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Research Article

Evaluation of Different Spray Frequency Levels of Fungicides against Ascochyta Blight (*Ascochyta fabae* S) Diseases of Faba Bean (*Vicia faba* L) in Northwestern Ethiopia

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Ascochyta blight disease is a major problem in faba bean (*Vicia faba* L) production that causes 90% to 100% yield loss. A field experiment was conducted to evaluate the efficacy of three fungicides with three spray frequency levels against Ascochyta blight disease of faba bean varieties. For the assessment of disease management, a total of 21 treatments were used, which comprised three fungicides, three spray frequencies, two varieties, and control. The field experiment was arranged in a randomized complete block design with factorial combinations of variety, fungicide, and spray frequency levels in three replications. An analysis of variance was performed for disease, yield, and yield related and plant growth parameter data, using the Statistical Analysis System (SAS, 2003) version 9.1.3 software. The economic data obtained from the field experiment was analyzed using the partial budget analysis method. The results showed that area under disease progress curve, percent severity index, disease progress rate, and percent disease incidence had strong mean significant differences ($p < 0.01$) between treated and untreated plots. Application of fungicide significantly increased plant height, stem girth, pod per plant, grain yield, and harvesting index ($p < 0.01$) over untreated plots. Greater total return (195,938 Ethiopian birr ha^{-1}), net return (101,761.3 Ethiopian birr ha^{-1}), and net benefit (34,768.17 Ethiopian birr ha^{-1}) were obtained by EH00102-4-1 variety, in two times Mancolaxyl treatment. The linear regression analysis result (R^2) indicated that the variation in average grain yield of EH00102-4-1 and local susceptible varieties, due to the mean area under the disease progress curve, was 64.50% and 68.64%, respectively. Therefore, the use of EH00102-4-1 variety, with two times Mancolaxyl spray frequency application, at early growth stage and the onset of the disease is suggested as an agronomic management option, in Northwestern Ethiopia.

1. Introduction

Faba bean (*Vicia faba* L) plays a key role in biological nitrogen fixation process by adding up to 40% soil organic nitrogen available for the next crop [1]. The report of Guar et al. [2] and Sillero et al. [3] revealed that faba bean can be used as a common breakfast food and major source of plant-based protein in the Middle East, Mediterranean region, China, and Ethiopia. Worldwide faba bean production occupied 2.43 million hectares and 4.40 million tons. Its world average grain yield productivity is around 1.81 t ha^{-1}. Faba bean production is concentrated in nine major agro-ecological regions: the Mediterranean Basin, the Nile Valley, Ethiopia, Central Asia, East Asia, Oceania, Latin America, Northern Europe, and North America [4]. China leads the world faba bean production both in area coverage and production [4].

Ethiopia is the world's second largest producer of faba bean next to China; its share is 21.03% and 40.5% of the world's production, respectively [4]. According to the reports of Gememechu et al. [5] and CSA, 2018 [6], in Ethiopia, faba bean takes the largest share of the area and production; it occupies a total of 443,107.88 ha of land with annual production of 838,803.20 tons. Its average national productivity is 1.77 t ha^{-1}, where Oromia, Amhara, South Nation and Nationality People (SNNP), hereafter regional state, and Tigray regional states are the major producing regions [5, 6]. These four regions cover almost all of the total faba bean production of the country. Oromia regional state alone takes the largest faba bean area (42.98%) and contributes to the highest production (48.26%) of the country, followed by Amhara regional state which takes 39.06% of the area and contributes 36.34% to the national's production [5, 6].

In the mid and highlands of Northwestern Ethiopia, faba bean is an economically important and the major pulse crop cultivated, which is used both as a staple food and cash crop that mitigates seasonal food shortages in the region [6, 7]. However, the productivity of faba bean stayed far below its potential (1.77 t ha^{-1}) due to abiotic and biotic factors [7, 8]. Among the various faba bean production problems, biotic factor has always been the major limiting constraint [9, 10]. The crop is severely attacked by seven major fungal diseases, of which the three most economically important foliar diseases are chocolate spot (*Botrytis fabae*), Ascochyta blight (*Ascochyta fabae* S), and Rust (*Uromyces viciae fabae*) [7, 10]. Ascochyta blight is an economically important disease of faba bean, which limits the growth, photosynthetic activity, and productivity of the crop [9, 11, 12].

According to the survey assessment reports of Hailu et al. [8], Ahmed et al. [13], Anteneh et al. [7], and Tessema et al. [10], Ascochyta blight disease is a major problem in the mid- and highlands of Northwestern Ethiopia, which causes total crop failure under severe epidemic conditions and leads to a yield loss that can be as high as 90% to 100% in highly susceptible faba bean varieties. The survey assessment report of Tessema et al. [10] also described that slope, weed infestation, farming system, cropping season, plant population, and land preparation are some of the agronomic factors that may influence the severity of Ascochyta blight disease.

Effective and integrated fungal disease management strategies of faba bean includes the choice of planting date, the use of healthy seed, the use of resistant faba bean varieties, and low seeding rate [14–17]. As discussed by Shtiebreg et al. [18], the removal of infected and infested plant debris, rotating faba bean with nonhost cereal crops, and wide row spacing could also play an important role in reducing fungal disease severity. However, if the fungal disease of faba bean is assumed to be in a serious condition, fungicide foliar sprays, once every two weeks (a total of eight applications), is recommended [9].

As reported by Matthews and Carpenter [19], Gan et al. [20] and Kumar et al. [9], 2 to 3 times foliar spray of Mancozeb at the rate of 2 kg ha^{-1}, Chlorothalonil, Carbendazim, Mankocide, and Mancolaxyl at the rate of 3 kg ha^{-1}, on the onset of the disease, at flowering and/or pod setting growth stages, could control fungal disease of faba bean, and can increased the yield of faba bean by 58% over untreated plots. Tripathi et al. [11] and McMurray et al. [21] reported that Ascochyta blight disease in faba bean can also be controlled in 3 time's foliar spray of carbendazim at the rate of 2.5 kg ha^{-1} in 10 days interval, during the onset of the disease.

As discussed by Sahile et al. [22] and Habtamu et al. [23], local susceptible and moderately tolerant faba bean varieties integrated with different fungicide spray frequency levels are the only available management options that could help to control the disease and mitigate yield loss of faba bean in north east and central Ethiopia. In addition, the application is also sensible, as there are no alternatives to shift to new management options in these study areas [22]. However, in Northwestern Ethiopia, faba bean varieties integrated with different fungicide spray frequency levels have not been given comparative attention or studied. Therefore, the present study was conducted to evaluate the efficacy of three fungicides with three spray frequency levels against Ascochyta blight disease of faba bean varieties.

