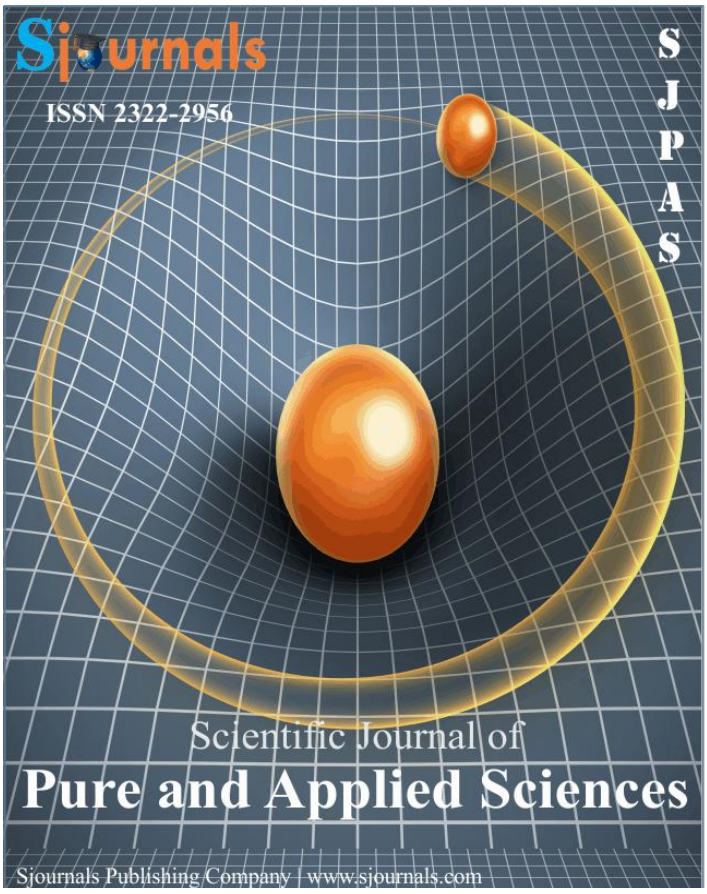

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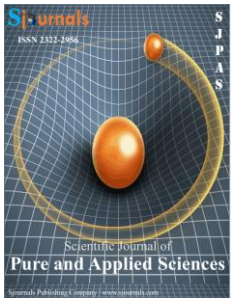

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Original article

Yield loss of faba bean (*Vicia faba* L.) due to chocolate spot (*Botrytis fabae* Sard.) in Sinana, Southeastern Oromia

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ABSTRACT

Field experiment was conducted at Sinana Agricultural Research Center in the 2014 main cropping season with the objective to assess yield losses caused by chocolate spot (*Botrytis fabae*) of faba bean varieties. The highest number of days to physiological maturity was recorded on the variety Shalo (141.6 days) and lowest in the variety Mosisa (138.5 days). The maximum biomass on hectare basis (6.6t/ha) was obtained from plot sprayed at weekly interval. The maximum relative grain yield loss were recorded from the varieties of Mosisa and local, 47.8% and 46.7% on unsprayed plots, respectively. Losses in hundred seed weight greater on the variety local than others, this variety had maximum hundreds seed weight loss of 16% when it was protected against the diseases. The local variety shows the maximum biomass loss compared to other varieties under unsprayed plots. This variety has a biomass loss of 33% under unsprayed plots. The highest marginal benefit (32022.9 ETB/ha) was obtained from variety Mosisa sprayed at weekly intervals and highest (233.7 ETB) marginal rate of return was obtained also from this variety when treated at weekly intervals.

