

Assessing the Prevalence and Management of Chocolate Spot (*Botrytis Fabae* L.) of Faba Bean (*Vicia Faba* L.) Using Host Resistance and Fungicide Spray Frequencies in Dabat District, North Western Ethiopia

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Research Article

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Posted Date: April 30th, 2025

DOI: <https://doi.org/10.21203/rs.3.rs-6556242/v1>

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Additional Declarations: The authors declare potential competing interests as follows:

Assessing the Prevalence and Management of Chocolate Spot (*Botrytis Fabae* L.) of Faba Bean (*Vicia Faba* L.) Using Host Resistance and Fungicide Spray Frequencies in Dabat District, North Western Ethiopia

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ABSTRACT

Faba bean (*Vicia faba* L.) is one of the oldest domesticated food legumes, cultivated for over 5,000 years. It is a vital crop for farming communities, especially in Ethiopia, where it provides an essential source of food, income, and soil fertility. However, one of the major challenges faced by faba bean farmers is Chocolate Spot disease, caused by the fungal pathogen *Botrytis fabae*. This disease is a significant yield limiter, with losses reaching up to 68% in some regions of Ethiopia. To address this issue, a study was conducted in the Dabat district of the South Gondar Administrative Zone during the 2022/2023 cropping season. The primary goal was to assess integrated management strategies for controlling Chocolate Spot in faba bean. The experiment involved three faba bean varieties—Local, Walki, and Hachalu—and four fungicide spraying frequencies (unsprayed, one-time spray, two-time spray, and three-time spray). The fungicide used was Trust Cymocop 439.5% WP, applied at a rate of 1.5 kg/ha. A randomized complete block design with three replications was employed, and the results revealed significant interactions between the variety of faba bean and the frequency of fungicide spraying.

The study found that the Walki variety, when sprayed three times with the fungicide, exhibited the lowest disease severity at 25.33%, compared to the Local variety, which had the highest severity at 52.33% when left unsprayed. The Area under Disease Progress Curve (AUDPC) was also significantly lower in Walki with three sprays (573%-unit day), suggesting that fungicide application coupled with resistant varieties can effectively manage Chocolate Spot disease.

This research highlights the importance of using resistant varieties and appropriate fungicide application to control Chocolate Spot disease and improve faba bean yields. However, to strengthen these findings, further research is recommended over multiple cropping seasons.

Keywords: AUDPC, Chocolate spot, disease assessment, faba bean, incidence

1. INTRODUCTION

Faba bean (*Vicia faba* L.), locally known as "Bakela," is a vital annual herbaceous plant in Ethiopia, thriving at elevations between 1800 and 3000 m above sea level with an annual rainfall of 700-1000 mm (ICARDA, 2006; Yekedem Bimrew and Hassen Shifa, 2018). The crop is extensively cultivated by small-scale farmers in various regions, including Arsi, Bale highlands, Central highlands (South-West, West, and North Showa), Tigray, North and South Wollo, North and South Gondar, East and West parts of Gojam, Wollega, Guji highlands, Hadiya, Sidama, and Gamogofa (Asnakech, 2014; Biruk Bereda, 2009; CSA, 2016; Merkuz Abera, 2017).

Ethiopia stands as the second-largest global producer of faba beans, contributing approximately 1,070,636.54 tons annually, with Oromia and Amhara regions leading in production (CSA, 2021). Despite its significance, the faba bean faces substantial challenges, particularly from the chocolate spot disease caused by *Botrytis fabae*. This disease has been reported as a significant threat to faba bean cultivation across various continents, including Europe, South East Asia, South America, Korea, India, Canada, Norway, the Middle East, North-east and Southern Africa, and Australia (Bouhassan *et al.*, 2004; Tivoli *et al.*, 2006).

Chocolate spot, prevalent in Ethiopia, has led to yield losses of up to 61% on susceptible and 34% on tolerant faba bean genotypes in the central highlands (Dereje Gorfu and Yaynu Haile, 2001). In some instances, unsprayed faba bean plots in northwest Ethiopia experienced higher yield losses of 67.5% (Samuel *et al.*, 2008). The disease is particularly severe in areas with high precipitation (>900 mm) and elevations exceeding 2000 m above sea level (Sahile Samuel *et al.*, 2008b).

Various management strategies have been employed globally to combat chocolate spot, including the use of resistant/tolerant genotypes, chemical fungicides, crop residue management, and adjusting sowing dates (Hawthorne, 2004). Resistant varieties and fungicides have proven effective but may not always be environmentally friendly and cost-effective (Ermias Teshome and Addisu Tagegn, 2013). The increasing importance of faba bean as an export crop in Ethiopia emphasizes the need for sustainable disease management practices.

Despite the growing interest in faba bean cultivation, there is limited information about the prevalence and management of chocolate spot in the Dabat district. This knowledge gap prompted the initiation of research aimed at managing chocolate spot disease through the integrated use of host resistance and fungicide frequencies in Northwest Ethiopia (Misgana

Mitiku, 2017). The study specifically aims to assess the effectiveness of combining different faba bean varieties with Trust-Cymocop 439.5 WP fungicide and determine the optimal fungicide application frequency and interval for effective disease management in the region.

2. MATERIALS AND METHODS

This study comprises two components, viz field assessment on chocolate spot disease and field experiment to determine the effect of faba bean varieties and fungicide spray frequencies on chocolate spot disease development and its effect on yield and yield components on faba bean in Dabat District, North Gondar, Ethiopia.

3.1. Assessment of Chocolate Spot Disease

3.1.1. Description of the study area

The study was conducted in Dabat district, North Gondar, Amhara region of Ethiopia during 2022 cropping season. Dabat is bordered in the south by Wegera district, in the west by Tach Armachiho district, in the northwest by Tsegeda district, and in the northeast by Debark district (DWARD0, 2021). The district is situated 13°09'60.00"N latitude and 37°39'59.99"E longitude. The altitude of the district ranges 1500 to 3200 m.a.s.l. The mean annual rainfall in the Dabat district *a* ranges 800 to 1400 mm. The main rainy season starts at the beginning of June and continues up to the end of September Dabat district is located 814 km and 75km from Addis Ababa and north Gondar city, respectively. The district has a total of 28,293ha of cultivated land and a population of 176,795. (DWARD0, 2022). The minimum and maximum temperature of the district is 18 and 35⁰ C respectively. The major Soil types are clay loam and loamy sand. Major crops grown in the area are wheat (*Triticum aestivum* L.), faba bean (*Vicia fabae*), barley (*Hordeum vulgare* L.), potato (*Solanum tubersum* L.) and teff (*Eragrostis teff* L.). Among these crops, faba bean accounts for 56.7% of production in the area (DWARD0, 2022).

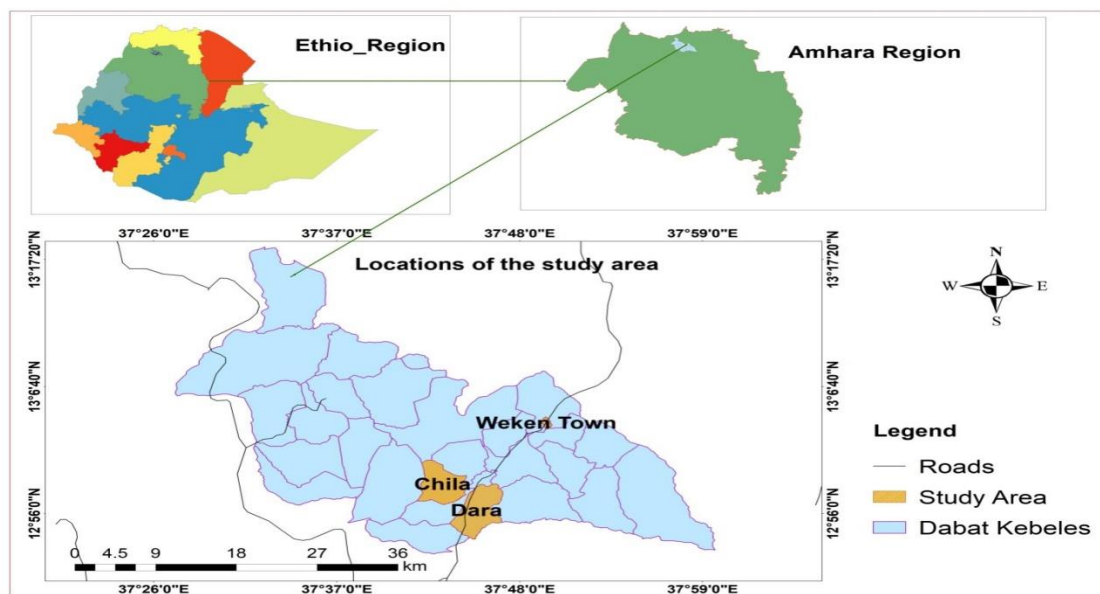


Figure 3.1 location map of the study area (Central Statistics Agency, 2023)

3.1.2. Field sampling procedures

In the district three kebeles administrations were purposively selected based on faba bean production status, and the hot spot area of disease problem. In each kebele administration, twenty (20) faba bean growing farmer fields were selected randomly. Totally 60 farmer's fields were assessed. In each sample field, quadrants (1m x 1m) were thrown by moving diagonally across each field from one end to the other in an 'X' pattern (Merkuz Abera and Getachew Alemayehu, 2012b; Samuel Sahile et al., 2008; Mesele Haile. ,2018). Faba bean fields were assessed at three growth stages; at flowering, pre podding and podding stage.

Disease incidence (the number of diseased plants, expressed as percentage of the total number of plants assessed) of faba bean chocolate spot was assessed by visual examination and counting of stands with disease on the leaves symptom of faba bean plants. The disease prevalence or distribution was recorded base on the kebeles administration farmer field infested out of the total kebeles administration farmer field observed. The data on Disease severity was assessed by considering 12 plants in each quadrant and averages were taken for each field. Percentage of infected leaf area was determined as the percentage of the total leaf surface covered with chocolate spot lesions based on the scale by taking randomly whole faba bean plants.

3.1.3. Data collected

Disease data

Disease Incidence and Severity

Three parameters; disease prevalence, severity and incidence were considered.

$$\text{Disease incidence} = \frac{\text{No. of diseased plants}}{\text{Total plants observed}} * 100$$

Source (Bernier et al. 1993; Ding et al., 1993; Wulita, 2015).

$$\text{Disease severity} = \frac{\text{Area disease coverage}}{\text{Total area covered observed}} * 100$$

Source (Wheeler, 1969)

Table 1 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 (6–25% of leaf area)
5	Some coalesced lesions with some defoliation diameter 3–5 mm (26– 50% of leaf area)
7	Large coalesced lesion sporulation lesions, 51-75 % defoliation and some dead plants
9	Extensive, heavy sporulation, stem girdling, blacking and death of more than 76 % leaf of plants

Source: Ding et al. (1993)

The severity grades were converted into percentage severity index (PSI) for ease of analysis according to the formula by Wheeler (1969). Whereas:

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

During the field survey; altitude, field history (preceding crops), field size, varieties of faba bean, planting date, fertilization, planting density, planting method, growth stage, soil types and fungicide management environmental parameters like onsets of rainy season and soil type, were assessed to determine the relationship with chocolate spot disease incidence and severity.