2. Materials and Methods

2.1. Experimental Site Description. The field experiment was conducted at farmers training center (FTC) hereafter for two years (2020 and 2021), in the main cropping season, under rain feed conditions, in Dabat District, Northwestern Ethiopia (Figure 1). The experimental site is located at 14°42′85.1″N latitude and 37°19′90.0″E longitude, with an altitude of 2720 meter above sea level (m.a.s.l.). It is 75 km north of the historical city of Gondar. The location represents the major faba bean producing area of the district. The cultivated land of the district was 36,213 ha and out of this, 2445 ha was used for faba bean cultivation, and 22,970 tons of faba bean were produced by the cropping seasons of 2019 to 2020 from this cultivation land. The local faba bean varieties production potential in the area was 1.6 t h^{-1} and the improved faba bean varieties' production potential was 2 t h^{-1} (Dabat Agriculture Department office, 2021 unpublished annual crop production report, and personal communication).

According to the survey assessment report of Anteneh et al. [7], the average annual minimum and maximum temperatures of the district are 15°C and 24°C, respectively. The area has a unimodal rainfall system. The average annual rainfall also ranges from 775 mm to 800 mm. In addition, the rainy season usually extends from May to the end of October, and the dominant soil in the district is Vertisol.

2.2. Evaluation of Fungicides, Spray Frequencies, and Varieties for the Management of Aschochyta Blight Disease. A field experiment was conducted in the main cropping season of the years 2020 and 2021 for the evaluation of faba bean Ascochyta blight disease using varieties, fungicides, and spray frequency levels. Two varieties of faba bean viz. Hachalu, moderately tolerant (EH00102-4-1) hereafter, and local susceptible varieties were used (Table 1).The varieties were obtained from Gondar Agricultural Research Center (GARC) hereafter.

Three fungicides viz. two systemic and contact fungicides (Mancolaxyl and Mankocide) and a contact fungicide, Mancozeb, were used individually in different spray frequency levels to test their efficacy against Ascochyta blight disease [9]. Spray frequency was scheduled at 10 days interval for applying contact fungicides and 14 days interval for

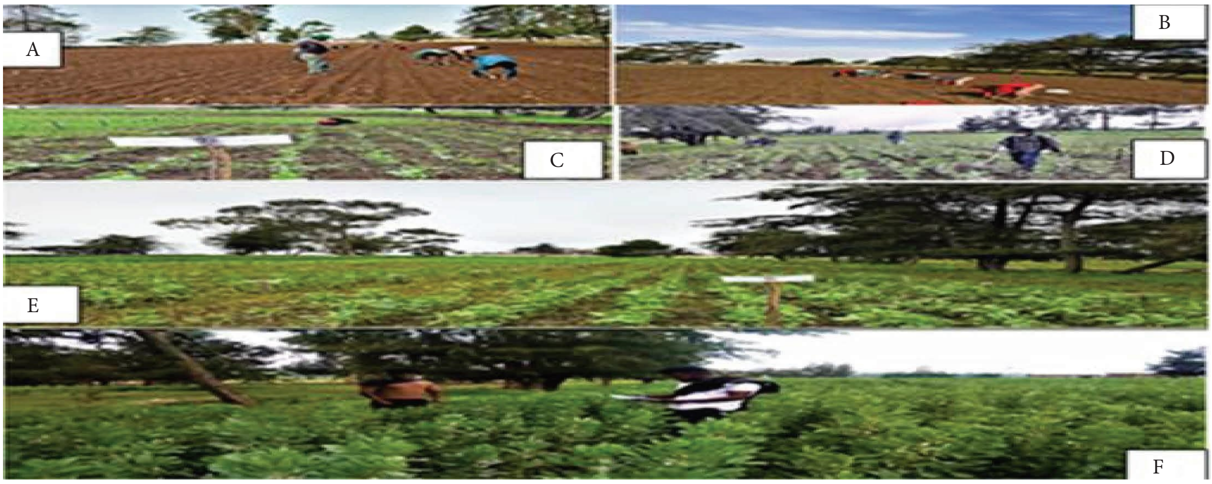

Figure 1: Field experiment sight, which demonstrates, faba bean planting (a, b), weeding (c), fungicide spray (d), mid-growth stage (e), and flowering stage (f).

Table 1: Faba bean varieties used for the experiment.

No.	Varieties	Seed source	AR (m.a.s.l)	YR	Seed class	Productivity (t ha^{-1})
1	Hachalu, (EH00102-4-1)	GARC/ HARC	1800–3000	2010	Breeders seed	2.5–3.5
2	Local susceptible	GARC	1800–3000	—	Breeders seed	1.7655

Source: Ethiopian Institute of Agricultural Research [24, 25].

systemic fungicides, with their recommended doses (Table 2). Mankocide and Mancolaxyl fungicides were applied at the rate of 3 kg ha^{-1}and Mancozeb fungicide at the rate of 2 k gha^{-1} [9]. Spraying of fungicides was started in the flowering and/or pod setting growth stages, at the onset of the disease and continued according to the spray schedule designated for each treatment (Table 2). Control plots were kept unsprayed during the experiment. Spraying of the fungicides was performed using knapsack sprayers with 400, 200, and 300 liters ha^{-1}of water for Mancozeb, Mankocide, and Mancolaxyl fungicides, respectively (Table 2).

2.3. Treatment and Experimental Design. For the assessment of disease management, a total of 21 treatments were used, which comprised three fungicides, three spray frequencies, two varieties, and control. The field experiment was arranged in a randomized complete block design with factorial combinations of variety, fungicide, and spray frequency levels in three replications. Each plot had an area of 12 m^2 and contained 10 rows of 4 m long. The space between plots and blocks were 1 m and 1.5 m, respectively. The space between plants was 10 cm and rows was 40 cm. Fungicides were applied at three spray frequency levels. The time of application was during flowering and/or at pod setting growth stages. Pure water was sprayed as a mock treatment in control plots. The middle 8 rows were considered for data collection to minimize border effects. Other agronomic practices were practiced as recommended.

2.4. Data Collection and Analysis

2.4.1. Disease Assessment. Disease parameter data such as percent severity index (PSI), percent disease incidence (PDI), area under disease progress curve (AUDPC), and disease progress rate (DPR) were collected and analyzed. The disease incidence and severity were recorded from twelve pretagged plants in the eight harvestable central rows of each plot. Disease assessment was taken every seven days interval, starting from the first appearance of the disease.

Disease incidence of Ascochyta blight was assessed by counting the number of diseased plants per total number of plants inspected and expressed as percentage (%) of total plants. PDI was computed (calculated) using the formula of Wheeler [27]:

$$\text{PDI} = \frac{\text{number of plants infected}}{\text{total number of plants observed}} \times 100. \quad (1)$$

Disease severity was recorded by estimating the percentage (%) of leaf area diseased using the 1–9 disease scoring scales of ICARDA [28]. The severity scales (grades) were then converted into PSI for analysis using the formula of Wheeler [27]:

$$\text{PSI} = \frac{\text{Snr}}{\text{Npr} \times \text{Mss}} \times 100, \quad (2)$$

where Snr = sum of numerical rating, Npr = number of plants (leaves) rating, and Mss = maximum severity scale.