1. Introduction

Faba bean (*Vicia faba* L.) is mainly grown in the highlands of Ethiopia between 1800-3000 m.a.s.l (Yohannes, 2000). Faba bean is very important as human food, animal feed, income sources and plays a key role in improving soil fertility and health. Currently, the total faba bean area under cultivation is estimated to be about 0.4 million ha with 838,938 ton of production (CSA, 2014/15). The average yield of faba bean under small-holder farmers is not more than 1.8 t ha^{-1} (CSA, 2014/15) but improved faba bean cultivars can provide more than 3 t/ha (MA, 2011). The high yield gap is attributed to susceptibility to biotic and abiotic stresses (drought, water logging and frost); low adoption of improved faba bean technologies due to shortage of seeds and weak extension system (Samuel et al., 2008; Mussa et al., 2008). The most important yield limiting biotic stresses are chocolate spot (*Botrytis fabae*), rust (*Uromyces fabae*), faba bean gall (*Olpidium* spp), root rots (*Fusarium* spp) 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) and yield losses vary from 34.1 to 61.2% (Dereje et al., 1988; Dereje and Yaynu, 2001; SARC, 2004). Breeding for high yield and chocolate spot resistant has resulted the release of moderately resistant cultivars, but chocolate spot severity increased during excessive wet seasons. In spite of wide cultivation of faba bean and widespread occurrence of chocolate spot, research efforts are concentrated in the central and northern highlands of the country. Therefore, the objective of this research was to estimate yield losses of faba bean due to chocolate spots in Bale highlands.

2. Materials and methods

2.1. Description of experimental

The experiment was conducted at research field of SARC. The location represents the highlands of major faba bean production area of Bale with high rainfall and is expected to be the suitable environment (hot spot) for the disease. Bale is characterized by bimodal pattern annual rain fall. The first rainy season occurs from March to June and the second from August to December. The two seasons are locally termed after the time of crop harvest as Ganna (Belg) and Bona (Meher), respectively.

2.2. Experimental materials and treatments

The experiment was conducted using four faba bean varieties (Local, Shalo, Mosisa and Walki). Based on their average disease score for the last three years conducted by SARC, Local variety was susceptible and Shallo was moderately susceptible, Mosisa and Walkias moderately resistant to chocolate spot. The fungicide was applied at a rate of 2.5 a.i kg/ha in three different spray schedules viz., every 7, 14 and 21 days and unsprayed plot was included. The seven day spray treatment started on the first day of chocolate spot symptom appearances. The experiment was laid out using randomized complete block design (RCBD) in factorial arrangement with three replications. There were a total of 16 treatments; which contained the combination of four faba bean varieties with four levels of fungicide spraying interval (including unsprayed checks). The plot size was 3m x 2.4m (7.2m2) having 6 seeding rows with 4 harvestable central rows while spacing of 1m, 0.5m and 0.4m, respectively were applied between block, plots and rows.

2.3. Yield loss estimation

The relative losses in yield and yield components of each variety will be determined as a percentage of that of the protected plots of the respective variety. Losses will be calculated separately for each of the treatments with different levels of disease, as:

$$RL\ (\%) = \frac{Y_1 - Y_2}{Y_1} \times 100$$

Where, RL (%) = Percentage of relative 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 and discussion

3.1. Effects of fungicide application and varieties on some yield components of faba bean

3.1.1. Days to flowering and days to physiological maturity

The main effects of fungicide application showed non-significant ($P \leq 0.05$) difference on days to flowering and days to physiological maturity of faba bean (Table 1). However, varietal effect showed significant ($P \leq 0.05$) difference on days to 50% flowering, and days to 90% physiological maturity. The highest numbers of days to physiological maturity was recorded in variety Shalo (141.6 days) and the lowest in the variety Mosisa (138.5 days). The mean days to physiological maturity of local and Walki were 139 and 139 days respectively (Table 1). The unsprayed plots had relatively the same days to maturity with other spray intervals (Table 1). The highest days to flowering was recorded on the variety Shalo (57.4 days) and the lowest was recorded on the local variety (54.7 days). But to the previous work of Sahile et al. (2008c) reported shorter days to maturity 2004 (131 days) and 2005 (126 days) on sprayed plots as compared to this results .

Table 1
Effects of faba bean varieties and fungicide spray schedules on days to flowering and days to physiological maturity at Sinana in 2014 main cropping season.

