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Research Article

Effect of Fungicide Application Rate and Frequency on development of Major Faba bean Diseases, Grain Yield and Yield Components of Faba Bean (*Vicia Faba L.*) at Southeastern Oromia, Bale

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Keywords: Faba bean; Botrytis fabae Sard; Uromyces *viciae-fabae*; Ascochyta fabae; AUDPC and Disease progress curve

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Abstract

The experiment was conducted at Sinana and Agarfa to determine the application rate and frequency of MATICO. Randomized Complete Block Design with three replications was used to lay out the experiment. Logistic model (ln[y/ (1-y)]) was used to estimate r. Correlation and regression analysis were employed to find the relationship between diseases' severity, yield, and yield-related traits. Analysis of Variance (ANOVA) for diseases parameters has shown significant differences ($p<0.05$) between treatments. The highest diseases parameters were recorded from unsprayed and plots sprayed with lower rates and frequency and the lowest was recorded from plots sprayed four tines at 2.5 kg/ha. ANOVA for yield and yield-related traits has shown significant variations ($P<0.05$) among treatments. The highest pods per plant (21), thousand Kernel Weight (664.7g), and grain yield (3319.4kg/ha) were recorded from plots sprayed four times at 2.5 kg/ha. Simple linear regression has revealed a significant association ($P<0.0001$) between grain yield and diseases severity and the Correlation of grain yield with diseases severity has depicted a significant negative correlation. The highest marginal rate of return (2126.31%) was obtained from plots sprayed twice at 2.5kg/ha. Therefore, two times application of MATICO WP at a rate of 2.5 kg/ha is recommended.

Introduction

Faba bean (*Vicia faba L.*) also known as the broad bean, horse bean, and field bean is among the earliest domesticated food legume crops [1]. In Ethiopia, it is one of the most important pulse crops produced. According to the report by [2], Faba bean has covered 437, 106.04 ha of land, and a total production volume of 921,761.54t yr^{-1} was harvested. Its high nutritive value both in terms of energy and protein contents (24-30%) has made the Faba bean one of the most important food legumes in the world. It is an excellent nitrogen fixer and Ethiopian farmers are aware of its role in improving soil health and fertility by fixing atmospheric nitrogen, and widely using them in rotation with cereals (Sahile et al.,). However, the national average yield under smallholder farmers in Ethiopia is as low as 2.1t ha^{-1} [2], despite the availability of varieties that can yield up to 4t ha^{-1} [3]. This is largely because Ethiopian farmers are cultivating low-yielding cultivars, diseases, weeds, and insect pests (Yohannes, 2000). The most important diseases are chocolate spot (*Botrytis fabae*), rust (*Uromyces viciae-fabae*), black rot (*Fusarium solani*), and Aschochyta blight (*Ascochyta fabae*). Orobanche spp. and Phelipanche spp. are among the most important parasitic weeds and Black bean aphid (*Aphis fabae*) are among the important Faba bean diseases limiting Faba bean yield in Ethiopia (Mussa, et al., Ahmed, et al.).

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Diseases are among the major yield constraining biotic factors challenging Faba bean production in Ethiopia. The environmental conditions in the Faba bean growing areas of Bale highlands are highly favorable for disease development. This necessitates having well-developed management options against major Faba bean diseases to reduce yield losses. The work done so far focuses only on the application of fungicide at its highest rate without considering the crop growth stage, although the flowering stage is identified to be highly susceptible to disease infection. Therefore, this work was done to find out the effect of reduced fungicide application rate and frequency at the flowering stage of chocolate spot development and progress.

Materials and methods

Description of experimental sites

The experiment was conducted for three years from 2017/18 to 2019/20 GC at the Agarfa sub-site and Sinana Agricultural Research Center (SARC) on-station research site. The locations represent the major Faba bean production areas of the Bale highlands and have high rainfall. These areas are suitable environments (hot spots) for the majority of Faba bean disease's development. They are characterized by a bimodal pattern of rainfall; where the short rainy season is from March to June locally known as "*Ganna (Belg)*" and the main season is from August to December which is called "Bona (*Meher*)". The two seasons are locally termed after the time of crop harvest. SARC is located at 7°7' N (latitude) and 40°10' E (longitude) at about 2400 m.a.s.l. SARC receives a mean annual rainfall of 875mm and an annual temperature range of 9–21 °C (Nefo, et al.,). The dominant soil type of Sinana is pellic vertisol and slightly acidic [4]. Agarfa is located at an altitude range of 2328-2505 m.a.s.l and receives a mean annual rainfall of 907 mm. The annual temperature range of Agarfa area is 10-24 °C and the dominant soil type is vertisol [5].