The effects of fungicides on the disease severity were calculated as AUDPC values (%-day) by using the formula of Campbell and Madden [29]:

Table 2: Fungicides with spray frequencies used for Ascochyta blight disease management.

Common name	Rate (kg/ha)	Active ingredient	FSF	Spray schedule
Mancozeb (Unizeb 80% WP)	2 kg/400 L	Manganese^{++}15.00%, zinc^{++}1.9%, ethylene bisdithiocarbamate ion 58.1%	One time	Disease onset
			Two times	Disease onset and once after 10 days interval
			Three times	Disease onset and two times at 10 days interval
Control	—	—	Untreated	Unsprayed
Mankocide (VITRA 50% WP)	3 kg/200 L	Mancozeb 15.0% copper hydroxide 46.1%	One time	Disease onset
			Two times	Disease onset and once after 14 days interval
			Three times	Disease onset and two times at 14 days interval
Control	—	—	Untreated	Unsprayed
Mancolaxyl (MAN700WP/01)	3 kg/300 L	Mancozeb 640 + metalaxyl 80	One times	Disease onset
			Two times	Disease onset and once after 14 days interval
			Three times	Disease onset and two times at 14 days interval
Control	—	—	Untreated	Unsprayed

Source: (pulse point 16, NSW agriculture, 19 November 2004) [26], FSF = fungicide spray frequency.

$$\text{AUDPC} = \sum_{i=1}^{n-1} 0.5\,(xi + (xi + 1))\,(ti + (1 - ti)), \quad (3)$$

where n is the total number of assessments, ti is the time of the i^{th} assessment in days from the first assessment date, and xi is the percentage of disease severity at i^{th} assessment.

To calculate the DPR, first the PSI data were transformed by using Logistic ($L = \log(y/(y-1))$ and Gombertez ($G = \text{Log}$ $(1/\text{Log}\ (1/Y))$ models, where $y = \text{severity}/100$. Then the transformed data were subjected to Statistical Analysis System (SAS) software version 9.13 (SAS 2003) and regressed by using the PROC REG procedure that helped to select the DPR of the fittest model.

The plant growth data such as plant height (PH), stem girth (SG), and growth phonology (days to 50% flowering and days to 95% maturity) were collected. The yield and related data such as number of pod per plant (NPPP), number of seed per pod (NSPP), grain yield (GY), relative yield loss (RYL), marginal rate of returns (MRR), and harvesting index (HI) were collected and calculated. The RYL, MRR, and HI data were calculated by using the formula provided by CIMMYT [30]:

$$\text{RYL}\,(\%) = \frac{\text{PY} - \text{AY}}{PY}\ X\,100, \quad (4)$$

where PY=potential yield and AY = actual yield.

$$\text{HI} = \frac{\text{economical yield (grain yield) (Kg/ha)}}{\text{biological yield (Kg/ha)}}\ \text{x}\,100. \quad (5)$$

Yield per plot was converted into yield of kg ha^{-1}.

$$\text{MRR}\,(\%) = \frac{\Delta NI}{\Delta \text{IC}}\ \text{X}\,100, \quad (6)$$

where MRR = marginal rate of returns, ΔNI = change in net income compared with control, and ΔIC = change in input cost compared with control.

2.4.2. Cost-Benefit Analysis. To evaluate the cost-benefit (economic) advantages linked with each treatment, a partial budget analysis [30] was performed, using the costs of inputs and the sales of outputs with the current prices of each harvesting season. The price (cost) of the inputs used, such as, fungicides, seed, and labor costs per plot, were recorded. The total variable cost (TVC) was calculated as the sum of input costs (seed, fungicide, and labor), while other production costs such as local material and spray equipment were treated as uniform across treatments. All costs per plot were converted in to hectare basis (kg ha^{-1}) and multiplied by the current average farm get price (Ethiopian birr per kilogram (ETB kg^{-1}). The gross benefit or total return (TR) was calculated as the sum of outputs (income from selling grain yield and dry biomass). The average farm get price (ETB kg^{-1}) of faba bean grain and dry biomass was assessed and recorded during the harvesting seasons. The net return (NR) of each fungicide treatment was obtained by deducting the TVC from TR. The net benefit (NB) or increase in net return due to fungicide application was calculated by deducting the NR from the return of the unsprayed plots. Sensitivity analysis was performed considering/assuming that faba bean grain and dry biomass sale prices were reduced by 10% as recommended by CIMMYT [30]. Therefore, faba bean grain yield was adjusted down by 10%, to resemble faba bean field experiment production from a bigger area (hectare). Dominance evaluation was performed by comparing the NB (increase in net return) values of treatments, i.e., treatments that had lower NB were considered as dominated treatments. The marginal rate of return (MRR %) was calculated as the ratio of change in net income compared with the control and change in input cost compared with the control. Treatments with MRR < 100% or negative values were considered as nonprofitable and excluded. The profitable (nonexcluded) treatments were compared (evaluated) by their NB values, i.e., those that had the highest NB were considered the most economically feasible, while those that had the lowest NB was considered the least economically feasible. Finally, all recorded data were analyzed for the evaluation of significance.

2.4.3. Statistical Analysis. Analysis of variance (ANOVA) was performed using the proc ANOVA procedure of the Statistical Analysis System (SAS) software (SAS, 2003). The least significant difference (LSD) was used to separate treatment means at 5% of significance level. To evaluate the cause and effect relationship of the pattern of disease epidemic (AUDPC) of faba bean Ascochyta blight disease with average grain yield, correlation and simple linear regression analyses of AUDPC and average grain yield were done [31].

3. Results and Discussion

3.1. Ascochyta Blight Disease Incidence and Severity. Application of fungicides, with spray frequencies, showed strong significant differences ($P < 0.01$) in disease incidence and severity, on both varieties (Table 3). The highest disease incidence (74.1%) and severity index (30.1%) were recorded in unsprayed control plots on local susceptible varieties, while the lowest disease incidence (60.8%) and severity index (13.98%) were recorded in two times Mancolaxyl treated plots, on EH00102-4-1variety. The mean disease severity index and disease incidence recorded, in unsprayed plots, on EH00102-4-1 variety, were 24.7% and 70.52%, respectively (Table 3).

The data analysis result in Table 3 indicates that the percent disease incidence and severity index of Ascochyta blight were significantly reduced in Mancolaxyl two times treated plots, on EH00102-4-1 variety, over the untreated plots that contained both faba bean varieties. This might be due to the fact that the systemic and contact fungicide Mancolaxyl might reduce the load of primary infection and the spread of secondary inoculums between neighboring plants, preventing further systemic disease development, as similarly reported by Matthew and Carpenter [19].