Factor	Days to flowering	Days to physiological maturity
Variety		
Local	54.75b	139.9
Shalo	57.41a	141.6
Mosisa	55.58b	138.5
Walki	56.83a	139.6
CV (%)	2.6	1.8
LSD (0.05)	1.200	2.07
Fungicide spray interval		
No spray	56.16a	140.8a
7	56.16a	140.1a
14	56.33a	139.5a
21	55.91a	139.3a
CV (%)	2.6	1.8
LSD (0.05)	NS	NS

Mean values in the same letter within a column are not significantly different at 5% probability level; NS = Non-significant; LSD = Least significant different.

3.1.2. Plant height and biomass

The main effects of Varieties and fungicide application interval showed non-significant ($P \leq 0.05$) difference on plant height. But interaction effect of fungicide with variety showed significant difference ($P \leq 0.05$) on plant height (Table 3). The main effects of Varieties and fungicide application interval showed significant ($P \leq 0.05$) difference on biomass. The higher plant height was obtained from plots sprayed every 7 and 14 days intervals, their respective height were 163cm and 166cm respectively. The maximum biomass on hectare basis (6.6 t ha^{-1}) was obtained from plot sprayed at weekly interval. The variety Shalo (6.5 t ha^{-1}) and Walki (6.49 t ha^{-1}) had higher biomass content on hectare basis than other local and Mosisa varieties (Table 2).

3.1.3. Node bearing pod, pod per plant and seed per pod

The main effects of varieties and fungicide application interval showed non-significant ($P \leq 0.05$) difference on node bearing pod, pod per plant and seed per pod of faba bean and also their interaction effects showed non-significant difference ($P \leq 0.05$) (Table 3).

Table 2
Effects of faba bean varieties and fungicide spray schedules on plant height and biomass at Sinana in 2014 main cropping season.

Factor	Plant height (cm)	Biomass (t/ha)
Variety		
Local	163.8a	5.54b
Shalo	164.9a	6.54a
Mosisa	161.9a	5.73b
Walki	163.5a	6.49a
CV (%)	2.7	10.5
LSD (0.05)	NS	0.541
Fungicide spray interval		
No spray	161.4a	5.61b
7	163.9a	6.63a
14	166.0a	6.10ab
21	162.9a	5.96b
CV (%)	2.7	10.5
LSD (0.05)	NS	0.541

Mean values in the same letter within a column are not significantly different at described probability level Ns = Non-significant; LSD = Least significant difference probability.

Table 3
Effect of chocolate spot on four faba bean yield components and other agronomic parameters varieties at Sinana in 2014 main cropping season.

Variety	Fungicide spray interval (days)	Nod/Plant	Pod/Plant	Seed/Pod	PH	BM	DF	DM
Local	No spray	25.53	19.13	2.567	165.00	5.00	54.33	141.00
	7	28.33	26.27	2.533	164.67	5.933	55.00	139.33
	14	26.73	23.00	2.533	166.67	5.483	55.00	140.67
	21	28.47	21.67	2.800	159.00	5.750	54.67	138.67
Shalo	No spray	23.67	19.80	2.600	167.67	6.250	57.33	144.00
	7	25.67	29.77	2.567	164.33	7.05	57.33	144.00
	14	25.07	22.73	2.400	165.67	6.300	59.00	139.33
	21	27.53	19.70	2.700	162.00	6.567	57.33	141.33
Mosisa	No spray	27.33	20.00	2.767	152.67	5.067	57.00	138.67
	7	32.93	38.93	2.633	161.00	6.550	56.00	139.00
	14	24.47	27.20	2.667	173.00	6.183	55.00	138.33
	21	31.53	26.20	2.500	161.00	5.150	54.33	138.33
Walki	No spray	27.60	20.93	2.467	160.33	6.150	56.00	139.67
	7	29.00	33.53	2.700	165.67	7.00	57.67	140.33
	14	24.73	27.70	2.50	158.67	6.433	56.33	139.67
	21	23.93	24.67	2.567	169.67	6.383	57.33	139.00
CV (%)		16.1	22.8	7.5	2.7	10.7	2.6	1.8
LSD (0.05)		NS	NS	NS	7.34	NS	NS	NS

CV = Coefficient of variation; LSD = Least significant difference; PH = Plant height; DF = Days flowering; BM = Biomass; DM = Days to maturity.