Treatments and design

The experiment was conducted using RCBD in three replications. An improved Faba bean variety 'Mosisa' and a fungicide MATCO WP (Metalaxyl 8% + Mancozeb 64% WP) were used as a test variety and fungicide, respectively.

Application of fungicide was done in four frequencies (1 times, 2 times, 3 times and 4 times sprays) and five application rates (0 kg/ha, 1 kg/ha, 1.5 kg/ha, 2 kg/ha and 2.5 kg/ha) at 7-10 days interval (Table 1). The plots size was 3m x 2.4 m having a total of 6 seeding rows out of which four rows were harvested for yield and thousand kernel weight measurement. Space between rows, plots, and replications was 0.4m, 2m, and 2m, respectively. Disease infection gradients were created by spraying a fungicide at different application rates and frequencies at the flowering stage (Table 1). Unsprayed control was included as a negative control for treatment comparison. Fungicide application was started at about flowering growth stage. Seed rate (125 kg/ha for small seeded varieties), fertilizer rate (100 kg/ha NPS), weeding, and other agronomic packages are applied as per the recommendation for the Faba bean.

Table 1: Treatments combination.

Treatment No.	Application rate	Frequency of spray
1	No spray	0
2	1 kg/ha	1
3	1 kg/ha	2
4	1 kg/ha	3
5	1 kg/ha	4
6	1.5 kg/ha	1
7	1.5 kg/ha	2
8	1.5 kg/ha	3
9	1.5 kg/ha	4
10	2 kg/ha	1
11	2 kg/ha	2
12	2 kg/ha	3
13	2 kg/ha	4
14	2.5 kg/ha	1
15	2.5 kg/ha	2
16	2.5 kg/ha	3
17	2.5 kg/ha	4

Data management and statistical analysis

Logistic, logit (y) = ln [(y/1-y)] [6] and Gompertz, -ln[-ln(Y)], [7] models were compared for estimation of disease parameters. The goodness of the fit of the models was tested using the coefficient of determination (R^2) and the Logistic model, logit (y) = ln [(y/1-y)], [6] was found to fit best to the data. Therefore, variables for field experiment data under different treatments were analyzed using the logistic model, logit (y) = ln[y/ (1-y)] with the SAS Procedure [8]. Diseases were distinguished from others based on their appearance on the plant, lesion shape, and color. Diseases were scored based on visual observation on a 1-9 scoring scale, where 1= No disease symptoms or very specks; 3= few small discrete lesions; 5= some coalesced lesions with some defoliation; 7= large coalesced sporulating lesions, 50% defoliation and some dead plant; and 9= Extensive lesions on leaves, stems and pods, severe defoliation, heavy sporulation, stem girdling, blackening and death of more than 80% of plants [9] and converted to percentage severity index (PSI) [10]. LSD technique at a 95% confidence interval was used for mean separation. Area Under Disease Progress Curve (AUDPC) and rate of disease progress (r) were calculated for each treatment (Shaner and Finney). One-way ANOVA was performed for disease parameters (PSI, AUDPC, and r) and agronomic parameters (number of pods per plant, number of seeds per pod, thousand kernel weight (g), and grain yield (kg/ha)) using SAS version 9.1.3. The association between disease parameters yield was assessed via Correlation and regression analysis.

$$PSI = \frac{\text{Sum of Numerical Ratings X100}}{\text{Number of Plants Scored X Maximum Score on Scale}} \quad (1)\ [10]$$

$$AUDPC = \sum_{i-1}^{n-1} 0.5(x_{i+1} + x_i)\left(t_{i+1} - t_i\right) \quad (2)\ (\textit{Shaner and Finney})$$