The result is in line with the work of Kumaar et al. [9], who reported that foliar spray of Mancolaxyl 700 WP, once every two weeks (a total of eight applications), controlled

Table 3: Effect of fungicides and spray frequencies on the disease parameters of Ascochyta blight in faba bean varieties.

		Variety							
		Hachalu (EH00102-4-1)				Local variety (baqyla)			
		Disease parameters				Disease parameters			
Fungicides	SF	DPR	AUDPC	PSI	PDI	DPR	AUDPC	PSI	PDI
Mancozeb	SF1	0.65^{f}	143.5^{d}	20.9^{c}	65.1^{de}	0.66^{f}	152.0^{d}	26.3^{c}	68.6^{de}
	SF2	0.57^{g}	134.3^{f}	19.4^{d}	61.8^{f}	0.58^{g}	142.8^{f}	24.8^{d}	65.3^{f}
	SF3	0.71^{de}	153.9^{b}	22.7^{b}	66.4^{cd}	0.72^{de}	162.4^{b}	28.1^{b}	69.9^{cd}
Mancocide	SF1	0.77^{c}	147.0^{c}	19.9^{dc}	67.1^{cb}	0.78^{c}	155.5^{c}	25.3^{dc}	70.6^{cb}
	SF2	0.68^{fe}	137.8^{e}	19.3^{de}	63.9^{e}	0.69^{fe}	146.3^{e}	24.7^{de}	67.3^{e}
	SF3	0.82^{b}	158.7^{a}	23.4^{b}	69.4^{b}	0.83^{b}	167.2^{a}	28.8^{b}	71.9^{b}
Mancolaxyl	SF1	0.65^{f}	138.5^{e}	14.6^{f}	64.1^{e}	0.66^{f}	147.0^{e}	20.0^{f}	67.6^{e}
	SF2	0.50^{h}	129.28^{g}	13.95^{f}	60.8^{f}	0.51^{h}	137.8^{g}	19.4^{f}	64.3^{f}
	SF3	0.76^{dc}	149.6^{c}	18.1^{e}	65.4^{cde}	0.77^{dc}	158.1^{c}	23.5^{e}	68.9^{cde}
	Control	0.92^{a}	157.69^{a}	24.70^{a}	70.52^{a}	0.92^{a}	166.19^{a}	30.1^{a}	74.1^{a}
	Mean	0.7	145.02	19.7	65.32	0.71	153.52	25.11	68.83
	CV%	3.96	1.14	3.81	1.61	3.9	1.07	2.99	1.53
	LSD ($P < 0.01$)	0.058**	2.83**	1.29**	1.81**	0.05**	2.83**	1.29**	1.81**

Means within the same column followed by the same letter are not significantly different at 5% and 1% probability levels. ** ($P < 0.01$) and * ($P < 0.05$), SF = spray frequencies, PDI = percent disease incidence, DPR = disease progress rate, AUDPC = area under disease progress curve, PSI = percent severity index, CV = coefficient of variance, and LSD = least significance difference.

chocolate spot and Ascochyta blight disease and increased faba bean yield by 58% over untreated plots. As discussed by Matthews and Carpenter [19], fungicides like Mancozeb, Chlorothalonil, and Mancolaxyl are the better options for the management of Ascochyta blight disease of faba bean. Furthermore, the research finding reports, Mohammed et al. [32], also described that, Mancolaxyl foliar spray two times within 10 to 20 days interval can reduce the disease severity of common bean Anthracnose (*Colletotrichum lindemuthianum)* by 30% over the control.

3.1.1. Disease Progress Rate and Area under Disease Progress Curve. The highest area under disease progress curve (166.19%) and disease progress rate (0.92) were recorded in unsprayed plots, on local variety. In plots treated with Mancolaxyl for two times, the lowest area under disease progress curve (129.28%) and disease progress rate (0.5) were recorded on EH00102-4-1 variety. Also, in unsprayed plots on EH00102-4-1 variety, 157.69% area under disease progress curve and 0.92 disease progress rates were recorded. The area under disease progress curve and disease progress rate showed strong significance difference ($P < 0.01$) between treated and untreated plots (Table 3).

In plots treated with Mancolaxyl for two times, on EH00102-4-1 variety, area under disease progress curve and disease progress rate was significantly reduced, over untreated plots that contained both faba bean varieties. This might be due to the fact that the contact and systemic fungicide Mancolaxyl might be effective in reducing the quantity of disease intensity, the apparent infection rate, and the duration of faba bean Ascochyta blight disease epidemics during the field experiment. Similarly, the research finding of Amelework et al. [31] showed that foliar sprays of Othello Top, Mancozeb, and Mancolaxyl significantly reduced the area under the disease progress curve of Ascochyta blight disease over the control plots.

According to the field experiment report of Amelework et al. [31], lower area under disease progress curve (1879%, 1919%, and 1968%) was also recorded in Othello Top spray every one week, Mancolaxyl spray every two weeks, and Mancolaxyl spray every one week, respectively, while higher area under disease progress curve (2839%) was recorded in unsprayed control plots. In line with the research finding of Amelework et al. [31], the disease parameter data analysis result of this study clearly indicated that Ascochyta blight percent disease incidence, percent disease severity index, area under disease progress curve, and disease progress rate were considerably reduced in Mancolaxyl two times treated plots over Mankocide treated and untreated plots, on both faba bean varieties.

3.2. Faba Bean Growth Parameters

3.2.1. Growth Phonology. In all fungicides with spray frequencies treated and untreated plots, on both faba bean varieties, the number of days taken to see 95% of maturity ranged between 120 and 122.3 days. The numbers of days taken to see 50% of flowering, in all fungicides with spray frequencies treated and untreated plots, on both faba bean varieties also ranged between 70 and 80 days (Table 4). The result in Table 4 describes that both the growth phonology parameters (95% DTM and 50% DTF) had no significant difference ($P < 0.01$) between fungicides with spray frequencies treated and untreated plots. Similarly, Mucella et al. 2004 [33] reported that fungicide treatment had not significant effect on legume crop growth phonology.

3.2.2. Plant Height and Stem Girth. In plots treated with Mancolaxyl for two times, on EH00102-4-1 variety, the highest plant height (90.58 cm) and stem girth (1.43 mm) were recorded, while, in untreated plots, on local susceptible variety, the lowest plant height (77.82 cm) and stem girth

Table 4: Effect of fungicides and spray frequencies on the growth parameters of faba bean varieties.

