^{de}	35.25c
Pendimenthalin 1kgha^{-1} + HW at 35DAS	44.33^{c}	75.00^{bc}	68.42^{cd}	71.58^{cd}	15.50^{bc}	129.58^{cd}	26.42^{ad}	1763.4^{cd}	33.08^{cd}
Two hand hoeing at 20 and 35DAS	43.67^{d}	74.83^{bc}	79.42^{bc}	73.08^{bcd}	16.67^{b}	147.17^{bc}	28.83^{abc}	1986.9^{bcd}	24.83^{de}
Pendimenthalin 1kgha^{-1}+HW at 20 and 35DAS	43.17^{de}	74.83^{bc}	74.08^{cd}	80.42^{abc}	19.50^{a}	119.17^{cde}	30.42^{ab}	2164.3^{abc}	18.33^{ef}
S- metolachlor 1kgha^{-1} + HW at 20 and 35DAS	42.67^{e}	74.67^{bc}	89.00^{ab}	85.25^{ab}	20.50^{a}	161.42^{ab}	31.83^{a}	2320.7^{ab}	8.92^{fg}
Error	0.58	1.56	260.19	226.29	7.30	1396.48	58.78	299183.54	137.83
LSD (0.05)	0.617	1.011	13.052	12.172	2.187	30.237	6.203	442.580	9.500
CV (%)	1.70	1.66	25.21	21.16	18.04	31.32	29.94	33.07	32.56

Where: Means with the same letter are not significantly different, FD-Flowering date, MD-Maturity date, SC-Stand count, Pht-Plant height, PPP-Pod per plant, SPP-Seed per plant, HSW-Hundred seed weight, Gykgha^{-1}-Grain yield in kilogram per hectare, RYL-Relative yield loss

3.2.4. Grain Yield of Common Bean

The ANOVA revealed that weed management practices and trial locations had a significant ($P < 0.01$) variation on common bean yield and yield-related components (Table 4). The grain yield identified from the weed-free plots (2,518.6 kg ha^{-1}) was the higher yield achieved from the experiment. However, statistically it was not vary from S-metolachlor at (1 kg ha^{-1}) supplemented with hand hoeing at 20 and 35 DAS (2,320.7 kg ha^{-1}) and pendimethalin at (1 kg ha^{-1}) supplemented with hand hoeing at 20 and 35 DAS (2,164.3 kg ha^{-1}). The minimum common bean grain yield was scored from unweeded plot (436.1 kg ha^{-1}) (Table 5). The maximum common bean grain yields obtained from the integrated weed management practices are due to higher weed management in experimental units. The lowest grain yields in the poor management practices caused from severe resource competition by weed densities. The result is supported with [15], who reported that the unweeded plot yields the lowest grain yield. Similarly, [26] reported that the combine use of pendimethalin and S-metolachlor (each at (1 kg ha^{-1}) with hand weeding at 35 DAS could raises common bean yields.

The maximum relative yield loss happened in the unweeded experimental units with the value of 83.33%. The correlation analysis between the evaluated treatments grain yield and weed dry matter showed that treatments with high weed dry matter exhibited minimum crop grain yields, while treatments that minimized weed dry matter achieved significantly maximum grain yields.

3.3. Economic Analysis

The economic analysis of the evaluated treatments revealed that the highest net benefit was obtained from the plots treated with S-metolachlor at (1 kg ha^{-1}), supplemented by hand hoeing at 20 and 35 DAS (59,845.6 ETB ha^{-1}) and a marginal rate of return (MRR) of (748.07%) (Table 6).

Table 6: Partial budget analysis for pre-emergence herbicides combine with hand hoeing in Common Bean at Yabello and Abaya

Treatments	AGY	TGB	TVC (ETB ha^{-1})	Δ TVC (ETB ha^{-1})	NB (ETB ha^{-1})	Δ NB (ETB ha^{-1})	MRR %
Unweeded	392.49	15699.6	2000	0	13699.6	13699.6	0
S- metolachlor 1kgha^{-1}	985.23	49261.5	6000	4000	33409.2	19709.6	492.74
Weed free	2266.74	113337	8000	6000	82669.6	68970	1149.5
Pendimenthalin 1kgha^{-1}	1089.45	54472.5	6000	4000	37578	23878.4	596.96
S- metolachlor 1.5kgha^{-1}	1136.52	56826	9000	7000	36460.8	22761.2	325.16
S- metolachlor 2kgha^{-1}	1571.76	78588	12000	10000	50870.4	37170.8	371.71
S- metolachlor 1kgha^{-1} + HW at 35DAS	1523.07	76153.5	8000	6000	52922.8	39223.2	653.72
Pendimenthalin 1kgha^{-1}+ HW at 35DAS	1587.06	79353	8000	6000	55482.4	41782.8	696.38
Two hand hoeing at 20 35DAS	1588.21	79410.5	8000	6000	55528.4	41828.8	697.15
Pendimenthalin 1kgha^{-1}+HW at 20 and 35DAS	1947.87	97393.5	10000	8000	67914.8	54215.2	677.69
S- metolachlor 1kgha^{-1}+HW at 20 and 35DAS	2088.63	104431.5	10000	8000	73545.2	59845.6	748.07

AGY=Adjusted grain Yield, TGB=Total growth benefit, TVC=Total Variable cost, NB=Net Benefit, MRR =Marginal Rate Return

4. Conclusion and Recommendation

The findings of the study shows that the spraying of S-metolachlor at (1 kg ha^{-1}), supplemented by hand hoeing at 20 and 35 DAS, obstructs weed dry matter and could cause increasing the yield and yield components of common beans. Consequently, weed parameters were negatively correlated with common bean yield components. The higher grain yield achieved from the weed-free treatment (2,518.6 kg ha^{-1}) was statistically not varied from the yield achieved with S-metolachlor at (1 kg ha^{-1}) supplemented by hand hoeing at 20 and 35 DAS (2,320.7 kg ha^{-1}), followed by pendimethalin at (1 kg ha^{-1}) supplemented by hand hoeing at 20 and 35 DAS (2,164.3 kg ha^{-1}). The application of S-metolachlor at (1 kg ha^{-1}) supplemented with hand hoeing at 20 and 35 DAS is the most beneficial options for weed management in common beans. Therefore, farmers in the study area should use the S-metolachlor at (1 kg ha^{-1}) supplemented by two hand hoeing at 20 and 35 DAS to rise common bean productivity.

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Data Availability Statement

My Files/Crop protection 2024/ Common bean Crop parameter (1)

AI Usage Disclosure

The authors declare AI was used for language editing

Author Contributions

Kemal Kitaba; formal analysis, writing — original draft, writing review and editing, Rameto Nura; formal analysis, writing — original draft, writing review and editing all authors. All authors have read and agreed to the published version of the manuscript.

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