

Full Length Research Paper

Utilizing fungicide sprays and host resistance to control chocolate spot (*Botrytis fabae* L.) of faba beans (*Vicia faba* L.) in Ethiopia

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Faba bean (*Vicia faba*) productivity is significantly impeded by a Chocolate Spot disease inflicted due to *Botrytis fabae*, resulting in up to 68% yield reductions in Ethiopia. For that reason a study was implemented in Chilga district during the 2022/2023 cropping season to assess the integrated management strategies. Materials and Methods conducted in three faba bean varieties of Local, Degaga, Gebelicho regardless from the other treatments Fungicides (Fungozeb 2.5 kg/ha, Mancozeb 80WP 2.5 kg/ha, Nativo SC300 0.45 L/ha) unsprayed control. This experiment was carried out in a randomized complete block design with three replications. Variety × Fungicide response analysis of disease severity indicated a significant interaction between variety and fungicide treatment. Use of Degaga alone or in combination with Fungozeb 2.5 kg/ha showed minimum disease severity (25.33% conversely, the unsprayed Local variety had the highest severity (52.33%) and AUDPC (11408%-unit days). The results indicate that Degaga treated with Fungozeb effectively controls chocolate spot and boosts yield. However, due to the study's one-year duration, further research is recommended for more conclusive evidence and lowest Area Under Disease Progress Curve (AUDPC) of 573%-unit days respectively.

Key words: Area under Disease Progress Curve (AUDPC), chocolate spot, disease assessment, faba bean, incidence.

INTRODUCTION

Faba bean (*Vicia faba* L.), local names as Bakela in Ethiopia, is an integral pulse crop predominantly produced by smallholder farmers under rainfed lowland condition at 1800 to 3000 m altitude where annual rainfall varies between 700 and 1000 mm (Kindie and Nigusie,

2019; Kassa et al., 2021). The tree is an important component of food security and contributes to both soil fertility (through nitrogen fixation) and household income.

Globally, Ethiopia is the second faba bean producer to produce more than one million tons of unprocessed faba

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beans in our country annually (Ethiopian Statistics Service [ESS], 2023). The crop is cultivated in highland zones (Arsi, Bale, Gondar, Tigray and Southern nations) of the region (Anega and Berihane, 2024).

Chocolate spot caused by *Botrytis fabae* is one of the most serious diseases threatening faba bean cultivation, especially in cool, humid highland regions. Susceptible varieties can lose 60% (Hunduma et al., 2023) or more of their yield, and tolerant ones can lose up to 35% due to the disease. Recent data from northwest Ethiopia show damage up to 67% in unsprayed fields (Anega and Berihane, 2024).

Management usually includes host resistance, fungicides, residue management and agronomic practices (Mitiku, 2017). Despite this, using fungicide is expensive, harmful to environment and unpredictable in efficiency (Sahar et al., 2011). Chocolate spot is one of the major threats in faba bean especially in upper land and its prevalence increases from time to time although there are few controlling practices conducted. Therefore, this study aims to assess key genotypes that are resistant along with fungicides (Fungozeb 80WP, Mancozeb 80WP, and Nativio SC 300WP) for sustainable management of control strategies and increased yield productivity beneficial to farmers.

MATERIALS AND METHODS

Description of the experimental site

The experiment was conducted during 2022 main cropping season at Chilga district, North Gondar Zone, Amhara Regional State. The site is located at 12° 34' 100 N and 37° 04' 650 E a distance of 810 and 61 km northwest of Addis Ababa and Gondar Town, respectively (Figure 1). The experimental site is found at an altitude of 2162 m.a.s.l and receives annual rainfall of 1100 mm with mean minimum and maximum temperatures of 18 and 25°C, respectively, and the soil is sandy loam in texture. The soil at the experimental site is reddish brown to clay with low infiltration and high organic matter content.

Experimental materials

In this experimental study, three faba bean varieties—Degaga, Gebelicho, and a local variety—were carefully chosen based on their varying resistance levels to chocolate spot. The selection criteria were derived from the resistance classifications provided by the Ethiopian Institute of Agricultural Research (EIAR, 2015). The sourced varieties originated from the Gondar Agricultural Research Center, while the local cultivar was acquired from the local market. This ensures a comprehensive representation of both improved varieties and those traditionally cultivated in the region.

Experimental treatments, design, and procedures

In this experimental study, three faba bean varieties, namely Degaga and Gebelicho (improved varieties), and one local variety, were utilized (Table 1). The experiment included a factorial combination of these varieties with three fungicide spray, along with an unsprayed treatment serving as a control check. This resulted in a total of 12 treatments, with 36 plots in a randomized complete

block design (RCBD) arranged in three replications.

To ensure the effectiveness of fungicide sprays without interference, a plastic sheet was employed during application, preventing inter-plot spray drift. The spacing between plots and blocks was 0.5 and 1 m, respectively. Each plot measured 2 m × 2.4 m, totaling 4.8 m² in area. Treatments were randomly assigned to each plot, which consisted of six rows spaced 0.4 m apart. The number of plants per row was 24, with a spacing of 0.1 m between plants. Data collection focused on the middle four rows to mitigate border effects, leaving two outer rows on both sides.

Seeds were sown using a row planting method at a depth of 5 cm to ensure uniform emergence. Fertilization involved Nitrogen Phosphorus Sulfur (NPS) at a rate of 100 kg ha⁻¹, and standard land preparation, weeding, and crop management practices were uniformly applied to each plot. The yield data were converted to tons per hectare for analysis.

To manage chocolate spot during the study, the fungicide Fungozeb 2.5 kg/ha, Mancozeb 80 WP 2.5 kg/ha, Nativio SC300 0.45 L/ha was employed. This fungicide, crucial for controlling fungal diseases, was procured from the local market. Its application will contribute to the evaluation of the faba bean varieties' performance under controlled conditions, shedding light on their resilience to chocolate spot and aiding future agricultural practices.

Ethics approval

This study did not involve any human participants or animals. The field experiments were carried out in compliance with institutional, national, and international guidelines and regulations. All necessary permissions for conducting the research were obtained from the appropriate local authorities and landholders in the Chilga District, Northwestern Ethiopia.