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Where, X_i= the PSI of disease at the i^{th} assessment

t_i= is the time of the i^{th} assessment in days from the first assessment date

n= total number of disease assessments

Partial budget analysis

The total cost of production and marginal benefits from each treatment was calculated using the partial budget analysis method. Similarly, the marginal rate of return (MRR) was computed considering the total variable costs in each treatment. The sum costs of fungicide, water, Sprayer rent, labor for spraying, Labor of water supply, and Labor for cleaning equipment were considered as a total variable cost. The grain yield and economic data were collected to calculate MRR and compare the advantage of fungicide spray at the flowering stage for the management of Chocolate spot disease over unsprayed plots. MRR has been used to measure the effect of additional investment on net returns [11]. MRR provides the benefit value obtained as a function of the additional investment.

$$MRR = \frac{DNI}{DIC} x\ 100 \quad (3)\ [11]$$

Where: - MRR- Marginal Rate of Return,

DNI-Difference in Net Income compared with control,

DIC- Difference in Input Cost compared with control.

Results and discussion

The experiment was conducted in the open fields depending on the natural infection of the disease. As a result, Chocolate spot, Ascochyta blight, and Rust disease appeared together. The combined one-way Analysis of variance over years and locations has shown statistically significant differences ($P<0.05$) between treatments for disease parameters and yield and yield components. The highest chocolate spot (53.55%), Rust (44.44%), and Ascochyta blight (42.59%) diseases severities were recorded from untreated control, plot sprayed once at 1 kg/ha and plot sprayed once at 1.5 kg/ha, respectively. The lowest chocolate spot (14.20%), Rust (11.11%), and Ascochyta blight (16.67%) diseases severities were recorded from plots sprayed 4 times at 2.5 kg/ha (Figure 1 and Table 2). In line with this finding, Sahile et al., have reported mean disease severity ranging from 25 to 46.6% in sprayed plots, in comparison with 56.7% in unsprayed plots. Similarly, lower

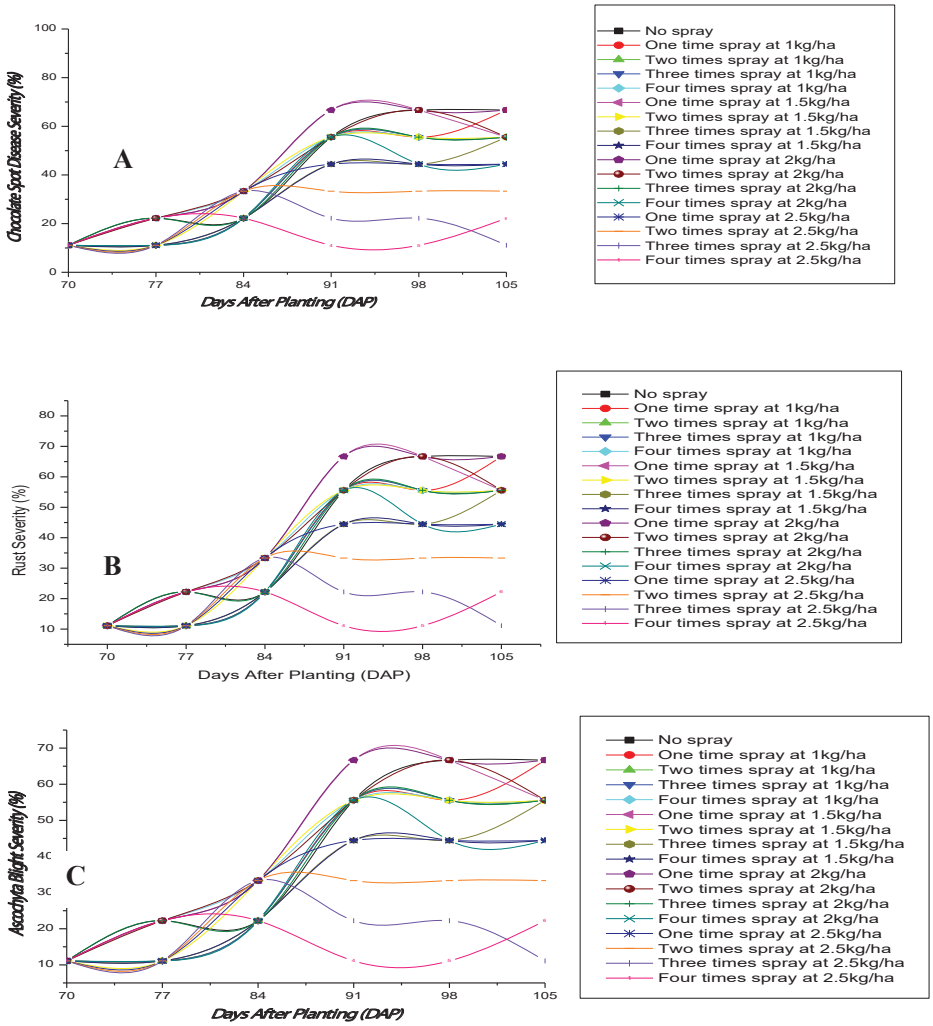

Figure 1: Influence of fungicide application rate and frequency on the Chocolate spot. (A), Rust (B), and Ascochyta blight (C) diseases development and progress over time.