3.1.4. Data analysis

The collected survey data were analyzed using SPSS software (SPSS, 2007) version 20 to determine disease incidence and severity. Mean and percent over District, and varieties grown, previous crop, plant density, sowing date, the altitude range and the crop growth stage were subjected to descriptive statistical analysis. The frequency and percentage of each variable class assessed is presented. Analysis was conducted to describe the distribution and association of chocolate spot incidence and severity in relation to independent variables. Disease incidence and severity were classified into distinct classes of binomial qualitative data. Class boundaries ($< 75\%$ and $\geq 75\%$) were chosen for disease incidence and ($< 35\%$ and $\geq 35\%$) for PSI data.

2.2. Management of chocolate spot (*Botrytis fabae* L.) of faba bean through integrated use of host resistance and fungicide frequencies sprays

2.2.1. Description of the experimental site

The experiment detailed in this study was carried out at Dabat Zuria Kebeles Administration (KAs) in Dabat district, focusing on farmer fields during the 2022/2023 cropping season. Dabat Zuria kebeles, situated at an altitude of 2720 meters above sea level, belongs to the Dega agro-ecological zone and features a clay loam soil type. According to data from the Dabat Zuria kebeles Administration, the area experiences a mean annual temperature of 19°C and receives an annual rainfall of 980 mm. The specific geographic coordinates of the study area are approximately 11.856°N latitude and 37.654°E longitude (DWARD, 2022), providing a comprehensive context for the experimental conditions.

2.2.2. Experimental materials

In this experimental study, three faba bean varieties—Hachalu, Walki, 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). Specifically, Walki demonstrated moderate resistance, Hachalu exhibited moderate susceptibility, and the local variety was identified as susceptible to chocolate spot. Acknowledging the findings of Samuel *et al.* (2008), which highlighted the general trend of local varieties being low-yielding and highly susceptible to both biotic and abiotic stresses, the inclusion of these diverse faba bean varieties adds depth to the study. 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.

2.2.3 Experimental treatments, design, and procedures

In this experimental study, three faba bean varieties, namely Walki and Hachalu (improved varieties), and one local variety, were utilized. The experiment included a factorial combination of these varieties with four fungicide spray frequencies: one, two, and three times spraying, 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 m and 1 m, respectively. Each plot measured 2 m x 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 Trust Cymocop 439.5 WP 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.

2.2.4. 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 formula:

This methodological framework aligns with established practices as outlined by Bernier et al. (1993), Ding *et al.* (1993), and Wulita (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 formula (1969):

$$\text{Disease incidence} = \frac{\text{No. of diseased plants}}{\text{Total plants observed}} * 100$$

Source (Bernier et al. 1993; Ding et al., 1993; Wulita, 2015).

$$\text{Disease severity} = \frac{\text{Area disease coverage}}{\text{Total area covered observed}} * 100$$

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

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 Vander Plank (1963). 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 (R²) (Van der Plank, 1963). 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 in to kg ha⁻¹.

Days to flowering (50%)- 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 - was recorded when 90% of the plant is physiologically matured.

Plant height (cm) -Average length of plant from the bottom to the tip of the plant was measured and recorded from 12 pre tagged plant in each experimental unit at full maturity stage

Numbers of pods per plant- 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 was measured using ruler from randomly selected 12 pre tagged plant in each experimental unit at maturity.

Number of seed per pod- 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):

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

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.

3.2.5. 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).

Cost Benefit Analysis

In this study, the economic analysis focused on the assessment of faba bean seed prices per variety (in birr/kg), and the total commodity price from each treatment was computed. Input costs, encompassing fungicides, cultivars, and labor, were quantified based on their respective frequencies of use. Additionally, the cost of spray equipment for application was factored in. Utilizing the gathered data, a cost-benefit analysis was conducted using partial budget analysis. This method organizes information on the costs and benefits associated with various agricultural alternatives to evaluate the profitability of new technologies or practices, following the guidelines established by CIMMYT (International Maize and Wheat Improvement Center) in 1988.

The economic advantage or disadvantage of implementing different fungicide application frequencies was determined through the computation of cost-benefit ratios. Several considerations were taken into account during this analysis: (i) Uniformity of costs for all varieties and agronomic practices, (ii) Inclusion of local labor costs for spraying based on each locality's rates, (iii) Calculation of costs, returns, and benefits on a per-hectare basis, (iv) Assumption that farmers adopt integrated management of chocolate spot when varieties offer a

100% marginal rate of return, and (v) The assumption that farmers in the area achieve 90% of the experimental (actual) yield.

3. RESULTS AND DISCUSSION

3.1 Assessment of Faba bean Chocolate Spot Disease

3.1.1 General features of the surveyed fields

Chocolate spot disease survey was conducted in 60 fields of three potential faba bean-growing KAs in Dabat district, North Gondar Administrative Zone. The frequency and percentage of each variable class assessed are presented. The fields surveyed (26.7%) were at an altitude ≥ 2700 m.a.s.l., 35.0% were in the altitude range of 2680–2699 m.a.s.l., and 38.3% were at an altitude of <2680 m.a.s.l. The soil types were brown (60%), followed by red soil (28.3%), and 11.7% were black soil types. The previous crops of the surveyed farmers were wheat (45.0%), teff (25.0%), and barley (30.0%) (Table 1). This has implications for the adoption of a crop rotation system to reduce the inoculum of the disease and increase production and productivity of the crop. The benefit was also reported by Misgana Mitiku (2017). Only 26.7% of the farmers were sown in a row planting pattern, and the rest, 73.3%, were sown in broadcast planting. In the surveyed areas, 14 farmers (23.3%) used fertilizer (NPS) from the total of 60 observed farmers. The highest plant population ($\geq 38/\text{m}^2$) was observed among 43 farmers (71.7%) and 17 farmers ($< 38/\text{m}^2$) (28.1%) of the total of 60 farmers. Faba bean fields were at three growth stages during the survey, with 23.3% at flowering, 13.3% at pre-podding, and 63.3% at the podding stage. About 36.7% of farmers were sprayed with fungicide, and the rest, 63.3%, were unsprayed in the surveyed fields. Weeding in general was not done in all fields.

Table 2 Variables with their respective frequency used in analysis for the survey data of chocolate spot of faba bean in district 2023 main cropping season.

Variable	Variable Class	Number of fields	
		Frequency	Percent
KAs	<i>Dara</i>	20	33.3
	<i>Chila</i>	20	33.3
	<i>Wokien/Z</i>	20	33.3
Altitude	≥ 2700 Masl	16	26.7
	2680-2699 Masl	21	35.0
	< 2680 Masl	23	38.3
Soil type	Red	17	28.3
	Black	7	11.7
	Brown	36	60
Field history	Wheat	27	45.0
	Barley	18	30.0
	Teff	15	25.0
SD	June 10-15	24	40.0
	June 16 -20	10	16.7
	June 21-25	26	43.3
Growth stage	Flowering	14	23.3
	Pre-podding	8	13.3
	Podding	38	63.3
Planting density	$\geq 38/\text{m}^2$	43	71.7
	<38/m ²	17	28.3
Fertilizer Usage	Use	14	23.3
	Not use	46	76.7
Fungicide	Use	22	36.7
	Not use	38	63.3
Planting Method	broadcasting	44	73.3
	Row	16	26.7
Variety	Local	37	61.7
	Walki	12	20.0
	Ashebka	7	11.7
	Dosha	4	6.7
PDI	$\geq 75\%$	36	60.0
	< 75%	24	40.0
PSI	$\geq 35\%$	39	65.0
	<35%	21	35.0

PSI= Percentage Severity Index; PDI= Disease Incidence

Table 3 Independent variable by disease contingency table for regression analysis of faba bean chocolate spot during 2023 cropping seasons in the surveyed area.

Variable	Variable class	Incidence		Severity	
		$\geq 75 \%$	$< 75 \%$	$\geq 35 \%$	$< 35 \%$
KAs	<i>Dara</i>	13	7	14	6
	<i>Chila</i>	7	13	8	12
	<i>Woken/Z</i>	16	4	17	3
Altitude	≥ 2700 Masl	16	-	16	-
	2680-2699 Masl	20	1	20	1
	< 2680 Masl	-	23	3	20
Soil type	Red	12	25	6	10
	Black	-	7	2	6
	Brown	7	11	35	1
Field history	Wheat	26	1	25	2
	Barley	4	8	12	6
	Teff	6	15	2	13
SD	June 10-15	8	-	23	1
	June 16 -20	19	1	10	-
	June 21-25	5	23	6	20
Growth stage	Flowering	-	14	1	13
	Prepodng	-	8	2	6
	Poding	36	2	36	2
Planting density	$\geq 38/\text{m}^2$	10	16	20	24
	$< 38/\text{m}^2$	8	26	8	12
Fertilizer Usage	Fertilizer use	-	14	8	22
	Fertilizer Not use	36	10	16	20
	Fungicide use	-	22	2	20
Fungicide	Fungicide	36	2	37	1
	Not use				
Planting Method	Broadcasting	36	8	37	7
	Row	-	16	2	14
Variety	Loc 1	19	18	22	15
	Walki	6	6	6	6

Ashebka	7	-	7	-
Dosha	4	-	4	-

Incidence is number of leaves infected and expressed as a percentage of the total number of leaves assessed and severity is percentage severity index (PSI) of chocolate spot infection on the plants.

4.1.3. Incidence and severity of chocolate spot disease in the surveyed areas

The survey results indicated that, almost all the fields surveyed were infected with chocolate spot with in different levels of severity. The highest mean chocolate spot incidence was observed from Wokien/ Z (84.47 %) followed by, Dara (78.35 %), while the lowest was recorded on Chila (66.01 %) *Kas*. The highest chocolate spot disease severity was observed from Wokien/Z (70.42 %), followed by Dara (54.35 %) , *and* also similarly the lowest was recorded at Chila (43.04 %) *Kas* (Table 3). All the two *KAs* which have maximum mean value of disease incidence and severity are located at high altitude (≥ 2700 m.a.s.l.). This might be the reason for their maximum intensity of disease. Sahile Samuel *et al.*, (2008c) reported that both disease incidence and severity were relatively higher above 2500 m.a.s.l. Mesele Haile (2018) also mentioned that disease severity was relatively higher at high altitudes than low altitudes. In Overall disease incidence and severity of the district was 74.4% and 39.6% respectively.