Data collected

Disease parameter

Disease incidence and severity: In the evaluation of disease progression within the experimental plots, a systematic approach was employed. Disease assessment was initiated at the onset of the ailment and conducted at seven-day intervals until crop maturity. A quadrant sampling method was employed on the entire plot, encompassing both diseased and healthy plants. Disease incidence was quantified using the following formula (Bernier et al. 1993; Alemayehu et al., 2015):

$$\text{Disease incidence} = \frac{\text{Number of diseased plants}}{\text{Total number of plants}} \times 100$$

This methodological framework aligns with established practices as outlined by Bernier et al. (1993) and Alemayehu et al. (2015). Simultaneously, disease severity was documented for 12 pre-tagged plants in each plot. Chocolate spot severity was recorded thrice at 7-day intervals from the disease onset, utilizing a 0–9 rating scale. Subsequently, severity grades were transformed into a Percentage Severity Index (PSI) employing Wheeler's (1969):

$$\text{Disease severity} = \frac{\text{Area of disease tissue}}{\text{Total tissue area observed}} \times 100$$

$$\text{PSI} = \frac{\text{sum of numerical rating}}{\text{No. of plant scored} \times \text{max scored scale}} \times 100\%$$

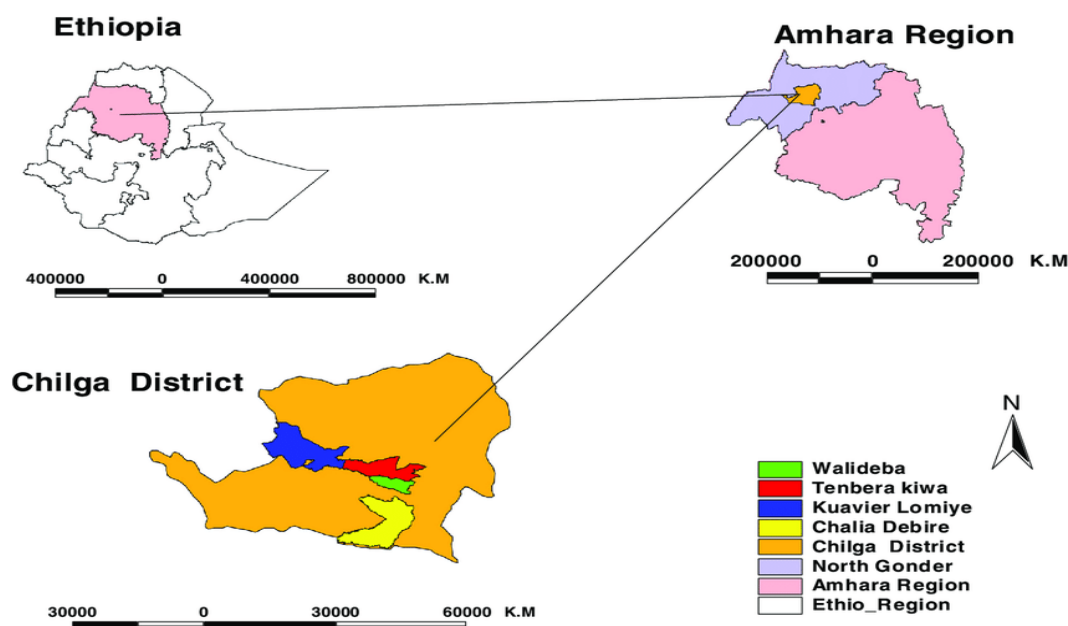


Figure 1. Map of the site.

Table 1. Treatment combinations.

1	Local + No Spray Fungicide
2	Local + Nativio SC300 0.45 L/ha
3	Local + Mancozeb 80WP 2.5 kg/ha,
4	Local + Fungozeb 2.5 kg/ha
5	Degaga + No Spray Fungicide
6	Degaga + Nativio SC300 0.45 L/ha
7	Degaga + Mancozeb 80WP 2.5 kg/ha,
8	Degaga + Fungozeb 2.5 kg/ha
9	Gebelicho + No Spray Fungicide
10	Gebelicho + Nativio SC300 0.45 L/ha
11	Gebelicho + Mancozeb 80WP 2.5 kg/ha
12	Gebelicho + Fungozeb 2.5 kg/ha

To evaluate chocolate spot disease severity, a standard scale was used to measure the severity of infection on faba bean leaves. Each leaf was visually surveyed, and a score and determined by both degree of leaf area infected, the presence of lesions, defoliation, or death of the plant. When using this approach, it is possible to assess the disease intensity uniformly and compare the results across fields and experiment treatments (Table 2).

To measure the overall disease progression, the Area under the Disease Progress Curve (AUDPC) was calculated from PSI, utilizing the formula outlined by Campbell and Madden (1990). This involved cumulative disease severity expressed as a proportion at each observation, the respective time of assessment, and the total number of observations. This comprehensive methodology provides a robust foundation for understanding the dynamics of disease incidence and severity throughout the crop cycle.

Disease progress rate: The progression of disease severity in seven-day intervals was subjected to regression analysis over time,

employing the methodology devised by Van der Plank (2013). This analysis facilitated the computation of disease progress rates for each crop variety. The apparent infection rate, expressed in disease units per day, was calculated by transforming disease severity data to a logistic model ($\ln [(Y/1-Y)]$) and Gompertz ($-\ln [-\ln(Y)]$), where Y and $1-Y$ denote the proportion of infected and healthy plants, respectively. The transformed values (y) were further regressed against time (as Days after Sowing, DAS), following the approach outlined by Campbell and Madden (1990). A meticulous comparison of the goodness of fit between the logistic model ($\ln [(Y/1-Y)]$) and Gompertz function revealed the latter's superiority, evident in consistently higher coefficients of determination (R^2) (Van der Plank, 2013). This choice enhances the precision of understanding disease dynamics, ensuring a robust analysis of disease progression rates across different crop varieties.

Crop parameter

Plant height at flowering, numbers of pods per plant, number of seeds per pod, and pod length were determined from the four middle rows of 12 pre-tagged plants and seed yield per plot were recorded from four middle harvested rows, and yield per plot converted into kg ha^{-1} .

Days to flowering (50%): This was collected as the number of days from crop emergence to the time when 50% of the plant in each treatment shows the flower bud.

Days to 90% maturity: This was recorded when 90% of the plant is physiologically matured.

Plant height (cm): This was taken at full maturity from 12 randomly selected plants of the central rows measured from the ground level to the top of the plant.

Numbers of pods per plant: They were counted from randomly selected 12 pre tagged plant in each experimental unit at maturity.

Pod length (cm): The average length of the pod from bottom to tip

Table 2. Percent of infection and scale for recording severity of chocolate spot.

Scale	Description
0	No disease symptoms
1	a few dot-like accounting for less than 5% of total leaf area
3	Separate spots less than 2 mm in diameter (6 to 25% of leaf area)
5	Some coalesced lesions with some defoliation diameter 3 to 5 mm (26 to 50% of leaf area)
7	Large coalesced lesion sporulation lesions, 51 to 75% defoliation and some dead plants
9	Extensive, heavy sporulation, stem girdling, blacking and death of more than 76 leaf of plants

Source: Bernier et al. (1993).

was measured using ruler from randomly selected 12 pre tagged plant in each experimental unit at maturity.

Number of seed per pod: This was counted from is randomly 12 pre tagged plants in each experimental unit at maturity.

100 seed weight (g): Weight in grams of 100 randomly chosen seed was measured by electronic balance.

Total grain yield (kg/ha): Grain yield was harvested from central rows by avoiding border effects and converted to kg/ha after adjusted to a constant moisture level of pulses grains (10%) using a moisture tester.