3.2. Relative losses in yield and yield components

3.2.1. Losses in grain yield

The variations in grain yield losses of faba bean varieties tested were inconsistent across the fungicide 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. In unsprayed plots, grain yield losses were notably higher in the variety Mosisa (Table 4). In all the varieties, only the weekly fungicide treatments significantly affected grain yield. The other fungicide spray treatments also affected grain yield in the entire varieties even if they does not same as weekly treatments. Nevertheless, grain yield losses were reduced by all fungicide treatments as compared to the unsprayed plot of the respective variety.

The maximum relative grain yield losses were recorded from the varieties of Mosisa and local, 47.8% and 46.7% on unsprayed plots, respectively. On these varieties relative yield loss of 34% and 45% and 16.4% and 26% were calculated, respectively when chocolate spot controlled with fungicide spray at the interval of 14 and 21 days, respectively. Similarly the previous work of Sahile et al. (2008c) reported the mean yield loss in the unsprayed plots due to the chocolate spot ranged from 35.8 to 41.5% in 2004 and 52.6-67.5% in 2005. The highest relative yield loss was (67.5%) obtained from FB: FP mixed cropping in unsprayed plot. With this agreement Rizk (1974) who mentioned that losses caused by chocolate spot disease ranged from 40% to 50% of the yield in the years of severe attack, and from 5% to 15% in the years of mold infection. Another reports by Abd El-Hak et al. (1984) found the seed yield loss due to chocolate spot disease was 58%.

On the varieties Shalo and Walki, a grain yield loss of about 30.4% and 29.1% were recorded when chocolate was allowed to develop naturally, respectively. On these varieties relative yield loss of 14.2% and 16% and 19% and 25% were calculated when chocolate spot controlled with fungicide spray at 14 and 21 days interval, respectively (Table 4). With this agreement by El-Sayed et al. (2011) reported that reduction in seed yield (loss%) of the cultivar 716 reached 18.66% naturally infected by chocolate spot (*Botrytis fabae* Sard.) plots compared to the protected plots in the first season, while in second season it was only 12.53%. In case of the CV. Giza 40 losses% in seed yield were 33.5% and 20.32% in the two seasons, respectively, while the CV. Giza 3 Mohassen showed 27.79% and 15.62% losses in the two seasons.

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 interval (days)	Grain yield (kg ha^{-1})	RL loss (%)	HSW (g)	RL loss (%)	Biomass (t ha^{-1})	RL loss (%)
Local	No spray	2021^{f}	46.7	42.10^{h}	16.54	5.50	33.2
	7	3798^{bc}	0	50.44^{efg}	0	8.23	0
	14	3175^{cde}	16.38	48.47^{g}	3.9	7.60	7.7
	21	2804^{def}	26.17	44.91^{h}	10.97	7.33	11
Shalo	No spray	2786^{ef}	30.5	51.88^{cdefg}	10	6.13	37
	7	4006^{bc}	0	57.69^{ab}	0	9.8	0
	14	3437^{cde}	14.21	54.69^{bcd}	5.2	8.73	10.9
	21	3356^{cde}	16.23	53.74^{cde}	6.84	8	18.4
Mosisa	No spray	3096^{cde}	47.82	51.26^{defg}	14	5.86	35
	7	5933^{a}	0	59.57^{a}	0	9.1	0
	14	3874^{bc}	34.7	54.69^{bcd}	15	8.56	6
	21	3251^{cde}	45	49.97^{fg}	16	7.13	22
Walki	No spray	3288^{cde}	29.1	49.29^{g}	11.17	6	38
	7	4639^{b}	0	55.49^{bc}	0	9.73	0
	14	3727^{cd}	19.64	53.98^{cde}	2.7	8.9	8.6
	21	3433^{cde}	25.98	53.53^{cdef}	3.5	8	18
CV (%)		13.5		3.8		11.6	
LSD (0.05)		796.8		3.271		NS	

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.

