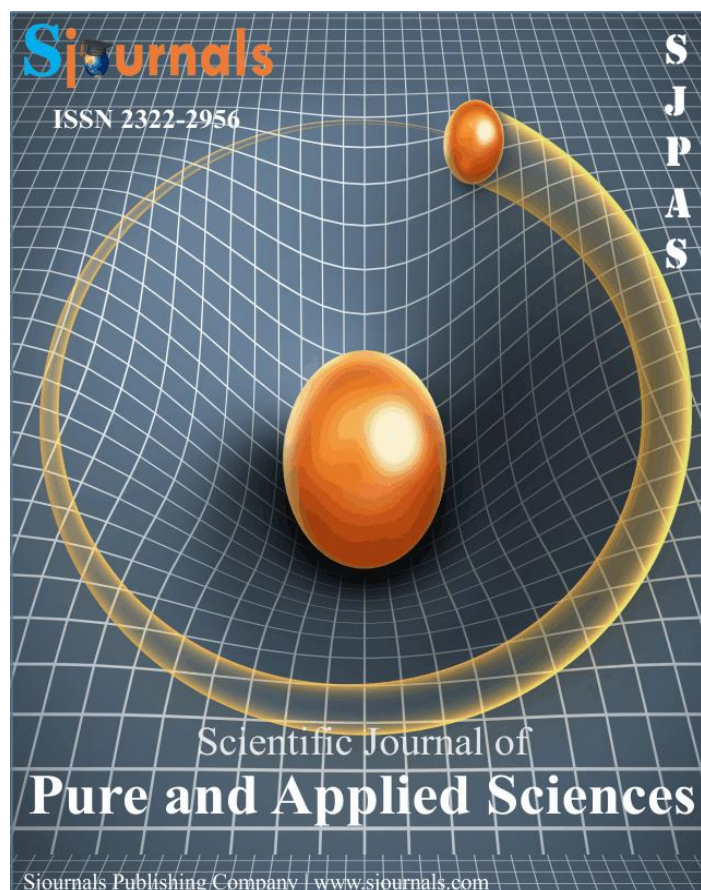


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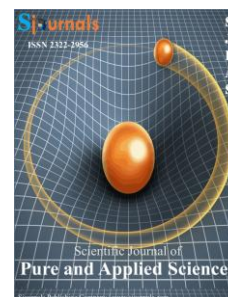
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Original article

The effect of pre-emergence Herbicide (Dual gold) and hand weeding frequencies on faba bean (*Vicia faba* L.) growth, yield and yield components in Bale Highlands, Southeastern Ethiopia

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ABSTRACT

Since weed is the major production constraints for faba bean production in Bale Highlands, Its management is quite important to increase the production and productivity. Due to such gaps, the experiment was conducted on research field of Sinana Agricultural research center and Agarfa sub-site in the Highlands of Bale, South-eastern Ethiopia under rainfed conditions during the main cropping season of 2015 and 2016 to evaluate the effect of pre-emergence herbicide (Dual gold 960 EC) in combination with hand weeding frequencies on yield and yield components of faba bean. The treatments consisted of five weed management options: (1) Weedy check, (2) Two times hand weeding at 25-30 and 40-45 days after emergence (DAE), (3) Sole dual gold, (4) Dual gold + once hand weeding at 25-30 DAE, and (5) Dual gold + two times hand weeding at 25-30 and 40-45 DAE. The trial was laid out in a randomized complete block design (RCBD) with three replications. The results indicated that a number of pods plant⁻¹, total biomass and seed yield kg ha⁻¹ and 1000 seeds weight were significantly influenced by different weed management options. The result showed that more than 38%, 27%, and 33% yield advantages were obtained when dual gold application in combination with one and two times hand weeding and only two times hand weeding was respectively used. Moreover, more than 7% yield advantage was obtained when dual gold plus two times hand weeding were practiced as compared to

only two times hand weeding. The highest net return was also obtained from dual gold application at the rate of 1.5 Lha⁻¹ plus two times hand weeding. Therefore, application of dual gold as a supplemental pre-emergence herbicide in combination with 1-2 times hand weeding could give economically optimum benefit and hence recommended for the end users. Alternatively, application of dual gold plus one time hand weeding at the later stage could also be used as an alternative weed management in areas where weed pressure is low and/or labor competition is very high during the critical period. However, it was needed to find out another pre or post-emergence herbicide which control weeds without supplement of hand weeding.