Relative yield loss (%): To quantify the impact of various treatments on yield, the relative loss in yield for each treatment was assessed as a percentage of the yield from the protected plots within the experiment. This determination was made separately for each treatment, considering yield components of faba bean. The calculation of yield loss was guided by the formulas established by Abay Guta et al. (2017):

$$RYL = (Y_p/Y_p - Y_T) \times 100$$

where RYL represents the relative yield loss in percentage, Y_p signifies the yield from the maximum protected plots, and Y_T signifies the yield from other experimental plots.

This approach provides a standardized measure to evaluate the efficacy of treatments by gauging the relative yield losses in comparison to the protected plots, facilitating a comprehensive understanding of treatment impact on faba bean yield components.

Correlation between yield and disease parameters

The correlations among the disease parameters and with the all-yield components were tested at 5% probability level and the reliable yield loss estimated on the basis of the severity level by employing regression equations.

Data analysis

In this study, the analysis of variance (ANOVA) utilized AUDPC values to assess and compare the disease severity among plots subjected to different treatments. The significance of treatment effects was determined through ANOVA, and post hoc analyses were performed using Fisher's protected least significance difference (LSD) test at a 0.05 level of probability, as outlined by Gomez and Gomez (1984). The statistical analysis was conducted using Statistical Analysis System (SAS) software version 9.2,

following the procedures recommended by (SAS Institute, 2008).

RESULTS AND DISCUSSION

Utilizing fungicide spray and host resistance to control chocolate spot of faba beans

Chocolate spot disease incidence

Analysis of variance in the current study revealed significantly varied ($P < 0.01$) main effects of varieties and frequencies of fungicide, spraying on the reduction of chocolate spot disease incidence recorded on all observation dates from 67 to 102 DAS (Table 3). The differences in disease incidence could be attributed to differential resistance levels by the various varieties. Local type was characterized with a quicker rate of disease progression with the terminal level of disease incidence at 68.00%, and this was followed by Gebelicho at 63.00% and Degaga at 58.92% by 102 DAS. This finding agrees with recent evidence highlighting that varietal differences have a major role in chocolate spot progress, with vulnerable cultivars being more affected and of faster development than moderately resistant varieties (Mengesha et al., 2022; Agegnehu and Fessehaie, 2006; Wolde and Mitiku, 2018). There were also remarkable differences ($P < 0.01$) among fungicide spraying treatments for disease incidence. The untreated plots had a starting disease incidence of 30.64% (67 DAS) and a finishing incidence of 72.67% (102 DAS), while the plots that were treated with 2.5 kg/ha Fungozeb 80WP had a starting incidence of 23.42% (67 DAS) and a finishing incidence of 57.22% (102 DAS). These results also supported the existing research findings that the application of protectant fungicides, including Mancozeb and Fungozeb, effectively inhibit the incidence of chocolate spot, particularly when applied at the right growth stage and frequency (Bugingo et al., 2025; Kebede et al., 2019).

In the present study, Fungozeb 80WP spraying at 2.5 kg/ha reduced disease incidence significantly with no notable difference in the performance of Mancozeb and Fungozeb 80WP being observed at the final assessment date (102 DAS) (Table 3). The finding is consistent with

Table 3. Interaction effect of faba bean varieties and fungicide application frequency on incidence of chocolate spot disease under field condition.

Variety	FS	67DAS	74DAS	81DAS	88DAS	95DAS	102DAS
Local	Unsprayed	36.93 ^a	42.00 ^a	46.00 ^a	56.00 ^a	62.00 ^a	78.00 ^a
	Nativo	28.00 ^b	34.00 ^b	43.00 ^b	50.00 ^b	58.67 ^{ba}	72.00 ^b
	Mancozeb	26.00 ^{bcd}	32.00 ^{bc}	40.67 ^{cd}	47.00 ^c	55.00 ^c	62.00 ^d
	Fungozeb	25.17 ^{def}	29.33 ^d	38.33 ^{ef}	44.67 ^{de}	55.67 ^{bc}	60.00 ^{ed}
Degaga	Unsprayed	27.00 ^{bcd}	34.00 ^b	40.00 ^{ed}	45.33 ^{dc}	52.33 ^{dc}	68.00 ^c
	Nativo	25.67 ^{cde}	32.00 ^{cb}	34.44 ^g	43.33 ^{ef}	46.00 ^e	58.00 ^{ef}
	Mancozeb	23.76 ^{efg}	30.00 ^{cd}	31.12 ^h	40.00 ^g	45.17 ^e	56.00 ^{fg}
	Fungozeb	22.09 ^g	26.67 ^e	28.00 ⁱ	33.67 ^h	42.67 ^e	53.67 ^g
Gebelicho	Unsprayed	28.00 ^b	40.00 ^a	42.00 ^{cb}	46.67 ^c	60.00 ^a	72.00 ^b
	Nativo	27.67 ^{bc}	31.33 ^{cd}	37.94 ^f	44.67 ^{de}	53.67 ^{cd}	62.00 ^d
	Mancozeb	25.33 ^{de}	29.33 ^d	35.33 ^g	42.67 ^f	50.33 ^d	60.00 ^{de}
	Fungozeb	23.01 ^{fg}	26.67 ^e	30.33 ^h	38.33 ^g	43.67 ^e	58.00 ^{ef}
LSD (0.05)		2.31	2.39	1.92	1.68	3.36	2.44
CV%		5.14	4.37	3.04	2.23	3.8	2.27

Means within the same column followed by the same letter(s) are not significantly different; FS = Fungicide Spray, DAS=Days after Sowing, LSD = Least significant Difference, CV= Coefficient of Variations.

previous research that both fungicides are effective for chocolate spot management, albeit their efficacy is typically comparable under heavy disease pressure (Yitayih et al., 2023; Mengesha et al., 2022).

Chocolate spot disease severity

Some differences ($P<0.001$) were observed between faba bean lines and fungicide spraying treatments at 74 days after sowing (DAS) and 81 DAS, respectively. On interaction analysis, very highly significant ($P<0.001$) differences were also observed in the severity of chocolate spot disease at 67 DAS and 102 DAS (Table 4). On the first date of assessment (67 DAS), the maximum disease severity was in the local variety (14.03%), followed by 10.13 and 11.59% in Degaga and Gebelicho, respectively. On the final assessment (102 DAS), the maximum disease severity was in the local variety (47.67%), while minimum severity was recorded in Degaga (33.75%). Gebelicho had a moderate level of terminal severity of disease at 37.00%, as was reported in recent research that Degaga and Gebelicho have moderate resistance to chocolate spot, whereas local varieties are very susceptible (Mengesha et al., 2022; Wolde and Mitiku, 2018; Agegnehu and Fessehaie, 2006).

