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Management of Chocolate Spot (*Botrytis fabae L.*) on Faba Bean in Bale Highland's, Ethiopia

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Abstract: Field experiment was conducted at Sinana Agricultural Research Center in the 2014 main cropping season with the objectives wasto study the reaction of faba bean varieties to infection of the chocolate spot and to assess yield losses caused by chocolate spot (*Botrytis fabae*) of faba bean four varieties. The highest mean final disease severity at (118 DAP) 38.29% was recorded on the main plots of the local variety and lowest mean final disease severity 32.75% was on the main plots of the variety Mosisa. The maximum Area Under the disease progress curves (AUDPC) was calculated on the unsprayed plots of local variety and Walki, which were 1817%-days and 1716.42%- days respectively. On unsprayed plots of variety local chocolate spot development was increasing at a rate of 0.03 units per day. For the variety local, chocolate spot severity index assessed from 90 DAP had significant negative correlation with yield and had highly significant negative correlation with hundred seed weight with coefficient of correlation ranging from($r=-0.67$ to $r=-0.62$, $P<0.05$ and r–0.71 to $r=-0.75$, $P<0.01$) for yield and hundred seed weight, respectively. The linear regression of AUDPC better described the relationships between faba bean yield and disease severity compared to percent severity index for the variety Shallo. The estimate showed that for each unit increase in percent of chocolate spot AUDPC, there was a grain yield loss of 1.19 kg/ha The estimated slope of the regression line obtained for the variety Shallo was -1.19. Based on coefficient of determination (R^2) value, the equations explained about 78% of variation in yield due to chocolate spot severity. Maximum relative grain yield losses of 47.8 and 46.7% were recorded due to chocolate spot severity on the varieties Mosisa and Sinana local, respectively.

Keywords: Disease Parameters, Chocolate Spot, Faba Bean, Highlands, Yield Losses

1. Introduction

Faba bean (*Vicia faba* L) is mainly grown in the highlands (1800-3000 m.a.s.l) of Ethiopia (Yohannes, 2000). Currently, the total faba bean area under cultivation is estimated to be about 443,074.68 ha with 838,938.381 ton of production (CSA, 2014). The average yield of faba bean under small-holder farmers is not more than 1.8 t ha^{-1} (CSA, 2014) but improved fababean cultivars can provide 2 t/ha (MoA, 2011). The low productivity of the crop is attributed to susceptibility to biotic and abiotic stresses (Samuel*et al*., 2008 and Mussa *et al*., 2008). The most important yield limiting biotic stresses are chocolate spot (*Botrytis fabae*), rust (*Uromyces fabae*), faba bean gall (*Olpidium* spp) black root rot (*Fusarium solani*) and Parasitic weeds (*Orobanche* and *Phelipanche spp*) (Mussa *et al*., 2008; Ahmed *et al*., 2010; Hailu *et al*., 2014).

Chocolate spot is a major limiting factor in the main faba bean growing regions of Ethiopia (1950-2400 m.a.s.l) (Dereje *et al*., 1988) and yield losses vary from 34.1 to 61.2% (Dereje and Yaynu, 2001; SARC, 2004). According to a survey conducted, this disease was prevalent in all the faba bean growing areas. In spite of wide cultivation of faba bean and widespread occurrence of chocolate spot, research efforts

were concentrated in central and northern highlands of the country. Therefore, the objectives of this experiment were to evaluate chocolate spot management practices and estimate yield losses in Bale highlands.

2. Materials and Methods

2.1. Experimental Site

The experiment was conducted at Sinana Agricultural Research Centre (SARC) located at 7°7'N (latitude) and 40°10'E (longitude) at 2400 meters above sea level recieving mean annual rainfall of 750 – 1000 mm and mean annual temperature of 9 – 21°C (Nefo *et al*., 2008). The location is suitable for chocolate spot epidemic development every year under natural conditions.

2.2. Treatments and Experimental Design

The experiment was conducted using four faba bean varieties; namely Sinana local (susceptible); Shalo (EH011-22-1) moderately susceptible; Mosisa (EH-99047-1) and Walki (EH9609-2) (moderately resistant).

The experiment was planted on August 13, 2014/15 cropping season. Different levels of chocolate spot epidemics were created by application of Mancozeb 80% WP (2.5 a.i kg/ha) at 7, 14 and 21 days intervals. Untreated plots were used as checks. During fungicide sprays, plastic sheet was used to minimize fungicide drifts to adjacent plots. The experiment was laid out in randomized complete block design in factorial arrangement with three replications. The plot size was 7.2 m^2 with 6 rows and the middle four rows were harvested.

2.3. Disease Parameters

Chocolate spot severity was assessed eight times at 7-day intervals on randomly selected 20 plants per plot using 1-9 rating scale where 1= no disease symptoms or very small specks; 3= few small discrete lesions; 5= some coalesced lesions with some defoliation; 7= large coalesced sporulating lesions, 50% defoliation and some dead plant; and 9= Extensive lesions on leaves, stems and pods, severe defoliation, heavy sporulation, stem girdling, blackening and death of more than 80% of plants (Bernier *et al*. 1984). Disease severity scores were converted in to percentage severity index (PSI) for analysis using the following formula.

