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Research Article

Effects of Sowing Dates and Fungicide Application on Chocolate Spot (*Botrytis fabae* Sard.) Disease of Faba Bean (*Vicia faba* L.) in Western Ethiopia

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Faba bean (*Vicia faba* L.) is a cool legume crop grown in the highlands of Ethiopia, and chocolate spot disease (*Botrytis fabae* Sard.) occurs in wide areas. There is a shortage of recorded data about the impact of chocolate spot disease on faba beans and their management practices in Ethiopia. The objectives of this study were to assess the influence of sowing dates and the frequency of foliar fungicide (mancozeb) application for the management of chocolate spots and determine the association of sowing dates with chocolate spot disease occurrence. The experiment was conducted in the 2019 and 2020 growing seasons at two locations in Shambu and Guduru, western Oromia, Ethiopia. The mean disease severity, AUDPC, and grain yield were found to be statistically significant differences ($P < 0.05$) among the treatments at both locations and years. A highly negative correlation of AUDPC with a grain yield was obtained for both locations and years. A high infection rate, disease severity, AUDPC, and low grain yield were recorded from the unsprayed treatment. Three applications of mancozeb spray on the first July sowing date have effectively reduced disease severity and significantly increased yield. However, cost-effective and environmentally eco-friendly disease management is an issue that has to be further investigated.

1. Introduction

Faba bean (*Vicia faba* L.) is a cool legume crop grown in the highlands of Ethiopia at an altitude range of 1800–3000 m above sea level [1]. In 2014, the international average annual production of faba beans was 4.4 million tons, with China being the largest producer in terms of both area harvested and production, with 933,000 hectares and 1.64 million tons, respectively [2]. Ethiopia is the second producer with 519,000 hectares of area harvested and 0.92 million tons of production [3].

Chocolate spot disease, caused by Botrytis fabae, is the most prevalent and substantial disease in faba bean production globally. The disease can also cause complete crop failure in extreme situations, and in Ethiopia, the disease is also the main yield-limiting biotic constraint [4–6]. The reduction in faba bean yields due to this disease can reach 60–80% in susceptible varieties [5, 7]. The environmental conditions of the Ethiopian highlands (relative humidity of 70% or higher and a temperature of 15 to 22°C) are respectable for chocolate spot disease occurrence and development [8].

In Ethiopia, long-term management of chocolate spot disease would likely require the adoption of resistant cultivars, fungicide use, biological control, and their combination with unique cultural practices including crop rotation and mixed cropping [9, 10]. The use of the sowing date is used for the management of chocolate spot disease. A diverse range of variations in the bean-disease-weed progression over time due to treating field plots with different planting dates and weed control practices and late planting restricted Rhizoctonia root rot progress and thus improved bean yield

[11]. The overseason progression of Rhizoctonia root rot and late plantings of bean cultivars decreased the disease development by 8–36% according to the linear-by-linear parameter *a* estimates for the three weed control treatments [11]. Moreover, a well-timed planting date in late spring can improve herbicide efficiency and reduce root rot intensity and weeds from environmental friendly bean farming perspective [12]. The integrated use of sowing dates with fungicides provides better control of this disease than using them individually [8, 13, 14]. The use of foliar fungicides on a regular basis during the growing season, beginning with the first onset of the disease and integrating with sowing days, can help manage the disease in the crop [15].

There may be a large range of faba bean crop production and a massive incidence of chocolate spot disease every year, but there is still a research gap to assess options for controlling the disease. Moreover, there have been complicated troubles with disease management practices. Even though the area in which the experiment was conducted has the potential for faba bean production and again, there is a very important disease prevalence and high severity, there was no research conducted before. Therefore, the study was to answer and fill the gaps in management practices that the best control methodof severity or intensity, the progress of disease development,and the prevalence of chocolate spot disease at the study area. This study will give a little bit of information about the disease; then, users and experts will take over and will give attention regarding the management of disease and increase the production and productivity of the crop as well as reduce yield loss.

Farmers are no longer familiar with fungicide application on faba bean crops, yet the times of fungicide application have not significantly reduced the infection of diseases. The objectives of this study were to assess the influence of sowing dates and the frequency of fungicide (mancozeb) application for the management of chocolate spot disease and determine the association of sowing dates with chocolate spot disease occurrence.

2. Materials and Methods

2.1. Experimental Site. The research was carried out in Shambu and Guduru, which are located in western Oromia, Ethiopia, at longitude 36°39′28.8″–37°40′11.2″E and latitude 9°9′24.6″–10°20′59.9″N and altitude 1350–3170 meter above sea level and 315 km west of Ethiopia's capital city, Addis Ababa.

2.2. Weather Conditions. The climatic condition of the area ranges from temperatures of 8–32°C and an annual rainfall of 900 mm–2000 mm. The climate of the study area is more frequently cold weather conditions, which are mainly modified by its higher elevation and the soil's clay loam textural class. The distribution of rainfall is unimodal and characterized by a prolonged wet season from May to October and short dry spell showers from mid-February to April (Figure 1).