		Variety							
		Hachalu (EH00102-4-1)				Local (baqyla)			
		Growth parameters				Growth parameters			
Fungicides	SF	PH	SG	DTF	DTM	PH	SG	DTF	DTM
Mancozeb	SF1	85.2^{dce}	0.95^{c}	70.3^{c}	120.7^{b}	82.7^{dce}	0.65^{c}	71.7^{cb}	120.7^{b}
	SF2	89.58^{ba}	1.35^{a}	72.0^{b}	120.7^{b}	87.1^{ba}	1.05^{a}	70.0^{c}	120.7^{b}
	SF3	84.6^{dce}	0.85^{dce}	70.3^{c}	120.3^{b}	82.1^{dce}	0.55^{dce}	70.3^{cb}	120.7^{b}
Mancocide	SF1	84.2^{de}	0.77^{dfe}	71.7^{b}	120.7^{b}	81.7^{de}	0.47^{dfe}	70.0^{c}	120.3^{b}
	SF2	88.6^{b}	0.82^{dfce}	80.0^{a}	122.3^{a}	86.1^{b}	0.52^{dfce}	80.0^{a}	122.3^{a}
	SF3	83.6^{e}	0.73^{fe}	70.0^{c}	120.3^{b}	81.1^{e}	0.43^{fe}	80.0^{a}	122.3^{a}
Mancolaxyl	SF1	86.2^{c}	1.12^{b}	70.0^{c}	120.7^{b}	83.7^{c}	0.82^{b}	73.3^{b}	120.7^{b}
	SF2	90.58^{a}	1.43^{a}	70.3^{c}	120.3^{b}	88.1^{a}	1.13^{a}	70.0^{c}	120.3^{b}
	SF3	85.6^{dc}	0.90^{dc}	72.0^{b}	120.7^{b}	83.1^{dc}	0.60^{dc}	70.0^{c}	120.7^{b}
	CONT	80.3^{f}	0.69^{f}	80.0^{a}	122.3^{a}	77.82^{f}	0.39^{f}	80.0^{a}	122.3^{a}
	Mean	85.83	0.96	72.67	120.9	83.34	0.66	73.53	121.1
	CV%	1.16	9.1	0.73	0.33	1.19	13.24	2.46	0.33
	LSD($P < 0.01$)	1.7^{**}	0.15^{**}	0.9^{NS}	0.68^{NS}	1.7^{**}	0.15^{**}	3.11^{NS}	0.68^{NS}

Means within the same column followed by the same letter are not significantly different at the 5% and 1% probability level. ** ($P < 0.01$) and * ($P < 0.05$), NS = no significant difference, SF = spray frequencies PH = plant height, SG = stem girth, DTF = 50% days to flowering, DTM = 95% days to maturity, CV = coefficient of variance, and LSD = least significant different.

(0.39 mm) were recorded. In plots treated with Mancolaxyl for two times, on EH00102-4-1 variety, 89.58 cm PH and 1.35 mm SG were recorded (Table 4). PH and SG had strong significance difference ($P < 0.01$) between fungicides; with spray frequencies treated and untreated plots (Table 4). As similarly, reported by Muehlbauer and Rajesh [34], this might be due to the synthesis of proteins, RNA, free amino acids and soluble sugars, activated by fungicide treatment, and it might be an advantage for the subsequent growth phase of the plant.

3.3. Faba Bean Yield and Yield Related Parameters

3.3.1. Seeds per Pod and Pod per Plant. The data analysis result in Table 5 indicates that NSPP had no significant difference ($P < 0.01$), while NPPP had strong significance difference ($P < 0.01$) between treated and untreated plots. In all fungicides with all spray frequency level treated plots, on both faba bean varieties, the NSPP recorded were 03. The NPPP recorded by EH00102-4-1 variety, in two times Mancozeb and Mancolaxyl treated plots were 28 and 31, respectively. In unsprayed control plots, on EH00102-4-1 and local susceptible varieties, 16 and 14 NPPP were obtained, respectively (Table 5).

This considerable increase of NPPP, might be, due to Mancolaxyl and Mancozeb fungicide treatments favored (activated) the plant to produce high tiller number and lateral branches, which in turn helped to increase plant population and the production of more pods per plant (Figure 1). Similarly, Gan et al. [35] and Chang et al. [36] reported that the increased grain yield with high plant population is attributable to the production of more pods per plant and more seeds per pod.

The decrease in NSPP and NPPP in unsprayed and Mankocide-treated plots, on both faba bean varieties, revealed that Ascochyta blight disease of faba bean had harmful effect against the production of NSPP and NPPP. This might be because as disease severity increases, NSPP and NPPP could be decreased. This research finding is in line with the work of Amin and Fufa [37] who reported that maximum NSPP and NPPP were recorded on sprayed plots by Othello Top and Mancozeb, whereas minimum NSPP and NPPP were recorded in plots without fungicide treatment.

3.3.2. Grain Yield, Harvesting Index, and Relative Yield Loss. In Mancolaxyl and Mancozeb, two times treated plots, on EH00102-4-1 variety, 4350.0 kg ha^{-1} and 4233.3 kg ha^{-1} average grain yield were obtained, respectively, while in untreated plots, on EH00102-4-1 and local susceptible varieties, 3100 kg ha^{-1} and 2675.0 kg ha^{-1} average grain yield were recorded, respectively. In Mancolaxyl and Mancozeb, two times treated plots, on local faba bean variety, 3933.33 kg ha^{-1} and 3816.67 kg ha^{-1} average grain yield were recorded (Table 5 and Figure 2).

On EH00102-4-1 variety, in Mancolaxyl and Mancozeb two times treated plots, 65.38 kg ha^{-1} and 48.64 kg ha^{-1} of harvesting index were recorded, respectively. In untreated control plots, on EH00102-4-1 and local susceptible varieties, 34.5 kg ha^{-1} and 31.51 kg ha^{-1} of harvesting index were recorded, respectively (Table 5). In Mancolaxyl and Mancozeb two times treated plots, on local susceptible variety, 62.38 kg ha^{-1} and 45.72 kg ha^{-1} of harvesting index were also recorded as mentioned. In two times Mancolaxyl and Mancozeb treated plots, on EH00102-4-1 variety, the lowest relative yield loss (18.89 kg ha^{-1} and 28.67 kg ha^{-1}) were recorded in the order mentioned, while in untreated plots, on EH00102-4-1 and local susceptible varieties, the highest relative yield losses (47.67 kg ha^{-1} and 50.67 kg ha^{-1}) were recorded, respectively (Table 5).

Grain yield, relative yield lose, and harvesting index had strong significant difference ($P < 0.01$) between fungicides with spray frequency treated and untreated

Table 5: Effect of fungicides and fungicide spray frequencies on yield and yield related parameters of faba bean varieties.