Data on altitude were grouped into three ranges (≥ 2700 m.a.s.l, 2680 m.a.s.l. _ 2699 m.a.s.l and < 2680 m.a.s.l). The highest mean chocolate spot disease incidence and severity were observed on fields located at an altitude ≥ 2700 m.a.s.l. (89.16 % and 77.26 %) and the lowest disease incidence and severity were observed at an altitude < 2680 m.a.s.l. (60.90 % and 32.73%) from the given ranges (Table 3). This was agreed with the survey done by Mesele Haile (2018) which shows disease severity becomes higher at high altitude than lower altitudes.

Anteneh Ademe *et al.* (2018) also reported that severity of chocolate spot disease was higher with an altitude ≥ 2700 m.a.s.l. At higher altitude, farmers are experienced continues faba bean production year after year. This continued growing may increases the inoculum level and could result in rapid intensification of the disease.

During the field survey three soil types were observed on the fields assessed (brown, red and black). Maximum disease incidence and severity were observed on black soils (85.78 % and 69.77 %) and the least disease incidence and severity were observed on red soil (57.50 % and 31.26 %) respectively. EIAR (2015) showed that red and brown soils are preferable for the production of faba bean than black soils; since black soils are vulnerable for water lodging and as a result the crops may be attack by root rot and chocolate spot disease. Amare Tadesse *et al.*

(2018) also indicated that faba bean crop will not grow well in highly compacted soils (clay soils: which are mostly black in color).

In the surveyed areas all farmers applied appreciated crop rotation system. Although farmers used good crop rotation system the highest disease incidence of chocolate spot was observed on farms which had wheat and Barley farm history with mean values (88.64% and 72.99%) respectively and the maximum disease severity was observed on farms which had Wheat farm history with mean value (68.27 %). This result may be due to the variation of surveyed field location. Most of the farms in the surveyed areas which had farm history of wheat were observed in highland altitudes (Dega) whereas barley and teff were observed in *woina dega* zones. Mesele Haile (2018) showed that the inoculum may carry-over from one season to the next on infected faba bean seed, stubble and volunteer plants. Gosaye Eshetu *et al.* (2018) reported that field history of legumes was more favorable than cereals for the incidence and severity of chocolate spot disease. But in this study, there were no farms which had field history of legumes. The minimum disease incidence and severity was observed on farm history of teff (57.97 % and 31.54%) respectively (Table 3). This result was similar with (Estayih Animawu, 2018) who showed that the mean minimum level of incidence and severity (57.97 % and 31.54%) was recorded from previous teff sown fields.

The maximum disease severity $\geq 38/\text{m}^2$ (64.51%) was recorded in high plant density while the minimum disease severity $< 38/\text{m}^2$ (34.24%) was recorded in low plant density (Table 3). This surveyed data agreed to high plant density can cause less light penetration in the crop canopy, reduce photosynthetic efficiency and may lead to chocolate spot epidemic. Similarly Samuel Sahile *et al.* (2008) reported that severity of chocolate spot disease is higher in a dense population of faba bean plants than sparsely populated, the severity increases due to more plant to-plant spread of the *Botrytis fabae* inoculum.

Depends on fungicide usage higher disease incidence was observed on farms which were unsprayed with fungicide with mean value 85.45% than farms which were sprayed with mean value 60.43% (Table 4.3). This indicates that application of fungicide might reduce the severity level. As Asnakech Tarekalign (2014) reported, late application of the chemical after flowering resulted in the non-effectiveness of the chemical. Sahile Samuel *et al.* (2008b) also reported that, different management options are recommended in Ethiopia for the disease including application

of fungicides such as chlorothalonil, Mancozeb and Trust Cymocop439.5 WP but have not been adopted by the farmers at large.

During the survey faba bean crop was at three different growth stages (flowering, pre-podding and podding). Maximum disease incidence and severity was observed at podding stages (85.46% and 69.26%) respectively and the least disease incidence and severity at flowering stage (57.17% and 28.38%) respectively (Table 3). This result become in agreement with the survey done by Gedyon Tamiru (2017) who showed lowest incidences and severities were recorded in fields where faba bean was at flowering stage. In contrast the survey result was disagreed with the survey assessed by Anteneh Ademe *et al.* (2018) who showed that highest disease severity of chocolate spot was recorded on fields during the flowering stage. Sahile Samuel *et al.* (2008c) showed that under favorable conditions, chocolate spot disease increases as the plants mature. Harrison (1988) also reported about the significant role of the amount and quality of inoculum delivered to the crop canopy as well as the time of arrival of inoculum in relation to the stage of the crop development on the increase of the disease. High mean disease incidence and severity was recorded from podding stages.

The mean value of both disease incidence and severity was higher in farms which had plant population $\geq 38/\text{m}^2$ (80.80% and 64.51%) than farms which had plant population $< 38/\text{m}^2$ with mean value (64.82% and 34.24%). Mesele Haile (2018) and Sahile Samuel *et al.* (2008c) reported that severity of chocolate spot disease is higher in a dense population of faba bean plants than sparsely populated, the severity increases due to more plant to-plant spread of the *Botrytis fabae* inoculum. When plant density increased it can cause less light penetration in the crop canopy, reduce photosynthetic efficiency and may lead to chocolate spot epiphytotic.

Data on the planting date were also grouped into Three (June 10 - June15, June16 – June 20, and June 21- June25). The mean value of disease incidence and severity was higher on farms which were planted on June (10-15) day with mean value (86.73% and 71.02%) than farms which were planted after June (21-25) day with mean value (63.72% and 37.31%) (Table 3). Gosaye Eshetu *et al.* (2018) showed that, planting date influences the incidence and severity of faba bean chocolate spot, high disease incidence and severity was recorded from early sown farms.

Table 3 Mean disease incidence and severity (PSI) of faba bean chocolate spot for different independent variables in 2023 cropping season in the surveyed areas.

Variable	Variable class	Chocolate spot			
		Incidence		Severity (PSI)	
		Mean	SD	Mean	SD
Kas	<i>Dara</i>	78.347	10.01284	54.348	19.25516
	<i>Chila</i>	66.013	16.30643	43.044	19.16955
	<i>Wokien /Z</i>	84.47	11.71239	70.42	17.00003
Altitude	≥2700 Masl	89.1625	7.19712	77.255	2.91855
	2680-2699 Masl	83.301	8.0176	65.111	9.91382
	< 2680 Masl	60.8991	9.30379	32.7317	12.73933
Soil type	Red	63.8853	9.77872	36.81	19.84026
	Black	57.4986	10.80954	31.2586	3.40143
	Brown	85.7794	8.5156	69.7683	9.78421
Field history	Wheat	88.6389	6.81368	68.2737	13.2784
	Barley	72.99	8.15066	57.7617	20.99925
	Teff	57.9687	10.04882	31.5427	11.68505
SD	June 10-15	86.7304	7.41651	71.0167	11.50358
	June 16 -20	83.844	10.54904	68.182	5.18021
	June 21-25	63.7165	11.89098	37.3085	17.68957
Growth stage	Flowering	57.1721	9.62633	28.3793	4.31105
	Pre-podding	66.075	4.99822	40.8813	18.9514
	Podding	85.4629	8.33425	69.26	11.7881
Planting density	≥38/m ²	80.806	13.83067	64.5137	17.11063
	<38/m ²	64.82	11.04259	34.2441	15.05867
Fertilizer Usage	Fertilizer use	62.7964	8.58317	31.87	9.94328
	Fertilizer Not use	80.3793	14.00204	63.2622	18.39385
Fungicide	Use	60.4309	9.24121	30.6841	8.30605
	Not Use	85.4505	8.35559	70.5576	9.70689

Planting Method	broadcasting	81.5695	12.73295	64.3673	17.38576
	Row	61.7213	10.0156	32.755	12.5559
	Local	72.7538	16.42222	54.1641	21.95461
	Walki	77.7908	10.84413	48.4992	23.93019
	Ashebka	84.7743	6.2005	65.7586	4.516
Variety	Dosha	89.45	7.72938	77.4675	1.19492

PSI=Percentage severity index; SD= standard deviation.

3.2 Management of chocolate spot (*Botrytis fabae* L.) of faba bean through integrated use of host resistance and fungicide frequencies sprays

3.2.1 Chocolate Spot Disease Incidence

The analysis of variance conducted in this study revealed highly significant differences ($P<0.01$) in the main effects of both varieties and fungicide spraying frequencies on the reduction of chocolate spot disease incidence recorded across all assessment dates from 67 to 102 days after sowing (DAS) (Table 2). The observed variation in disease incidence could be attributed to the differing levels of resistance exhibited by the various varieties.

The local variety exhibited a more rapid disease progression, reaching the highest final disease incidence level of 68.00%, followed by Hachalu and Walki at 63.00% and 58.92%, respectively, by 102 DAS. This observation aligns with earlier findings by Sahile et al. (2008b) and Guta *et al.* (2017), suggesting that disease development rates are influenced by the crop's resistance level, with higher rates on susceptible varieties and lower rates on resistant ones.

Significant differences ($P<0.01$) were also observed among fungicide spraying frequencies in terms of disease incidence. Unsprayed plots showed an initial disease incidence of 30.64% (67 DAS) and a final incidence of 72.67% (102 DAS), while plots sprayed three times with 1.5 kg/ha Trust Cymocop439.5WP fungicide exhibited an initial incidence of 23.42% (67 DAS) and a final incidence of 57.22% (102 DAS). Guta *et al.* (2018) previously reported that Trust Cymocop439, applied at a rate of 1.5 kg/ha every week at the threshold level, reduced disease incidence and severity.

In this study, three times spraying at the same frequency and rate significantly reduced disease incidence, with no significant difference observed between three times and two-times spraying frequencies of Trust Cymocop439.5WP at the final assessment date (102 DAS) (Table 4).

Table 4 Main effects of faba bean varieties and fungicide application frequency on incidence of chocolate spot disease under field condition.