Fungicide spraying impacts uncovered the most serious disease severity on the unsprayed plots and lowest on Fungozeb 80WP sprayed plots at 2.5 kg/ha (30.56%) at the final observation (102 DAS). This aligns

with recent research proving that protectant fungicides such as Fungozeb and Mancozeb reduce the intensity of chocolate spot immensely if sprayed at the appropriate times (Bugingo et al., 2025; Yitayih et al., 2023; Kebede et al., 2019).

Regarding the interaction of varieties and fungicide spraying, the highest severity of the unsprayed local variety (52.33%), followed by Gebelicho (46.00%) and then Degaga (41.67%) was observed. Minimum severity was recorded in 2.5 kg/ha Fungozeb 80WP treated plots (Table 4). These results coincide with recent evidence that the use of resistant varieties together with fungicide sprays is the best control measure for chocolate spot in Ethiopian highlands (Mengesha et al., 2022; Bugingo et al., 2025).

Area under disease progress curve

Analysis of variance showed a highly significant difference ($P<0.001$) among faba bean varieties, fungicide spraying treatments, and their interactions for Area under the Disease Progress Curve (AUDPC). The local variety possessed the highest value of AUDPC (1121%-day), whereas Degaga possessed the lowest value (747%-day). Gebelicho possessed a moderate value of AUDPC (893%-day) in comparison with Degaga and the local variety. This conforms to the latest discovery that Degaga possesses relatively higher resistance to chocolate spot compared to local and other susceptible

Table 4. Interaction effect of faba bean varieties and fungicide application frequency on severity of chocolate spot disease under field condition.

Variety	FS	67 DAS	74 DAS	81 DAS	88 DAS	95 DAS	102 DAS
Local	Unsprayed	21.93 ^a	34.00 ^a	42.00 ^a	44.00 ^a	44.00 ^a	52.33 ^a
	Nativo	13.00 ^b	29.33 ^b	31.33 ^b	36.00 ^b	38.67 ^b	50.00 ^{ba}
	Mancozeb	11.00 ^{bcdef}	24.00 ^d	28.00 ^{cd}	31.33 ^c	35.00 ^{cd}	48.00 ^{bc}
	Fungozeb	10.17 ^{cdef}	20.09 ^f	23.33 ^e	24.67 ^d	35.67 ^{cd}	40.33 ^{de}
Degaga	Unsprayed	12.00 ^{bcd}	24.00 ^d	26.00 ^d	26.67 ^d	31.33 ^{ef}	41.67 ^d
	Nativo	10.67 ^{cdef}	16.00 ^h	22.00 ^{ef}	25.33 ^d	26.00 ^g	38.00 ^{ef}
	Mancozeb	8.76 ^f	15.67 ^h	16.17 ^g	20.00 ^{ef}	25.167 ^{gh}	30.00 ^g
	Fungozeb	9.09 ^{ef}	10.21 ⁱ	13.00 ^h	18.33 ^f	22.67 ^h	25.33 ^h
Gebelicho	Unsprayed	13.00 ^b	26.00 ^c	30.00 ^{bc}	36.00 ^b	37.33 ^{bc}	46.00 ^c
	Nativo	12.33 ^{bc}	22.00 ^e	26.00 ^d	32.00 ^c	33.67 ^{ed}	40.00 ^{de}
	Mancozeb	11.33 ^{bcde}	18.11 ^g	20.33 ^f	23.33 ^{ed}	30.33 ^f	36.00 ^f
	Fungozeb	9.67 ^{def}	15.10 ^h	16.67 ^g	20.00 ^{ef}	23.67 ^{gh}	26.00 ^h
LSD (0.05)		2.33	1.82	2.33	3.33	2.68	2.38
CV%		11.54	5.06	5.61	5.20	4.96	3.55

Means within the same column followed by the same letter(s) are not significantly different; FS = Fungicide Spray, DAS=Days after Sowing, LSD = Least significant Difference, CV= Coefficient of Variations.

varieties (Agegnehu and Fessehaie, 2006; Wolde and Mitiku, 2018; Mengesha et al., 2022).

Fungicide spraying highly affected AUDPC values ($P<0.001$). The highest AUDPC value (1155%-day) was obtained from unsprayed plots, while the lowest (715%-day) was observed in Fungozeb 80WP-treated plots at 2.5 kg/ha. Recent studies support that frequent application of protectant fungicides such as Mancozeb and Fungozeb highly reduce AUDPC values by slowing disease progress (Yitayih et al., 2023; Kebede et al., 2019; Bugingo et al., 2025). Besides, AUDPC is becoming a reliable measure for determining host resistance and fungicide performance in field trials (Mengesha et al., 2022).

The spraying $\times$ variety interaction effect resulted in a significantly reduced AUDPC ($P<0.001$). The sprayed local variety treated with Fungozeb 80WP at 2.5 kg/ha recorded mean AUDPC values of 1135, 1035, and 903%-day, respectively. Meanwhile, the unsprayed local variety recorded a mean AUDPC value of 1408%-day (Table 5). Premium lines Degaga and Gebelicho recorded mean AUDPC values of 796, 675, 573%-day, and 979, 810, 669%-day, respectively, on spraying. Nevertheless, the unsprayed Degaga and Gebelicho recorded mean AUDPC values of 944 and 1112 %-day, respectively (Table 8). The highest mean AUDPC value (1408%-day) was in the unsprayed local variety, while the lowest (573%-day) was in Degaga sprayed with Fungozeb 80WP at 2.5 kg/ha (Figure 2). These findings align with current research that mixing resistant varieties

with fungicide sprays considerably decrease AUDPC and postpone disease occurrence compared to untreated controls (Mengesha et al., 2022; Bugingo et al., 2025; Yitayih et al., 2023). The disease progress curves of chocolate spot disease (Figures 2 to 4) again demonstrate the effect of Fungozeb 80WP at 2.5 kg/ha on disease severity in the three faba bean varieties—Local, Degaga, and Gebelicho.

The development of chocolate spot disease on faba bean varieties over time was assessed by calculating the percentage severity index for each of the different fungicide spray treatments. The disease progression curves for the Local, Degaga, and Gebelicho varieties show how the application of fungicide impacted on the severity of the disease over the growing season (Figures 3 to 5).

Disease progress rat

The logistic model $[\ln(y/1-y)]$ (Van der Plank, 2013) and Gompertz models were compared to select the model that best fit to describe the development rate of chocolate spot disease. Model selection was based on the coefficient of determination (R^2) with the Gompertz model giving a better description of the trend of disease development than the logistic model. The Gompertz model was thus used to estimate the disease progress rate parameters.

As explained by Campbell and Madden (1990), the rate

Table 5. Interaction effect of faba bean varieties and fungicide spraying frequency on area under disease progress curve and infection rate of chocolate spot disease under field condition.