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Table 2: Effects of fungicide spray rate and frequency on disease severity, AUDPC, and r of Chocolate spot, Rust, and Ascochyta blight diseases.

Treatment	Chocolate spot (%)	Choc. spot-AUDPC	Choc. spot-r	Rust (%)	Rust AUDPC	Rust-r	Asco. blight (%)	Asco. blight AUDPC	Asco. blight -r
No spray	53.55	2350.4	0.01458	41.95	1450.81	0.14793	40.70	1438.11	0.05368
1 times X 1kg/ha	48.67	2058.8	0.01348	44.44	1555.56	0.14410	37.04	1283.33	0.07150
2 times X 1kg/ha	47.49	1850.01	0.00687	38.89	1361.11	0.07491	36.40	1269.98	0.02508
3 times X 1kg/ha	43.37	1526.6	0.00546	34.54	1217.48	0.03478	35.76	1268.56	0.02534
4 times X 1kg/ha	39.59	568.9	0.01147	32.08	1114.04	0.04127	38.89	1400.00	0.02165
1 times X 1.5kg/ha	47.05	1854.8	0.00547	41.33	1490.22	0.03054	42.59	1555.56	-0.00590
2 times X 1.5kg/ha	42.59	1514.4	0.00348	41.96	1451.07	0.06416	37.04	1322.22	0.02296
3 times X 1.5kg/ha	42.58	1513.5	0.00325	42.51	1436.94	0.02688	31.48	1088.89	0.04211
4 times X 1.5kg/ha	41.36	1485.1	0.00311	29.63	1050.00	0.01937	29.60	1049.48	0.01427
1 times X 2kg/ha	40.74	1448.3	0.00425	35.17	1243.67	0.03821	44.35	1578.63	0.04630
2 times X 2kg/ha	43.79	1532.4	0.00589	30.17	1033.93	0.04148	40.72	1477.00	0.00637
3 times X 2kg/ha	35.8	458.6	0.00241	27.78	972.22	0.02427	37.62	1346.59	0.01957
4 times X 2kg/ha	32.05	365.4	0.00112	30.80	1087.07	0.01293	31.48	1127.78	0.00722
1 times X 2.5kg/ha	38.27	547.6	0.00254	32.67	1190.91	0.00670	32.09	1140.48	0.01173
2 times X 2.5kg/ha	30.26	359.4	-0.00098	29.59	1022.91	0.01825	25.90	932.30	0.00565
3 times X 2.5kg/ha	20.96	289.4	-0.00086	18.72	666.17	-0.00245	19.12	712.70	-0.00729
4 times X 2.5kg/ha	14.20	238.3	-0.00063	11.67	408.72	0.00031	16.05	570.37	0.00328
CV (%)	15.1	19.5	11.34	12.23	15.99	13.72	18.24	17.76	16.77
$LSD_{(0.05)}$	9.29	586.4	0.00114	3.43	115.54	0.0231	1.2604	35.34	0.0064

Note: AUDPC- Area Under Disease Progress Curve, r- apparent infection rate, Choc. Spot- Chocolate spot, Asco. blight- Ascochyta blight.