Varieties	67DAS	74DAS	81DAS	88DAS	95DAS	102DAS
Local	29.03 ^a	34.33 ^a	42.00 ^a	49.42 ^a	57.83 ^a	68.00 ^a
Walki	24.63 ^c	30.67 ^b	33.40 ^c	40.58 ^c	46.54 ^c	58.92 ^c
Hachalu	26.00 ^b	31.83 ^b	36.40 ^b	43.08 ^b	51.92 ^b	63.00 ^b
Mean	26.55	32.28	37.27	44.36	52.1	63.31
LSD 0.05	1.15	1.19	0.96	0.84	1.68	1.22
S0	30.64 ^a	38.67 ^a	42.67 ^a	49.33 ^a	58.11 ^a	72.67 ^a
S1	27.11 ^b	32.44 ^b	38.46 ^b	46.00 ^b	52.78 ^b	64.00 ^b
S2	25.03 ^c	30.44 ^c	35.72 ^c	43.22 ^c	50.17 ^c	59.33 ^c
S3	23.42 ^d	27.56 ^d	32.22 ^d	38.89 ^d	47.33 ^d	57.22 ^d
LSD	1.33	1.38	1.11	0.97	1.94	1.41
0.05%						
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; DAS=Days after Sowing, LSD = Least significant Difference, CV= Coefficient of Variations; S0=Zero spray, S1=Fungicide Once spray, S2=Fungicide Two times spray, S3=Fungicide Three times spray.

Table 5 Interaction Effect of faba bean varieties and fungicide application frequency on incidence of chocolate spot disease under field condition.

Varieties	FSF	67DAS	74DAS	81DAS	88DAS	95DAS	102DAS
Local	S0	36.93 ^a	42.00 ^a	46.00 ^a	56.00 ^a	62.00 ^a	78.00 ^a
	S1	28.00 ^b	34.00 ^b	43.00 ^b	50.00 ^b	58.67 ^{ba}	72.00 ^b
	S2	26.00 ^{bcde}	32.00 ^{bc}	40.67 ^{cd}	47.00 ^c	55.00 ^c	62.00 ^d
	S3	25.17 ^{def}	29.33 ^d	38.33 ^{ef}	44.67 ^{de}	55.67 ^{bc}	60.00 ^{ed}
Walki	S0	27.00 ^{bcd}	34.00 ^b	40.00 ^{ed}	45.33 ^{dc}	52.33 ^{dc}	68.00 ^c

	S1	25.67 ^{cde}	32.00 ^{cb}	34.44 ^g	43.33 ^{ef}	46.00 ^e	58.00 ^{ef}
	S2	23.76 ^{efg}	30.00 ^{cd}	31.12 ^h	40.00 ^g	45.17 ^e	56.00 ^{fg}
	S3	22.09 ^g	26.67 ^e	28.00 ⁱ	33.67 ^h	42.67 ^e	53.67 ^g
Hachalu	S0	28.00 ^b	40.00 ^a	42.00 ^{cb}	46.67 ^c	60.00 ^a	72.00 ^b
	S1	27.67 ^{bc}	31.33 ^{cd}	37.94 ^f	44.67 ^{de}	53.67 ^{cd}	62.00 ^d
	S2	25.33 ^{de}	29.33 ^d	35.33 ^g	42.67 ^f	50.33 ^d	60.00 ^{de}
	S3	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; DAS=Days after Sowing, LSD = Least significant Difference, CV= Coefficient of Variations; S0=Zero spray, S1=Fungicide Once spray, S2=Fungicide Two times spray, S3=Fungicide three times spray.

3.2.2. Chocolate Spot Disease Severity

Significant differences ($P < 0.001$) were observed among faba bean varieties and fungicide spraying frequencies at 74 and 81 days after sowing (DAS), respectively. Interaction analysis revealed very highly significant ($P < 0.001$) variations in chocolate spot disease severity at 67 DAS and 102 DAS (Table 3).

On the initial assessment date (67 DAS), the local variety exhibited the highest disease severity (14.03%), while Walki and Hachalu recorded lower values of 10.13% and 11.59%, respectively. At the final assessment (102 DAS), the local variety had the highest disease severity (47.67%), while Walki showed the lowest severity (33.75%). Hachalu displayed a moderate level of final disease severity at 37.00%, consistent with findings by Guta *et al.* (2017), which suggested Walki and Hachalu cultivars to be moderately resistant to faba bean chocolate spot disease.

Fungicide spraying frequency results indicated the highest disease severity on unsprayed plots, with the minimum recorded from three times spraying frequency (30.56%) at the final assessment (102 DAS). The interaction effect of fungicide spraying frequency and varieties on

chocolate spot disease severity was very highly significant ($P < 0.01$) at all assessment dates (Table 5).

In the interaction effects of varieties and fungicide spraying frequency, the unsprayed local variety exhibited the maximum disease severity (52.33%), followed by Hachalu and Walki varieties (46.00% and 41.67%, respectively), while the least severity was recorded from three times fungicide spraying frequency (Table 4). This study's results align with previous research indicating the efficacy of Trust Cymocop439.5WP fungicide in managing chocolate spot disease in faba beans. Teshome and Tagging (2013), Sahile *et al.* (2008a), and Kora *et al.* (2016) reported similar findings on the effectiveness of Trust Cymocop439.5WP in reducing disease severity and enhancing faba bean yield

Table 6 Main effects of faba bean varieties and fungicide application frequency on severity of chocolate spot disease under field condition.

Varieties	67DAS	74DAS	81DAS	88DAS	95DAS	102DAS
Local	14.03 ^a	26.86 ^a	31.17 ^a	34.00 ^a	38.33 ^a	47.67 ^a
Walki	10.13 ^c	16.47 ^c	19.29 ^c	22.58 ^c	26.29 ^c	33.75 ^c
Hachalu	11.59 ^b	20.30 ^b	23.25 ^b	27.83 ^b	31.25 ^b	37.00 ^b
Mean	11.92	21.21	24.57	29.28	31.96	39.47
LSD 0.05	1.16	0.91	1.17	1.67	1.34	1.19
S0	15.64 ^a	28.00 ^a	32.67 ^a	35.56 ^a	37.56 ^a	46.67 ^a
S1	12.00 ^b	22.44 ^b	26.44 ^b	31.11 ^b	32.78 ^b	42.67 ^b
S2	10.36 ^c	19.26 ^c	21.50 ^c	24.89 ^c	30.17 ^c	38.00 ^c
S3	9.64 ^c	15.14 ^d	17.67 ^d	21.00 ^d	27.33 ^d	30.56 ^d
LSD (0.05)	1.34	1.05	1.35	1.92	1.55	1.37
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; DAS=Days after Sowing, LSD = Least significant Difference, CV= Coefficient of Variations; S0=Zero spray, S1=Fungicide Once spray, S2=Fungicide Two times spray, S3=Fungicide Three times spray

Table 7. Interaction Effect of faba bean varieties and fungicide application frequency on severity of chocolate spot disease under field condition.

Varieties	FSF	67DAS	74DAS	81DAS	88DAS	95DAS	102DAS
Local	S0	21.93 ^a	34.00 ^a	42.00 ^a	44.00 ^a	44.00 ^a	52.33 ^a
	S1	13.00 ^b	29.33 ^b	31.33 ^b	36.00 ^b	38.67 ^b	50.00 ^{ba}
	S2	11.00 ^{bcdef}	24.00 ^d	28.00 ^{cd}	31.33 ^c	35.00 ^{cd}	48.00 ^{bc}
	S3	10.17 ^{cdef}	20.09 ^f	23.33 ^e	24.67 ^d	35.67 ^{cd}	40.33 ^{de}
Walki	S0	12.00 ^{bcd}	24.00 ^d	26.00 ^d	26.67 ^d	31.33 ^{ef}	41.67 ^d
	S1	10.67 ^{cdef}	16.00 ^h	22.00 ^{ef}	25.33 ^d	26.00 ^g	38.00 ^{ef}
	S2	8.76 ^f	15.67 ^h	16.17 ^g	20.00 ^{ef}	25.167 ^{gh}	30.00 ^g
	S3	9.09 ^{ef}	10.21 ⁱ	13.00 ^h	18.33 ^f	22.67 ^h	25.33 ^h
Hachalu	S0	13.00 ^b	26.00 ^c	30.00 ^{bc}	36.00 ^b	37.33 ^{bc}	46.00 ^c
	S1	12.33 ^{bc}	22.00 ^e	26.00 ^d	32.00 ^c	33.67 ^{ed}	40.00 ^{de}
	S2	11.33 ^{bcde}	18.11 ^g	20.33 ^f	23.33 ^{ed}	30.33 ^f	36.00 ^f
	S3	9.67 ^{def}	15.10 ^h	16.67 ^g	20.00 ^{ef}	23.67 ^{gh}	26.00 ^h
LSD		2.33	1.82	2.33	3.33	2.68	2.38
(0.05)							
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; DAS=Days after Sowing, LSD = Least significant Difference, CV= Coefficient of Variations; S0=Zero spray, S1=Fungicide Once spray, S2=Fungicide Two times spray, S3=Fungicide Three times spray

3.2.3 Area under disease progress curve

The analysis of variance revealed a highly significant difference ($P < 0.001$) among faba bean varieties, fungicide spraying frequencies, and their interaction effects on the Area under the Disease Progress Curve (AUDPC). The Local variety exhibited the highest AUDPC value (1121 %-day), while the lowest was recorded in the Walki variety (747 %-day). Hachalu displayed a

moderate AUDPC value (893 %-day) compared to Walki and Local varieties, aligning with Guta *et al.*'s (2017) findings on Walki moderate resistance to faba bean chocolate spot disease.

Fungicide spraying frequencies significantly influenced AUDPC values ($P < 0.001$). The highest AUDPC value (1155 %-day) was observed in unsprayed varieties, contrasting with the least value (715 %-day) recorded in varieties treated with three times spraying frequency of Trust Cymocop439.5WP fungicide at 1.5 kg/ha. Jeger (2004) highlighted the significance of comparing disease progress curves and AUDPC in evaluating practical disease management strategies.

The interaction effect of varieties and fungicide spraying frequency resulted in a very highly significant reduction in AUDPC ($P < 0.001$). The Local variety, when sprayed once, twice, and thrice with Trust Cymocop439.5WP at 1.5 kg/ha, displayed mean AUDPC values of 1135, 1035, and 903 (% unit/day), respectively. Conversely, the unsprayed Local variety exhibited a mean AUDPC value of 1408 % unit/day (Table 5). Improved varieties Walki and Hachalu showed mean AUDPC values of 796, 675, 573 %-day, and 979, 810, 669 %-day when sprayed once, twice, and thrice, respectively. Unsprayed Walki and Hachalu exhibited mean AUDPC values of 944 and 1112 (% unit-day), respectively (Table 8). The highest mean AUDPC value (1408 % unit-day) was observed in the unsprayed Local variety, and the lowest (573 %-day) was in Walki sprayed thrice with Trust Cymocop 439.5WP at 1.5 kg/ha (Figure.1). This aligns with Kora *et al.*'s (2017) findings, suggesting that weekly fungicide spraying on improved varieties significantly reduces AUDPC values compared to other schedules and unsprayed controls. The chocolate spot progress curves (Figures 2-4) demonstrate how different frequencies of Trust Cymocop fungicide application influenced disease severity across three faba bean varieties: Local, Walki, and Hachalu.