The average severity from the 20 plants per plot was used for analysis.

$$\text{PSI} = \frac{\text{Snr}}{\text{Nps x Msc}} \text{ X } 100$$

Where:

Snr = sum of numerical ratings

Nps = number plants scored

Msc = maximum score on the scale

The area under disease progress curve (AUDPC) was worked out using the formula (Campbell and Madden 1990).

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

Where, X_i= the PSI of diseaseat the i^{th} assesment

t_i= is the time of the i^{th} assessment in days from the first assessment date

n= total number of disease assessments

Logistic, [ln [(Y/1-Y)], (Vander Plank 1963) and Gompertz, -ln[-ln(Y)], (Berger, 1981) models were compared for estimation of disease parameters from each treatment. These parameters were used in analysis of variance to compare the disease progress among the treatments.

AUDPC models (integral point model) using the AUDPC values were also developed to see if they better describe the disease-yield loss relationships. The correlation coefficient (r- value) was calculated to explain the degree of relationship between the different parameters. Disease severity values recorded on the twenty pre- tagged plants at weekly interval was correlated with grain yield and yield components and agronomic parameters of each variety.

2.4. Yield and Its Components

Data on days to 50% flowering, days to physiological maturity were taken on plot bases. However plant height, pods per plant, seeds per pod, nods bearing pods, 100 seed weight, and biomass yield was recorded from 20 randomly selected plants.

The relative percentage of yield and yield component losses were determined using the following formula

$$\text{RYL (\%)} = \frac{(Y1-Y2)}{Y1} \times 100$$

Where, RL% =percentage of relative yield loss (reduction of the parameters; i.e. yield, yield component),

Y_1 = mean of the respective parameter on protected plots (plots with maximum protection)

Y_2 = mean of the respective parameter in unprotected plots (i.e. unsprayed plots or sprayed plots with varying level of disease).

3. Results

3.1. Disease Parameters

3.1.1. Disease Progress Curves

Chocolate spot was observed on the experimental plot on all varieties at the flowering stage of the crop. The severity level in unsprayed plots of the variety Sinana local which is susceptible to chocolate spot were statistically at parallel with that of the variety Mosisa and Walki during all the successive assessments of the disease. There was pronounced difference in chocolate spot severity between Sinana local, Shallo and Mosisa after 97 DAP (Figure 1). Up to 61% chocolate spot severity was recorded on unsprayed plot of susceptible local variety, while on average the severity of 54% on was

recorded on Walki (Figure 1). Mean chocolate spot severity of up to 47% and 44% were recorded on unsprayed plots of Shalo and Mosisa respectively (Figure 1). All most complete control was achieved by the application of mancozeb at 7-day intervals on all varieties at SARC. At the last date of disease assessment the lowest chocolate spot severity (11.11%) was observed on all varieties (Figure 2).

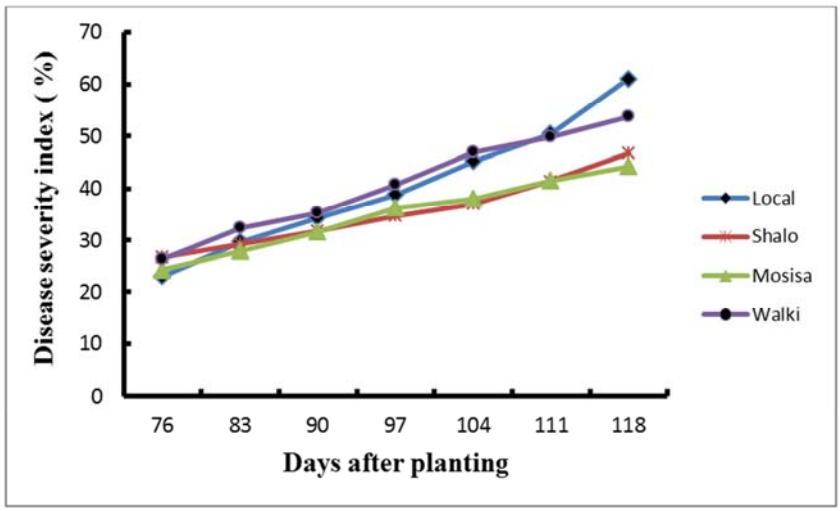

Figure 1. *Disease progress curve of chocolate spot on unsprayed plot of four faba bean varieties, 2014/15 main cropping season, Sinana.*

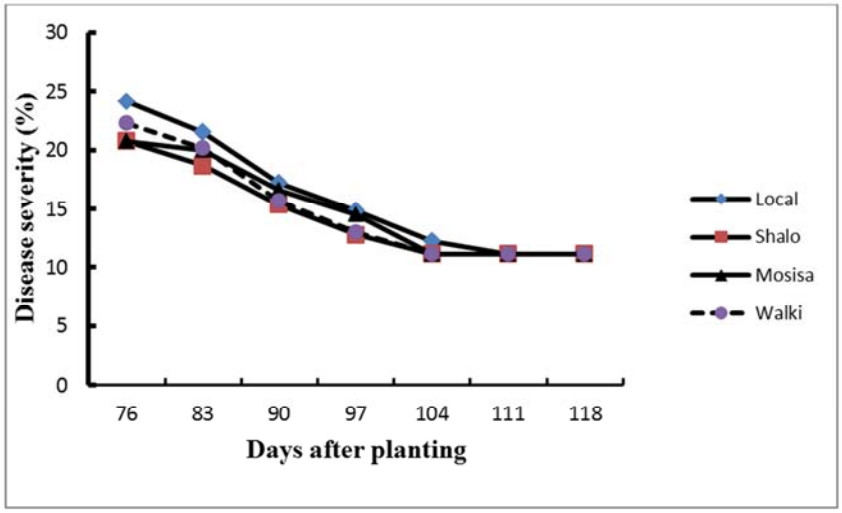

Figure 2. *Disease progress curve of chocolate spot on weekly sprayed plot of four faba bean varieties, 2014/15 main cropping season, Sinana.*