Variety	FS	AUDPC	Infection rate
Local	Unsprayed	1408 ^a	0.027
	Nativo	1135 ^b	0.026
	Mancozeb	1035 ^c	0.024
	Fungozeb	903 ^e	0.024
Degaga	Unsprayed	944 ^{de}	0.020
	Nativo	796 ^f	0.019
	Mancozeb	675 ^g	0.018
	Fungozeb	573 ^h	0.015
Gebelicho	Unsprayed	1112 ^b	0.022
	Nativo	979 ^d	0.022
	Mancozeb	810 ^f	0.021
	Fungozeb	669 ^g	0.021
LSD 0.05		48.51	0.0023
CV%		3.11	6.40

Means within the same column followed by the same letter(s) are not significantly different; FS = Fungicide Spray, AUDPC = Area under disease progress curve; LSD = Least significant Difference's= Coefficient of Variation.

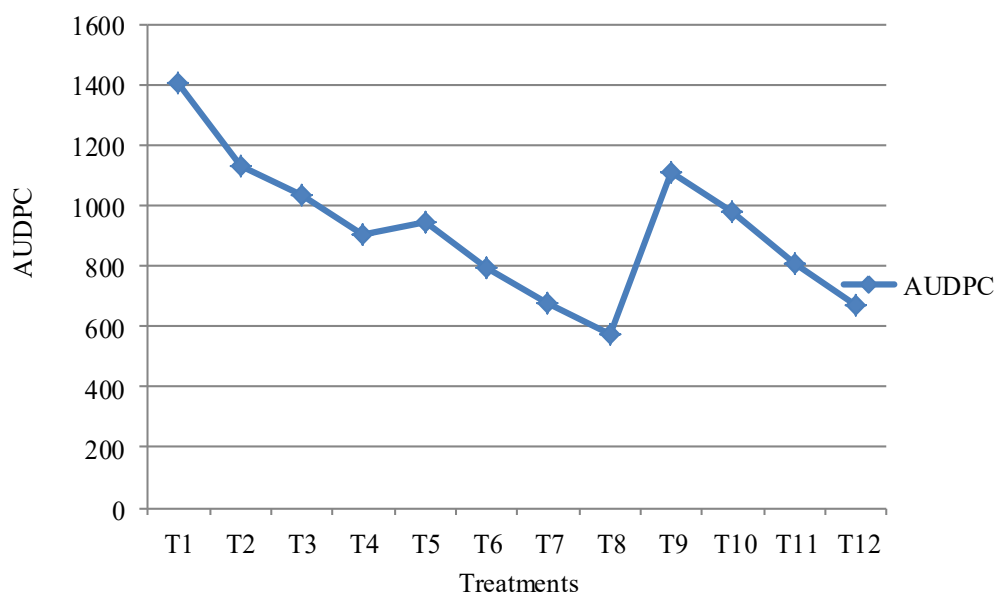


Figure 2. Area under disease progress curve (AUDPC) of chocolate spot disease in relation to varieties of Faba bean treated with different fungicide spraying. T1=Local + No Spray Fungicide, T2=Local + Nativo SC300 0.45L/ha, T3 =Local + Mancozeb 80WP 2.5 kg/ha, T4=Local + Fungozeb 2.5 kg/ha, T5=Degaga + No Spray Fungicide, T6=Degaga + Nativo SC300 0.45 L/ha, T7=Degaga + Mancozeb 80WP2.5 kg/ha, T8=Degaga + Fungozeb 2.5 kg/ha, T9=Gebelicho + No Spray Fungicide, T10=Gebelicho + Nativo SC300 0.45 L/ha, T11=Gebelicho + Mancozeb 80WP 2.5 kg/ha, T12=Gebelicho + Fungozeb 2.5 kg/ha.

of infection of chocolate spot disease is linearly related to the natural logarithm of diseased to healthy tissue ratio

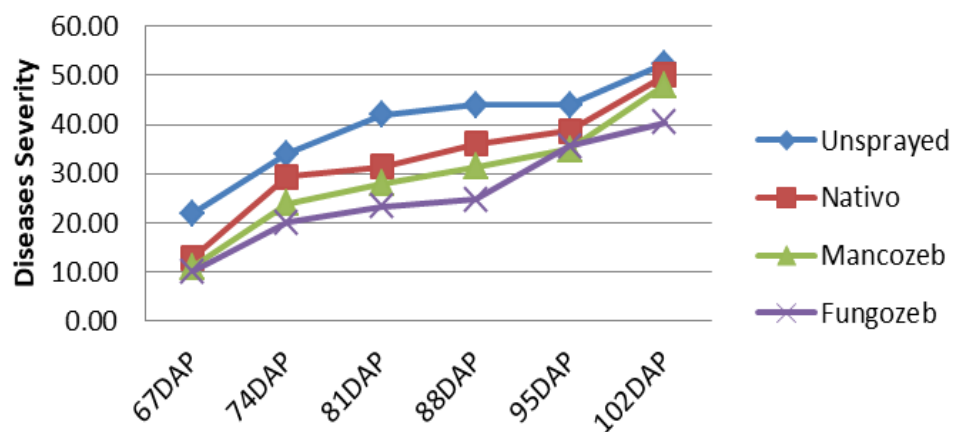


Figure 3. Chocolate spot progress curve based on percentage severity index as influenced by different spray of fungicide on Local variety.

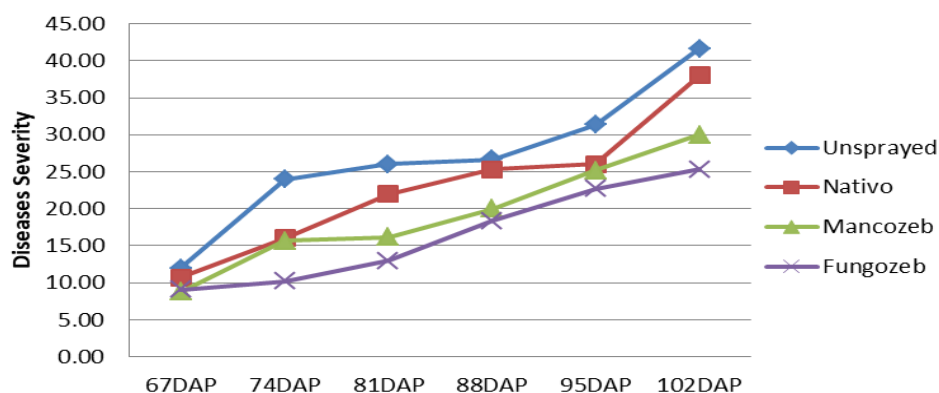


Figure 4. Chocolate spot progress curve based on percentage severity index as influenced by different spraying fungicide on Degaga variety.