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1. Introduction

Faba bean (*Vicia faba* L.) is one of the most important pulse crops worldwide. Since, it is used as nitrogen fixing plant; capable of returning atmospheric nitrogen into soil and a source of highquality protein (Amin, 1988). It is one of the greatest production areas among major pulse crops grown in Ethiopia (CSA, 2012). However, its productivity is very low compared to its potential productivity which is 1.3 ton per hectare as compared to world average 1.8 ton per hectare (FAOSTAT, 2010). The main factor attribute to low yield is abiotic factor; which poor weed control option is the most important one that influence its production and productivity. Weeds are a challenging problem to pulse crop in general and to faba bean production in particular. Since, the crop is poor competitive to both broadleaf and grass weed species from early establishment to the flowering stage (Getachew and Rezene, 2006) that it requires control measures at this critical period. They also reported that different weed management options were significantly affected growth and yield components of the crop. Similarly, research finding reported by Fessehaie (1994) indicated that about 24% of yield loss was observed in faba-weed competition. Bale highland was a wheat belt area where many alternative choices of herbicides to control weeds and mechanization for postharvest handling of the cereal crops were available However, hand weeding is the only option to control weeds from faba bean fields due to unavailability of pre and/or post-emergence herbicides to control weeds in the area. But, dual-gold 960 E C is one of the pre-emergence herbicides which is available to kill both grassy and broadleaf weeds at the early and later stage of the crop growth to reduce yield loss. Moreover, integrated weed management approaches, like pre-emergence application combined with hand weeding practices can be the best options for sustainable weed management practices. However, in the study area, no work has been done, particularly on the effect of dual gold application in weed control from faba bean field. Therefore, the present study was aimed at evaluating the effect of pre-emergence herbicide (dual gold) application and hand weeding frequencies on faba bean and to see the economic feasibility of the herbicide.

2. Materials and methods

2.1. Experimental sites

The experiment was conducted on research field of Sinana Agricultural research center and Agarfa sub-site, Highlands of Bale, Southeastern Ethiopia under rainfed conditions during 2015 and 2016 main cropping season. Sinana is located at a distance of about 463 km from Addis Ababa at about 7°07' North longitude and 40°10' East latitude, at an altitude of about 2400 meters above sea level. On other hand, Agarfa is located at a distance of about 460 km from Addis Ababa situated at 38°40'to 46°3' East latitude and 4° to 8°11' North longitude, at an altitude of about 2350 meters above sea level. The areas were characterized by bimodal rainfall pattern which is locally named "Bona" and "Ganna" season which named based on the time of crop harvest. Soils are characterized by Cambisol and Vertisol at Sinana and Agarfa respectively. The preceding crops planted in experimental sites were bread wheat, which is the precursor of the current faba bean.

2.2. Experimental treatments and design

For this experiment, faba bean variety called “Mosisa” was used as a test crop. It was released from Sinana agricultural research center in 1999/2000. The treatments consisted of five weed management options: (1) Weedy check, (2) Two times hand weeding at 25-30 + 40-45 days after emergence (DAE), (3) Sole pre-emergence herbicide (Dual gold 960 EC) application, (4) Dual gold + one hand weeding at 25-30 DAE and (5) Dual gold + two hand weeding at 25-30 and 40-45 DAE. The experiment was laid out in randomized complete block design (RCBD) replicated three times. Each plot consisted of 3meter long 6 rows spaced 40cm a part. The size of each plot was 3m x 2.4m (7.2m²) and the adjacent blocks and plots were separated by 1.5m and 0.6m distances, respectively. The net central unit area of each plot consisted of 4 rows for sample measurements, leaving aside plants in the two outer rows and those at both ends of each of the rows to avoid border effects. The distance between plants were 10cm. 1.5 lit per hectare of pre-emergence herbicide (Dual gold 960 EC with 200 lit per hectare of water was used at third date of planting as per the recommendation of the chemical. The recommended seed rate 125 kg per hectare and 100 kg per hectare NPS fertilizer were uniformly supplied for each treatment at planting.