3.1.2. Chocolate Spot Severity

Faba bean varieties during the study period showed significant ($P \leq 0.05$) difference when the disease developed naturally in unsprayed plot starting from 104 DAP. At the fifth date of disease assessment (104 DAP), the highest percent severity index of chocolate spot on local was 30.89% and the lowest 28.16% severity index of chocolate spot was for that of the moderately resistant variety Mosisa (Table 1). Significant ($P \leq 0.05$) difference in chocolate spot severity among plots of faba bean varieties starting from 104 DAP (Table 1). The highest mean initial disease severity at (76 DAP) was 24.07% recorded on local variety and lowest mean initial disease severity 22.5% was on the variety Mosisa. The highest mean final disease severity at (118 DAP) 38.29% was recorded on the variety Sinana local and lowest mean final disease severity 32.75% was on the variety Mosisa.

The percentage severity index due to fungicides spray schedules was showed significant difference ($P \leq 0.05$) from 83 and 104 DAP respectively (table 1). The highest mean initial PSI was 25% in unsprayed plots and the lowest mean initial disease severity (76 DAP) was 21.94% in weekly sprayed plots. At 83 DAP assessment date, the chocolate spot percent severity index (29.77%) on the Mancozeb untreated plot was significantly ($P \leq 0.05$) different from weekly (20%), every 14 (24%) and every 21(26%) days mancozeb treated plots (Table 1). The highest mean final disease severity index (51.45%) was recorded on the unsprayed plots and the lowest mean final disease severity (11.11%) was on the weekly sprayed plots. Interaction of disease severity between the spray interval and variety was significant ($P \leq 0.05$).

Table 1. *Effects of variety and fungicide sprays on chocolate spot percent severity index 2014 main cropping season.*

	percent severity index[1,2,3]						
Treatments	**PSI_1**	**PSI_2**	**PSI_3**	**PSI_4**	**PSI_5**	**PSI_6**	**PSI_7**
Sinana local	24.07a	26.19a	27.48a	29.03a	30.89a	33.25a	38.29a
Shallo	23.81a	25.17a	26.15a	27.18a	28.52ab	31.07ab	34.08bc
Mosisaa	22.50a	24.05a	25.42a	27.08a	28.16b	30.52b	32.75c
Walki	23.06a	25.00a	25.88a	28.14a	30.34ab	32.86ab	35.93ab
CV%	13.5	11.3	10.3	10.9	9.5	8.9	9.95
LSD(0.05)	NS	NS	NS	NS	2.34	2.36	2.92
Spray interval							
No spray	25.05a	29.77a	33.23a	37.63a	41.80a	45.86a	51.45a
7	21.94b	20.07c	16.21d	13.77c	11.38a	11.11c	11.11c
14	22.96ab	24.00b	26.50c	29.00b	30.92c	34.41b	37.92b
21	23.48ab	26.40b	29.00b	31.01b	33.796b	36.32b	40.55b
CV%	13.5	11.3	10.3	10.9	9.5	8.9	9.95
LSD (0.05)	NS	2.36	2.24	2.52	2.34	2.36	2.92

3.1.3. Area under Disease Progress Curve (AUDPC)

The effects of fungicide treatment by variety showed significant ($P<0.05$) difference within treatment combinations (Table 2). The maximum area under disease progress curve was calculated on the unsprayed plots of variety local and Walki, Which were 1817%-day and 1716.42%- day respectively. Spraying fungicide every week on these varieties significantly reduced the AUDPC value compared to the rest fungicide spray schedules and the unsprayed control. The AUDPC of the weekly sprayed plot of the varieties Sinana local and Walki were 677%-day and 614%-days. The AUDPC of the variety Shallo and Mosisa on the weekly sprayed plots and unsprayed plots were 594.74%-day and 625.07%-day and 1476.09%-day and 1467.4%-day respectively (Table 2). Two other spray schedules (every 14 and 21 days) was not significantly reduced the area under disease progress curve on all the varieties (Table 2). Area under disease progress curve was reduced by 57%, 64%, 59% and 60% through weekly sprayed interval on the varieties Mosisa, Walki, Shallo and Sinana local respectively. Even though spraying of fungicide at 14 days interval did not reduce AUDPC significantly ($P\leq0.05$), it reduced the AUDPC by 24%-days, 14%-days, 20%-days and 31%-days as compared to unsprayed plots on the variety Sinana local, Shallo, Mosisa and Walki respectively.