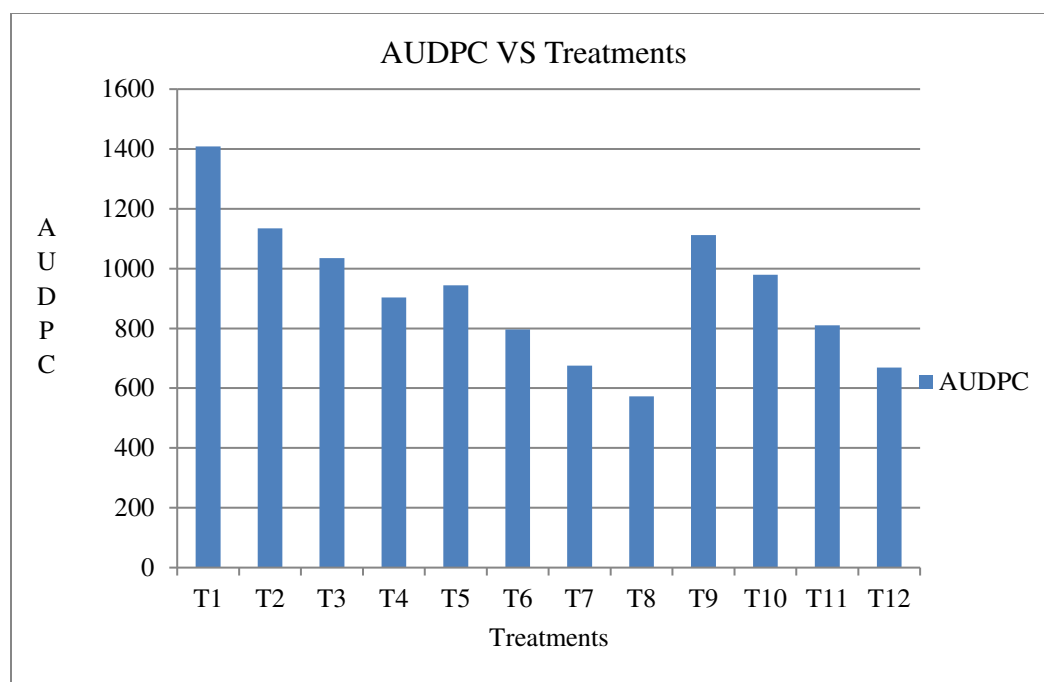


Figure 1. Area under disease progress curve (AUDPC) of chocolate spot disease in relation to varieties of Faba bean treated with different fungicide spraying frequency

T =Treatment (T1 =unsprayed Local with 1.5 kg/ha of Trust Cymocop 439.5 WP fungicide;T2=one times sprayed Local with 1.5 kg/ha of Trust Cymocop 439.5 WP; T3= two times sprayed Local with 1.5 kg/ha of Trust Cymocop 439.5 WP ; T4= three time Local; T5= unsprayed Walki with 1.5 kg/ha of Trust Cymocop 439.5 WP;T6 = one times sprayed Walki with 1.5 kg/ha of Mancozeb;T7= two times sprayed Walki with 1.5 kg/ha of Trust Cymocop 439.5 WP;T8= three times Walki ;T9= Unsprayed Hachalu with 1.5 kg/ha of Trust Cymocop 439.5 WP; T10= one times sprayed Hachalu with 1.5 kg/ha of Trust Cymocop 439.5 WP;T11=two times sprayed local with 2.5 kg/ha of Trust Cymocop 439.5 WP;T12= Three times sprayed Hachalu.

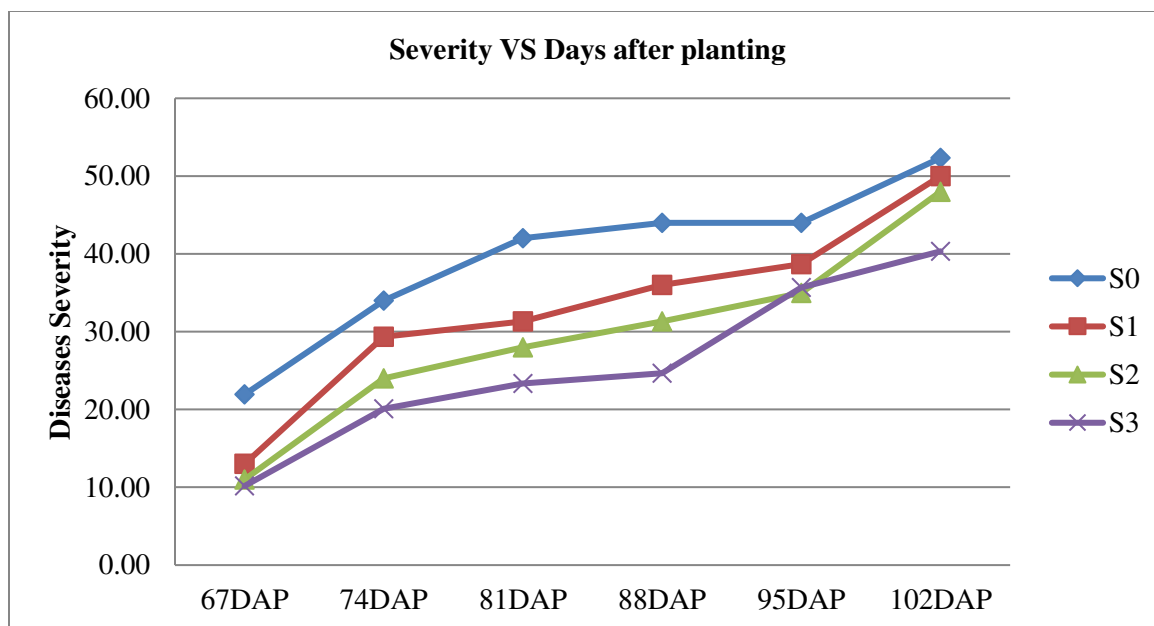


Figure 1. Chocolate spot progress curve based on percentage severity index as influenced by different rates of Trust Cymocop fungicide on Local variety.

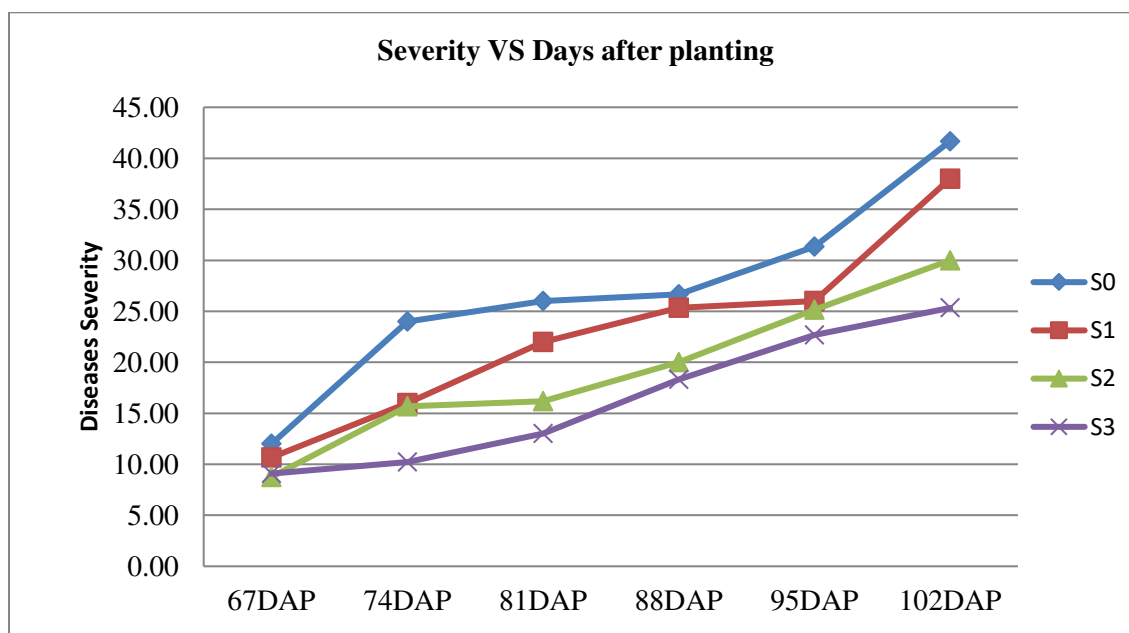


Figure 2. Chocolate spot progress curve based on percentage severity index as influenced by different spraying frequency of Trust Cymocop fungicide on Walki variety.

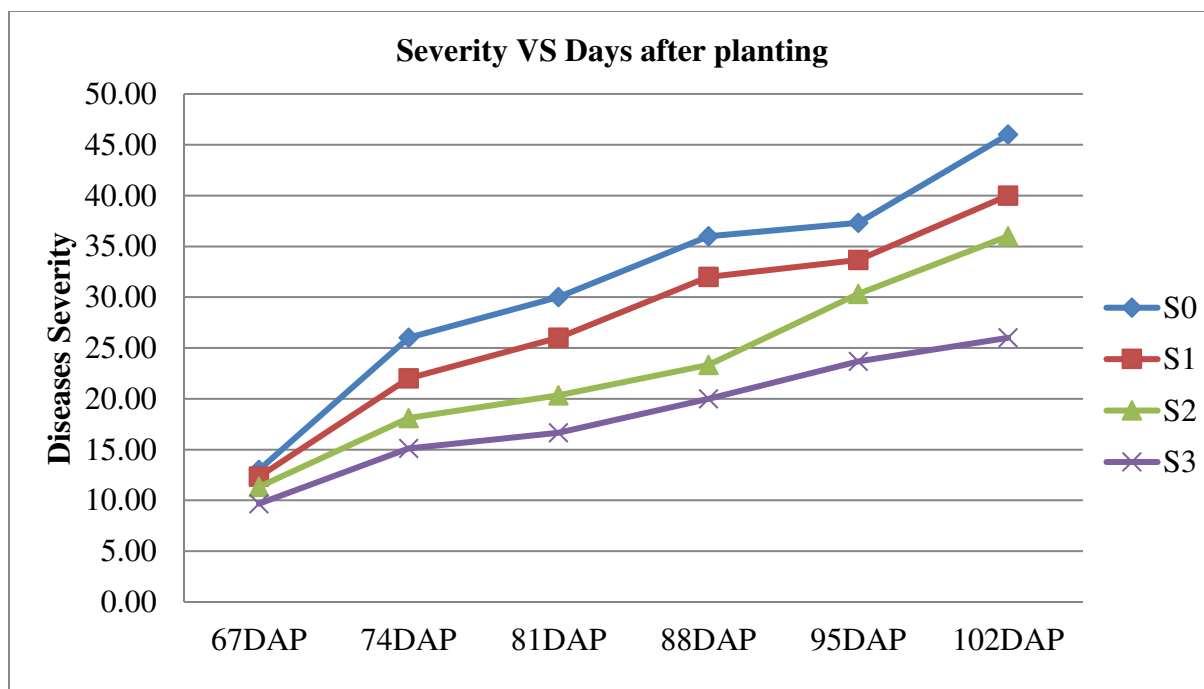


Figure 3. Chocolate spot progress curve based on percentage severity index as influenced by Different spraying frequency of Trust Cymocop fungicide on Hachalu Variety.