2.3. Experimental Design and Treatments. The experiment was conducted for two consecutive cropping seasons (2019 and 2020) at two locations (Shambu and Guduru). The plot size was 2 m × 2 m with 6-seedling rows, 1 m spacing between blocks, 0.5 m between plots, and 0.4 m to 0.1 m interrow and intra-row spacing, respectively. Mancozeb 80% WP spray frequencies (SpF) designed for treatments were unsprayed (SpF0) as control, one-time spray (SpF1) (which was applied at the first appearance of disease symptom), two-times spray (SpF2) and three-times spray (SpF3), were applied at three-week intervals at a rate of 2.5 kg a.i. ha−1. There were three times of sowing (TOS): June 24 (TOS1), July 1 (TOS2), and July 8 (TOS3). A local faba bean cultivar from surrounding farmers was used for the experiment, and the seed and fertilizer rates were used based on standards (275 kg·ha^{-1}) and P2O5 (46 kg·ha^{-1}) and UREA (18 kg·ha^{-1}), respectively [16]. The experiments were arranged in a randomized complete block design (RCBD) in a factorial combination. To avoid fungicide drift, a wild oat (*Avena sativa* L.) crop was planted between blocks and plots.

2.4. Disease Data Collection

2.4.1. Disease Severity. Chocolate spot severity was assessed on 10 randomly selected and pretagged plants per plot at weekly intervals from the first time the disease appeared in the experimental trials until the crop was mature. Disease assessment was carried out from the first disease occurrence of one to two chocolate spot lesions that appeared under the faba bean leaf. Disease assessment was commenced between 50 days after sowing (DAS) to 120 days after sowing (DAS) for faba bean physiological maturity in all treatments. Disease symptoms were scored weekly on the basis of a 5-class visual scale, with 1 = no symptoms or very small spots; 2 = very small and discrete lesions; 3 = some coalesced lesions with some defoliation; 4 = large coalesced sporulation lesions, 50% defoliation, and some plants dead; and 5 = extensive lesions on leaves, stems and pods, severe defoliation, heavy sporulation, blackening, and death of more than 80% of the plants [14, 15].

$$\text{Disease severity} = \frac{\text{nxv}}{5\text{N}} * 100, \quad (1)$$

where n is the number of plants in each category, v is the numerical value of the symptom category, N is the total number of plants, and 5 is the maximum numerical value of the symptom category.

2.4.2. Area under the Disease Progress Curve (AUDPC). For assessment of disease severity over time, the area under the disease progress curve (AUDPC) was calculated. The weight for each evaluation is the time gap between the midpoint of the previous time interval and the midpoint of the next time interval [17, 18].

$$\text{AUDPC} = \sum_{i=1}^{n-1} \left[0.5\left(x_i + x_{i+1}\right)\right]\left[t_{i+1} - t_i\right], \quad (2)$$