Table 2. *Area under disease progress curve (AUDPC) for the chocolate spot on four faba bean varieties under different fungicide spray schedules at Sinana, 2014 main season.*

Varieties	**AUDPC (% days)[1]**					
	No spray	**7 days intervals**	**14 days intervals**	**21 days intervals**	**Mean**	**LSD(0.05)**
Sinana local	1817^{a}	677^{d}	1284^{c}	1351^{bc}	1282.25	173.7
Shallo	1476^{b}	595^{d}	1266^{c}	1341^{bc}	1169.5	101.5
Mosisaa	1467^{b}	625^{d}	1169^{c}	1299^{bc}	1140	101.5
Walki	1716^{a}	614^{d}	1190^{c}	1288^{c}	1202	245.9
Mean	1619	627.75	1227.25	1318.75		

[1] Area under disease progress curve.

3.1.4. Rate of Disease Progress

Based on the logistic model, the regression equation used to describing the rate of chocolate spot progress was significant for all sprayed and unsprayed plots of all varieties. The coefficient of determination (R^2) was 54% to 84% for unsprayed plot and 38% to 59% for weekly sprayed plots were produced when the linearized form of chocolate spot severity was regressed over time in days after planting (Table 3).

The interaction analyses of fungicide application by varieties showed significant ($P\leq0.05$) difference from 97 DAP onwards (Table 3). On unsprayed plots of variety local chocolate spot development was increasing at a rate of 0.03 units per day. This rate was retarded by about five times by the fungicide application at weekly interval (Table 3). Fungicide sprayed at weekly interval reduced the rate of chocolate spot progress significantly ($P\leq 0.05$). The other fungicide spray schedules (at 14 days) also affected the infection rate of chocolate spot significantly but fungicide spray schedules every 21 days interval was not affected the progression of infection rate significantly. The rates of infection on the local variety sprayed at the interval of 14 and 21 days were 0.007 and 0.009 units per day, respectively. Accordingly, unsprayed Sinana local variety (0.03 units-day^{-1}) exhibit the fastest progress rate and weekly sprayed for all varieties the slowest (0.004 units-day^{-1}) disease progress rate (Table 3).

On the variety Shallo, chocolate spot was increasing at a rate of 0.01 units per day when it was allowed to develop naturally. The weekly fungicide spray on this variety reduced the rate of chocolate spot progress to 0.0034 units per day. The 14 days interval fungicide treatment reduced chocolate infection rate on this variety to nearly half of the rate of unsprayed plot. Chocolate spot infection rate on plots receiving fungicide sprayed at the interval of 14 and 21 days

was significantly reduced rate of disease infection on this variety (Table 3).

Infection rate of 0.01 units per days was observed on the variety Mosisa under unsprayed plots. The weekly fungicide sprayed plots on this variety reduced the disease infection rate to 0.0037 units per day. The range of apparent infection rate in this experiment (0.003-0.03) was slightly closer to the range (0.033-0.036) reported by Samuel *et al.* (2008a) but relatively slower rate.

Table 3. *Rate of chocolate spot infection of faba bean varieties under different fungicide spray schedules at Sinana, 2014 main season.*

Variety	Fungicide spray	Disease progress rate (unit /day)	SE of rate[a]	R^2 (%)[b]	Significance (P)
	interval(days)				
Local	No spray	0.03	0.002	54.27	0.003
	7	-0.004	0.002	48.48	0.007
	14	0.007	0.002	64.29	0.00
	21	0.009	0.002	26.62	0.1
	Mean	0.0125		48.42	
Shallo	No spray	0.011	0.002	78.87	0.001
	7	-0.003	0.002	59.32	0.00
	14	0.007	0.002	43.32	0.02
	21	0.008	0.002	41.50	0.00
	Mean	0.007		55.75	
Mosisaa	No spray	0.011	0.002	84.12	0.03
	7	-0.004	0.002	38.02	0.00
	14	0.006	0.002	84.41	0.00
	21	0.008	0.002	77.00	0.00
	Mean	0.007		70.88	
Walki	No spray	0.019	0.002	71	0.00
	7	-0.004	0.002	44	0.015
	14	0.008	0.002	73	0.00
	21	0.009	0.002	65	0.00
	Mean	0.01		63.25	

[a] Standard error of main factor; [b] Coefficient of determination or proportion explained by the mode.

3.2. Losses of Seed Yield and Its Component

The analysis of two-way interaction of fungicide spray intervals by varieties also showed significant ($P \leq 0.05$) differences among all faba bean varieties. The highest (5933 kg ha^{-1}) grain yield was obtained from the variety Mosisa sprayed with Mancozeb every seven days interval and the lowest (2021 kg ha^{-1}) yield was obtained from unsprayed plots of the variety local. The variety Walki also gave higher (4639 kg ha^{-1}) grain yield when sprayed with Mancozeb every seven days intervals (Table 4). Similar result was reported by Sahile *et al.* (2008c) the mean grain yield of 5.4 t/ha across the four cropping systems was recorded from a 7 day spray interval and Unsprayed plots had significantly lower grain yields (1.9 t/ha) compared to sprayed plots. The maximum relative grain yield losses were recorded from the varieties of Mosisa and Sinana local, 47.8 and 46.7% on unsprayed plots, respectively. On the varieties Shallo and Walki, a grain yield loss of about 30.4% and 29.1% were recorded when chocolate was allowed to develop naturally, respectively.