4.2.4. Disease progress rat

Logistic $\ln [(y/1-y)]$, Vander Plank (1963), and Gompertz models were assessed to determine the most suitable fit for describing the rate of chocolate spot disease development. The selection was based on the coefficient of determination (R^2), with the Gompertz model outperforming the logistic model in capturing disease progression. Accordingly, the Gompertz model was employed to determine disease progress rate parameters.

The chocolate spot infection rate, as per Campbell and Madden (1990), is linked to the logarithm of the ratio of diseased to healthy tissues. Significant differences ($P < 0.01$) in disease progress rate were observed among varieties, fungicide frequencies, and their interaction. Varieties Local, Hachalu, and Walki exhibited disease progress rates of 0.025, 0.020, and 0.020 units/day, respectively. Based on fungicide spraying frequencies, rates of 0.023, 0.022, 0.022, and 0.019 units/day were recorded for unsprayed, one-time spray, two-times spray, and three-times spray of Trust Cymocop 439.5WP fungicide at 1.5 kg/ha, respectively (Table 5). These findings highlight a faster disease progression on unsprayed plots.

The interaction effect of Local variety with one-time, two-time, and three-time spray frequencies showed disease progress rates of 0.026, 0.024, and 0.024 units/day, respectively, compared to

unsprayed plots (0.027 units/day). Similarly, Walki with one-time, two-time, and three-time spray exhibited rates of 0.019, 0.018, and 0.015 units/day, respectively, compared to unsprayed (0.020 units/day) plots. Additionally, Hachalu with one-time, two-time, and three-time spray showed rates of 0.022, 0.021, and 0.021 units/day, respectively, compared to unsprayed plots (0.02179 units/day) (Table 5 and table 6).

These results underscore a faster disease progression on unsprayed plots compared to those treated with Trust Cymocop fungicide. This aligns with Sahile Samuel et al. (2008a), demonstrating that fungicide-treated plots retard the apparent infection rate. Similarly, Guta *et al.* (2017) reported the effectiveness of Mancozeb 80% WP-sprayed varieties in reducing the apparent infection rate of chocolate spot disease compared to unsprayed varieties.

The maximum apparent infection rate was recorded in Local unsprayed plots (0.025 units/day), while the minimum was observed in Walki sprayed with three-times spray frequencies (0.015 units/day). This finding aligns with Estayih Animawu (2018), emphasizing the integrated use of resistant varieties with fungicides to effectively reduce the apparent infection rate of chocolate spot disease.

Table 8. Main effects of faba bean varieties and fungicide spraying frequency on area under disease progress curve and apparent infection rate of chocolate spot disease under field condition.

Varieties	AUDPC	infection rate
Local	1121 ^a	0.025
Walki	747 ^c	0.020
Hachalu	893 ^b	0.020
Mean	920.08	0.022
LSD (0.05)	24.25	0.001
S0	1155 ^a	0.023
S1	970 ^b	0.022
S2	840 ^c	0.022
S3	715 ^d	0.019
LSD (0.05%)	28.01	0.0014
CV	3.11	6.40

Means within the same column followed by the same letter(s) are not significantly different; AUDPC = Area under disease progress curve; LSD = Least significant Difference's= Coefficient of Variations; S0=Zero spray, One time Fungicide spray, S2= Two times Fungicide spray, S3= Three times Fungicide spray

Table 9. 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.

Varieties	FSF	AUDPC	Infection rate
Local	S0	1408 ^a	0.027
	S1	1135 ^b	0.026
	S2	1035 ^c	0.024
	S3	903 ^c	0.024
Walki	S0	944 ^{de}	0.020
	S1	796 ^f	0.019
	S2	675 ^g	0.018
	S3	573 ^h	0.015
Hachalu	S0	1112 ^b	0.022
	S1	979 ^d	0.022
	S2	810 ^f	0.021
	S3	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; AUDPC = Area under disease progress curve; LSD = Least significant Difference's = Coefficient of Variations; S0=Zero spray, S1= One time Fungicide spray, S2= Two times Fungicide spray, S3= Three times Fungicide spray

3.3 Effect of Treatments on Yield and Yield Components

3.3.1 Date to 50% flowering and days to 90 % maturity

The mean days to 50% flowering varied among faba bean varieties, ranging from 45.33 to 60.67 days. Variety Hachalu exhibited the longest duration to reach 50% flowering (60.67 days), indicating genetic variations in faba bean, as observed by Alemayehu *et al.* (2018), who reported a range from 61.3 to 58.7 days. Fungicide application frequencies significantly influenced the days to 90% maturity of faba bean, with Walki and Local varieties showing 131 and 132 days, respectively. Variety Hachalu recorded the longest duration of 134 days to 90% maturity.

However, no significant differences were observed among the varieties, suggesting that genetic background and environmental conditions may contribute to this variation.

Significant differences ($P \leq 0.01$) in days to 90% maturity were noted between weekly spray intervals and unsprayed plots across all varieties. Weekly fungicide application resulted in the longest duration to 90% maturity compared to other spray schedules. Walki, Local, and Hachalu varieties showed 132.67, 131.33, and 134.00 days, respectively, when sprayed weekly, as opposed to untreated plots with maturity dates of 117.67, 92.67, and 119 days, respectively. This highlights the positive impact of frequent fungicide use in reducing disease infection and enhancing plant physiological functions. The shortest durations to 90% maturity were recorded in untreated and 21-days treated plots for all varieties. These findings align with Abay Guta *et al.* (2017), who reported that fungicide-treated faba bean cultivars exhibited a longer time to maturity compared to untreated plots (Table 9).

3.3.2. Plant height

Based on the analysis of variance, plant height exhibited a highly significant difference ($P < 0.01$) among various varieties at maturity stages (Table 10). Variety Walki demonstrated the maximum plant height at maturity, reaching 127.09 cm, while the local variety exhibited the minimum height at 87.37 cm, followed by variety Hachalu at 118.28 cm (Mussa Jarso *et al.* , 2008).

Furthermore, plant height also displayed a highly significant difference ($P < 0.01$) concerning fungicide spraying frequency (main effects) (Table 7). The maximum plant height was observed in plots sprayed three times with the fungicide Trust Cymocop439.5WP at a rate of 1.5 kg/ha (140.17 cm and 121.81 cm), whereas unsprayed plots recorded the minimum height at 79.94 cm during maturity (Mussa Jarso *et al.* , 2008).

Analyzing the interaction effect of varieties and fungicide spraying frequency, plant height exhibited a highly significant difference ($P < 0.01$) (Table 8). Varieties Walki and Hachalu treated with a three-time fungicide spraying frequency of 1.5 kg/ha Trust Cymocop439.5WP demonstrated the maximum plant height at maturity (151.07 cm and 141.90 cm). In contrast, unsprayed varieties, particularly local, recorded the minimum height (44.60 cm). Shahzad *et al.* (2007) emphasized that crop height is predominantly governed by the genetic makeup of a genotype and can also be influenced by environmental factors.

3.3.3. Pod length, Number of pods per plant and number of seeds per pod

The study conducted by Samuel Sahile *et al.* (2008) investigated the impact of fungicide spraying frequency on pod length, number of pods per plant, and seeds per pod in different varieties of faba beans. Among the varieties, Walki exhibited the highest mean pod length (9.14 cm), followed by Hachalu (8.85 cm), while the local variety had the lowest mean pod length (3.91 cm) (Table 10). The analysis of variance indicated a highly significant interaction effect ($P < 0.001$) between variety and fungicide spraying frequency on pod length. Notably, the three-time fungicide spraying frequency resulted in the maximum pod length (10.38 cm), whereas the untreated variety had the minimum pod length (3.84 cm).

The main effect of fungicide spraying frequency also showed a very highly significant difference ($P < 0.001$) on the number of pods per plant, with the highest observed in the Walki variety (9.14 pods per plant) and the lowest in the local variety (3.91 pods per plant) (Table 9). This aligns with the findings of Abay *et al.* (2017), highlighting significant differences in pods per plant among faba bean varieties.

Furthermore, the main effects of fungicide spraying frequency revealed that the three-times spraying frequency, with 1.5 kg/ha of Trust Cymocop439.5WP fungicide, resulted in the maximum pods per plant, while the unsprayed varieties recorded the minimum. This is consistent with the research of Hawthorne (2004), who demonstrated that fungicide application increased the number of pods per plant compared to unsprayed conditions.

The interaction effect between varieties and fungicide spraying frequency also had a significant impact ($P < 0.001$) on the number of pods per plant. Maximum pods per plant were recorded in Walki and Hachalu varieties with three times fungicide spraying frequency, while unsprayed varieties exhibited the minimum. These findings support the observations of Dagne Kora *et al.* (2016), emphasizing the positive correlation between shorter fungicide spray frequencies, disease reduction, and increased yield.

Additionally, the study highlighted a significant difference ($p < 0.001$) in the number of seeds per pod among varieties, with Walki and Hachalu showing significant differences compared to unsprayed local varieties. This observation further emphasizes the importance of fungicide application and its interaction with different varieties in influencing faba bean characteristics (Table 10).

3.3.4. Hundred Seed weight

In the investigation of seed weight in different faba bean varieties and the impact of fungicide spraying frequency, the study revealed significant variations. The highest seed weight was observed in the Hachalu variety, with a mean value of 77.80 g, followed by Walki with a mean value of 67.61 g, while the local variety exhibited the least seed weight at 52.7 gm/m (Table 10). These variations were attributed to genetic differences in seed size. This finding is consistent with the research of Abay *et al.* (2017), which identified variations in 100 seed weight among faba bean varieties and fungicide-treated crops.

The study also highlighted very highly significant effects ($P < 0.001$) in seed weight among the main effects of Trust Cymocop 439.5 WP fungicide spraying frequency. Specifically, the application of Trust Cymocop439.5WP fungicide at a rate of 1.5 kg/ha, three times during the growing season, resulted in the highest seed weight (86.53 g) compared to unsprayed plots (39.62 g). This observation indicated that Trust-Cymocop fungicide application effectively reduced seed infections, consequently improving seed quality by mitigating the impact of diseases.

