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Research Article

Integrated management of chocolate spot (*Botrytis fabae Sard*) through host resistance and fungicide application in the highlands of Bale, Southeastern Ethiopia

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Abstract

Because of its nutritional value, Faba bean (*Vicia faba L.*) is one of the most important food legumes both as energy and protein source. It is among the most important pulse crops produced in Ethiopia in general and on the highlands of Bale in particular. Field experiment was conducted at Sinana Agricultural Research Center on-station using RCBD with three replications to study the integrated effect of fungicide (sprayed at various frequencies) and faba varieties to manage chocolate spot. The experiment consisted of five (5) fungicide application frequencies and two Faba bean varieties (Gebelcho and Mosisa). Logistic model, [ln [(Y/1-Y)] was used to calculate the disease parameters such as disease progress rate (r) and AUDPC. The partial budget analysis was carried out to asses financial profitability of fungicide application for the management of chocolate spot. ANOVA showed statistically significant difference ($P<0.05$) among the treatments for the disease parameters. The lowest chocolate spot severity (23.15%) and the best chocolate spot disease control was achieved from Gebelcho variety sprayed four times. Similarly, the lowest r (-0.00453units/day) and AUDPC (823.1 %-days) were recorded from Gebelcho variety sprayed four times. Regarding yield and yield components, ANOVA showed significant differences ($P<0.05$) among the treatments. The highest number of pods per plant (15.28) was recorded from Gebelcho variety sprayed 2 times whereas, the highest TKW of 662.60 g was recorded from Gebelcho variety sprayed three times. In terms of grain yield, the maximum grain yield of 3515.44 kg/ha was obtained from Mosisa variety sprayed four times and four times spray of Gebelcho variety gave the second highest grain yield of 3313.70kg/ha. Partial budget analysis has shown the maximum marginal benefit of 41044.8ETBha^{-1} obtained from Mosisa variety sprayed four times at weekly interval while the second marginal benefit of 38624.4ETBha^{-1}was obtained from Gebelcho variety sprayed four times at weekly interval. The maximum MRR of 1726.11 % was obtained from Mosisa variety sprayed once and the second highest MRR (1592.84 %) was calculated from Gebelcho variety sprayed four times. Therefore, the recommendation is made depending on the results from the biological studies and partial budget analysis. For small scale farmers, it is recommended to produce Mosisa variety by spraying mancozeb 80% WP once to maximize the financial benefit from faba bean production. But, for small scale farmers who can afford, it is recommended to produce faba bean variety Mosisa sprayed three times by a fungicide mancozeb 80%. However, for large scale farmers who are producing faba bean for export market are recommended to produce faba bean variety Gebelcho sprayed four times at 7-10 days interval.

Introduction

Faba bean (*Vicia faba* L.) is among the most important pulse crops produced in Ethiopia covering about 459, 183.51 ha of land with a total annual production of 697, 798.39tyr^{-1} [1]. The interest of farmers to produce faba bean in Ethiopia is growing because of the fact that its demand on the export market is increasing [2]. It is also one of the most important food legumes due to its high nutritive value both in terms of energy and protein contents (24-30%) and also is an excellent nitrogen fixer. However, its average yield under smallholder farmers is very low, ranging from 1 to 1.2tha^{-1} [3]. Lack of or low adoption of high yielding cultivars, diseases, weeds and insect pests together with abiotic factors are the major constraints for Faba bean production [4]. Chocolate spot (*Botrytis fabae Sard.*) is one of economically important diseases that damages all

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parts of the crop and reduces faba bean production globally [5]. Similarly, it is one of the major faba bean yield limiting biotic factors for faba bean production in Ethiopia. Yield losses of up to 61% on a susceptible cultivar, and 34% on a tolerant cultivar were recorded in Ethiopia [6,7]. For its management, there are a number of possible options such as the use of moderately resistant/tolerant varieties, application of fungicides, biological control, induced resistance and cultural practices [3].