Effects of varieties and fungicide spray interval showed significant ($P \leq 0.05$) difference in hundred seed weight for all varieties integrated with fungicide spray intervals (Table 4). The highest (59.57g) 100- seed weight was obtained when faba bean variety Mosisa sprayed with Mancozeb at the interval of every seven days. The lowest 100- seed weight (42.1g) was obtained from the local varieties in unsprayed plots. Losses in hundred seed weight greater on the variety Sinana local than others, this variety had maximum hundred seed weight loss of 16% when it was not protected against the disease. All the fungicide treatments reduced hundred seed weight of variety Mosisa as well. In this variety the loss in hundred seed weight was about 14% on unsprayed plots. The reduction in hundred seed weight was relatively lower particularly for the variety Walki. The losses were 11%, 2.7% and 3.5% for the unsprayed, every 14 and 21 days spray interval respectively.

Table 4. *Yield and yield components of faba bean varieties and the corresponding losses due to chocolate spot under different spray schedules at Sinana, 2014 main season.*

Variety	Fungicide spray	Grain yield (kg ha^{-1})	RL losses (%)	HSW (g)	RL losses (%)
	Interval(days)				
Local	No spray	2021^{f}	46.7	42.10^{h}	16.54
	7	3798^{bc}	0	50.44^{efg}	0
	14	3175^{cde}	16.38	48.47^{g}	3.9
	21	2804^{def}	26.17	44.91^{h}	10.97
	Mean	2949.5		46.48	
	CV (%)	17.4		3.6	
Shallo	No spray	2786^{ef}	30.5	51.88^{cdefg}	10

Variety	Fungicide spray	Grain yield (kg ha^{-1})	RL losses (%)	HSW (g)	RL losses (%)
	7	4006^{bc}	0	57.69^{ab}	0
	14	3437^{cde}	14.21	54.69^{bcd}	2
	21	3356^{cde}	16.23	53.74^{cde}	6.84
	Mean	3396.25		54.5	
	CV (%)	6.9		4.7	
Mosisaa	No spray	3096^{cde}	47.82	51.26^{defg}	14
	7	5933^{a}	0	59.57^{a}	0
	14	3874^{bc}	34.7	54.69^{bcd}	15
	21	3251^{cde}	45	49.97^{fg}	16
	Mean	4038.5		53.87	
	CV (%)	14.4		4.2	
Walki	No spray	3288^{cde}	29.1	49.29^{g}	11.17
	7	4639^{b}	0	55.49^{bc}	0
	14	3727^{cd}	19.64	53.98^{cde}	2.7
	21	3433^{cde}	25.98	53.53^{cdef}	3.5
	Mean	3772		53.07	
	CV (%)	14.4		3.6	
CV%		13.5		3.8	
LSD(0.05)		796.8		3.271	

Mean Values in the same letter within a column are not significantly different at 5% probability level; Ns= Non significant; LSD= Least significant difference; HSW= hundred seed weight; RL=Relative loss.

3.3. Correlation Analyses Among Disease Parameters and Yield Losses

Chocolate spot PSI 90 DAP had significant negative correlation with yield and had highly significant negative correlation with hundred seed weight with coefficient of correlation ranging from(r= -0.67 to r= -0.62, $P<0.05$ and r= –0.71 to r = -0.75, $P<0.01$) for yield and hundred seed weight for the sinana local, respectively. For the variety Mosisa, chocolate spot severity index assessed from 97 DAP had shown significant negative correlation with yield and pod per plant (r= -0.57 to r= -0.62, $P \leq 0.05$) and (r= -0.62 to r= -0.69, $P \leq 0.01$) respectively. But correlation analysis between chocolate spot severity index assessed at weekly interval with other yield components and agronomic parameter such as plant height, seed per pod and node bearing pod did not produce significant relationship but they exhibited negative relationships.

AUDPC values were highly and negatively correlated with yield, biomass and pod per plant for all varieties except the hundred seed weight of variety Mosisa and Walki which were not significant difference in relationships with AUDPC (Table 5). For the faba bean variety Shallo, there were strong negative associations of the yield and pod per plant with AUDPC (r = -0.80) and (r=-0.92, $P \leq 0.01$) respectively.

Table 5. *Correlation coefficient (r) between chocolate spot severities index assessed at different times, AUDPC and final rate, yield and yield components of faba bean at Sinana, 2014 main season.*