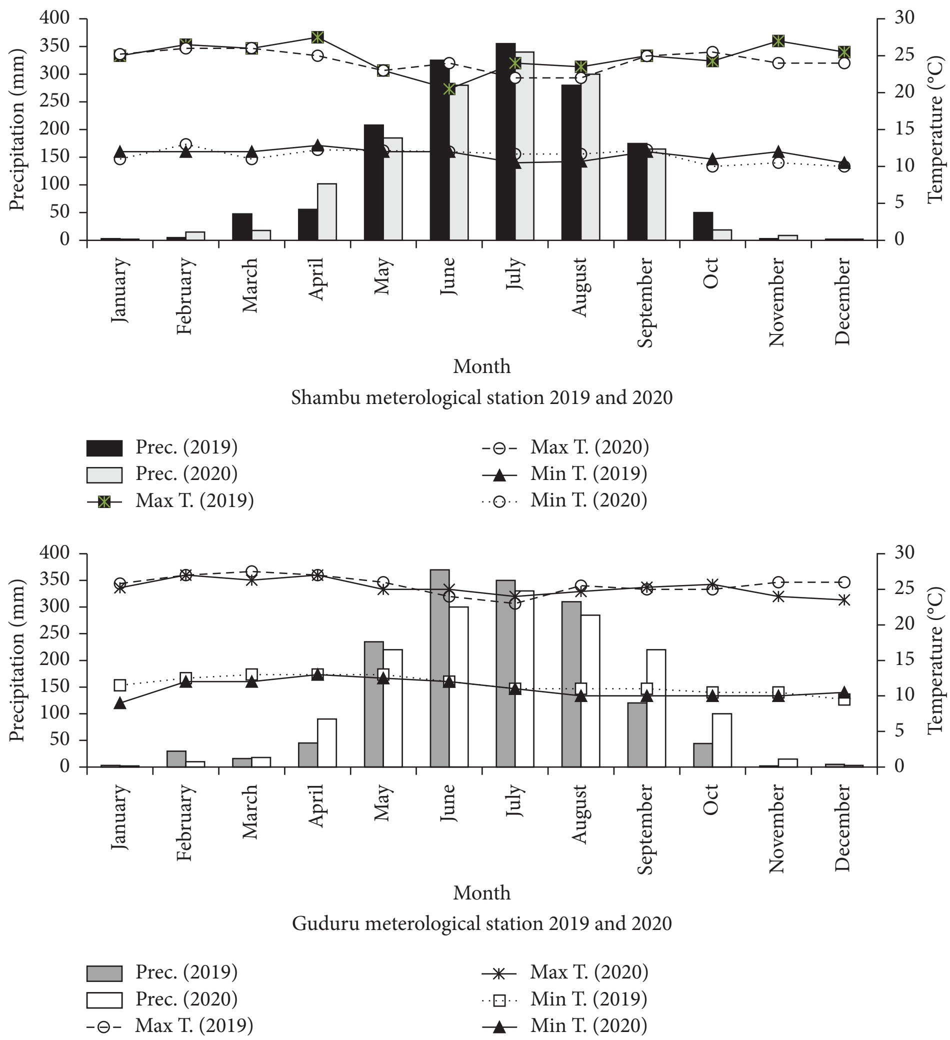

Figure 1: Monthly total rainfall, mean maximum, and minimum temperature of the study area.

where x_i is the average infection coefficient of the i^{th} note, x_{i+1} is the average infection coefficient of the $i+1^{\text{th}}$ note, $t_{i+1} - t_i$ is the number of days between the i^{th} note and the $i+1^{\text{th}}$ note, and n is the number of observations.

2.4.3. Apparent Infection Rate. The apparent infection rate was calculated based on the slope of the logistic regression line of disease severity over time as follows [15]:

$$r = \frac{\text{logit}\,(yf - yi)}{(tf - ti)}, \tag{3}$$

where "r" is the apparent infection rate, "ti" is the time of the initial disease measurement, "tf" is the time of the final disease measurement, "yi" is the proportion of infection measured at the time "ti," and "yf" is the proportion of infection measured at the time "tf."

2.4.4. Association of the Yield with AUDPC. For single-point models with linear relations, the AUDPC integral model was utilized to forecast the yield loss [16].

$$\text{W} = \beta 0 + \beta 1\text{AUDPC}, \tag{4}$$

where "W" is the yield of the crop and $\beta 0$ and $\beta 1$ are parameters. If AUDPC affects the yield, then the $\beta 1$ parameter is negative.

The percentage grain yield loss was determined according to [19] as follows:

$$\text{Relative yield loss}\,(\%) = \left(\frac{Y_{\text{bt}} - Y_{\text{lt}}}{Y_{\text{bt}}}\right) * 100, \tag{5}$$

where "Y_{bt}" is the yield of base treatment (three spray frequencies) and "Y_{lt}" is the yield of lower treatment.

2.5. Data Analysis. Disease progress was transformed with a logistic model, $ln\ [y/(1-y)]$ [20], and the collected data from experimental sites were subjected to analysis of variance with SAS computer software version 9.3 [21]. The grain yield was plotted against AUDPC for linear regression analysis, and the variation of regression was estimated using the coefficient of determination (R^2). Means were separated using the LSD test at a 5% probability level.

3. Results and Discussion

3.1. Disease Severity, Grain Yield, and Relative Yield Loss. Chocolate spot disease severity was significantly different ($P < 0.05$) among the treatments at both locations and in both years. At the Shambu location in 2019, the highest disease severity was recorded at the time of sowing on June 24 (TOS1) in the unsprayed/control treatment (SpF0) (33.72%), while the minimum disease severity was recorded at the time of sowing on July 8 (TOS3) in the three-time spray treatment (SpF3) (3.92%). In 2020, the highest disease severity was recorded at the time of sowing on July 1 (TOS2) in the unsprayed/control treatment (SpF0) (34.87%), while the minimum disease severity was recorded at the time of sowing on July 8 (TOS3) in the three-time spray treatment (SpF3) (4.38%). The results show that spraying mancozeb three times significantly ($P < 0.05$) reduced the yield loss in both season and location. At Shambu in 2019, the mean maximum yield loss was obtained at the time of sowing on July 8 (TOS3) in the unsprayed/control treatment (49.59%), while in 2020, it was obtained at the time of sowing on July 1 (TOS2) in the unsprayed/control treatment (SpF0) (46.37%). Application of mancozeb also increased the mean grain yield of faba bean at both locations in both years. At the Shambu location in 2019, the highest mean grain yield was recorded at the time of sowing on July 1 (TOS2) in the three-time spray treatment (SpF3) (3070 kg·ha^{-1}), while the minimum mean grain yield was recorded at the time of sowing on July 8 (TOS3) in the unsprayed/control treatment (SpF0) ((1533.33 kg·ha^{-1}) (Table 1).