		Variety									
		Hachalu (EH00102-4-1)					Local (baqyla)				
		Yield and yield related parameters					Yield and yield related parameters				
Fungicide	SF	NSPP	NPPP	GY	RYL	HI	NSPP	NPPP	GY	RYL	HI
Mancozeb	SF1	2.7	25.0^{dc}	3908.3^{de}	33.7^{e}	44.0^{fe}	3.0	23.0^{dc}	3491.7^{de}	36.7^{e}	41.0^{fe}
	SF2	3.0	28.0^{b}	4233.3^{ba}	28.7^{f}	48.6^{d}	3.0	26.0^{b}	3816.7^{ba}	31.7^{f}	45.7^{d}
	SF3	3.0	22.0^{f}	3858.3^{e}	39.2^{d}	42.9^{fe}	2.7	20.0^{f}	3433.3^{e}	42.2^{d}	39.9^{fe}
Mancocide	SF1	3.0	20.7^{g}	3766.7^{f}	43.7^{c}	42.3^{f}	3.0	18.7^{g}	3350.0^{f}	46.7^{c}	39.3^{f}
	SF2	2.7	24.0^{de}	3791.7^{e}	38.6^{d}	45.4^{e}	3.0	22.0^{de}	3366.7e	41.6^{d}	42.4^{e}
	SF3	3.0	17.0^{h}	3866.7^{e}	46.0^{b}	37.5^{g}	3.0	15.0^{h}	3450.0f	49.0^{b}	34.5^{g}
Mancolaxyl	SF1	3.0	26.0^{c}	4141.7^{bc}	20.7^{h}	54.4^{b}	2.7	24.0^{c}	3716.7^{bc}	23.7^{h}	34.5^{b}
	SF2	3.0	31.0^{a}	4350.0^{a}	18.9^{i}	65.4^{a}	3.0	29.0^{a}	3933.3^{a}	21.9^{i}	62.4^{a}
	SF3	2.7	23.0^{fe}	4058.3^{dc}	24.8^{g}	51.4^{c}	3.0	21.0^{fe}	3641.7^{dc}	27.8^{g}	48.4^{c}
	CONT	3.0	16.0^{h}	3100.0^{g}	47.7^{a}	34.5^{h}	3.0	14.0^{h}	2675.0^{g}	50.7^{a}	31.5^{h}
	MEAN	2.9	23.27	3908.3	34.2	46.6	2.9	21.3	3487.6	37.2	43.65
	CV%	9.62	2.52	2.39	2.21	3.16	9.04	2.76	2.69	2.03	3.37
	LSD ($P < 0.01$)	0.48^{NS}	1.01**	0.188**	1.29**	2.53**	0.46^{NS}	1.01**	0.19**	1.29**	2.52**

Means within the same column followed by the same letter are not significantly different at the 5% and 1% probability levels, ** ($P < 0.01$) and * ($P < 0.05$), NS = no significant difference, SF = spray frequencies, NSPP = number of seed per pod, NPPP = number of pod per plant, GY = green yield (kg ha^{-1}), HI = harvesting index (kg ha^{-1}), RYL = relative yield loose (kg ha^{-1}), CV = coefficient of variance, and LSD = least significant different.

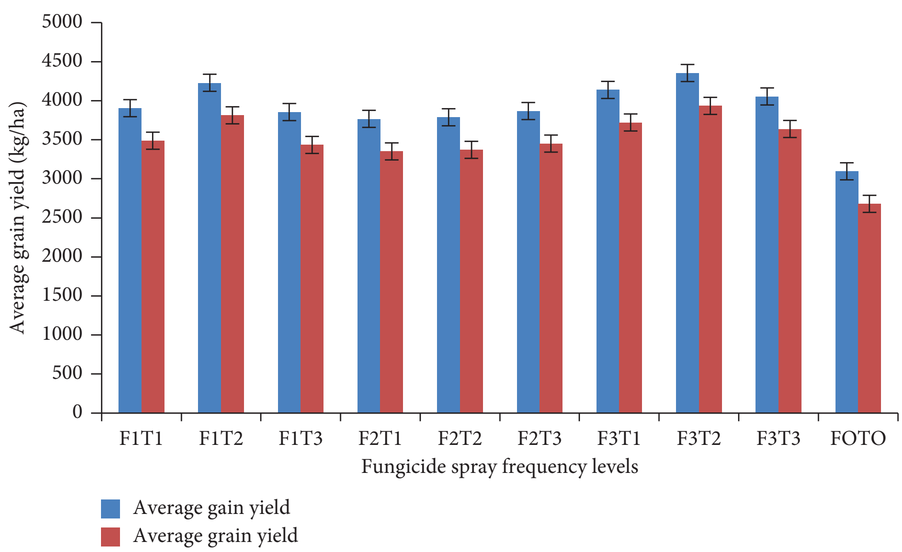

Figure 2: Bar graph of average grain yield vs fungicide spray frequency levels.

plots. Therefore, harvesting index and grain yield were considerably increased in two times, Mancolaxyl and Mancozeb treated plots, on EH00102-4-1 and local susceptible variety, over Mankocide treated and untreated plots, on both faba bean varieties. This might be due to the fact that photosynthesis reduction, stem to weaken or break, poor seed set, and general plant blight caused by Ascochyta blight disease might be reduced as a result of Mancolaxyl and Mancozeb fungicide treatment compared to Mankocide treated and untreated plots. Similarly, Chongo et al. [38] and Amin and Fufa [37] reported that fungicide application has significantly increased hundred seed weight, grain yield, and harvesting index and significantly reduced the relative yield lose over the untreated plots.

According to the field experiment report of Amin and Fufa [37] and Chongo et al. [38], fungicide application in legume crop chickpea has a substantial impact on grain yield, where the highest (4790 kg ha^{-1}) grain yield was obtained from Othello Top + Mancolaxyl fungicide treatment over untreated plots which had a yield loss, which ranged from 10.9% to 41.3%. Similarly, the data analysis result in Table 5 of this study also showed that, RYL was considerably decreased in Mancolaxyl and Mancozeb two times treated plots, on both faba bean varieties over Mankocide treated and untreated plots.

The report of Amelework et al. [31], on the evaluation of fungicide spray frequency for the management of chickpea Ascochyta blight (*Ascochyta rabiei* (Pass) Lab) in Alem Tena, East Showa, Ethiopia, under field experiment condition, showed that, in Othello Top + Mancolaxyl fungicide treated plots, 2261.4 kg ha^{-1} grain yield was recorded, followed by Mancozeb sprayed plots (2209.5 kg ha^{-1}). However, the lowest grain yields were recorded on the control plot (1046.7 kg ha^{-1}); as a result, the mean grain yield of chickpea was increased by 96.9% due to fungicide treatment. The authors also added that grain yield in sprayed plots has 2061.3 kg ha^{-1}, while the grain yield obtained from un-sprayed plots is smaller than that from sprayed plots (1046.7 kg ha^{-1}).

The data analysis result in Table 5 and the bar graph in Figure 2 indicate that, under severe Ascochyta blight infection, the grain yield of faba bean is highly reduced. Therefore, Ascochyta blight disease of faba bean has great negative impact on the productivity of the crop.

