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Research Article

Integrated Management of Haricot Bean Foliage Beetle in Northeastern Ethiopia

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A field experiment was conducted to determine the integrated effect of planting dates, insecticides, and their interaction on the reduction of yield and yield related components of haricot bean caused by haricot bean foliage beetle damage at Sirinka Agriculture Research Center, Ethiopia. Planting dates were normal planting (NP) and late planting (10 days after normal planting) (LP), while insecticides comprised Apron star seed dressing (A) and without insecticide (WI). The combined analysis revealed that late planting combined with Apron star seed dressing (LPA) resulted in the highest yield (1223.7 Kg/ha). On the other hand, normal planting date without insecticide application (NPWI) gave the lowest yield (209.6 kg/ha) and the maximum yield loss (209.6%). The cost-benefit analysis showed that use of LPA gave by far better high net profit over control. Thus, LPA are recommended for haricot bean foliage beetle management in northeastern Ethiopia.

1. Introduction

Haricot bean (*Phaseolus vulgaris* L.) plays a vital role in human nutrition, especially proteins, and ensures food security in Sub-Saharan Africa [1]. In Ethiopia, haricot bean is one of the most economically important cash crops grown by small-scale farmers [2]. However, insect pests and diseases are considered the principal biotic constraints of haricot bean production in Ethiopia [3].

Bean foliage beetles (*Ootheca* species) are widely distributed in eastern Africa and attack beans, cowpeas, and other leguminous crops as well as okra and other members of the hibiscus family [4]. An early sign of trouble is the presence of large swarms of foliage beetles on young beans in the field. This often follows the early rains. They feed voraciously and may cause total defoliation of the crop. The presence of young seedlings of the host plant (beans) appears to stimulate adult emergence of the beetles from hibernation in the soil. Little emergence occurs in the absence of bean or other host plants. The above ground damage is caused by the adult beetles but larvae cause damage below ground. Larval feeding on roots causes patches of yellowed plants in the field. Such plants are stunted, dry up prematurely, and may bear empty pods [5].

There are limited options available for bean leaf beetle management, and foliar insecticide applications and insecticidal seed treatments are the primary methods of bean leaf beetle management [6, 7]. Delayed planting of beans also helps to avoid susceptible stages of the crop coinciding with peaks in the pest population cycle [8]. Integrating different management options for the management of insect pests like foliage beetle is of global interest [9]. Thus, the objective of this study is to determine the effect of planting dates, insecticides, and their interaction on the reduction of yield and yield related components of haricot bean caused by foliage beetle damage.

2. Materials and Methods

2.1. Description of the Study Area. The field experiment was conducted at Sirinka in 2012 and 2013 main cropping seasons. Sirinka is located between 110 41′ 13″ and 110 45′ 11″ N latitude and 390 31′ 15″ and 390 43′ 2″ E longitude with an altitude of 1850 m.a.s.l and situated 508 km away from Addis Ababa, the capital of Ethiopia. The annual rainfall of the area is up to 980 mm (ten years average). The area has bimodal rainfall, the main cropping season (June-August), and short rainfall, which is locally known as "belg" (March and April). The common planting dates of the area extend from the end of June to mid-July. The average maximum and minimum temperatures of the area are 26 and 13°C, respectively. The dominant soil types of the trial site are Eutric Vertisols and Eutric Cambisol.

2.2. Treatments and Experimental Design. The experiment was laid out in a randomized complete block design (RCBD) with a factorial combination of treatments in three replications, where planting dates and insecticides were tested in factorial combination. Planting dates were normal planting and late planting (10 days after normal planting). The insecticides were Apron star seed dressing and without insecticide. Seeds were dressed with Apron star at a rate of 250 gm/100 kg seed and shaken in a plastic bag for uniform distribution.