In 2020, the highest mean grain yield was recorded at the time of sowing on July 1 (TOS2) in the three-time spray treatment (SpF3) (2983.3 kg·ha^{-1}), while the minimum grain yield was recorded at the time of sowing on July 1 (TOS2) in the unsprayed/control treatment (SpF0) (1600 kg·ha^{-1}) (Table 1).

At Guduru location in 2019, the highest mean disease severity was recorded at the time of sowing on June 24 (TOS1) in the unsprayed/control treatment (SpF0) (28.38%), while the minimum mean disease severity was recorded at the time of sowing on July 8 (TOS3) in the three-time spray treatment (SpF3) (4.65%). In 2020, the highest mean disease severity was recorded at the time of sowing on June 24 (TOS1) in the unsprayed/control treatment (SpF0) and time of sowing on July 1 (TOS2) in the unsprayed/control treatment (SpF0) (31.77%), while the minimum disease severity was recorded at the time of sowing on July 8 (TOS3) in the three-time spray treatment (SpF3) (4.02%). At Guduru in 2019, the mean maximum yield loss was obtained at the time of sowing on July 1 (TOS2) and time of sowing on July 8 (TOS3) in the unsprayed/control treatment (SpF0) (49.35%), while in 2020, it was obtained at the time of sowing on July 1 (TOS2) in the unsprayed/control treatment (SpF0) (53.6%). The minimum relative yield loss was obtained at the time of sowing on June 24 (TOS1) in the three-time spray (SpF3) treatment in both years at both locations. At Guduru location in 2019, the highest mean grain yield was recorded at the time of sowing on July 1 (TOS2) in the three-time spray treatment (SpF3) (3225 kg·ha^{-1}), while the minimum mean grain yield was recorded at the time of sowing on July 1 (TOS2) and time of sowing on July 8 (TOS3) in the unsprayed/control treatment (SpF0) (1633.33 kg·ha^{-1}). In 2020, the highest mean grain yield was recorded at the time of sowing on July 1 (TOS2) in the three-time spray treatment (SpF3) (3125 kg·ha^{-1}), while the minimum grain yield was recorded at the time of sowing on July 1 (TOS2) in the unsprayed/control treatment (SpF0) (1450 kg·ha^{-1}) (Table 2).

3.2. Area under the Disease Progress Curve (AUDPC). The mean AUDPC (%-days) was found to be statistically significantly different ($P < 0.05$) among the treatments at both locations in both years. At Shambu location in 2019, the highest mean AUDPC was recorded at the time of sowing on June 24 (TOS1) in the unsprayed/control treatment (SpF0) (1907.50%-days), while the minimum mean AUDPC was obtained at the time of sowing on June 24 (TOS1) in the three-time spray treatment (SpF3) (276.50%-days). In 2020, the highest mean AUDPC was recorded at the time of sowing on June 24 (TOS1) in the unsprayed/control treatment (SpF0) (1928.50%-days), while the minimum AUDPC was recorded at the time of sowing on June 24 (TOS1) in the three-time spray treatment (SpF3) (275.33%-days). At Guduru location in 2019, the highest mean AUDPC was recorded at the time of sowing on July 1 (TOS2) in the unsprayed/control treatment (SpF0) (1814.17%-days), while the minimum mean AUDPC was recorded at the time of sowing on June 24 (TOS1) in the three-time spray treatment (SpF3) (199.50%-days). In 2020, the maximum mean AUDPC was recorded at the time of sowing on July 1 (TOS2) in the unsprayed/control treatment (SpF0) (1802.50%-days), while the lowest mean was recorded at the time of sowing on June 24 (TOS1) in the SpF3 three-time spray treatment (SpF3) (196.00%-days). The combination of some fungicide strategies and time of sowing (TOS) was not significant, and the main impact on disease severity was due to fungicide application rather than sowing dates. The AUDPC decreased where mancozeb was applied regardless of the sowing date with the smallest AUDPC in the three-time spray (SpF3) strategy (Figure 2).

TOS1, TOS2, and TOS3 stand for the time of sowing on June 24, July 1, and July 28, respectively,whereas SpF0, SpF1, SpF2, and SpF3 stand for spray frequency (unsprayed/control, one-time spray, two-times spray, and three-times spray, respectively) and SE stands forstandard error of mean.

3.3. Apparent Infection Rate. From the linear regression of the logistic model, ln $(y/(1-y)$, the apparent infection rate (unit day^{-1}) was calculated in both years at both locations. At Shambu location in 2019, the highest apparent rate was observed at the time of sowing on June 24 (TOS1) and time of sowing on July 8 (TOS3) in the unsprayed/control treatment (SpF0) which was found faster by 0.916 logit day^{-1}, followed by time of sowing on July 1 (TOS2) in the unsprayed/control treatment (SpF0) (0.59 logit day^{-1}), whereas the lowest disease rate was observed at the time of sowing on July 1 (TOS2) and time of sowing on June 24

Table 1: Chocolate spot disease severity, grain yield, and yield loss of faba bean at Shambu location.