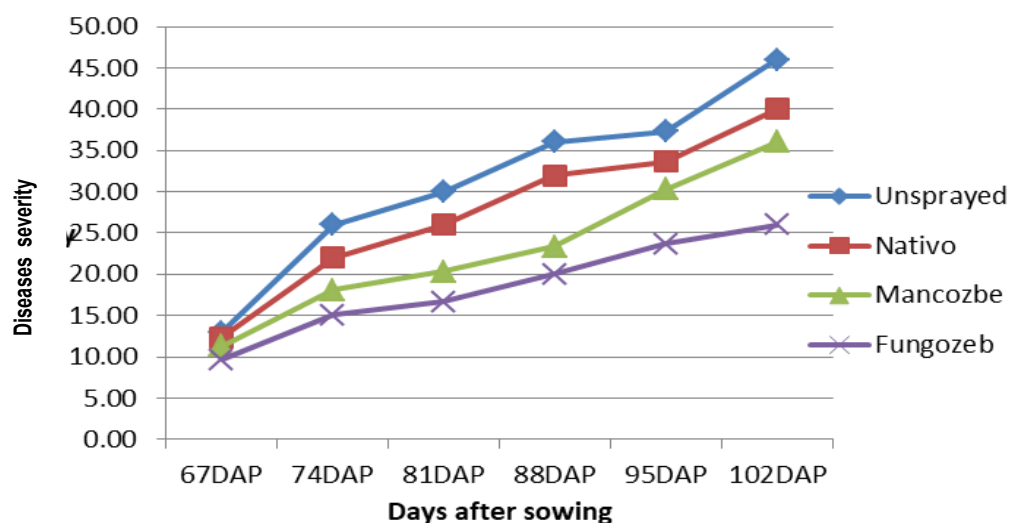


Figure 5. Chocolate spot progress curve based on percentage severity index as influenced by Different spraying of fungicide on Gebelicho Variety.

The varieties, fungicide treatments, and interaction significantly differed ($P < 0.01$). The local Gebelicho and Degaga varieties recorded progress rates of 0.025, 0.020, and 0.020 units/day, respectively. In respect of fungicide application, 0.023, 0.022, 0.022, and 0.019 units/day rates of disease progress in the unsprayed plots and Fungozeb 80WP 2.5 kg/ha sprayed plots were observed (Table 6), indicating faster development of the disease in the unsprayed plots.

Variety by spray frequency interaction also illustrated this pattern. Local variety recorded 0.026, 0.024, and 0.024 units/day progress of disease with Nativo SC300 (0.45 L/ha), Mancozeb 80WP (2.5 kg/ha), and Fungozeb 80WP (2.5 kg/ha) sprays, respectively, compared to 0.027 units/day in control plots. Similarly, Degaga had 0.019, 0.018, and 0.015 units/day in rising spray frequencies, while Gebelicho had 0.022, 0.021, and 0.021 units/day, compared to 0.02179 units/day without spraying (Table 7).

These results indicate a higher development rate of chocolate spot disease in the unsprayed plots, which is evidenced by recent studies that fungicide-treated plots considerably lower apparent infection rates and delay epidemic onset (Kebede et al., 2019; Yitayih et al., 2023; Bugingo et al., 2025). Besides, improved types such as Degaga have registered low infection at fungicide cover, which explains their dual use in integrated management (Agegnehu and Fessehaie, 2006; Mengesha et al., 2022). The highest visible infection rate of 0.025 units/day occurred in the unsprayed local type and the least (0.015 units/day) in Degaga sprayed with Fungozeb 80WP at 2.5 kg/ha. This agrees with recent evidence that the synergism of moderately resistant genotypes with fungicide sprays provides synergistic control of epidemic progress and achieves sustainable control of chocolate spot (Wolde and Mitiku., 2018; Mengesha et al., 2022).

Effect of treatments on yield and yield components

Days to 50% flowering and 90% maturity

Days to 50% flowering varied among faba bean varieties, ranging from 45.33 to 60.67 days. Varieties Gebelicho were the latest to reach 50% flowering (60.67 days), indicating genetic variation in the flowering duration. This finding is consistent with recent research on the assessment of Ethiopian faba bean genotypes, where flowering ranged from 57 to 62 days depending on varietal variation (Wolde and Mitiku, 2018).

Days to 90% physiological maturity were significantly influenced by fungicide spray. Degaga and Local matured in 131 and 132 days, respectively, while Gebelicho took 134 days to mature. Although varietal differences in maturity were not significantly different, varietal maturity differences exhibited genetic background and environment interaction.

There were noteworthy differences ($P \leq 0.01$) in days to maturity between fungicide-treated and unsprayed plots. Maturity was postponed by weekly fungicide spray, with Degaga, Local, and Gebelicho taking 132.67, 131.33, and 134.00 days, respectively, compared to 117.67, 92.67, and 119.00 days in unsprayed plots. This shows that fungicide protection reduced the severity of the disease, allowing prolonged physiological activity because of healthier canopy retention. Similar trends were reported by Bugingo et al. (2025) and Mengesha et al. (2022) where growth period was extended by fungicide treatments via the suppression of chocolate spot epidemics.

Plant height

Analysis of variance indicated significant variation ($P < 0.01$) in plant height between the faba bean varieties at maturity. Degaga had the tallest plant (127.09 cm), followed by Gebelicho (118.28 cm), while the local variety had the shortest plant (87.37 cm). This result is in agreement with earlier varietal trials which indicated firm genetic control of height under conditions in Ethiopia (Agegnehu and Fessehaie, 2006).

Fungicide sprays also impacted plant height considerably. Fungozeb 80WP (2.5 kg/ha) sprayed plots realized 140.17 cm, whereas sprayed plots were limited to only 79.94 cm at harvest. Yitayih et al. (2023) also reported the same advances in plant vigor by fungicide sprays, which showed from their findings that chemical protection assists in increasing photosynthetic capacity and biomass accumulation.

Variety $\times$ fungicide interaction also showed that Degaga and Gebelicho sprayed with Fungozeb had the tallest plants (151.07 and 141.90 cm), while local varieties sprayed were the shortest (44.60 cm). The same has been reported by Kebede et al. (2019) and underlined synergistic effect of genetics and disease suppression on architecture in the crop.

Pod length, pods per plant, and seeds per pod

Yield of the variety and fungicide sprays significantly ($P < 0.001$) influenced the pods. Degaga recorded the highest mean pod length at 9.14 cm, followed by Gebelicho with 8.85 cm, while the local had the lowest of 3.91 cm. The longest pods were 10.38 cm in Degaga when sprayed three times, compared to 3.84 cm in unsprayed local plots.

Pod number per plant was also significantly impacted, with Degaga producing the maximum number of pods (9.14 pods/plant) under fungicide protection, while the local variety produced the least (3.91 pods/plant). Mengesha et al. (2022) obtained similar findings, where pod number was enhanced by fungicide sprays by

Table 6. Interaction effects of faba bean varieties and fungicide spraying frequency on Days to 50% flowering, days to 90 % maturity, pod length and plant height.