Host resistance is one of the most acceptable and economically profitable chocolate spot management options. However, host resistance alone is not a reliable management option of chocolate spot as faba bean varieties lack reliable resistance to the disease. Therefore, it is important to integrate faba bean varieties with fungicides and other cultural practices for the proper management of chocolate spot. The environmental conditions in the Faba bean growing areas of Bale highlands are conducive for chocolate spot development. A survey of chocolate spot disease in central Ethiopia showed 68% disease intensity [8]. As a result this disease need well developed management options. Sustainable management of chocolate spot needs epidemiological knowledge based management options based on fungicides, resistant cultivars and their integration with different cultural practices [9]. Indicated an option of early planting for the management of the disease. However, early planting may not be practical in regions where unreliable and erratic rainfall occurs frequently. Besides the importance of chocolate spot on Bale highlands, the effort towards the management of this disease is very minimal.

Objective

The study was conducted to study the integrated effect of fungicide (sprayed at various frequencies) and faba varieties to manage chocolate spot.

Materials and methods

The field experiment was conducted during "bona" (main) cropping season at Sinana Agricultural Research Center (SARC) on-station and Agarfa sub-site field trials, for two consecutive years, 2017/18 and 2018/19 . SARC is located at 463km away from the capital, Finfine to the south-east. Its geographic location is 07° 07' N latitude and 40° 10'E longitude with an elevation of 2400 masl. The area receives an annual rain fall of 750–1000mm and has an annual temperature range of 9-21 °C [10]. The experiment was laid out in RCBD with 3 replications. Two faba bean varieties, Gebelcho (released from Holeta Agricultural Research Center in 2006 GC) moderately resistant to chocolate spot and Mosisa (released from Sinana Agricultural Research Center in 2013 GC) susceptible and tolerant to chocolate spot were used in this experiment. A fungicide Mancozeb 80% WP was sprayed in five (5) frequencies (0 times, 1 times, 2 times, 3 times and 4 times) at a rate of 2.5kg/ha. The plot size was 2.4m ×3m which contains 6 seeding rows. Between row, plot and replication spacing was 0.4m, 2m and 1.5m, respectively. The seed rates were 37 seeds for a 3m long row (on the basis of 125kg/ha recommendation from SARC for small seeded varieties (Mosisa)) and 40 seeds for a 3m long row (on the basis of 175-200kg/ha recommendation from SARC for large seeded varieties (Gebelcho)). The fertilizer rate of 100 kg NPS/ha was applied as non-experimental variable. The disease development was rated using 1-9 scoring scale, where, 1= No disease symptoms or very small 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 [11]. Disease scores were converted to Percent Severity Index (PSI) [12].

Data collected

The field data such as disease (severity and incidence) data, number of pods per plant, number seeds per pod, number of seeds per plant and data from laboratory which are TKW and grain yield were collected at an optimal time for collection. The disease severity data collected based on scoring scale was converted to percent severity index for analysis. All the collected data were fed to computer, cleaned and subjected to SAS statistical package for analysis.

Data management and statistical analysis

Logistic, [ln [(Y/1-Y) [5] and Gompertz, -ln[-ln(Y)] [13], models were compared to estimate the disease parameters from each treatment. The logistic model was chosen based on the test of Goodness of the fit of the models using coefficient of determination (R^2). Therefore, variables for field experiment data under different treatments were analyzed using logistic model, ln[y/ (1-y)] with the SAS Procedure [14]. Mean separation was made based on List Significance Difference (LSD) technique at 5% probability level. AUDPC [15] and disease progress rate (r) values were calculated for each plot using the formula indicated below. ANOVA was performed for disease severity index [12], AUDPC [15] and rate of disease progress (r). The association of disease parameters with yield and yield related parameters was assessed using correlation and regression analysis.

$$PSI = \frac{\text{Sum of Numerical Ratings X100}}{\text{Number of Plants Scored X Maximum Score on Scale}}$$

$$AUDPC = \sum_{i-1}^{n-1} 0.5(x_{i+1} + x_i)\left(t_{i+1} - t_i\right)$$

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

Cost-Benefit analysis

The partial budget analysis was performed following the standard methodology, taking the variable costs in each treatment in to account (Table 1). The Marginal Rate of Return (MRR) was computed for each treatment (Table 2). The total income from each treatment was obtained as Sale Revenue (SR)

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Table 1: Variable costs associated with fungicide application for the management of Chocolate spot for Faba bean production.