Treatment		2019 Disease severity (%)	2019 Grain yield (kg·ha^{-1})	2019 Relative yield loss (%)	2020 Disease severity (%)	2020 Grain yield (kg ha^{-1})	2020 Relative yield loss (%)
SpF0	TOS1	33.72	1575.00	48.69	33.99	1625.00	45.53
	TOS2	32.77	1558.33	48.91	34.87	1600.00	46.37
	TOS3	31.13	1533.33	49.59	32.91	1625.00	45.53
SpF1	TOS2	25.78	2050.00	33.21	22.87	1950.00	34.64
	TOS3	25.13	2025.00	33.61	22.18	1966.67	34.08
	TOS1	24.48	1991.67	34.52	22.52	2008.33	32.68
SpF2	TOS3	9.47	2550.00	16.94	8.53	2425.00	18.72
	TOS2	8.47	2491.67	18.31	8.96	2475.00	17.04
	TOS1	8.19	2550.00	16.94	7.70	2425.00	18.72
SpF3	TOS2	4.09	3070.00	0.00	4.47	2983.33	0.00
	TOS1	3.99	3050.00	0.65	4.91	2979.25	0.14
	TOS3	3.92	3041.67	0.92	4.38	2975.00	0.28
CV (%)		9.48	1.65		10.11	2.03	
$LSD^{0.05}$		2.76^{**}	63.17^{**}		2.89^{**}	76.09^{**}	

Table 2: Chocolate spot disease severity, grain yield, and yield loss of faba bean at Guduru location.

Treatment		2019 Disease severity (%)	2019 Grain yield (kg·ha^{-1})	2019 Relative yield loss (%)	2020 Disease severity (%)	2020 Grain yield (kg·ha^{-1})	2020 Relative yield loss (%)
SpF0	TOS1	26.36	1725.00	46.51	31.67	1475.00	52.80
	TOS2	28.38	1633.33	49.35	30.52	1450.00	53.60
	TOS3	25.82	1633.33	49.35	31.67	1475.00	52.80
SpF1	TOS2	21.12	2250.00	30.23	22.78	2125.00	32.00
	TOS3	20.05	2066.67	35.92	22.27	2091.67	33.07
	TOS1	19.85	2333.33	27.65	23.28	2041.67	34.67
SpF2	TOS3	8.45	2750.00	14.73	8.24	2625.00	16.00
	TOS2	9.50	2750.00	14.73	8.68	2541.67	18.67
	TOS1	8.27	2775.00	13.95	8.24	2625.00	16.00
SpF3	TOS2	5.36	3225.00	0.00	4.28	3125.00	0.00
	TOS1	4.72	3150.00	2.33	4.54	3075.00	1.60
	TOS3	4.65	3141.67	2.58	4.02	3041.67	2.67
CV (%)		3.79	4.05		6.38	1.91	
$LSD^{0.05}$		0.98^{**}	165.6^{**}		1.79^{**}	73.65^{**}	

(TOS1) in the three-time spray treatment (SpF3) (−2.803 logit day^{-1}). In 2020, the highest apparent rate was observed at the time of sowing on June 24 (TOS1) and time of sowing on July 8 (TOS3) in the unsprayed/control treatment (SpF0) which was found faster by 0.916 logit day^{-1}, followed by time of sowing on July 1 (TOS2) in the unsprayed/control treatment (SpF0) (0.59 logit day^{-1}), whereas the lowest rate was recorded at the time of sowing on June 24 (TOS1) and time of sowing on July 8 (TOS3) in the three-time spray treatment (SpF3) which was found faster by −2.803 logit day^{-1} (Table 3).

At Guduru location in 2019, the highest apparent rate was observed at the time of sowing on July 1 (TOS2) in SpF0 (0.59 logit day^{-1}), followed by time of sowing on June 24 (TOS1) and time of sowing on July 8 (TOS3) in the three-time spray treatment (SpF3) (0.29 logit day^{-1}), whereas the lowest rate was observed at the time of sowing on July 1 (TOS2) and time of sowing on July 8 (TOS3) in the three-time spray treatment (SpF3) (−2.803 logit day^{-1}). In 2020, the highest apparent rate was observed at the time of sowing on July 1 (TOS2) in the unsprayed/control treatment (SpF0) (0.92 logit day^{-1}), followed by time of sowing on June 24 (TOS1) and time of sowing on July 8 (TOS3) in the unsprayed/control treatment (SpF0) (0.59 logit day^{-1}), whereas the lowest rate was observed at the time of sowing on June 24 (TOS1) and time of sowing on July 8 (TOS3) in the three-time spray treatment (SpF3) which was found faster by −2.803 logit day^{-1}. In both years, the spray frequency (SpF) of mancozeb affected the disease progression rate with a negative coefficient of correlation and a high percentage of coefficient of determination (Table 4).