The disease and growth parameter data analysis result in Tables 3 and 4, respectively describe that Mancolaxyl and Mancozeb fungicides with two times spray frequency levels could protect Ascochyta blight disease epidemic on both faba bean varieties. As a result, the average grain yield obtained by EH00102-4-1 variety, in two times Mancozeb and Mancolaxyl treated plots, considerably increased from 4233.3 kg ha^{-1} to 4350.0 kg ha^{-1} as mentioned. The average grain yield obtained by local susceptible variety in two times Mancozeb and Mancolaxyl treated plots also considerably increased from 3816.7 kg ha^{-1} to 3933.3 kg ha^{-1} in the order mentioned, while the average grain yield obtained by both varieties in Mankocide treated and untreated plots was relatively reduced (Table 5 and Figure 2).

3.4. Cost Benefit Evaluation. The highest TR (195, 937 ETB ha^{-1} and 190, 312.5 ETB ha^{-1}) was obtained in two times Mancolaxyl and Mancozeb treated plots, on EH00102-4-1 variety, respectively, while the lowest TR (139, 312.5 ETB ha^{-1} and 120, 562.5 ETB ha^{-1}) was obtained in untreated plots, on EH00102-4-1 and local susceptible varieties, in the order mentioned. The highest NR (101,760.8 ETB ha^{-1} and 96,135.8 ETB ha^{-1}) was obtained in two times Mancolaxyl and Mancozeb treated plots, on EH00102-4-1 variety as mentioned. The lowest NR (66,992.5 ETB ha^{-1} and 48,242.5 ETB ha^{-1}) was also obtained in untreated plots, on EH00102-4-1 and local susceptible varieties, respectively. The MRR (%) recorded by EH00102-4-1 variety, in two times Mancolaxyl and Mancozeb treated plots was 159.10% and 133.34%, respectively. The MRR obtained by local susceptible variety in two times Mancolaxyl and Mancozeb treated plots was 158.21% and 133.34% in the order mentioned (Table 6).

On both faba bean varieties, in Mankocide one time, two times, and three times treated plots, 38.23%, 42.40%, and 58.82% MRR were obtained, as mentioned. The MRR obtained by both faba bean varieties, in one time Mancozeb treated plots was 66.42%, while in three times Mancozeb treated plots, on EH00102-4-1 and local susceptible varieties, 56.13% and 55.3% MRR were recorded, respectively. In Mancolaxyl three times treated plots, on both faba bean varieties, 97.31% MRR was obtained. The increase in net return or net benefit (NB) obtained by Mancolaxyl and Mancozeb two times treated plots, on EH00102-4-1 variety was 34,768.3 ETB ha^{-1} and 29,143.3 ETB ha^{-1}, respectively. In one time and two times Mankocide treated plots, on both faba bean varieties, 8356.8 ETB ha^{-1} and 9268.3 ETB ha^{-1}, increase in net return or net benefit (NB) were obtained, respectively (Table 6).

The partial budget analysis results in Table 6 indicated that the highest NB (34,768.3 ETB ha^{-1} and 34,580.8 ETB ha^{-1}) was obtained, in two times Mancolaxyl treated plots, on EH00102-4-1 and local susceptible varieties, respectively, while the lowest NB (8356.8 ETB ha^{-1} and 9268.3 ETB ha^{-1}) was obtained in one time and two times Mankocide treated plots, on both faba bean varieties, respectively. The NB obtained, in two times Mancozeb treated plots, on both faba bean varieties was 29143.3 ETB ha^{-1}; in addition, the partial budget analysis results in Table 6 also indicated that the MRR (%) on both faba bean varieties, in Mankocide one time, two times, and three times treated plots was less than 100% (MRR < 100%). MRR < 100% was also recorded in one time and three times Mancozeb treated plots, on both faba bean varieties. The MRR obtained by both varieties in two times Mancolaxyl and Mancozeb treated plots were greater than 100% (MRR > 100%).

In line with this research finding, the report of Rechcing and Rechcing [39] indicated that in Canada, the timely and efficient use of fungicides has remained a major factor in the successful management of Ascochyta blight disease and the economic viability of pulse crops. According to the survey assessment and field experiment reports of Belachew et al. [40], in two times Bayleton, Chlorothalonil, and Redomil sprayed plots, (7341 ETB ha^{-1}), (4421 ETB ha^{-1}), and (7063.5 ETB ha^{-1}) net benefit and 320.75%, 34.41%, and 446.44% MRR was obtained in the order mentioned. In addition, on local faba bean variety, in two times Redomil treated plots 5311.0 ETB ha^{-1} net benefit was recorded. On this variety, in two times Redomil treated plots 380.94% MRR was also obtained.

Mankocide with one time, two times, and three times spray frequencies, as well as Mancolaxyl and Mancozeb fungicides with one time and three times spray frequencies are the least economically feasible for Ascochyta blight disease management in faba beans, under field experiment condition, in Northwestern Ethiopia, while Mancolaxyl fungicide with two times spray frequency is the most economically feasible for Ascochyta.

3.5. Correlation and Regression Analysis. To evaluate the cause and effect relationship of the pattern of disease epidemic (AUDPC) of faba bean Ascochyta blight (*Ascochyta fabae* S.) disease with average grain yield, simple linear regression and correlation analyses of AUDPC and average grain yield were done. There was a significant negative relationship between the mean AUDPC and average grain yield in both faba bean varieties (Figures 3 and 4). The linear regression analysis result (R^2) indicated that about 64.50% variation in average grain yield of EH00102-4-1 variety was due to the mean AUDPC value and the remaining portion may be due to other factors, and the linear regression equation indicated that, if there is

Table 6: Partial budget analysis for the management of faba bean Ascochyta blight using varieties, fungicides, and spray frequencies under field conditions during the main cropping seasons of 2021-2022.