2.3. Partial budget analysis

The partial budget analysis was done using CIMMYT (1998) to identify the rewarding treatments. Actual yields from experimental plots were adjusted down ward by 10% to reflect the difference between the experimental yield and the yield that farmers could expect from the same treatment. This is due to optimum plant population density, timely labor availability and better management in weed control and better security under experimental conditions (CIMMYT, 1998). To find out the gross return the price of faba bean (Sale price of 12.50 Birr kg⁻¹) prevailing in the local market at the time of harvest which is the average of one month was taken into account. Similarly, the variable costs that vary included the cost of input; the field price of Dual gold herbicide during planting time was 450 Birr lit⁻¹. That means it includes the herbicide cost plus the cost of transportation from the point of sale to the farm. The labor cost for its application 1-3 days after planting was 50 Birr ha⁻¹. On the other hand, labor cost for integrated use of herbicide and hand weeding frequencies were; one and two times hand weeding which followed dual gold application and one times hand weeding were valued as 2100 and 1500 Birr ha⁻¹ respectively. In similar manner the only two times hand weeding treatment of the first hand weeding (25-30 DAE) was 2700 Birr ha⁻¹ due to weed pressure was high in the absence of herbicide in the early growth stage of the crop.

2.4. Data collection

Data were collected on: Days to flower, days to maturity, plant height, number of pods per plant, number of seeds per pod, aboveground dry biomass yield, seed yield and 1000 seed weight were recorded from each net plot. Thus, Days to flower was determined by counting the number of days from the date of emergency to the period when 50% of the plants had flower based on visual observations. Days to maturity was determined by counting the number of days from the date of emergency to the period when 90% of the plants had reached the physiological maturity based on visual observations. Plant height (cm) was measured in meter from five randomly selected plants in each net plot area from the base to the tip (apical bud) of the main stem at physiological maturity. Number of pods per plant was determined by counting the number of pods from each randomly selected non-border five plants and the average count was taken as number of pods per plant.

Number of seeds per pod was determined by dividing the total number of seeds from five randomly selected non-border plants by the total number of pods from each selected five plants. Aboveground biomass yield (kg ha⁻¹) were determined as; at physiological maturity, plants from the central four rows of a net plot size 1.6m x3m (4.8m²) were manually harvested close to ground surface using sickle. Then the harvested plants were sun dried in open air and then weighed to determine the aboveground biomass yield per hectare. Seed yield (kg ha⁻¹) was measured after threshing the sun dried plants harvested from each net plot size 4.8m² and the cleaned seed yield was weighted using an electronic balance and adjusted at 10.5% seed moister content. Finally, yield per plot was converted to per hectare basis. 1000 seed weight (g): was determined by counting 1000 seeds randomly sampled from seed lots of each treatment and weighted using an electronic balance.

2.5. Data analysis

All the collected data was analyzed using SAS statistical software version 9.1.3 (2009). The treatments were compared for their significance using calculated least significance difference (LSD) values at 5% level of probability. Treatment effects from the two locations and across years of the experiment followed a similar trend. Thus, the data from the two independent locations and across years were combined in the analysis.

3. Results and discussion

3.1. Flowering and maturity date

Analysis of variance showed flowering and maturity date of faba bean was not significantly influenced by the different weed management options (Table 1). The result indicated that though the variation was non-significant, weedy check treatment was flowered and matured early as compared to the other intensive weed management treatments. This might be due to weed competition effect for resources which caused forced phenological growth of the crop.