Varieties	FS	DF	DM	PH (cm)	PL (cm)
Local	Unsprayed	34.00 ⁱ	92.67 ^e	44.60 ⁱ	2.02 ^g
	Nativo	41.67 ^h	125.00 ^{abcd}	75.87 ^h	3.44 ^{fg}
	Mancozeb	49.33 ^{efg}	129.00 ^{bac}	101.47 ^{fg}	2.52 ^g
	Fungozeb	56.33 ^{cd}	131.33 ^{ab}	127.53 ^{cd}	4.67 ^{def}
Degaga	Unsprayed	43.67 ^{gh}	117.67 ^d	104.43 ^f	5.70 ^d
	Nativo	48.67 ^{fg}	121.33 ^{bdc}	117.60 ^{de}	7.93 ^c
	Mancozeb	55.67 ^{cde}	127.33 ^{abcd}	135.27 ^{bc}	9.87 ^b
	Fungozeb	66.67 ^b	132.67 ^a	151.07 ^a	13.04 ^a
Gebelicho	Unsprayed	50.33 ^{def}	119.00 ^{cd}	90.80 ^g	3.80 ^{efg}
	Nativo	52.00 ^{cdef}	126.33 ^{abcd}	111.70 ^{ef}	8.87 ^{bc}
	Mancozeb	57.33 ^c	131.60 ^{ab}	128.70 ^{cd}	10.17 ^b
	Fungozeb	83.00 ^a	134.00 ^a	141.90 ^{ab}	12.57 ^a
LSD (0.05)		6.4	11.32	11.49	1.82
CV%		7.1	5.39	6.12	14.69

FS = Fungicide Spray, DF = days to flowering, DM = days to maturity, PH= plant height, PL= Pod Length.

Table 7. Interaction effects of faba bean varieties and fungicide spraying on number of pods per plant, number of seeds per pod, hundred seed weight, grain yield and relative yield loss.

Variety	FS	NPPP	NSPP	HSW (g)	GY (tonha ⁻¹)	RYL
Local	Unsprayed	8.46 ^h	4.03 ^g	23.10 ^g	1.78 ^h	49.37 ^a
	Nativo	11.29 ^{gef}	5.60 ^{ef}	48.93 ^f	2.52 ^g	28.32 ^b
	Mancozeb	12.76 ^{cdef}	6.67 ^{de}	62.33 ^e	2.59 ^g	26.39 ^b
	Fungozeb	14.75 ^b	8.93 ^c	76.43 ^{cd}	3.53 ^e	0.00
Degaga	Unsprayed	11.02 ^{fg}	5.67 ^{ef}	31.97 ^g	3.68 ^d	20.86 ^{cd}
	Nativo	13.12 ^{bcdde}	7.57 ^d	70.77 ^{de}	3.83 ^c	17.70 ^{de}
	Mancozeb	14.34 ^{bc}	9.97 ^c	79.20 ^{bcd}	4.11 ^b	11.68 ^f
	Fungozeb	19.10 ^a	13.17 ^a	88.50 ^{ab}	4.65 ^a	0.00
Gebelicho	Unsprayed	9.90 ^{gh}	5.20 ^{fg}	63.81 ^e	3.21 ^f	22.38 ^c
	Nativo	12.25 ^{def}	6.93 ^d	72.03 ^{cde}	3.41 ^e	17.70 ^{de}
	Mancozeb	13.49 ^{bcd}	8.90 ^c	80.70 ^{bc}	3.53 ^e	14.64 ^{ef}
	Fungozeb	17.54 ^a	11.93 ^b	94.67 ^a	4.14 ^b	0.00
LSD (0.05)		1.97	1.23	9.93	0.13	3.98
CV%		8.82	9.21	8.88	2.25	13.50

FS = Fungicide Spray, NPPP=Number of pods per plant, NSPP= Number of seeds per plant, HSW=Hundred seed weight, Grain Yield, RYL= Relative Yield Loss, LSD= least Significant difference, CV= coefficient of variations.

reducing early leaf senescence.

Number of seed pods was also enhanced by the use of fungicides, with Degaga and Gebelicho producing many

more seeds under intensive spraying compared to unsprayed local controls. The same finding was documented by Wolde and Mitiku (2018), attributing the

role of reduced severity of disease in reproductive growth.

Hundred seed weight

Major variation in 100-seed weight existed among varieties. Gebelicho had the highest (77.80 g), with Degaga (67.61 g) and the local variety having the lowest (52.70 g). Spray application with Fungozeb 80WP (2.5 kg/ha) raised seed weight to 86.53 g versus a mere 39.62 g in unsprayed plots, reflecting efficient disease suppression.

Variety $\times$ fungicide interactions were highly significant ($P < 0.001$). Fungozeb-treated Gebelicho produced the heaviest seeds (94.67 g), followed by Degaga (85.50 g), and the lowest was achieved in the unsprayed local plots (76.43 g). The result aligns with Yitayih et al. (2023) and Bugingo et al. (2025), who found that fungicide application significantly contributed to seed filling and improved grain quality.

Grain yield

Grain yield was highly influenced ($P < 0.001$) by variety and sprays of fungicides. Degaga produced the highest (3.96 t/ha), followed by Gebelicho (3.54 t/ha), while local variety registered the lowest (2.62 t/ha). The highest yield (4.65 t/ha) was from Degaga sprayed with Fungozeb, while the lowest (1.78 t/ha) was registered from the unsprayed local variety.

This pattern is in concordance with Kebede et al. (2019) and Mengesha et al. (2022), who found that fungicide sprays greatly increased yield by lowering the intensity of chocolate spot. Dual application of resistant varieties such as Degaga together with fungicide protection attained maximum productivity and stability of the yield under the condition of overwhelming disease pressure (Agegnehu and Fessehaie, 2006; Bugingo et al., 2025).

Relative yield loss

Relative yield loss was significantly affected ($P < 0.01$) by variety and fungicide spraying. The local variety that was not sprayed recorded the highest loss (49.37%), while Gebelicho under two sprays of fungicide recorded the least (11.68%). The lowest absolute yield (1.78 t/ha) was also recorded by the unsprayed local variety, while sprayed Degaga plots had a zero-yield loss.

These results agree with Yitayih et al. (2023) and Bugingo et al. (2025), which confirmed that the use of fungicides notably minimizes yield loss, though susceptible genotypes are highly vulnerable when not sprayed. Mengesha et al. (2022) also emphasized that

integrated approaches using fungicides and host resistance are essential to faba bean yield gap closure.

Correlation analysis of disease and yield parameters

Association tests between disease variables and yield parameters were also conducted through simple correlation analysis in faba bean (*Vicia faba* L.). The findings indicated high positive correlation among different yield parameters. Conversely, all the yield parameters were with high negative correlation with key disease indicators including area under the disease progress curve (AUDPC), disease severity, and infection rate.

Specifically, AUDPC indicated significant negative correlations with the number of pods per plant ($r = -0.86^{**}$) and grain yield ($r = -0.92^{**}$), and disease severity was significantly negatively correlated with the number of pods per plant ($r = -0.81^{**}$) and grain yield ($r = -0.91^{**}$) (Table 8). These results indicate that the development of disease drastically weakens yield-contributing traits.