Furthermore, the interaction of varieties and fungicide spraying frequency had a highly significant effect ($P < 0.001$) on hundred seed weight. The maximum hundred seed weight (94.67 g) was recorded in the Hachalu variety treated at three times the fungicide spraying frequency, followed by Walki (85.50 g), while the unsprayed local variety exhibited the minimum hundred seed weight (76.43 g) (Table 10). This aligns with the findings of Dagne Kora *et al.* (2016), emphasizing that shorter fungicide spray intervals contribute to disease reduction and increased yield compared to unspray plots.

Additionally, Dagne Kora *et al.* (2017) reported that integrating a moderately resistant variety with Trust Cymocop439.5WP spray further reduced disease incidence and enhanced grain yield, as well as seed weight in faba beans. This supports the conclusion that chocolate spot disease negatively impacts grain yield and quality by reducing the weight of 100 seeds (Dagne Kora *et al.*, 2017).

3.3.5. Grain yield

The analysis of variance revealed a highly significant ($p < 0.001$) impact of the interaction between faba bean varieties and fungicide spraying frequency on yield, as presented in (Table 9). Notably, the Walki variety demonstrated the highest mean grain yield at 3.96-ton ha⁻¹, while the

local variety exhibited the lowest yield at 2.62-ton ha⁻¹. This disparity underscores the significant differences observed among varieties, with Walki outperforming others.

Furthermore, the application of Trust Cymocop 439.5WP fungicide at a rate of 2.5 kg ha⁻¹, three times during the spraying frequency, resulted in the highest faba bean yield, aligning with findings by Yekedem Bimrew and Hassen Shifa (2018). Kora *et al.* (2016) also corroborated that Trust Cymocop 439.5WP positively impacted faba bean yield compared to unsprayed controls.

The synergistic effect of Walki, Hachalu, and local varieties with a three-times fungicide spraying frequency at 1.5 kg ha⁻¹ produced the highest grain yield at 4.65-ton ha⁻¹, 4.14-ton ha⁻¹, and 3.21-ton ha⁻¹, respectively, as detailed in (Table 10). In parallel, Samuel Sahile *et al.* (2008) emphasized the disease-suppressing impact of fungicide spray, supporting increased yields. Similarly, Abay Guta *et al.* (2017) advocated for integrated disease management, involving improved cultivars and fungicide protection, to enhance yield and yield components.

Turning attention to yield loss, the analysis of variance demonstrated a highly significant effect ($p < 0.001$) resulting from the combination of variety and fungicide spraying frequency (Table 10). In Northern Ethiopia, research highlighted that the use of improved faba bean varieties reduced chocolate spot disease incidence and severity, consequently minimizing yield losses (Samuel Sahile *et al.*, 2010).

The local variety, when left unsprayed (control), suffered the highest relative yield loss at 49.37%, whereas Hachalu varieties, sprayed twice with 1.5 kg/ha of Trust Cymocop 439.5WP fungicide, exhibited a lower yield loss of 11.68% (Table 10). This aligns with Dereje Gorfu and Yaynu Haile's (2001) report, emphasizing varying yield losses due to chocolate spot disease. Misgana Mitiku (2017) further warned of complete crop loss under conducive environmental conditions for chocolate spot disease.

3.3.6 Relative yield loss

The study conducted on faba bean varieties reveals a significant impact of the combination of variety and fungicide application schedule on yield loss ($p < 0.01$), as evidenced by the analysis of variance (Table 11). Notably, the highest grain yield (4.65 tons ha⁻¹) was achieved by employing three sprays of Trust Cymocop 439.5WP fungicide on the Walki variety, while the unsprayed local variety yielded the lowest (1.78 tons ha⁻¹). The three-time fungicide application effectively reduced yield loss across all varieties, with the unsprayed local variety experiencing the highest loss (26.03%) and the sprayed varieties showcasing minimal losses.

These findings align with earlier research by Dereje Gorfu and Yaynu Haile (2001), who observed varying yield losses in faba beans due to chocolate spot disease in Ethiopia. Mitiku (2017) further highlighted the potential for complete crop loss under conducive environmental conditions. The current study corroborates these observations, emphasizing a reduction in seed weight in unsprayed varieties compared to their sprayed counterparts. This concurs with Kora *et al.*'s (2016) study, demonstrating that fungicide application effectively mitigates diseases and enhances yield.

The interaction effect of variety with fungicide application reveals variations in hundred seed weight, with the Hachalu variety achieving the highest (94.67 g) and the unsprayed local variety the lowest (23.10 g). Correspondingly, yield loss is highest in the unsprayed local variety (49.37%) and minimal in the Walki variety with three-time fungicide application (0.0%) (Table 12). This underscores the efficacy of three-time fungicide sprays in reducing seed weight yield loss across all faba bean varieties.

The outcomes of this study align with Samuel *et al.*'s (2010) research in Northern Ethiopia, emphasizing the role of improved faba bean varieties in reducing chocolate spot disease incidence and severity, consequently minimizing yield loss. The evidence presented underscores the importance of strategic fungicide application to enhance faba bean yield and mitigate the impact of diseases.

Table 11. Main effects of faba bean varieties and fungicide spraying frequency on Date to 50% flowering , days to 90 % maturity , plant height number of pods per plant, number of seeds per pod , hundred seed weight grain yield and relative yield loss.

Varieties	DF	DM	PH (cm)	PL (cm)	NPPP	NSPP	HSW (g)	GY ton ha ⁻¹	RY
Local	45.33 ^c	119.50 ^b	87.37 ^c	3.91 ^b	11.81 ^c	6.31 ^c	52.7 ^c	2.60 ^c	26.03 ^a
Walki	53.67 ^b	124.75 ^{ba}	127.09 ^a	9.14 ^a	14.39 ^a	9.09 ^a	67.61 ^b	4.07 ^a	12.56 ^b
Hachalu	60.67 ^a	127.75 ^a	118.28 ^b	8.85 ^a	13.29 ^b	8.24 ^b	77.80 ^a	3.57 ^b	13.68 ^b
Mean	53.22	124	110.91	7.3	13.17	7.88	66.04	3.41	17.42
LSD 0.05%	3.2	5.66	5.74	0.91	0.98	0.61	4.97	0.06	1.99
S0	42.67 ^d	109.78 ^c	79.94 ^d	3.84 ^d	9.79 ^d	4.97 ^d	39.62 ^d	2.89 ^d	30.87 ^a
S1	47.44 ^c	124.22 ^b	101.72 ^c	6.75 ^c	12.21 ^c	6.70 ^c	63.91 ^c	3.25 ^c	21.24 ^b
S2	54.11 ^b	129.33 ^{ba}	121.81 ^b	8.23 ^b	13.53 ^b	8.51 ^b	74.08 ^b	3.54 ^b	17.57 ^c
S3	68.67 ^a	132.67 ^a	140.17 ^a	10.38 ^a	17.13 ^a	11.34 ^a	86.53 ^a	4.11 ^a	0.00
LSD (0.05%)	3.69	6.54	6.63	1.05	1.14	0.71	5.73	0.08	2.30
CV%	7.1	5.39	6.12	14.69	8.82	9.21	8.88	2.25	13.50

FSF = Fungicide Spray Frequencies , DF = days to flowering, DM = days to maturity , PH= plant height, PL= Pod Length , NPPP=Number of pods per plant , NSPP= Number of seeds per plant ,HSW=Hundred seed weight , Grain Yield , RY= Relative Yield Loss , LSD= least Significant difference, CV= coefficient of variations, S0=Zero spray, S1=Fungicide Once spray, S2=Fungicide Two times spray, S3=Fungicide Three times spray

Table 12. Interaction effects of faba bean varieties and fungicide spraying frequency on Days to 50% flowering , days to 90 % maturity , plant height number of pods per plant, number of seeds per pod , hundred seed weight grain yield and relative yield loss.

Varieties	FSF	DF	DM	PH (cm)	PL (cm)	NPPP	NSPP	HSW (g)	GY (tonha ⁻¹)	RY
Local	S0	34.00 ⁱ	92.67 ^e	44.60 ⁱ	2.02 ^g	8.46 ^h	4.03 ^g	23.10 ^g	1.78 ^h	49.37 ^a
	S1	41.67 ^h	125.00 ^{abcd}	75.87 ^h	3.44 ^{fg}	11.29 ^{gef}	5.60 ^{ef}	48.93 ^f	2.52 ^g	28.32 ^b
	S2	49.33 ^{efg}	129.00 ^{bac}	101.47 ^{fg}	2.52 ^g	12.76 ^{cdef}	6.67 ^{de}	62.33 ^e	2.59 ^g	26.39 ^b
	S3	56.33 ^{cd}	131.33 ^{ab}	127.53 ^{cd}	4.67 ^{def}	14.75 ^b	8.93 ^c	76.43 ^{cd}	3.53 ^e	0.00
Walki	S0	43.67 ^{gh}	117.67 ^d	104.43 ^f	5.70 ^d	11.02 ^{fg}	5.67 ^{ef}	31.97 ^g	3.68 ^d	20.86 ^{cd}
	S1	48.67 ^{fg}	121.33 ^{bdc}	117.60 ^{de}	7.93 ^c	13.12 ^{bcde}	7.57 ^d	70.77 ^{de}	3.83 ^c	17.70 ^{de}
	S2	55.67 ^{cde}	127.33 ^{abcd}	135.27 ^{bc}	9.87 ^b	14.34 ^{bc}	9.97 ^c	79.20 ^{bcd}	4.11 ^b	11.68 ^f
	S3	66.67 ^b	132.67 ^a	151.07 ^a	13.04 ^a	19.10 ^a	13.17 ^a	88.50 ^{ab}	4.65 ^a	0.00
Hachalu	S0	50.33 ^{def}	119.00 ^{cd}	90.80 ^g	3.80 ^{efg}	9.90 ^{gh}	5.20 ^{fg}	63.81 ^e	3.21 ^f	22.38 ^c
	S1	52.00 ^{cdef}	126.33 ^{abcd}	111.70 ^{ef}	8.87 ^{bc}	12.25 ^{def}	6.93 ^d	72.03 ^{cde}	3.41 ^e	17.70 ^{de}
	S2	57.33 ^c	131.60 ^{ab}	128.70 ^{cd}	10.17 ^b	13.49 ^{bcd}	8.90 ^c	80.70 ^{bc}	3.53 ^e	14.64 ^{ef}
	S3	83.00 ^a	134.00 ^a	141.90 ^{ab}	12.57 ^a	17.54 ^a	11.93 ^b	94.67 ^a	4.14 ^b	0.00
LSD (0.05)		6.4	11.32	11.49	1.82	1.97	1.23	9.93	0.13	3.98
CV%		7.1	5.39	6.12	14.69	8.82	9.21	8.88	2.25	13.50

FSF = Fungicide Spray Frequencies , DF = days to flowering, DM = days to maturity , PH= plant height, PL= Pod Length , NPPP=Number of pods per plant , NSPP= Number of seeds per plant ,HSW=Hundred seed weight , Grain Yield , RY= Relative Yield Loss , LSD= least Significant difference, CV= coefficient of variations, S0=Zero spray, S1=Fungicide Once spray, S2=Fungicide Two times spray, S3=Fungicide Three times spray.