3.2. Plant height

The result of mean separation from the mean of the two locations across years indicated in Table 1 showed plant height was not significantly influenced by the different weed management method. Though, it was statistically non-significant; the highest values were obtained under intensive weed management methods (Dual gold application plus one and two times hand weeding) while the lowest was obtained at only dual gold applied treatments. In agreement with this result, Rahmatizadeh et al. (2013) reported the highest height was recorded at Bentazon plus one hand weeding while the lowest at control treatment in red bean (*Phaseolus calcaratus* L). Similarly, Kavurmaci et al. (2010) also reported the tallest plant was obtained in weed free treatment, while the smallest was observed at control treatment. On the other hand, Getachew et al. (2017), who conducted at two locations on cowpea as a test crop, found that the highest plant height was obtained from weedy check plot than intensive weed controlled plots. They pointed out that, weed infested plot was compete for resources, especially for light throughout the season which resulted in enhanced plant height under weedy check.

3.3. Number of pods per plant

Analysis of variance revealed that the highest number of pods per plant (12.3) was recorded at application of dual gold plus once hand weeding at 25-30 DAE though; it was statistically at par with other treatments except under use of only dual gold application. The highest number of pods per plant observed under integrated use of herbicide plus hand weeding might be due to integrated role of herbicide and hand weeding in weed control. Thus, application of a suitable herbicide at the early growth stage control early germinated weeds efficiently and hand weeding at later growth stages removed late comer weeds which makes crop the winner of competition which resulted in the formation of more number of pods per plant. Similar result was reported by Rahmatizadeh et al. (2013), who explains the integrated role of both herbicide and hand weeding in weed control.

3.4. Number of seeds per pod

Different weed control options showed non-significant effect on number of seeds per pod of faba bean. This result was in line with Getachew and Mekdes (2016) who observed the different weed management practices (Different herbicides, herbicide plus hand weeding at different week interval after emergency) showed non-significant influence on number of seeds per pod of cowpea. However, contrary to the current result, Amaregouda et al. (2016) reported the highest number of seeds per pod under weed free treatment while, the lowest was obtained under weed infested treatment. This might be attributed to effective weed control during the early growth stage of the crop helped; in better development of infrastructure of the plant and less competition for nutrients, radiation and water from weeds facilitated for the better growth and development of the crop.

3.5. Biomass yield

Results pertaining to biomass yield indicated that significant differences among treatments was observed (Table 1). The highest value was obtained when dual gold application plus two times hand weeding and use of only two times hand weeding followed by dual gold plus one times hand weeding, but all are statistically at par.

whereas, the lowest biomass yield was recorded under sole use of dual gold application and weedy check. The maximum biomass yield under intensive weed management might be due to the effect of weed control from the early establishment of the crop by the use of herbicide and hand weeding that significantly reduced the completion effect. Moreover, plants under weed free environment were obtain efficient resource utilization, better translocation of water and nutrients, and more number of nodules per plant which fix more amount of atmospheric nitrogen and supplied to the vegetative parts or sink resulting in higher production of above ground biomass yield. Agreement with this result (Getachew et al., 2017), reported the highest biomass yield were obtained at one hand weeding plus hoeing at 4 weeks after crop emergency which was non-significantly different from one hand weeding plus hoeing at 3 weeks after emergency, and complete weed free treatments. The main reason might be better condition in soil rhizosphere which improved the competitive ability of the crop and favored more vegetative growth. Moreover, Mizan et al. (2009); reported the increased biomass yield of the crop was highly governed by the length of weed free period.

Table 1

Effect of pre-emergency Herbicide (Dual-gold) on faba bean growth, yield and components of yield at Sinana and Agarfa, in 2015 and 2016 cropping seasons.