Adults of foliage beetle are predominantly feeding on the youngest leaves of the bean plant. Accordingly, leaf damage was assessed from randomly selected plants of central rows of each plot. The degree of leaf area damage was estimated as the percentage of round holes fed by foliage beetle. Number of dead plants after two-month period was also recorded. Data on the number of pods per plant was from five randomly sampled plants per net plot at harvest and number of seeds per pod was recorded from ten randomly sampled pods per net plot at harvest. Grain yield (kg/ha) was determined by harvesting all plants from the net plot and converting it on per hectare basis at 10% moisture content. Relative yield loss was computed using the following formula [10]:

$$\mathrm{RYL} = \frac{(\mathrm{YP} - \mathrm{YT})}{(\mathrm{YT})} \times 100 \quad (1)$$

where RYL = relative percent loss, YP = yield from the maximum protected plot (in this study late planting and seed dressed plots), and YT = yield from other plots of treatments.

2.3. Cost-Benefit Analysis. The seed price (Birr ton^{-1}) of haricot bean was obtained from the local market at Sirinka and total sale from one hectare was computed. The price of common bean seed was Birr 666.67/100 kg. The price of Apron star, which was used for seed treatment, was Birr 10/10 gm. Cost of labor at Sirinka was 15 Birr per man per days. Cost of dressing equipment for 90 kg seed per hectare was also calculated and taken as Birr 100.0 day^{-1}. Based on the data obtained, the cost-benefit analysis was performed using a partial budget analysis. Partial budget analysis is a method of organizing data and information about the cost and benefit of various agricultural alternatives [11]. Partial budgeting is employed to assess the profitability of any new technologies (practice) to be imposed on the agricultural business. Marginal analysis is concerned with the process of making choice between alternative factor-product combinations considering small changes. The marginal rate of return is a criterion which measures the effect of additional capital invested on net returns using new management compared with the previous one [11]. It provides the value of the benefit obtained per the amount of additional cost incurred percentage. The formula is as follows:

$$MRR = \frac{DNI}{DIC} \quad (2)$$

where MRR is marginal rate of returns, DNI is difference in net income compared with control, and DIC is difference in input cost compared with control.

The following points were considered during cost benefit analysis using partial budget analysis.

(i) Costs for all agronomic practices were uniform in all treatments.

(ii) Costs, return, and benefit were calculated on the basis of per hectare.

(iii) Farmers in the area were assumed to obtain 0.9% of experimental (actual) yield.

2.4. Data Analysis. Data on the number of pods per plant, seeds per pod, and seed yield were analyzed using SAS software [12]. Means were separated using LSD at P=0.05.

3. Results and Discussion

The combined effect of Apron star seed dressing and planting dates on the reduction of yield and yield components caused by foliage beetle damage has been conducted at Sirinka Agricultural Research Center, Ethiopia, under field condition for two years during 2012 and 2013. The two-year combined result revealed that there was a highly significant effect on the number of plants with the damaged symptom, the number of dead plants, yield, and yield-related traits due to planting date, insecticide application, and their interaction.

3.1. Effect of Planting Date and Insecticide Application on Number of Plants with Damaged Symptom, Degree of Damage, and Number of Dead Plants. The effect of planting date, Apron star seed dressing, and their interaction was significant ($P<0.05$) on the number of plants with damaged symptom and number of dead plants. The result showed that Apron star seed dressing during late planting showed a lower number of plants with foliage beetle damaged symptom and number of dead plants (Table 1; Figure 1). On the other hand, plots without Apron star seed dressing during normal planting date had the highest number of plants with damaged symptom and number of dead plants (112 and 65, respectively) (Table 1; Figure 1). In agreement with our study, early planting coincides with peak beetle emergence and causes severe feeding activity [13–15]. To the contrary, late planting has low level of feeding injury [13–15]. In addition, systemic seed treatment is the main strategy for the control of beetles and it provides protection for about three weeks after sowing [15].

3.2. Effect of Planting Date and Insecticide Application on Yield and Yield Components

3.2.1. Number of Pods per Plant. The result of the present study showed that the interaction effect of planting time and insecticide application was significantly ($P<0.05$) higher

Table 1: Effect of the combination of planting date and seed dressing on number of damaged symptoms and dead plants of haricot bean in 2012 and 2013 main cropping season.