disease severity from sprayed plots and higher disease severity for unsprayed plots were recorded [12]. The highest chocolate spot AUDPC (2350.4 %-days), Rust AUDPC (1555.56 %-days), and Ascochyta blight AUDPC (1578.63 %-days) were recorded from the unsprayed plot, plot sprayed once at 1kg/ha and plot sprayed once at 1.5kg/ha, respectively. Apparent infection rates of 0.01458, 0.01458, and 0.07150 units^{-1} days were calculated from the unsprayed plot, unsprayed plot, and plot which have received a one-time application at 1kg/ha, respectively. This finding agrees with Samuel et al., [13], who reported that the application of fungicide has reduced r and disease severity. Whereas, the lowest Chocolate spot AUDPC (238.3 %-days) and r (-0.00063 units^{-1}) were calculated from the plot sprayed four times at 2.5kg/ha. Whereas, the lowest Rust (408.72 %-days) and Ascochyta blight (570.37 %-days) AUDPC were recorded from the plot sprayed four times at 2.5 kg/ha and the lowest r of -0.00245 units^{-1} day for Rust and -0.00729 units^{-1} day for Ascochyta blight were recorded from plots sprayed three times at a rate of 2.5 kg/ha. Fungicide spray affects the development and progress of Faba bean diseases severity and AUDPC [13-24].

Regarding agronomic performance, one-way ANOVA has depicted that a statistically significant difference (P<0.05) exists between treatments. ANOVA for the number of seeds per plant has shown no significant difference (P<0.05) between treatments. Whereas, ANOVA for the number of Pods per Plant, Thousand Kernel Weight (TKW (g)), and Grain yield (kg/ha) have shown statistically significant differences (P<0.05) between treatments (Table 3). The highest number of pods (21), TKW (664.67g), and Grain yield (3319.4kg/ha) were recorded from the plot sprayed four times at 2.5kg/ha (Table 3).

Correlation and regression analysis

Correlation analysis

Simple pair-wise Pearson Correlation analysis has been performed to determine the relationship between chocolate spot, Rust, and Ascochyta blight disease parameters and yield parameters. ANOVA has shown a statically significant relationship (P<0.005) between disease parameters and yield parameters. Similarly, some of the yield parameters have shown a very strong positive influence on grain yield.

Chocolate spot, Rust and Ascochyta blight diseases severity have significant and highly strong negative correlation with number of pods per plant (r=-0.84324, P<0.0001; r= -0.81568, P<0.0001 and r= -0.68554, P<0.0001), TKW (r= -0.85503, P<0.0001; r= -0.79667, P<0.0001 and r= -0.86229, P<0.0001) and grain yield (r= -0.91540, P<0.0001; r= -0.83911, P<0.0001 and r= -0.72643, P<0.0001), respectively. Similarly, number of pods per plant (r= 0.85612, P<0.0001) and TKW (r= 0.83312, P<0.0001) have strong positive correlation with grain yield (Table 4).

Regression analysis

Simple linear regression analysis was undertaken in order to assess the association between chocolate spot, Rust, and Ascochyta blight diseases severity and Faba bean grain yield. The regression analysis result has revealed statistically significant associations (P<0.0001) between chocolate spot, Rust, and Ascochyta blight diseases and grain yield. The estimated slope of the regression line obtained for chocolate spot disease severity, Rust and Ascochyta blight diseases were

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Table 3: Effect of fungicide spray rate and frequency on Faba bean yield and yield components.

Treatment	No. Pod/plant	No. Seed/pod	TKW (g)	Grain Yield (kg/ha)
No spray	7.67	3.00	350.00	1075.00
1 times X 1kg/ha	7.00	2.67	340.00	1091.7
2 times X 1kg/ha	8.00	3.00	365.00	1097.7
1 times X 1.5kg/ha	10.00	3.33	406.00	1158.3
2 times X 2kg/ha	14.00	2.00	386.33	1729.2
3 times X 1kg/ha	8.00	3.00	395.00	1276.4
2 times X 1.5kg/ha	10.67	3.00	405.00	1179.2
3 times X 1.5kg/ha	8.00	3.00	392.67	1273.6
4 times X 1.5kg/ha	9.00	2.00	489.00	4548.6
1 times X 2kg/ha	10.00	2.00	365.00	1737.5
4 times X 1kg/ha	9.00	2.00	405.00	1381.9
1 times X 2.5kg/ha	16.00	4.00	593.00	1958.3
3 times X 2kg/ha	14.33	3.00	456.00	1819.4
4 times X 2kg/ha	17.00	3.00	556.00	2265.3
2 times X 2.5kg/ha	15.00	3.67	601.00	2929.2
3 times X 2.5kg/ha	18.67	3.00	645.00	3204.2
4 times X 2.5kg/ha	21.00	4.00	664.67	3319.4
CV (%)	18.65	11.74	9.74	18.26
$LSD_{P\leq0.05}$	7.01	NS	265.62	808.64

Table 4: Correlation between Chocolate spot, Rust, Ascochyta blight diseases parameters, yield, and Yield Components of Faba bean.