No.	Treatment	Fungicide		List of items and activities as a source of costs (Ethiopian Birr)						
		Rate (kgha^{-1})	Frequency	Fungicide Cost (ETH Birr/kg)	Sprayer rent	Labor cost to spray	Labor cost for water supply	Cleaning equipment	Cost for water	Total variable cost
1	Mosisa No spray	0	0	0	0	0	0	0	0	0
2	Gebelcho No spray	0	0	0	0	0	0	0	0	0
3	Mosisa one time spray	2.5	1	200	25	25	20	5	10	285
4	Gebelcho one time spray	2.5	1	200	25	25	20	5	10	285
5	Mosisa two times spray	2.5	2	400	50	50	40	10	20	570
6	Gebelcho two times spray	2.5	2	400	50	50	40	10	20	570
7	Mosisa three times spray	2.5	3	600	75	75	60	15	30	851
8	Gebelcho three times spray	2.5	3	600	75	75	60	15	30	851
9	Mosisa four times spray	2.5	4	800	100	100	80	20	40	1140
10	Gebelcho four times spray	2.5	4	800	100	100	80	20	40	1140

Table 2: Cost-benefit analysis of fungicide applications against Chocolate spot for Faba bean production.

No.	Treatment	Fungicide (kgha^{-1})	Yield (kgha^{-1})	SR (ETB ha^{-1})	MC (ETB ha^{-1})	MB (ETB ha^{-1})	MRR (%)
1	Mosisa No spray	0	2072.2	24866.4	0	24866.40	0.00
2	Gebelcho No spray	2.5	1705.5	20466	0	20466.00	0.00
3	Mosisa one time spray	2.5	2505.9	30070.8	285	29785.80	1726.11
4	Gebelcho one time spray	2.5	1899	22788	285	22503.00	714.74
5	Mosisa two times spray	2.5	2513.5	30162	570	29592.00	829.05
6	Gebelcho two times spray	2.5	2090.7	25088.4	570	24518.40	710.95
7	Mosisa three times spray	2.5	3160.7	37928.4	851	37077.40	1434.90
8	Gebelcho three times spray	2.5	2433.1	29197.2	851	28346.20	686.63
9	Mosisa four times spray	2.5	3515.4	42184.8	1140	41044.80	1419.16
10	Gebelcho four times spray	2.5	3313.7	39764.4	1140	38624.40	1592.84

SR: Sale Revenue; MC: Marginal Cost; MB: Marginal Benefit; MRR: Marginal Rate of Return

from the produced and sold faba bean in a rate of 12 ETB per kilogram of the product. The Marginal Cost (MC) is computed as a sum of all the variable costs incurred for the faba bean production and the Marginal Benefit (MB) is calculated as a difference of sale revenue and marginal cost (Tables 1,2).

The production cost and benefit from each treatment was analyzed using partial budget analysis. Similarly, the Marginal Rate of Return (MRR) was computed by considering the total variable costs incurred in each treatment. In this experiment the sum cost of fungicide, water, sprayer rental, labor for spraying, labor for water supply and labor for cleaning equipment were considered as variable costs. The MRR was used as major criteria which measures the effect of additional investment on net returns [16]. MRR provides the benefit value obtained as a function of the additional investment for the management of Chocolate spot in percentage.