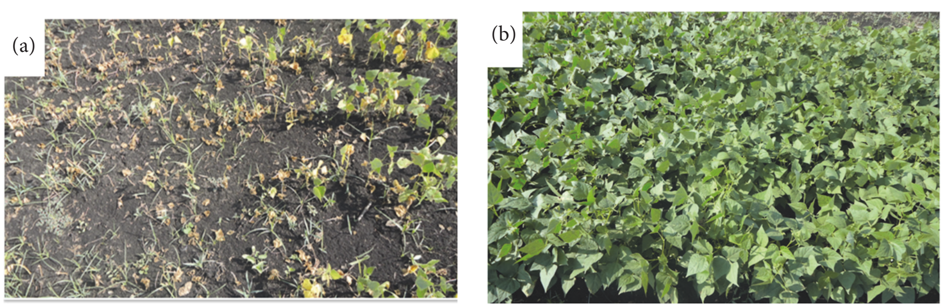
Planting date	Seed dressing	NPDS[a]	NDPL[a]
Normal planting	Apron star	43.7 ± 7.07^{b}	37.8 ± 4.83^{b}
	No Apron star	112 ± 10.92^{a}	65 ± 16.07^{a}
Late planting[b]	Apron star	27.4 ± 3.90^{d}	8 ± 2.91^{d}
	No Apron star	36.9 ± 1.58^{c}	15.7 ± 3.39^{c}
CV (%)		8.53	77.15
LSD (5%)		5.59	48.19

[a]Percentage (mean of three replications); NPDS, number of plants showing disease symptom; NDPL, number of dead plants; [b]10 days after normal planting; means followed by the same letter (s) within a column are not significantly different (P=0.05).

Table 2: Effect of the combination of planting date and insecticide application on yield and yield components of haricot bean in 2012 and 2013 main cropping season.

Planting date	Seed dressing	Number of pods per plant[1]	Number of seeds per pod[1]	Seed yield (Kg/ha)[1]
Normal planting	Apron star	8.13 ± 2.33^{b}	4.48 ± 0.77^{a}	669.3 ± 60.36^{c}
	No Apron star	5.02 ± 1.38^{c}	2.83 ± 0.27^{b}	209.6 ± 53.85^{d}
Late planting[b]	Apron star	12.0 ± 1.06^{a}	5.61 ± 0.39^{a}	1223.7 ± 100.52^{a}
	No Apron star	9.0 ± 1.19^{b}	5.01 ± 0.45^{a}	802.4 ± 73.05^{b}
CV (%)		23.85	15.03	27.27
LSD (5%)		2.74	1.14	130.48

[1]Percentage of disease incidence (mean of three replications); NPDS, number of plants showing disease symptom; NDPL, number of dead plants; [b]10 days after normal planting; means followed by the same letter (s) within a column are not significantly different (P=0.05).



(a) (b)

Figure 1: Efficacy of integrated management of foliage beetle: (a) normal planting without Apron star seed dressing and (b) late planting with Apron star seed dressing.

in affecting the number of pods per plant (Table 2). The highest number of pods per plant (12) was registered from late planting date combined with Apron star seed dressing. The significant reduction in the number of pods per plant may be attributed to the reduction of high insect pressure at the initial growth stage as reported by Tolera [16].

3.2.2. Number of Seeds per Pod. Analysis of the two-year data showed that there is an interaction effect between planting date and insecticide application in affecting the number of seeds per pod. The highest number of seeds per pod was recorded during late planting date combined with Apron star seed dressing (5.61) (Table 2). On the other hand, the normal planting date without insecticide application showed the lowest number of seeds per pod (2.83). This may be attributed to severe defoliation and root damage that consequently results in a higher reduction in the photosynthetic assimilates.

3.2.3. Seed Yield. The result of the two-year experiments data showed that there was a significant ($P<0.05$) interaction effect between planting date and insecticide application. The highest seed yield (1223.7 Kg/ha) was recorded from normal planting plus Apron star seed dressing (1223.7 Kg/ha). The lowest seed yield was obtained from normal planting without insecticide application (Table 2). The highest yield loss due to foliage beetle damage was recorded during normal planting without any insecticide application (Table 3).

Table 3: Yield losses caused by haricot bean foliage beetle on haricot bean under different treatments during 2012 and 2013 main cropping season.