Variety	Yield& yield components	PSI_i	PSI_f	AUDPC	Final rate
Sinana local	Grain yield	0.05^{ns}	-0.62*	-0.63**	-0.59*
	HSW	0.23^{ns}	-0.73**	-0.71**	-0.64*
	Biomass	-0.06^{ns}	-0.74**	-0.75**	-0.77**
	Pod per plant	0.33^{ns}	-0.89**	-0.86**	-0.85**
Shallo	Grain yield	-0.74**	-0.76**	-0.80**	-0.68*
	HSW	-0.37^{ns}	-0.72**	-0.71**	-0.68*
	Biomass	-0.77**	-0.76**	-0.75**	-0.71**
	Pod per plant	-0.63*	-0.90**	-0.92**	-0.79**
Mosisaa	Grain yield	-0.29^{ns}	-0.59*	-0.58*	-0.66*
	HSW	-0.20^{ns}	-0.53ns	-0.44^{ns}	-0.53^{ns}
	Biomass	-0.44^{ns}	-0.71**	-0.75**	-0.76**
	Pod per plant	-0.18^{ns}	-0.69*	-0.63*	-0.75**
Walki	Grain yield	-0.38^{ns}	-0.76**	-0.76**	-0.77**
	HSW	0.28^{ns}	-0.18ns	-0.16^{ns}	-0.29ns
	Biomass	-0.26^{ns}	-0.73**	-0.74**	-0.79**
	Pod per plant	-0.11^{ns}	-0.69*	-0.63*	-0.67*

PSI_i = initial percent severity index; PSI_f = final percent severity index; HSW=100 seed weight; ns= non-significant;*=significant;**=highly significant.

3.4. Simple Regression Analysis Between Chocolate Spot Severities with Yield of Four Faba Bean

The linear regression of chocolate spot severity index on grain yield and yield related components revealed significant difference for all varieties. The linear regression of percent severity index assessed at (111 DAP), (118 DAP) and (104 DAP) of disease score described better relationship between faba bean yield and

disease severity index compared to AUDPC in the varieties of Mosisa, Walki and Sinana local, respectively because of higher coefficient of determination (R^2). The relationships described the model accounted for 57.2-88.4% of the variance.

The estimated slope of the regression line obtained for the variety Mosisa was -99. The estimate showed that for each unit increase in percent severity index of chocolate spot, there was a grain yield loss in variety Mosisa of 99 kg/ha at 111 DAP (Figure 3). Based on coefficient of determination (R^2) value, the equations explained about 88.4% of variation in yield due to chocolate spot severity. F-statistics calculated showed highly significance ($P \leq 0.01$) of the over all probability of the equation.

But the linear regression of AUDPC better described the relationships between faba bean yield and disease severity compared to percent severity index for the variety Shallo. The estimate showed that for each unit increase in percent of chocolate spot AUDPC, there was a grain yield loss of 1.19 kg/ha (Figure 4). The estimated slope of the regression line obtained for the variety Shallo was -1.19. Based on coefficient of determination (R^2) value, the equations explained about 78% of variation in yield due to chocolate spot severity. For the variety Walki, chocolate spot severity at 118 DAP was found to be the best predictor of loss in yield due to disease. The estimated slope of the regression line obtained for the variety Walki was -35. For each unit percent increase in chocolate spot severity at this stage resulted in grain yield loss of about 35kg/ha (Figure 5). The equation explained about 57.2% of variation.

The estimated slope of the regression line obtained for the variety local was -53.8. The estimate showed that for each unit increase in percent severity index of chocolate spot, there was a grain yield loss in variety local of 53.8 kg/ha at 104 DAP (Figure 6). Based on coefficient of determination (R^2) value, the equations explained about 63% of variation in yield due to chocolate spot severity.

3.5. Weather Conditions

The weather conditions in the cropping seasons (Table 6) differed in the amount of precipitation and the period of rainfall, which would have affected disease at different plant growth stages. In the cropping season, there was 165 mm, 110mm and 58mm of rainfall in September, October and November respectively, at flowering, podding and pod filling stage.

Table 6. *Number of rainy days, total rain fall, relative humidity percent and maximum and minimum temperature at Sinana, from July – December 2014 during faba bean growing period.*

				Daily temperature	
Month	**Number ofrainy days**	**Total rain fall (mm)**	**Relative humidity (%)**	**Maximum (°C)**	**Minimum (°C)**
July	10	81	81.5	20.9	12.06
August	18	212.5	80.6	20.88	11.73
September	22	165.5	85.6	19.85	11.78
October	23	110	86.5	18.9	11.5
November	15	58	84	19.3	10.9
December	1	0.5	71.03	20.43	9.7
Mean	14.83	104.58	81.53	20.04	11.27