$$MRR = \frac{DNI}{DIC} \times 100$$

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

There was statistically significant difference ($P<0.05$) among treatments for all the disease parameters, Chocolate spot Disease Severity (%), AUDPC (%-days) and Disease Progress Rate (r) (units per day) (Table 3). On both varieties, there was not statistical difference between treatments for chocolate spot severity during the first two scoring periods. Similar the work of [17] and [18] justifies this result and they reported that there is not statistically justifiable difference between treatments regardless of the resistant level of faba bean varieties during the early stage of disease development. The maximum chocolate spot severity of 50 % was recorded from unsprayed susceptible variety Mosisa. The second highest chocolate spot disease severity of 48.15 % was recorded from Gebelcho variety with no fungicide spray whereas lower chocolate spot severity of 23.15% and 29.32 % were recorded from Gebelcho variety sprayed four times and three times, respectively. Its agreed with similarly reported work that recorded the highest disease severity from unsprayed susceptible local variety while the lowest disease severity was recorded from moderately resistant Degaga variety sprayed at seven days interval [19]. Considering variety Mosisa, the lowest disease severity recorded was 29.63% after spraying the fungicide four times while the highest severity of 50% was recorded from unsprayed plot (Table 3). Again, this result is supported by [19] as they found that application of fungicide radically reduced disease severity and they observed high disease pressure on unsprayed plots. Chocolate spot severity showed an increasing trend with time as fungicide application frequency was decreasing (Figure 1). This trend was similarly reported by [17,19] when they found the increasing trend of diseases severity and other disease parameters with

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the decreasing in fungicide application. Similarly [20] have also reported the reduction of disease severity as the fungicide application was reducing.

ANOVA for chocolate spot disease progress rate (r) has shown statistically significant difference ($P<0.05$) between treatments. Higher disease progress rates (r) of 0.23360 units/day and 0.21370 units/day were recorded from unsprayed plots of Mosisa and Gebelcho varieties, respectively. On the other hand, lower disease progress rates of -0.00453 units/day and -0.00262 units/day were recorded from Gebelcho variety sprayed three times and four times, respectively. The same result was reported from the work of [21]. They reported the suppression of the apparent disease infection rate in sprayed plots by about six (6) times over unsprayed plots.

Table 3: Effect of Faba bean varieties and Fungicide application Frequencies on Chocolate spot Disease Severity (%), AUDPC (% days) and Disease Progress Rate (r).

Treatment	Chocolate spot PSI (%)	r (units/day)	AUDPC (%-days)
Mosisa No spray	50.00	0.23360	1730.6
Gebelcho No spray	48.15	0.21370	1672.2
Mosisa one time spray	42.59	0.04232	1477.8
Mosisa two times spray	41.05	0.07252	1406.5
Gebelcho one time spray	37.35	0.04293	1283.3
Gebelcho two times spray	34.57	0.00667	1212.0
Mosisa three times spray	34.26	0.00946	1199.1
Mosisa four times spray	29.63	0.00093	1050.0
Gebelcho three times spray	29.32	-0.00262	1037.0
Gebelcho four times spray	23.15	-0.00453	823.1
$LSD_{0.05}$	7.88	0.10	273.44
CV(%)	18.36	14.35	18.29

Regarding AUDPC, statistically significant difference was observed between treatments ($P<0.05$). The highest AUDP (1730.6%-days) was recorded from unsprayed plot of Mosisa (susceptible) variety whereas the lowest AUDPC (823.1%-days) was recorded from Gebelcho (moderately resistant) variety sprayed four times (Table 4). Similarly [22] reported the highest AUDPC of 1817%-days from susceptible faba bean variety which has not received any fungicide spray and the lowest AUDPC of 595%-days from moderately resistant variety which has received fungicide spray at seven (7) days interval.

With regard to grain yield and yield components, ANOVA showed significant differences ($P<0.05$) among the treatments for number of pods per plant (No. pod/plant), Thousand Kernel Weight (TKW) and grain yield (grain yield (kg/ha)). The highest number of pods per plant (15.28) and the lowest number of pods per plant (11.17) were recorded from Gebelcho variety sprayed two times and 1 time, respectively [23.24] reported that the highest number of pods per plant was recorded from moderately resistant variety sprayed with a fungicide. The highest and the lowest TKW of 662.60 g and 417.73 g were recorded from Gebelcho variety sprayed three times and Mosisa variety with no fungicide spray, respectively. Application of fungicide on moderately resistant faba bean variety increases thousand kernel weights of the faba bean grain [20,23]. Similarly [23,24], have also reported the reduction trend of faba bean TKW as the fungicide spray is decreasing.