3.4. Association of AUDPC with the Grain Yield. The correlation between the AUDPC and faba bean grain yield was found to have a significant difference ($P < 0.05$) in both locations and years. At Shambu in 2019, the grain yield was

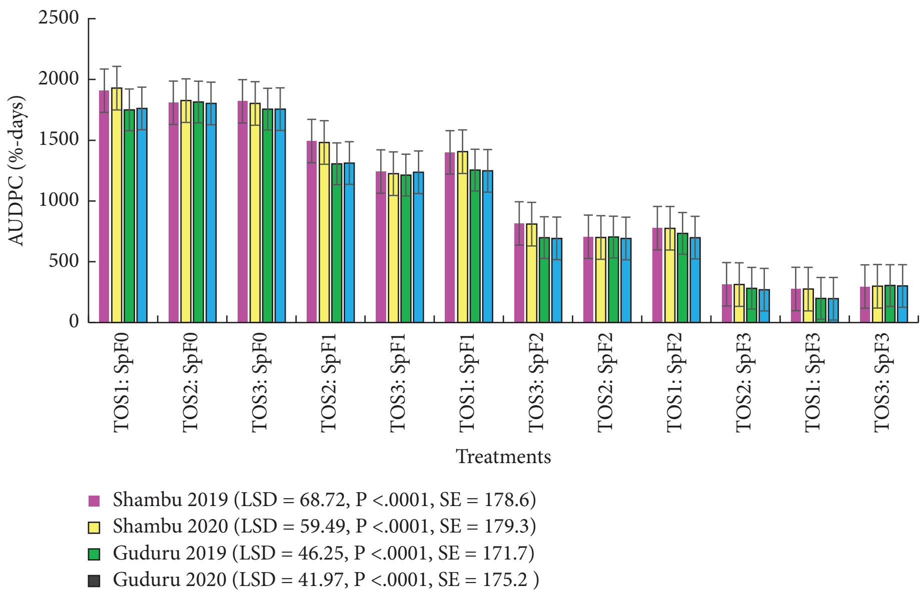

Figure 2: AUDPC (%-days) with the standard error of chocolate spot disease at Shambu and Guduru in 2019 and 2020.

Table 3: Apparent infection rate (logit day−1) from a logistic model (ln (y/(1 − y), and the parameter estimates for a chocolate spot disease at Shambu in 2019 and 2020 cropping seasons an apparent infection rate by coefficient of determination.

Treatment		2019				2020			
		Rate	Intercept	r^{a}	R^{2b}	Rate	Intercept	r	R^2
SpF0	TOS1	0.916	−0.0312	0.0505	0.98	0.916	−0.036	0.054	0.98
	TOS2	0.588	0.0009	0.0423	0.97	0.588	−0.005	0.041	0.98
	TOS3	0.916	−0.0164	0.0482	0.98	0.916	−0.013	0.046	0.98
SpF1	TOS2	0.288	−0.0109	0.0382	0.94	0.000	−0.002	0.035	0.94
	TOS3	−0.288	0.0173	0.0282	0.92	−0.288	0.024	0.026	0.94
	TOS1	−0.288	0.0173	0.0305	0.97	−0.288	0.017	0.031	0.97
SpF2	TOS3	−0.916	0.0162	0.0184	0.81	−0.916	0.013	0.038	0.89
	TOS2	−1.299	0.0189	0.0147	0.85	−1.299	0.025	0.013	0.86
	TOS1	−0.916	0.0289	0.0147	0.79	−1.299	0.038	0.013	0.89
SpF3	TOS2	−2.803	0.0915	−0.0078	0.73	−2.565	0.094	−0.008	0.75
	TOS1	−2.803	0.0825	−0.0071	0.75	−2.803	0.084	−0.008	0.77
	TOS3	−2.565	0.0918	−0.0086	0.76	−2.803	0.089	−0.008	0.71

negatively correlated with the AUDPC with a 98% coefficient of determination. The regression shows that the grain yield decreased by a −0.93 coefficient of correlation for one unit of disease increment. In 2020, the grain yield was negatively correlated with the AUDPC with a 97% coefficient of determination. The regression shows that the grain yield decreased by a coefficient of correlation of −0.85 for one unit of disease increment.

At Guduru location in 2019, the grain yield was negatively correlated with AUDPC with a 98% coefficient of determination (R^2). The regression shows that the grain yield decreased by −0.99 as one unit of disease increment. In 2020, the grain yield was negatively correlated with AUDPC with a 99% coefficient of determination (R^2). The regression shows that the grain yield decreased by a −1.04 coefficient of correlation for every unit of disease increment. From the regression analysis, the disease pressure on the grain yield was higher at Guduru location than in Shambu in both years (Figure 3).