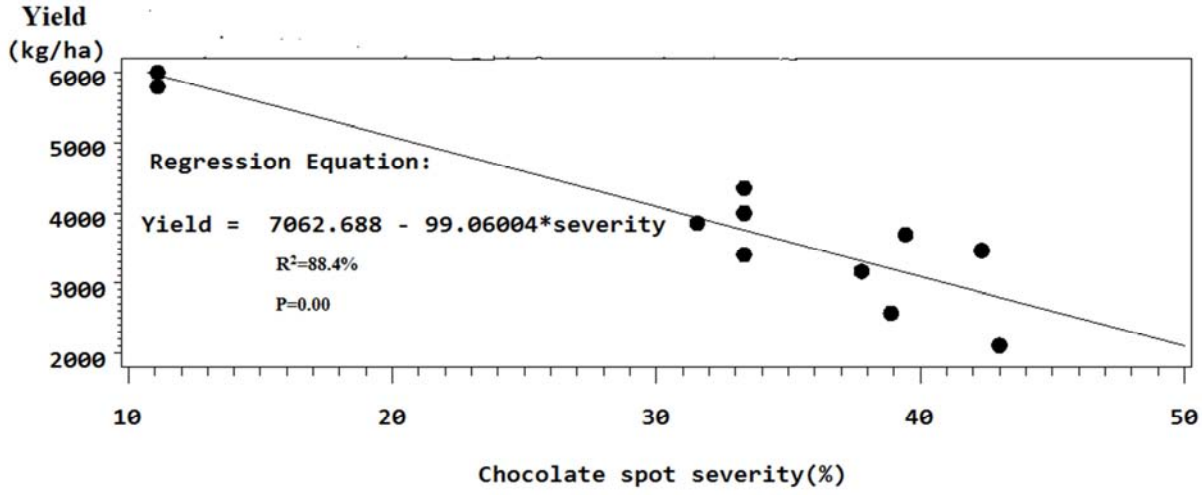

Figure 3. *Estimated relationship between losses in grain yield of variety Mosisaa and chocolate spot severity index (at 111 DAP) at Sinana, 2014 main cropping season.*

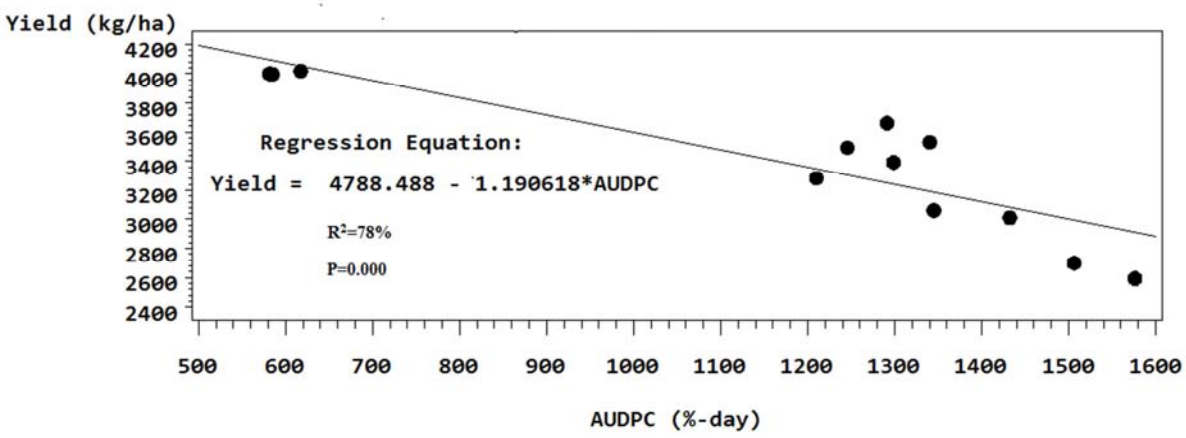

Figure 4. *Estimated relationship between losses in grain yield of variety Shallo and chocolate spot AUDPC at Sinana, 2014 main cropping season.*

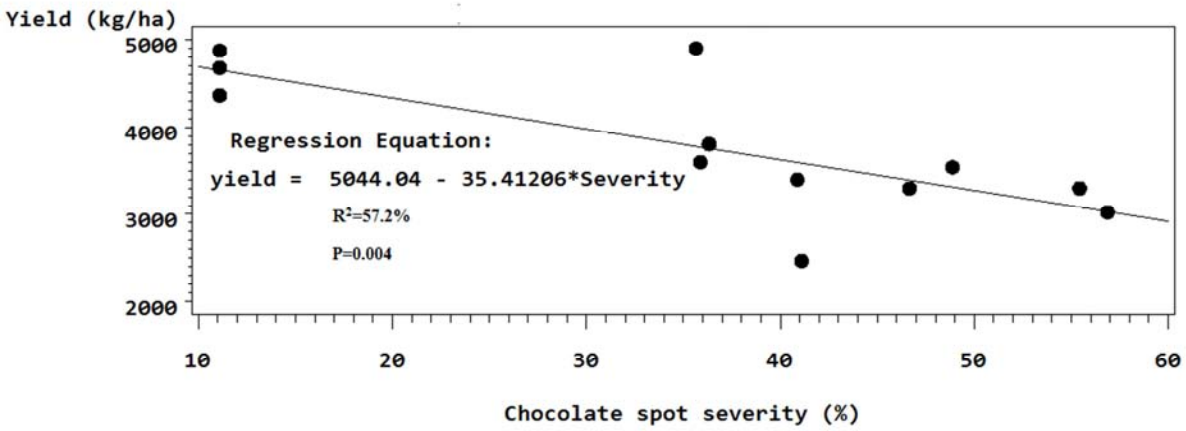

Figure 5. *Estimated relationship between losses in grain yield of variety Walki and chocolate spot severity index (at 118 DAP) at Sinana, 2014 main cropping season.*