Regarding grain yield, the highest grain yield of 3515.44kg/ha was recorded from variety Mosisa sprayed four times whereas the lowest grain yield of 1705.5kg/ha was recorded from Gebelcho variety with no fungicide spray (Table 2). The fungicide application frequency influences faba bean yield as faba bean grain yield shows a decreasing trend with decreasing

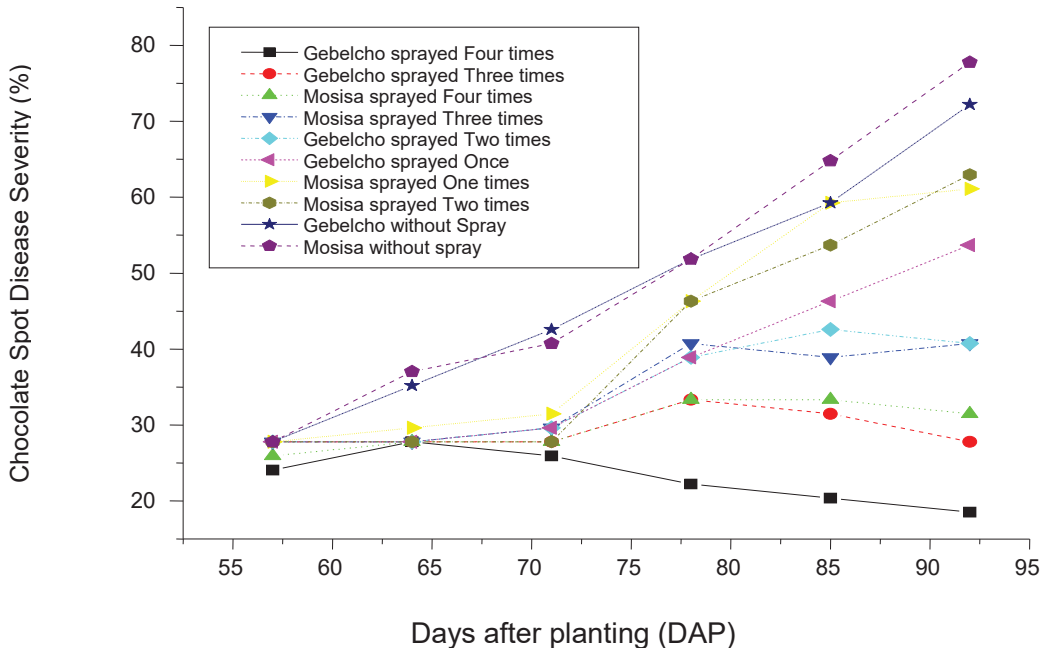

Figure 1: Influence of fungicide spray and varieties on chocolate spot development.

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Table 4: The effect of varieties and fungicide application on disease severity, yield and yield components of faba bean

Treatment	No. pod/plant	No. seed/plant	TKW	Grain yield (kg/ha)
Mosisa No spray	13.78	14.06	417.73	2072.20
Gebelcho No spray	13.61	15.06	564.43	1705.50
Mosisa one time spray	12.50	16.11	435.17	2505.90
Gebelcho one time spray	11.17	13.72	639.27	1899.00
Mosisa two times spray	15.17	19.28	431.10	2513.5
Gebelcho two times spray	15.28	18.06	660.87	2090.70
Mosisa three times spray	12.83	15.22	442.43	3160.70
Gebelcho three times spray	13.94	16.28	662.60	2433.10
Mosisa four times spray	12.94	17.56	435.17	3515.40
Gebelcho four times spray	13.33	13.33	646.80	3313.70
$LSD_{(0.05)}$	3.63	NS	62.02	914.29
CV(%)	23.29	15.36	10.02	32.57

fungicide application frequency [21]. Similarly [23,24] and [22] have found that faba bean grain yield has decreased when the fungicide application decreases and they found the highest grain yield from plots which have received the highest frequency fungicide application. Host plant resistance is also one of the varietal factor which influences fungicide application frequency and faba bean grain yield. This study has revealed the effect of host plant resistance on faba bean yield. Mosisa variety is found to be susceptible and tolerant to chocolate spot disease while Gebelcho variety is moderately resistant to chocolate spot. At all level of fungicide spray, the highest chocolate spot disease severity was recorded from Mosisa variety. But, regardless of the disease severity scores of Mosisa variety, the highest grain yield was recorded from Mosisa variety at all frequencies of fungicide spray. This is because of the tolerance of the Mosisa variety to chocolate spot.