3.4. Correlation analysis of Disease and Yield Parameters

Association tests were conducted among disease variables and yield parameters through simple correlation analysis in a study on Faba beans (*Vicia faba*). The findings revealed a robust positive correlation among various yield parameters. However, all yield parameters exhibited a strong negative correlation with key disease indicators such as the area under the disease progress curve (AUDPC), disease severity, and infection rate. Specifically, AUDPC demonstrated a highly negative correlation with the Number of Pods per Plant (-0.86**) and grain yields (-0.92**), while severity exhibited a highly negative correlation with Number of Pods per Plant (-0.81**) and grain yields (-0.91**) (Table 13).

The study emphasized the significant interrelationship among disease parameters, with AUDPC, severity, and infection rate showing highly significant ($P \leq 0.001$) correlations. In line with previous research by Guta *et al.* (2017), the results underscored a strong negative correlation between disease severity and yield components, coupled with positive correlations among yield parameters. Additionally, the findings align with Kora *et al.* (2017), who reported a negative relationship in correlation analyses between chocolate spot severity, AUDPC, and various yield components and agronomic parameters such as plant height, pod length, number of pods per plant, and seed per pod.

Table 13. Association test for disease and yield parameter.

Variables	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.

The regression analysis of the final severity (98DAS) as predictor with yield (dependent variable) showed a highly significant ($p < 0.001$) relationship. The regression equation of the grain yield (t ha^{-1}) = $-10.95x + 77.11$ ($R^2 = 88.05\%$, $P = 0.00015$) demonstrated reduction of about -10.95 t ha^{-1} grain yield with the increase of 1% severity (Figure 5). The values of coefficient of determination (R^2) explained that 88.05 % of the losses in grain yield were due to the effect of the faba bean “chocolate spot” disease infection of faba bean estimated as the final severity on the yield loss (%). (The independent variable x indicates the disease severity level in percentage). Similarly, regression analysis of the final severity (102 DAS) as predictor with hundred seeds weight.

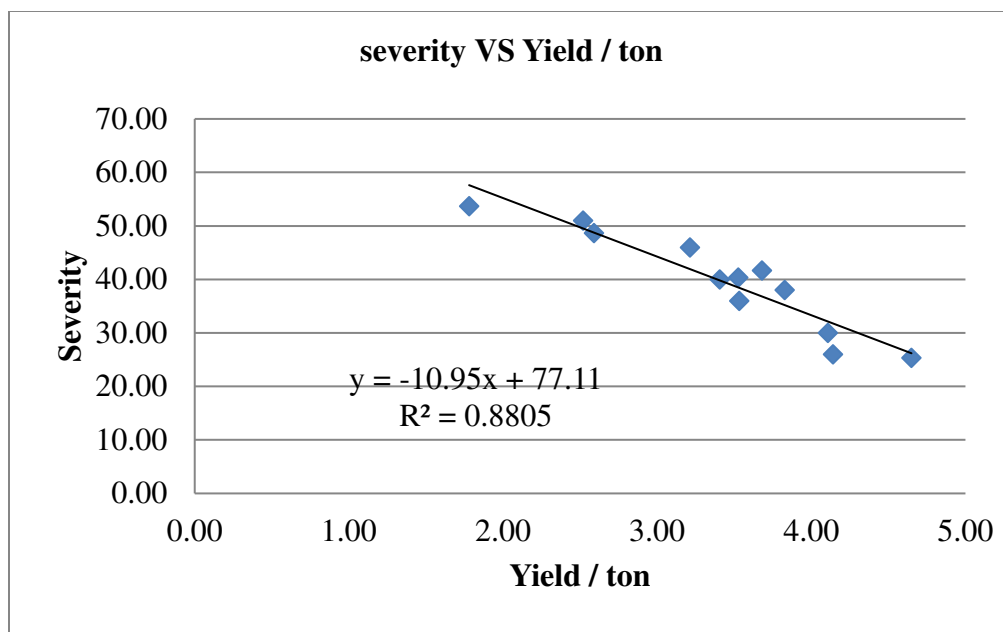


Figure 5. Linear regressions of grain yield and terminal severity

3.5. Economic Analysis

The maximum net benefit (207885 ETB ha⁻¹) was recorded from Walki variety treated with 3 times spray of fungicide application compared to unsprayed Walki variety (164955 ETB ha⁻¹) and Walki variety treated at 2 times spray of fungicide application recorded high net benefit (183873 ETB ha⁻¹) compared to 1 times spray of Walki variety (171417 ETB ha⁻¹) (Table 14).

The highest net benefit (184935 ETB ha⁻¹) was recorded from Hachalu variety treated at 3 times spray of fungicide application compared to unsprayed Hachalu variety (143805 ETB ha⁻¹) and Hachalu variety treated at 2 times spray of fungicide application recorded high net benefit (157773 ETB ha⁻¹) compared to 1 times spray of Hachalu variety (152517 ETB ha⁻¹)

Local variety treated with 3 times spray of fungicide had highest net benefit (157485 ETB ha⁻¹) compared with its respective unsprayed plot (79455 ETB ha⁻¹), 2 times spray plot (115473 ETB ha⁻¹) and 1 times spray plot (112467 ETB ha⁻¹) of local variety with Trust Cymocop439.5 WP fungicide (Table 14). this result indicated that 3 times spray of Trust Cymocop439.5 WP fungicide had maximum net benefit compared to the rest spray frequencies.

The data analysis indicated that the highest Marginal rate of return was maintained from local variety treated with 1 time ,3 times fungicide spraying frequency (14587.5 and 11462.5) respectively followed by variety Hachalu treated with unsprayed, and 3 times fungicide spraying

frequency 1.5kg/ha of Trust Cymocop439.5 WP fungicide (8900.0, and 9431.3). Moreover, Walki variety treated with 1 time, 2 times and three times fungicide spraying frequency with 1.5kg/ha of Trust Cymocop439.5 WP fungicide was recorded promising Marginal rate of return with mean values of (8650.0 and 8337.3) respectively (Table 14).

Table 14 . Partial budget analysis for chocolate spot management of faba bean crop.

Var	Fun	yield ton/ha	AY%	PP/Ton	GB/ha	TVC	NB	MRR
Local	S0	1.78	1.602	50,000	80100	645	79455	-
Walki	S0	3.68	3.312	50,000	165600	645	164955	-
Hachalu	S0	3.21	2.889	50,000	144450	645	143805	8900.0
Local	S1	2.52	2.268	50,000	113400	933	112467	11462.5
Local	S2	2.59	2.331	50,000	116550	1077	115473	2087.5
Local	S3	3.53	3.177	50,000	158850	1365	157485	14587.5
Walki	S1	3.83	3.447	50,000	172350	933	171417	2243.8
Hachalu	S1	3.41	3.069	50,000	153450	933	152517	3025.0
Walki	S2	4.11	3.699	50,000	184950	1077	183873	8650.0
Hachalu	S2	3.53	3.177	50,000	158850	1077	157773	3650.0
Walki	S3	4.65	4.185	50,000	209250	1365	207885	8337.5
Hachalu	S3	4.14	3.726	50,000	186300	1365	184935	9431.3

Var=varieties, AGY= Adjusted grain yield ton, TVC= Total Variable Cost, GY= Grain Yield, GB=Gross benefit, NB=Net Benefit, MRR= Marginal rate of return, ; S0=Zero spray, S1=Fungicide One spray, S2=Fungicide Two spray, S3=Fungicide Three spray

4. CONCLUSION AND RECOMMENDATIONS

Chocolate spot is a major economically important disease in faba bean-growing areas, particularly in Dabat district, North Gondar Administrative Zone, Ethiopia. The disease manifests with varying levels of incidence and severity, negatively affecting faba bean yields and its components, such as hundred seed weight. The widespread occurrence of chocolate spot is largely attributed to farmers' reliance on local susceptible varieties and their failure to use effective fungicide treatments. This study, based on both survey and field experiment results,

identified several critical factors influencing the prevalence and severity of the disease in the region.

The survey results indicated that altitude, cropping history, planting density, soil type, and growth stage were key variables influencing chocolate spot incidence and severity. Specifically, lower altitudes, late sowing, red and brown soil types, and planting densities of $\leq 38/\text{m}^2$ were found to exacerbate disease intensity. Additionally, the majority of farmers grow local varieties that are highly susceptible to the disease and do not apply fungicides in a timely or proper manner. This underscores the need for better disease management practices.

The field experiments further demonstrated that the application of fungicides, particularly Trust Cymocop439.5WP, combined with the use of resistant faba bean varieties like Walki, could significantly reduce disease severity. Walki was found to exhibit notable resilience against chocolate spot, especially when treated with three applications of Trust Cymocop439.5WP fungicide at a rate of 1.5 kg/ha. This combination not only reduced disease incidence but also improved overall yield and the economic return on investment. The integration of resistant varieties with an appropriate fungicide application schedule proved to be a highly effective strategy for controlling chocolate spot and boosting faba bean production.

Based on these findings, it is recommended that farmers adopt the Walki variety, which has shown resistance to chocolate spot, and apply Trust Cymocop439.5WP fungicide three times at the recommended rate to maximize disease control and increase yields. In addition, farmers should be educated on the correct fungicide application techniques, including timing, frequency, and dosage, to ensure the best results. Future research should focus on replicating these findings over multiple years and in different regions to further validate these strategies and develop more comprehensive recommendations for managing chocolate spot. Overall, these practices will contribute to the sustainable production of faba beans in the study area, improving both yield and economic outcomes for farmers.

Acknowledgments

The authors thank Gondar Agricultural Research Center and for generously providing seeds of improved faba bean varieties and Dilla University for financial support of the research

Funding Ethiopia minster of education

Data availability the data supporting the findings of this study are available from the corresponding author, Dinku Atnafu Anega , Abaynew Jemal Jenber , and Yehizbalem Azmeraw Tadesse upon reasonable request.

Declarations

Conflict of interest the authors declare that they have no competing interests.

Ethical declarations

The research was not involving humans and animals as experimental units. The research was conducted by keeping the research ethics

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