	Chocolate spot (%)	Rust (%)	Ascochyta blight (%)	number of pods/ plant	TKW (g)	Grain yield (kg/ ha)
Chocolate spot (%)						
Rust (%)	0.84133**					
Ascochyta blight (%)	0.79993**	0.72691**				
Number of pods/plant	-0.84324***	-0.81568***	-0.68554***			
TKW (g)	-0.85503***	-0.79667***	-0.86229***	0.88284***		
Grain yield (kg/ha)	-0.91540***	-0.83911***	-0.72643***	0.85612***	0.83312***	

Note: ** highly correlated and *** very highly correlated

-61.59, -66.28, and -64.95, respectively. These estimates indicate that for each unit increase in percent chocolate spot, Rust, and Ascochyta blight severity, there will be Faba bean grain yield loss of 61.59 kg/ha, 66.28 kg/ha, and 64.95 kg/ha, respectively (Figure 2A, 2B, 2C). The coefficient of determination (R^2) values calculated for each disease has confirmed that for chocolate spot, Rust, and Ascochyta blight the equations explained 83.8%, 70.4%, and 52.8% of losses in Faba bean grain yield was occurred due to chocolate spot, Rust and Ascochyta blight diseases, respectively (Figure 2A,B,C).

Partial budget analysis

The partial budget analysis method was employed to carry out an economic analysis to determine the profitability of the treatments. The total variable costs in each treatment were taken into account to do the analysis. The sale revenue, marginal cost, marginal benefit, and marginal rate of return (MRR) were computed for each treatment (Table 6). The total income from each treatment was obtained as sale revenue (SR) from the product at a rate of 14 ETB per kilogram of Faba bean. The marginal cost (MC) was computed as a total sum of all production costs that varied and marginal benefit (MB) was calculated as a difference between sale revenue and marginal cost (Table 5 and Table 6). The highest marginal benefit (43109.8 ha^{-1} ETB) was recorded from plots sprayed with a fungicide MATCO WP three times in a week's interval at a rate of 2.5 kg/ha which is followed by 42123.6 ha^{-1} ETB and 39842.8 ha^{-1} ETB from plots sprayed four times and two times at 2.5 kg/ha, respectively. The lowest marginal benefit of 15000.8 ha^{-1} ETB was recorded from plots sprayed once at a rate of 1kg/ha (Table 6).

The highest MRR (ETB 2126.31 %) was recorded from plots sprayed twice at a rate of 2.5 kg/ha. This indicates that for every ETB 1.00 invested on MATCO WP to spray against Faba bean diseases, there will be a gain of about ETB 21.26 ha^{-1} $season^{-1}$. The second and third highest MRRs of 2021.13% and 1604.33% were calculated from plots sprayed once and three times at a rate of 2.5kg/ha, respectively. This implies that for every ETB 1.00 invested on a fungicide MATCO, the return will be ETB 20.21 and 16.04, respectively ha-^{1} season^{-1} (Table 6).

Therefore, from the economic profitability viewpoint, production of moderately resistant Faba bean variety Mosisa sprayed MATCO PW one to two times at the flowering stage at a rate of 2.5kg/ha is the most profitable Faba bean diseases management practice for smallholder farmers at the current Faba bean market price.

Conclusion and recommendation

The application of a fungicide MATICO WP has influenced Chocolate spot, Rust, and Ascochyta blight diseases' development and progress over time. Similarly, the agronomic performances of the Faba bean were highly influenced by the application rate and frequency of the fungicide. The disease severities were recorded and AUDPC and r were computed as the parameters of the major disease. Whereas, the lowest diseases severity, AUDPC, and r were recorded from plots that have received four times application of a fungicide MATICO WP at a rate of 2.5kg/ha. This indicates that the application of a fungicide MATICO WP is an important Faba bean production package.