Treatments	Days to flower	Days to maturity	Plant height (cm)	Number of pods per plant	Number of seeds per pod	Biomass yield (kg/ha)	Seed yield (kg/ha)	Thousand seed weight (g)
Weedy check	61	121	101.9	9.8 ^{ab}	2.4	6305.0 ^b	2058.6 ^b	481.9 ^{ab}
Dual gold application	62	122	99.6	9.2 ^b	2.3	7225.1 ^b	2201.5 ^b	500.1 ^a
Dual gold + Hand weeded (1x)	63	125	107.0	12.3 ^a	2.1	9030.7 ^a	2808.2 ^{ab}	461.0 ^b
Dual gold + Hand weeded (2x)	63	124	104.6	10.6 ^{ab}	2.4	9539.9 ^a	3309.2 ^a	471.3 ^b
Hand weeded (2x)	62	123	101.7	10.0 ^{ab}	2.5	9308.4 ^a	3084.2 ^a	479.1 ^{ab}
Mean	62	123	103	10.4	2.3	8281.8	2692.3	478.7
LSD (5%)	Ns	Ns	Ns	2.50	Ns	1461.4	757.83	24.25
CV (%)	4.92	4.42	13.69	29.42	19.75	14.74	34.34	6.18

Means followed by same letter(s) are not significantly different at 5% probability levels following Least Significant Difference (LSD), CV = Coefficient of Variation, Ns = Non-significant.

3.6. Seed yield

The highest seed yield (3309.2 kg ha⁻¹) was obtained as a result of dual gold application plus two times hand weeding and use of only two times hand weeding followed by dual gold plus one times hand weeding, but all are statistically at par. The lowest seed yield was, however, recorded under sole use of dual gold application and weedy check. The current result clearly revealed that more than 38% and 33% yield advantages could be obtained when dual gold application in combination with two times hand weeding and only two times hand weeding were used followed by dual gold application in combination with one times hand weeding (27%). Even though yield performance under combined uses of dual gold application and one and two times hand weeding and only two times hand weeding were not significant, more than 7% yield advantage could be obtained when both pre-emergence herbicide and two times hand weeding were practiced as compared to only two times hand weeding. This yield increment might be due to the contribution of herbicide that considerably controls the weed infestation, particularly at the early establishment of the crop that significantly reduces the competition. Hence, application of dual gold 1-3 days after planting of the crop is very crucial to control early weed emergence. However, at least one time hand weeding at a later stage is the most important practices as it was significantly increased the yield performance of the crop compared to weedy check. In agreement with this result, Diwash et al. (2014) reported combined use of herbicide plus hand weeding resulted in significantly higher seed yield of green gram. Kumar et al. (2006) also obtained significant black gram yield increase with the application of pendimethalin supplemented with one hand weeding at 45 days after sowing. Another study by Rahmatizadeh et al. (2013) also reported the

maximum seed yield of red bean was achieved in application of herbicide plus once hand weeding treatment. This might be alone herbicide or hand weeding control methods were less effective in reducing the number of weeds per unit area; instead of both chemical and hand weeding control methods. Similar result has also been drawn by Roslon and Fogelfors (2003) that proper weed management gave higher yields of the crops.

3.7. Thousand seed weight (g)

The maximum 1000 seeds weight (500.1g) was obtained when sole application of dual gold and followed by only two times hand weeding (479.1g) and weedy check (481.9 g), but all means showed statistical parity. Whereas, the lowest values (461 and 471.3 g) were recorded by application of dual gold plus once and two times hand weeding respectively. This result indicated that 1000 seed weight was inversely correlated with a number of pods plant⁻¹. This implies that plant under intensive weed management practices bears or forms more number of pods per plant due to less resource competition with weeds. Thus, more number of pods per plant might be resulted in more number of seeds per plant which might resulted in severe competition for resources between seeds. As a result, there was low 1000 seeds weight was recorded. Contrary to the current result, Getachew and Mekdes (2016) reported seeds raised under complete weed free plots were recorded the highest 100 seeds weight which was statistically at par with most treatments. They justified the scenario as plants raised under weed free environment utilized available resources to their maximum benefit leading to increased seeds weight. Moreover, they also observed; the more and vigorous leaves under weed free environment might have improved the supply of assimilate to be stored in the seed which leads to increased seed weight. The lowest seed weight was recorded in weedy check which was in par with one hand weeding at 2 weeks after emergency plus 1.5 kg ha⁻¹ of S-metolachlor which was in consistent with (Madukwe et al., 2012), who reported cowpea plants in unweeded plots were gave the lowest 100 seed weight. Meseret et al. (2008) however, reported non-significant differences in 1000 seeds weight due to weed management practices in common bean.