4. Discussion

Even though the study area has the potential for faba bean production there is a very important disease prevalence and high severity like chocolate spot. Therefore, this study answered and filled the gaps in management practices that the best control method of severity or intensity, the progress of disease development,and the prevalence of chocolate spot disease of the study area. This study also gave a little bit of information about the chocolate spot disease management alternative. Thus, the end users of this research and experts will take over and will give attention regarding the management of chocolate spot disease and increase the production and productivity of the crop as well as reduce yield loss. Yield loss data, disease progress in relation to control

Table 4: Apparent infection rate (logit day^{-1}) from a logistic model (ln(y/(1 − y)), and the parameter estimates for chocolate spot disease at Guduru in 2019 and 2020 cropping seasons.

Treatment		2019				2020			
		Rate	Intercept	R	R^2	Rate	Intercept	r	R^2
SpF0	TOS1	0.288	−0.0445	0.0491	0.95	0.588	−0.0536	0.0514	0.96
	TOS2	0.588	−0.0055	0.0441	0.98	0.916	−0.0145	0.0464	0.96
	TOS3	0.288	0.0091	0.0409	0.98	0.588	2.00	0.0432	0.98
SpF1	TOS2	−0.288	−0.0155	0.0336	0.92	0.000	−0.0245	0.0359	0.92
	TOS3	−0.588	0.0073	0.0268	0.97	0.000	−0.0173	0.0332	0.92
	TOS1	−0.288	−0.0064	0.0314	0.97	−0.588	0.0027	0.0291	0.96
SpF2	TOS3	−1.299	0.0322	0.0096	0.88	−1.299	0.0131	0.0151	0.83
	TOS2	−1.299	0.0253	0.0129	0.86	−1.792	0.0344	0.0106	0.9
	TOS1	−1.299	0.0516	0.0079	0.81	−1.792	0.0516	0.0079	0.81
SpF3	TOS2	−2.803	0.0755	−0.0064	0.67	−2.565	0.0812	−0.0073	0.67
	TOS1	−2.565	0.0618	−0.0059	0.95	−2.803	0.0587	−0.0051	0.9
	TOS3	−2.803	0.0887	−0.0078	0.72	−2.803	0.0887	−0.0078	0.72

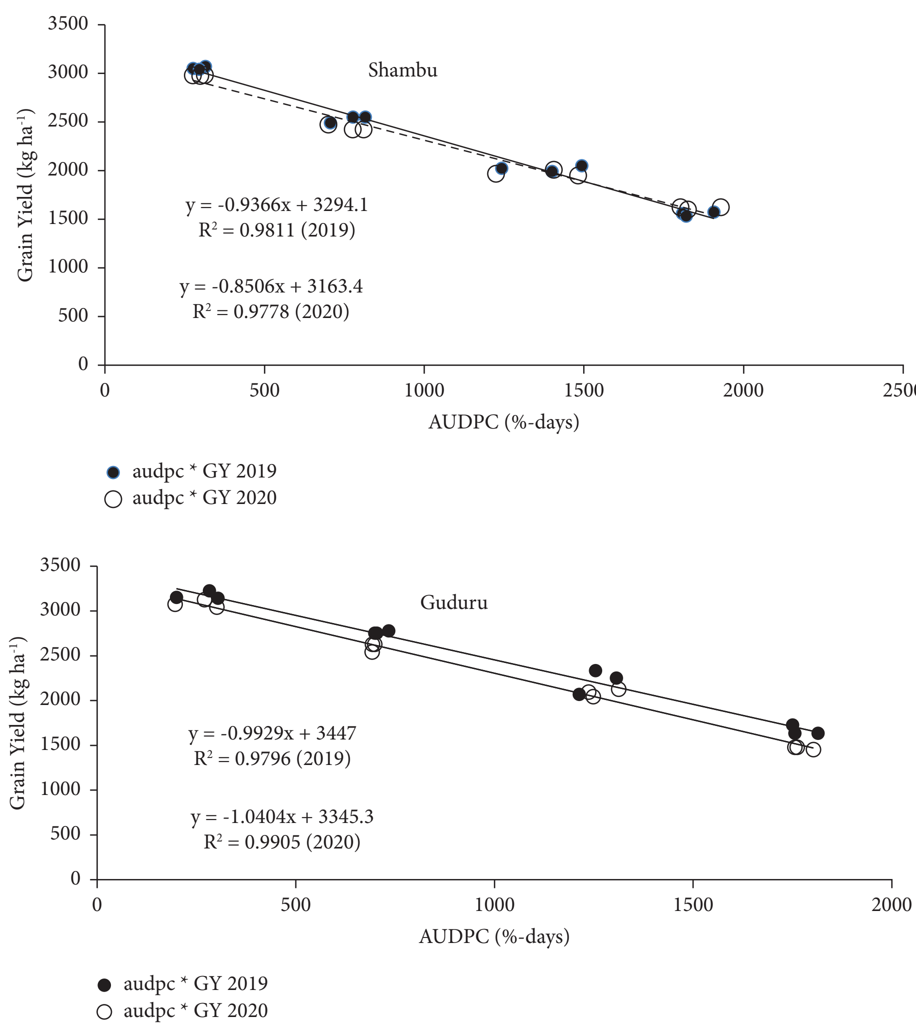

Figure 3: Linear relationship of the grain yield and AUDPC at Shambu and Guduru in 2019 and 2020.

methods under sowing time, and fungicide application were done for the first time in this study area made the research to be a novel.