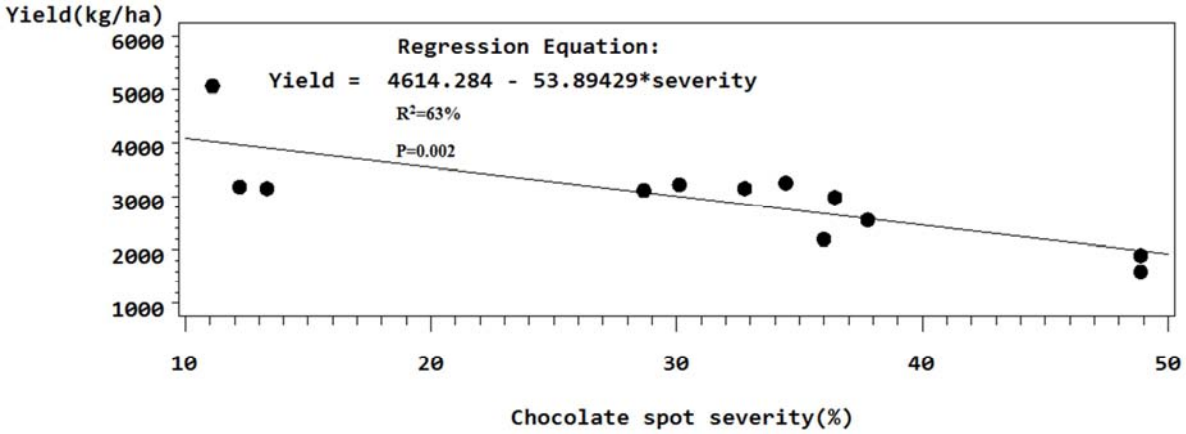

Figure 6. *Estimated relationship between losses in grain yield of variety local and chocolatespot severity index (at 104 DAP) at Sinana, 2014 main cropping season.*

4. Discussion

Faba bean (*Vicia faba* L.) is consider as an old legume food grow on a large areas in the world, the crop great nutritional value for both human and animal consumption having a high content of protein, about (28%). Chocolate spot disease is the most important disease affecting faba bean plants in Ethiopia causing considerable reduction in seed yield. In Bale highlands, chocolate spot epidemics occurs frequently and caused yield losses since farmers grow local susceptible landraces and do not apply fungicides to manage the disease. The objectives was to study the reaction of faba bean varieties to infection of the chocolate spot and to assess

yield losses caused by chocolate spot (*Botrytis fabae*) of faba bean four varieties. In this study, four cultivars of faba bean and four fungicide spray intervals cropping systems were compared. Results have revealed that the fungicide application consistently reduced chocolate spot severity and increased the yield correspondingly. Shorter fungicide spray intervals reduced the disease and increased the yield compared to the unsprayed plots. The weekly fungicide for all faba bean varieties reduced the severity of chocolate spot to the minimum level (11.11%) starting the fifth scoring dates (104 DAP). Similarly the work of El-Sayed *et al*. (2011) reported that on Variety Giza 3 Mohassen and Sakha 1 severity of infection at the fifth score were 43.67% and 46.670%. Under naturally infected plots, were 39% and 35.33%, while under protected plots, were 2.0% and 1.443%, respectively. The Highest areas under disease progress curve was recorded on Local variety (1282%-days). During the experimental period at SARC, the mean minimum and maximum temperatures were more or less similar in the months of July–December, but the rainfall varied. The relative humidity was above 80%. Habtu and Dereje (1985) reported that high rainfall and humidity favoured chocolate spot, and under these conditions it could reach epidemic levels within a few days (Table 6). More rainfall occurred in August and September in the experimental field, which might have favored the initiation of infection and might have also been responsible for the faster disease progress rate even if it was decreases in next months. Good distributed and relatively high amounts of rainfall and wet conditions (high relative humidity and dew) under physiologically optimum temperatures for the pathogen have been reported to increase chocolate spot epidemics (Harrison, 1988).

From the linear relationships of chocolate spot severity the coefficient of determination (R^2) was obtained from 54% to 84% for unsprayed plot and 38% to 59% for weekly sprayed plots. Faba bean grain yield was highly influenced by the severity of chocolate spot. The range of apparent infection rate in this experiment (0.003-0.03) was recorded. This is slightly closer to the range (0.033-0.036) reported by Samuel *et al*. (2008a) but relatively slower rate. The rate of the disease progress was relatively slow in all the treatment combinations. This could be the result of low precipitation during the cropping period (Table 6).

Correlation analysis revealed significant negative relationship between chocolate spot severity index and yield, biomass, hundred seed weight, pod per plant. This result is in agreement with the result of Samuel *et al*. (2008c) which states that disease parameters of Chocolate spot severity was negatively related to grain yield of faba bean from the mid-season disease assessment at 71 DAP until the last day of the assessment and also negatively correlated with the 100-seed weight.

Correlation analysis between chocolate spot severity index assessed at weekly interval with other yield components and agronomic parameter such as plant height, seed per pod and node bearing pod did not produce significant relationship but they exhibited negative relationships.

The linear regression of the chocolate spot severity index was used for predicting the yield loss in faba bean. It is because chocolate spot severity index linear regression better indicated the relationships of yield loss and the disease than the AUDPC linear regression because of higher coefficient of determination (R^2). Grain yield losses were reduced by fungicide spray schedules or intervals as compared to the unsprayed plot of the respective treatments. Hawthorne (2004) indicated that the application of Mancozeb as a protective fungicide helps to reduce yield loss due to chocolate spot as it prevents pod abortion and plant damage.

The results of this study show that chocolate spot disease has reduced the grain yield and quality by reducing 100-seed weight. Integration of moderately resistant variety with Mancozeb spray reduced the disease and increased the grain yield, as well as the seed weight.

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