3.8. Partial budget analysis

The Partial budget analysis for different weed control options in faba bean production revealed that the use of pre-emergence herbicide (Dual gold 960 EC) combined with different hand weeding frequencies gave a different economic return as compared to weedy check, and either use of only pre-emergence herbicide or hand weeding alone (Table 2).

Table 2

Economic and marginal analysis of weed control practices at Sinana and Agarfa, Highlands of Bale, 2015 and 2016 cropping seasons.

Treatments*	Yield (kg/ha)	AdY (kg/ha)	GI (Birr)	VC (Birr)	NB (Birr)	MRR (%)	Residual
Weedy check	2058.6	1852.74	23159.25	-----	23159.25	----	23159.25
Dual gold application	2201.5	1981.35	24766.88	725	24041.88	122.0	23316.88
Dual gold + Hand weeded (1x)	2808.2	2527.38	31592.25	2,825	28767.25	225.0	25942.25
Hand weeded (2x)	3084.2	2775.78	34697.25	4250	30447.25	118.0	26197.25
Dual gold + Hand weeded (2x)	3309.2	2978.28	37228.50	4,625	32603.5	575.0	27978.5

AdY = Adjusted Yield, GI = Gross Income, VC = Variable Cost, NB = Net Benefit, MRR = Marginal Rate of Return.

Thus, Dual gold application at the rate of 1.5 lit ha⁻¹ plus two times hand weeding at 25-30 and then at 40-45 DAE gave the highest net benefit (32603.5 Birr) and marginal rate of return (575%). Alternatively, application of dual gold combined with one time hand weeding is economically better than two times hand weeding alone, particularly at critical labor competition for other farming activities, since its MRR is greater implying that more return could be obtained as per unit cost investment required to control the weed using dual gold application plus one time hand weeding. This implies that uses of pre-emergence herbicide as a supplemental weed control options is very optimal in addition to hand weeding at the later stage. Similar to this result, Diwash et al. (2014) indicated maximum net returns and benefit: cost ratio was obtained from use of herbicide than hand weeding. Since, hand weeding was associated with less benefit to cost ratio; owing to higher cost of farm labor. However, hand weeding significantly reduced weed biomass and improved seed yield. Therefore, it can be concluded that

the use of dual gold (960 EC) application at 1-3 days after planting in combination with two times hand weeding at 25-30 and then at 40-45 DAE could be used as the best weed management options for faba bean production. Alternatively, combined use of dual gold plus one time hand weeding at a later stage could also be advisable for the control of weed in areas where labor competition is very high at critical period of time that need more labor for other farming activities.

3.9. Conclusion

Weed is the major production constraints, particularly for faba bean production in Bale Highlands, and hence its management is quite paramount important to increase the production and productivity. The result of this experiment revealed that 1.5 lit ha⁻¹ dual gold 960 EC applications in combination with two hand weeding at 25-30 and 40-45 DAE was given the highest yield and economically shown the maximum net benefit. Moreover, the highest marginal rate of return was also obtained from combined uses of dual gold plus two times hand weeding. In addition, application of dual gold plus one times hand weeding at the later stage could also be used as an alternative weed management in areas where labor competition is very high during critical period. Therefore, integrated uses of pre-emergence herbicide with one or/and two times hand weeding practices can be recommended and advisable to be used by the end users in Bale highland areas. However, further research is required to find out another pre or post-emergence herbicide which can control weed problems without supplemental hand weeding practices.

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