This study showed that combining foliar application of fungicide mancozeb on later sowing dates can decrease the severity of chocolate spot compared to no foliar fungicide or earlier sowing dates. As the frequency of foliar mancozeb application increased, the severity of the disease decreased. Chocolate spot disease development was lowest in the experiments receiving three-time spray (SpF3) fungicide mancozeb application at the time of sowing on July 8 (TOS3) experiments. Disease development was highest and increased the fastest where no fungicide was applied to control pathogens. Different reports state that fungicide applications have been shown to cause a significant reduction in disease severity between sprayed and nonsprayed treatments [22].

There was a negative correlation between the AUDPC and grain yield. The values by which the yield was reduced for each unit of AUDPC increased might be received as the regression coefficient of each treatment, and disease intensity has decreased by the application of fungicide. The change in disease severity over time might be due to planned treatment by foliar application of a fungicide [23, 24]. Multiple regressions demonstrated significant associations of bean class, cultivation methods, planting dates, previous crops, soil clay, and urea use with isolation frequency of *F. oxysporum* and seed production in bean crops [19], and also, systematic understanding of agroecological descriptors of the variability within root rot epidemics will certainly assist to develop environmentally friendly programs for disease management and sustainable production. The interactions of a wide range of agronomic and soil characteristics also affect root rot epidemics and bean production, and one of the main unknowns in plant pathology is a comprehensive knowledge of the complete array of agroecological conditions capable of suppressing soil-borne plant pathogens [25].

The apparent infection rate per unit time of fungal pathogenic chocolate spots became numerous among all treatments, both locations and years. The application of fungicide reduced the apparent infection rate, and the negative values from the transformation data analysis indicated that, with increasing fungicide application frequency, the rate of disease development is decreased from those negative values. That is, disease progression is rapid as long as sufficient healthy tissue is accessible for further infection. The area under the disease progress curve (AUDPC) and linear and quadratic coefficients for colonization regressed on time were also included in multivariate analysis [19].

The grain yield increased as a result of an increase in fungicide application with disease intensity. In this study, SpF3 (three-time spray) in one growing season would control chocolate spot disease and increase the grain yield. This shows that the chocolate spot causes grain yield loss [5]. The AUDPC linear regression was used to predict yield loss in bean crops because the associations between yield loss and disease severity are established in the AUDPC linear regression [19]. In a previous study, chocolate spot disease was minimized and grain yield increased with shorter fungicide spray intervals [26].

Strategical foliar sprays of fungicide mancozeb are often used to prevent grain yield loss and chocolate spot disease in fields [27]. In northern Syria, sowing dates influenced the severity of chocolate spot disease, where the earliest sowing dates resulted in the lowest severity [13]. The chemical used should be decided using a cost-benefit analysis [28]. Those outcomes consist of improved grain yield and quality, better shelf life, pathogen inoculum reduction, and increased income for the farmer [27].

The combination of crop protection and production goals can lead to systems that are entirely based on ecological ideas, which optimize resource usage and may be more sustainable to prevail in sensible agriculture research results to farmers that are both persuasive and practical [27, 29]. Therefore, the strategical use of foliar fungicide application may be of great interest in the possibility of controlling the disease [15]. It needs to be integrated with cultural practices that can prevent a serious disease epidemic, but the chemical control of the disease should not be either ignored or described as ineffective [23, 26].

Along with the conducive temperature and prolonged wet conditions of the area when the crop is at the vegetative stage, it can be made a good environmental condition for chocolate spot disease [10]. According to [22], more rainfall occurred in June, July, and August of the 2004 and 2005 cropping seasons, which may have delayed the onset of infection and may also have contributed to an earlier disease progression rate. As a result, the plant stage was sensitive to chocolate spot disease outbreaks throughout these months. Chocolate spot outbreaks have been linked to well-distributed and relatively large quantities of rainfall, as well as high relative humidity at physiologically ideal temperatures for pathogens [8, 15].

Thus, mostly, the fungicide frequency showed differences, and therefore, the occurrence of the disease has been affected more by mancozeb application frequency than by the time of sowing. Of the treatments, one time of foliar application of mancozeb has not been recommended for the management of chocolate spots. To improve disease control, foliar application of mancozeb fungicides in conjunction with cultural practices such as appropriate sowing dates would be critical. For instance, host resistance (faba bean) in integration with cultural practices relevant to the location, which include crop rotation like with field peas, has to be considered a priority study location for chocolate spot control. However, cost-effective and environmentally eco-friendly disease management is an issue that has to be further investigated.

Data Availability

The raw data collected and analyzed during this current study are available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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