Partial budget analysis

Partial budget analysis has depicted the highest marginal benefit of 41044.8ETB ha^{-1} from Mosisa variety sprayed with Mancozeb 80% WP four times at weekly interval and the second highest marginal benefit of 38624.4ETB^{-1} was recorded from Gebelcho variety sprayed four times. The lowest marginal benefit of 20466ETBha^{-1} was obtained from unsprayed Gebelcho variety with no fungicide spray (Table 2). Similarly, the highest marginal rate of return (1726.11%) was obtained from Mosisa variety sprayed once and the second highest marginal benefit of 1592.84% was recorded from Gebelcho variety sprayed four times using a fungicide mancozeb 80% WP. This indicates that for every 1.00 ETB invested to spray Mancozeb 80% WP to produce faba bean, it gives a return of 17.26ETB and 15.93ETB from Mosisa variety sprayed once and Gebelcho variety sprayed four times, respectively. Therefore, partial budget analysis has depicted that production of Faba bean variety Mosisa sprayed once with Mancozeb 80% WP for the management of chocolate spot optimizes the profitability from faba bean production under small scale agriculture/small holder farmers' condition and production of faba bean variety Mosisa with four times application of fungicide also gives high marginal rate of return (1419%) and the highest marginal benefit of 41044.8ETB ha^{-1}. For those farmers who produces faba bean for export market, production of Gebelcho variety sprayed four times with a fungicide Mancozeb 80% WP maximizes the benefit from faba bean production.

Discusion and conclusion

Faba bean (*Vicia faba L.*) is one of the most important pulse crops produced in Bale highlands. It is also one of the most important food legumes due to its high nutritive value terms of protein contents (24-30%) and also is an excellent nitrogen fixer. Regardless of the potential of the area to grow faba bean, there are numerous biotic and abiotic constraints limiting productivity of the crop. Chocolate spot disease is one of the major faba bean diseases limiting Faba bean productivity on the highlands of Bale. Chocolate spot epidemic occurs and causes significant yield losses in the highlands of Bale as most of the farmers are growing local cultivars.

The results from this experiment have shown that the application of fungicide, Mancozeb 80% WP has resulted in significant disease severity reduction and subsequent increment in yield. Hence, Fungicide is one of the key production packages of faba bean on the highlands of Bale and similar faba bean growing agro-ecologies. The highest grain yield of 3515.4kg/ha was recorded from Mosisa variety sprayed four times and the lowest grain yield of 1705.50 kg/ha was obtained from Gebelcho variety with no spray. Partial budget analysis has depicted the highest Marginal Benefit (MB) of 41044.8ETBha^{-1} and the lowest MB of 20466ETBha^{-1} from Mosisa variety sprayed four times and Gebelcho variety with no fungicide sprays, respectively. The highest Marginal Rate Of Return (MRR) of 1726.11% and the lowest MRR of 686.63% were obtained from Mosisa variety sprayed once and Gebelcho variety sprayed three times, respectively. The plot with the highest marginal benefit (41044.8 ETBha^{-1}) has found to have the third maximum MRR of 1419.16%.

For small holder farmers Mosisa variety supported by three times of fungicide spray to maximize the marginal benefit to 41044.8 birr/ha for those who can afford to spray a fungicide three times. For large scale farmers who are producing the crop for export market, it is wise to recommend variety Gebelcho with four times application of a fungicide mancozeb 80% WP for the management of chocolate spot which can give them a MRR of 1592.84% as this variety is a large seeded variety and has high demand on international market because of its seed size. The integrated system in general increased faba bean productivity and income benefit which can be recommended especially under subsistence farming system in Ethiopia.

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