		Variety													
		Hachalu (EH00102-4-1)							Local (baqyla)						
		Cost benefit analysis							Cost benefit analysis						
Fungicide	SF	AGY	TR	TVC	NR	NB	MC	MRR (%)	AGY	TR	TVC	NR	NB	MC	MRR (%)
Mancozeb	SF1	3904.2	175688	94177	81510.8	14518	21857	66.4	3487.5	156938	94176.7	62760.8	14518.3	21857	66.4
	SF2	4229.2	190312.5	94177	96135.8	29143.3	21857	133.3	3812.5	171563	94176.7	77385.8	29143.3	21857	133.3
	SF3	3854.2	173438	94177	79260.8	12268	21857	56.1	3433.3	154500	94176.7	60323.3	12080.8	21857	55.3
Mankocide	SF1	3767.3	169526	94177	75349.4	8356.8	21857	38.2	3350.6	150776	94176.7	56599.4	8356.9	21857	38.2
	SF2	3787.5	170438	94177	76260.8	9268.3	21857	42.4	3370.8	151688	94176.7	57510.8	9268.3	21857	42.4
	SF3	3867.3	174027	94177	79849.8	12857	21857	58.8	3450.6	155276	94176.7	61099.6	12857.1	21857	58.8
Mancolaxyl	SF1	4137.5	186188	94177	92010.8	25018	21857	114.5	3720.8	167438	94176.7	73260.8	25018.3	21857	114.5
	SF2	4354.2	195937	94177	101760.8	34768.3	21857	159.1	3933.3	177000	94176.7	82823.3	34580.8	21857	158.2
	SF3	4054.2	182438	94177	88260.8	21268	21857	97.3	3637.5	163688	94176.7	69510.8	21268.3	21857	97.3
	CONT	3095.8	139312.5	72320	66992.5	0	0	0	2679.2	120562.5	72320	48242.5	0	0	0

AGY = average grain yield (kg/ha), TR = total return (birr/ha), TVC = total variable cost (birr/ha) NR = net return (birr/ha), NB = net benefit (birr/ha), MC = marginal cost, MRR = marginal rate of return, and SF = spray frequencies.

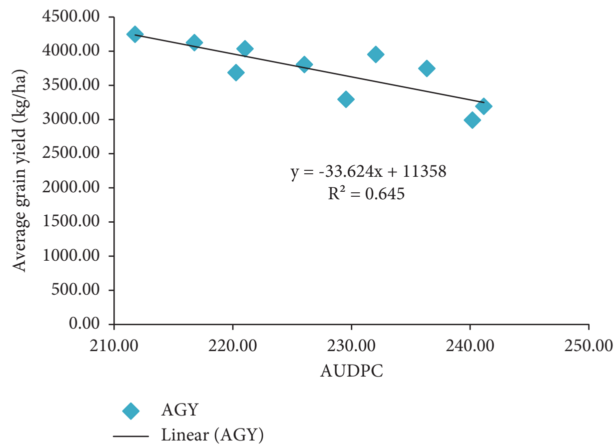

Figure 3: The linear relationship between mean AUDPC and average grain yield of EH00102-4-1 variety.

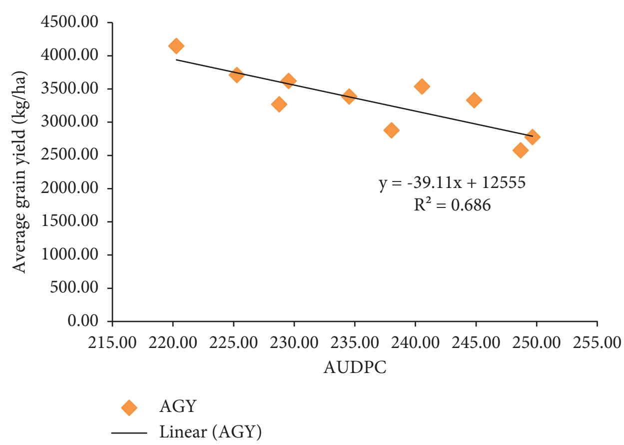

Figure 4: The linear relationship between mean AUDPC and average grain yield of local susceptible variety.

a unit increase in mean AUDPC value, grain yield is decreased by 33.62 times (Figure 3).

The linear regression analysis result (R^2) in Figure 4 indicates that about 68.64% variation in the yield of susceptible local variety was due to the mean AUDPC value and the remaining portion may be due to other factors, and the linear regression equation also indicated that if there is a unit increase in mean AUDPC value, grain yield is decreased by 39.12 times. The correlation and regression analysis results in Figures 3 and 4 indicated that under condition of severe infection, Ascochyta blight disease has great negative impact on the grain yield of faba bean.

4. Conclusion

Application of fungicides, with spray frequencies, shows strong significant differences ($P < 0.01$) in PDI, PSI, DPR, and AUDPC on both faba bean varieties. The disease epidemics effect of Ascochyta blight was significantly reduced in Mancolaxyl and Mancozeb two times treated plots, on both faba bean varieties. In two times Mancolaxyl treated plots, on both varieties, plant height and stem girth were significantly increased, while in untreated and Mankocide treated plots on both faba bean variety, plant height and stem girth were considerably reduced. In Mancolaxyl and Mancozeb two times treated plots on both varieties, the height average grain yield and harvesting index were obtained, while in untreated plots and in one time, two times, and three times Mankocide treated plots on both varieties, the lowest average grain yield and harvesting index were obtained. In two times Mancolaxyl and Mancozeb treated plots, on both varieties, the lowest relative yield lose was recorded, while in untreated plots and in one time, two times, and three times Mankocide treated plots, on both varieties, the highest relative yield lose was recorded.

Therefore, PH, SG, HI, and GY were considerably increased in two times, Mancolaxyl and Mancozeb treated plots, on both varieties. While RYL, PDI, PSI, DPR, and AUDPC were considerably decreased in Mancolaxyl and Mancozeb two times treated plots, on both faba bean varieties. This indicated that under severe Ascochyta blight disease infection, GY, HI, PH, and SG of faba bean are highly reduced. DPR, AUDPC, PSI, PDI, and RYL were considerably increased.

The highest TR, NR, and NB were obtained by both varieties, in two times Mancolaxyl and Mancozeb treated plots, while the lowest TR, NR, and NB were obtained by both varieties, in untreated and Mankocide one time, two times, and three times treated plots. In one time and three times Mancolaxyl treated plots, on both varieties, relatively lower TR, NR, and NB were obtained. In addition, lower TR, NR, and NB were also obtained in one time and three times Mancozeb treated plots, on both varieties. MRR >100% were obtained by both varieties, in two times Mancolaxyl and Mancozeb treated plots, while MRR <100% were obtained by both varieties, in untreated and Mankocide one time, two times, and three times treated plots.

Therefore, Mankocide with one time, two times, and three times spray frequencies, as well as Mancolaxyl and Mancozeb fungicides with one time and three times spray frequencies are the least economically feasible for Ascochyta blight disease management, in both faba bean varieties, under field experiment condition, while Mancolaxyl fungicide with two times spray frequency is the most economically feasible for Ascochyta blight disease management, in both faba bean varieties, under field experiment condition, in Northwestern Ethiopia, followed by Mancozeb fungicide with two times spray frequency levels. In general, Mancolaxyl and Mancozeb fungicides, with two times spray frequency levels could protect Ascochyta blight disease epidemics, on both faba bean varieties. As a result, Mancolaxyl two times spray frequency levels starting from the early growth stage of the crop and at disease onset could be suggested as the first choice to be applied by the locale farmers of the region followed by Mancozeb, to effectively manage the disease in northwestern Ethiopia.

Data Availability

The data used to support the findings of this study will be provided upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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