Planting date	Seed dressing	Relative yield loss (%)
Normal planting	Apron star	(669.3) 82.8
	No Apron star	(209.6) 483.8
Late planting[a]	Apron star	(1223.7) 0.0
	No Apron star	(802.4) 52.5

[a]10 days after normal planting; values in parenthesis indicate the seed yield in Kg/ha.

Table 4: Result of partial budget analysis for the integrated management of haricot bean foliage beetle during 2012 and 2013 main cropping season.

Treatment	No	Cost-benefit data							
		1	2	3	4	5	6	7	8
		Adj. yield (t ha-1) (yield x 0.9)	Price (Birr t-1)	Sale revenue (1x2)	Total input cost (Birr ha-1)	Marginal cost (Birr ha-1)	Net profit (3-4) (Birr ha-1)	Marginal benefit (Birr ha-1)	Marginal rate of return (7/5) (%)
LPA		1.27	6333.4	8020.0	932.6	402.0	7087.5	6261.3	1557.5
NPA		0.64	6333.4	4071.0	932.6	402.0	3138.4	2312.2	575.2
LPWI		0.83	6333.4	5256.2	530.6	0.0	4725.6	3899.5	734.9
NPWI		0.21	6333.4	1356.8	530.6	0.0	826.2	0.0	0.0

LPA = late planting with Apron star seed dressing; NPA = normal planting with Apron star seed dressing; LPWI = late planting without Apron star, and NPWI = normal planting without Apron star.

Table 5: Sensitivity analysis for the management of haricot bean foliage beetle during 2012 and 2013 main cropping season.

Treatments	Cost increase price decrease	Cost increase price constant	Cost constant price decrease
LPA	6226.3	7032.1	6319.6
NPA	2668.8	3079.3	2762.0
LPWI	4171.7	4700.1	4224.8
NPWI	609.6	742.2	662.6

LPA = late planting with Apron star seed dressing; NPA = normal planting with Apron star seed dressing; LPWI = late planting without Apron star, and NPWI = normal planting without Apron star.

The present study showed that late planting combined with Apron star seed dressing significantly reduced the effect of foliage beetle thereby increasing seed yield (Table 3). This is in line with the previous findings [17] that delay planting exposes seedlings to the feeding activity of overwintered bean leaf beetles for a limited time. Thus, later planted fields can escape incoming overwintered bean leaf beetle adults entering fields during the normal planting date.

The present study revealed the effect of seed treatment in reducing yield loss caused by foliage damage. The result of this study was supported by the report of Lam *et al.* [18] that seed dressing before planting and colonization results in potential control of early colonizing beetles and larvae which has an impact on the population of successive generations emerging the same growing season. Use of insecticide seed treatment is effective to control early season insect pests and produce vigorous crop thereby increasing crop yield [19].

3.3. Cost-Benefit Analysis. The result of cost-benefit analysis over the two-year data (Table 4) showed that the maximum net benefit (7087.5 Birr/ha) was obtained from late planting combined with Apron star seed dressing. On the other hand, normal planting without seed dressing showed the least net benefit (826.2 Birr/ha).

The higher marginal rate of return was obtained from late planting combined with Apron star seeds dressing (1557.5%). The highest cost-benefit ratio was obtained from late planting without insecticide application (1:9) followed by late planting combined with Apron star seed dressing (1:7.6). For every one birr investment of variable cost, there was a gain of 9 and 7.6 Birr from late planting without insecticide application and late planting with Apron star dressing, respectively. The sensitivity analysis showed that, for either increase or decrease of chemical cost as well as seed price, use of Apron star seed dressing with late planting showed the highest net benefit (Table 5).

4. Conclusions

The present study showed that the highest number of pods per plant, seeds per pod, and seed yield was obtained from the use of Apron star seed dressing combined with late planting. This treatment was very much effective in reducing the yield loss caused by foliage beetle. Cost-benefit analysis also showed that use of Apron star combined with late planting is economically feasible management option. Thus, combined use of apron star and late planting is highly recommended for the management of foliage beetle in northeastern Ethiopia.

Data Availability

The data used to support the findings of this study are included within the article.

Disclosure

The first author is a lecturer in the University of Gondar, Ethiopia and now he's doing PhD in South Korea.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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