It also indicated significant interrelationships among disease parameters themselves, where AUDPC, severity, and infection rate exhibited extremely significant ($P \leq 0.001$) correlations. These patterns mirror accumulative and compound effects of disease pressure on plant performance. These findings are supported by more current studies. Mengesha et al. (2022) determined that severity of chocolate spot was significantly negatively correlated with number of pods per plant, grain yield, and hundred seed weight, supporting the direct decrease of productivity from enhanced disease pressure. Likewise, Kifle et al. (2022) reported significant negative correlations between AUDPC and yield traits, demonstrating the harmful effect of disease progression on faba bean agronomic performance. Further, Abera and Semagn (2022) found that increased severity of chocolate spot was significantly correlated with reduced plant height, pod number, and grain yield, further emphasizing the importance of early disease management. Additionally, Berhan and Bekele (2021) observed that combined application of fungicides and resistance varieties significantly minimized AUDPC values and maintained higher yields, in support of the hypothesis that disease suppression is important for stable yields.

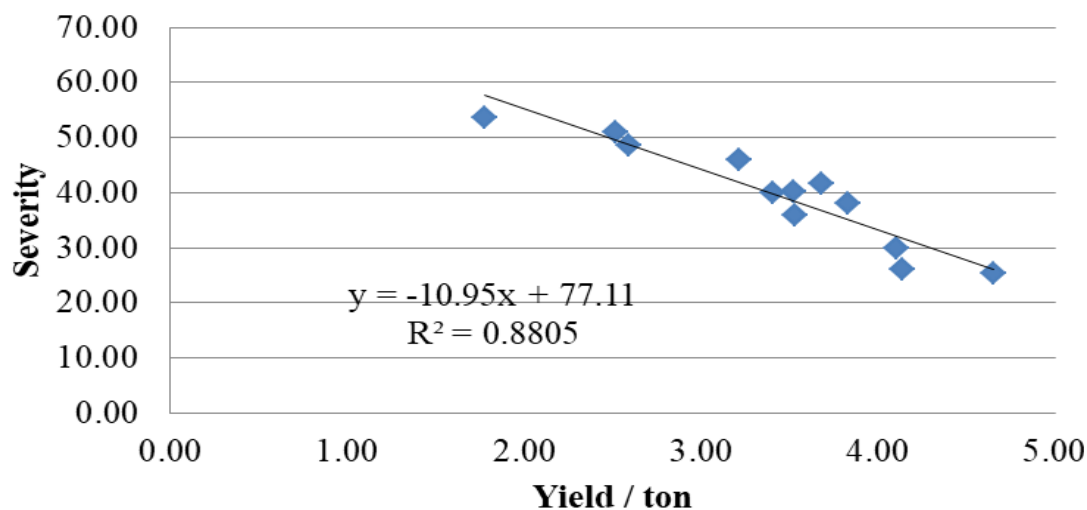
Generally, the patterns of correlation indicate that chocolate spot not only reduces yield directly but also reduces the characteristics of yield, further authenticating the necessity of including host resistance and fungicide application towards sustainable production of faba bean.

The last severity (98 DAS) as the regression in the regression analysis was significantly ($p < 0.001$) correlated with the yield (dependent variable). The grain yield ($t\ ha^{-1}$) = $-10.95x + 77.11$ ($R^2 = 88.05\%$, $P = 0.00015$) regression equation validated the reduction of about $-10.95\ t\ ha^{-1}$ grain yield with the 1% severity increase (Figure 6). Coefficient of determination (R^2) values

Table 8. Association test for disease and yield parameter.

Variable	PH	PL	NPPP	NSPP	HSW	Yield	RYL	TDS	AUDPC	R
PH	1									
PL	0.81***	1								
NPPP	0.66***	0.73***	1							
NSPP	0.86***	0.85***	0.79***	1						
HSW	0.85***	0.77***	0.69***	0.82**	1					
Yield	0.89***	0.83***	0.70***	0.80**	0.73***	1				
RYL	-0.87***	-0.73***	-0.77***	-0.83**	-0.82***	-0.87***	1			
TDS	-0.83***	-0.89***	-0.81**	-0.89**	-0.77***	-0.90***	0.82***	1		
AUDPC	-0.85***	-0.86***	-0.85**	-0.84**	-0.75***	-0.92***	0.86***	0.93***	1	
R	0.52**	0.64***	0.43*	0.61*	0.44**	0.61***	0.42**	0.78***	0.56**	1

***, **, *, Correlation is very highly significant at the ($P < 0.001$) and (P at 0.01) highly significance level and (0.05) significant level; AUDPC = Area under Disease Progress Curve, PH = Plant Height, NPPP = Number of Pods per Plant, PL = pod length, NSPP = number of seeds per pod, HSW = hundred seeds weight, RYL = relative yield loss, TDS = terminal disease severity, R = rate of infection

**Figure 6.** Linear regressions of grain yield and terminal severity.

demonstrated that 88.05% of the grain yield loss was due to the impact of faba bean "chocolate spot" disease infection of faba bean as the estimated terminal severity on the percentage of the yield loss. (The independent variable x is the level of the disease severity in percentage). Similarly, regression analysis of the terminal severity (102 DAS) as predictor on hundred seeds weight.

CONCLUSION AND RECOMMENDATIONS

Chocolate spot (*Botrytis fabae*) remains a serious issue confronting faba bean (*V. faba* L.) production within the Chilga district, imposing a significant impact on yield and yield components, particularly hundred seed weight. Widespread cultivation of susceptible local types and low

application of fungicides by farmers exacerbate the issue. Environmental parameters such as altitude, sowing time, plant density, and prior crops were found to have tremendous impacts on disease development based on this study.

Most importantly, host plant resistance integrated with fungicide application worked very well. The Degaga variety with partial resistance integrated with Fungozeb 80WP at 2.5 kg/ha significantly reduced disease incidence, severity, and AUDPC values and enhanced yield and economic return at the same time. The findings are evident that adopting integrated disease management compared to relying on a single practice is the most environmentally sound and profitable approach to controlling chocolate spot and enhancing faba bean productivity in the research area.

Farmers in Chilga district and other similar agro-

ecologies are encouraged to adopt the Degaga variety since it is partially resistant to chocolate spot and performs well in terms of yield. Fungozeb 80WP at 2.5 kg/ha should be sprayed during critical growth stages, particularly early flowering and podding, to effectively check disease development and limit loss of yield. The use of resistant varieties with appropriate fungicide application at the appropriate time should be promoted as a normal practice, with added resistance to disease occurrence and superior economic returns. In addition, extension programs should provide training to farmers regarding the benefits of resistant varieties, the use of fungicides, and integrated disease management strategies in a view to enhance adoption rates. To validate these findings and extend them to different agro-ecologies, further multi-location and multi-season research is recommended, along with investigations of further management strategies such as crop rotation, optimum planting rate, and biological control methods to further reduce chocolate spot pressure.

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CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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