The highest grain yield of 3319.4 kg/ha and 3204.2 kg/ha were achieved from plots sprayed four times and three times by a fungicide MATICO at a rate of 2.5kg/ha, respectively. While the lowest grain yield of 1075 kg/ha and 1091.7 kg/ha were recorded from an unsprayed plot and a plot sprayed once at 1 kg/ha. Economic analysis has depicted that the maximum marginal benefit (MB) of 43109.8 ETB ha^{-1} and 42123.6 ETB ha^{-1} were computed from plots sprayed three times and four times at a rate of 2.5 kg/ha, respectively. The lowest marginal benefit (MB) of 15000.8 ETB ha^{-1} and 15050 ETB ha^{-1} were calculated from unsprayed plots and plots sprayed once at 1 kg/ha. Whereas, the highest marginal rate of return (MRR) 2126.31%

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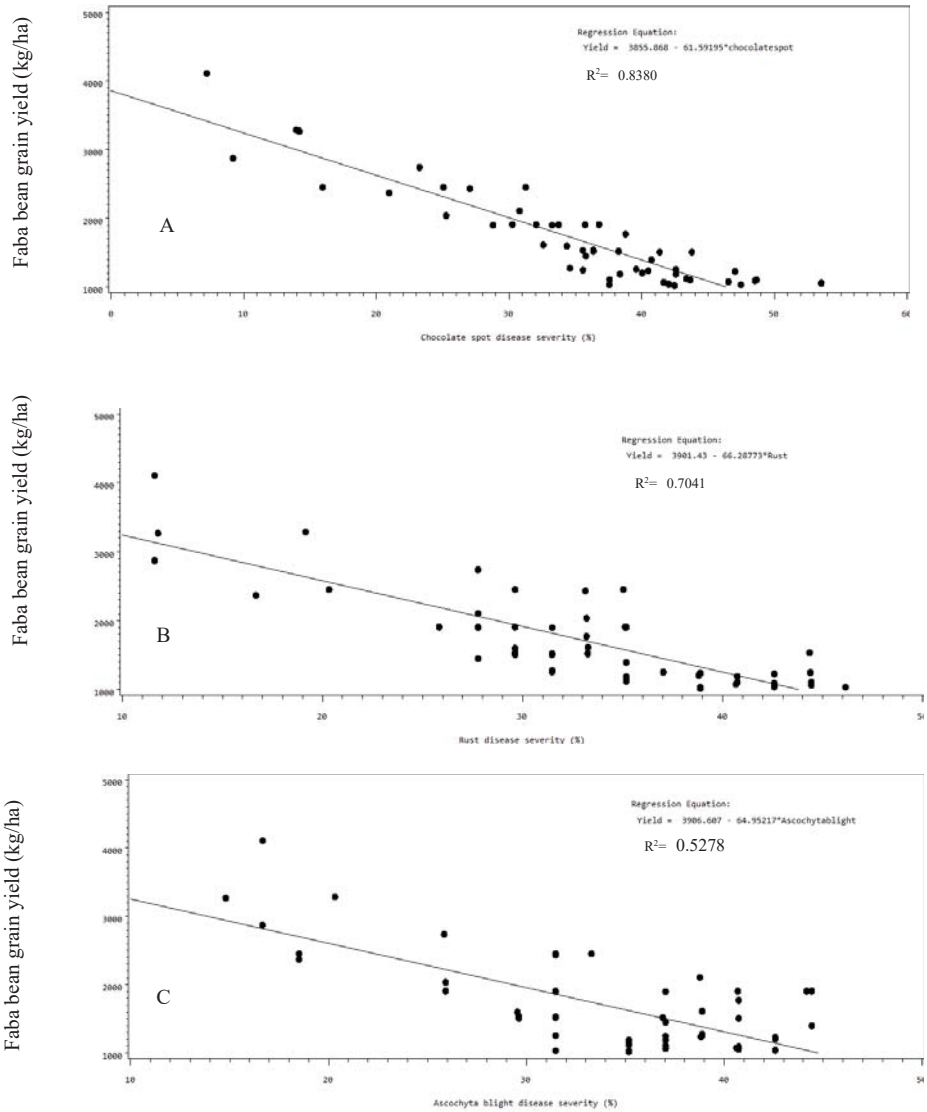

Figure 2: Association between losses in Faba bean grain yield and Chocolate spot (A), Rust (B), and Ascochyta blight diseases severity (C).

Table 5: Total variable costs of fungicide application and associated costs for protected plots at Sinana in 2017/18, 2018/19, and 2020/21 GC main cropping season.

No.	Treatment	List of items and activities as a source of costs (Ethiopian Birr)								
		Fungicide			Sprayer rent	Labor cost to spray	Labor cost for water supply	Cleaning equipment	Cost of water	Total variable cost
		Rate ($kgha^{-1}$)	Frequency	Cost (ETH Birr)						
1	No spray	0	0	0	0	0	0	0	0	0
2	1 times X 1kg/ha	1	1	200	20	35	15	5	8	283
3	2 times X 1kg/ha	1	2	400	40	70	30	10	16	566
4	1 times X 1.5kg/ha	1.5	1	300	20	35	15	5	8	383
5	2 times X 2kg/ha	2	2	800	40	70	30	10	16	966
6	3 times X 1kg/ha	1	3	600	60	105	45	15	24	849
7	2 times X 1.5kg/ha	1.5	2	600	40	70	30	10	16	766
8	3 times X 1.5kg/ha	1.5	3	900	60	105	45	15	24	1149
9	4 times X 1.5kg/ha	1.5	4	1200	80	140	60	20	48	1548
10	1 times X 2kg/ha	2	1	400	20	35	15	5	8	483
11	4 times X 1kg/ha	1	4	800	80	140	60	20	48	1148
12	1 times X 2.5kg/ha	2.5	1	500	20	35	15	5	8	583
13	3 times X 2kg/ha	2	3	1200	60	105	45	15	24	1449
14	4 times X 2kg/ha	2	4	1600	80	140	60	20	48	1948
15	2 times X 2.5kg/ha	2.5	2	1000	40	70	30	10	16	1166
16	3 times X 2.5kg/ha	2.5	3	1500	60	105	45	15	24	1749
17	4 times X 2.5kg/ha	2.5	4	4000	80	140	60	20	48	4348

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Table 6: Cost-benefit assessment of fungicide application rate and frequency against major diseases of Faba bean at Sinana in 2017/18, 2018/19, and 2020/21 GC main cropping season.

No.	Treatment	Fungicide (kgha^{-1})	Yield kgha^{-1}	SR (ETB ha^{-1})	MC (ETB ha^{-1})	MB (ETB ha^{-1})	MRR (%)
1	No spray	0	1075.0	15050	0	15050.0	
2	1 times X 1kg/ha	1	1091.7	15283.8	283	15000.8	-17.39
3	2 times X 1kg/ha	2	1097.7	15367.8	566	14801.8	-43.85
4	1 times X 1.5kg/ha	1.5	1158.3	16216.2	383	15833.2	204.49
5	2 times X 2kg/ha	4	1729.2	24208.8	966	23242.8	848.12
6	3 times X 1kg/ha	3	1276.4	17869.6	849	17020.6	232.11
7	2 times X 1.5kg/ha	3	1179.2	16508.8	766	15742.8	90.44
8	3 times X 1.5kg/ha	4.5	1273.6	17830.4	1149	16681.4	141.98
9	4 times X 1.5kg/ha	6	1548.6	21680.4	1548	20132.4	328.32
10	1 times X 2kg/ha	2	1737.5	24325	483	23842.0	1820.29
11	4 times X 1kg/ha	4	1381.9	19346.6	1148	18198.6	274.27
12	1 times X 2.5kg/ha	2.5	1958.3	27416.2	583	26833.2	2021.13
13	3 times X 2kg/ha	6	1819.4	25471.6	1449	24022.6	619.23
14	4 times X 2kg/ha	8	2265.3	31714.2	1948	29766.2	755.45
15	2 times X 2.5kg/ha	5	2929.2	41008.8	1166	39842.8	2126.31
16	3 times X 2.5kg/ha	7.5	3204.2	44858.8	1749	43109.8	1604.33
17	4 times X 2.5kg/ha	10	3319.4	46471.6	4348	42123.6	622.67

SR = Sales revenue; MC = Marginal cost; MB = Marginal benefit; MRR = marginal rate of retur

and, 2021.13% were obtained from sprayed twice and once at a rate of 2.5kg/ha. On the other hand, the lowest MRR of -43.85% and -17.39 were calculated from plots sprayed twice and once at a rate of 1kg/ha, respectively.

Therefore, based on the result of biological study and economic analysis results, 1-2 times spray of a fungicide MATICO WP at a rate of 2.5 kgha^{-1} at the flowering stage of the crop is recommended for the management of Faba bean Chocolate spot, Rust and Ascochyta blight diseases to optimize financial benefit from Faba bean production.

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