3.2.2. Losses in hundred seed weight

Hundred seed weight is an important component of yield mostly affected by chocolate spot. The reduction in hundred seed weight is mainly due to the effect of the disease on the size and mass of the seed. Losses in hundred

seed weight greater on the variety 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 had significant effect on the hundred seed weight and the reduction in hundred seed weight was observed to increase consistently as the frequency of fungicide application decreased. Fungicide spray at 14 and 21 days interval resulted in 3.9% and 11% losses in hundred seed weight on this variety (Table 4).

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 relative reduction in hundred seed weight for the spray treatments at 14 and 21 days interval was also maximum on this variety were 15% and 16% respectively. 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.

3.2.3. Losses in biomass

The maximum loss in biomass was recorded on the variety Walki and followed by Shalo. The disease reduced biomass by 38% on unsprayed plots of this variety. The biomass measures from plots sprayed at 14 and 21 days interval were different among each other and reduced biomass by 8.6% and 18% respectively. For the variety Shalo, biomass loss of 37% was recorded under natural chocolate spot epidemics. Spraying fungicide every 14 and 21 days interval reduced a biomass loss to 11% and 18% respectively (Table 4). The local variety shows the minimum biomass loss as compared to other varieties under unsprayed plots. This variety has a biomass loss of 33% under unsprayed plots (Table 4). The maximum biomass loss for the variety Mosisa was 35% under unsprayed plots and 6% and 22% biomass were reduced where the plots were sprayed at the interval of 14 and 21 days.

3.3. Cost/benefit analysis

The cost and benefit of each treatment was analyzed partially and the marginal rate of return was computed by considering the variable cost available in the respective treatment (Table 5). Partial budget analysis of marginal cost and marginal benefit depicted the highest (ETB 32022.9 ha^{-1}) marginal benefit was obtained from faba bean variety Mosisa sprayed with Mancozeb at weekly intervals, followed by Walki (ETB 23870.7 ha^{-1}) and the lowest (ETB12732.3 ha^{-1}) obtained from unsprayed local variety (Table 5).

Table 5
Cost/benefit assessment of fungicide application interval against chocolate spot on four faba bean varieties at Sinana in 2014 main cropping season.

Variety	Fungicide spray interval (days)	Yield (kg ha^{-1})	Adjusted yield (%)	SR (ETB ha^{-1})	MC (ETB ha^{-1})	MB (ETB ha^{-1})	MRR (%)
Local	No spray	2021	1818.9	12732.3	0	12732.3	0
	7	3775	3418.2	23927.4	5355	18572.4	109
	14	3175	2857.5	20002.5	2295	17707.5	216.7
	21	2804	2523.6	17665.2	1530	16135.2	222.4
Shalo	No spray	2786	2507.4	17551.8	0	17551.8	0
	7	4006	3605.4	25237.8	5355	19882.8	43.5
	14	3437	3093.3	21653.1	2295	19358.1	78.7
	21	3356	3020.4	21142.8	1530	19612.8	134.7
Mosisa	No spray	3096	2786.4	19504.8	0	19504.8	0
	7	5933	5339.7	37377.9	5355	32022.9	233.7
	14	3874	3486.6	24406.2	2295	22111.2	113.5
	21	3251	2925.9	20481.3	1530	18951.3	-36.2
Walki	No spray	3288	2959.2	20714.4	0	20714.4	0
	7	4639	4175.1	29225.7	5355	23870.7	58.9
	14	3727	3354.3	23480.1	2295	21185.1	20.5
	21	3433	3089.7	21627.9	1530	20097.9	-40.3

SR = Sale revenue; MC = Marginal cost; MB = Marginal benefit; MRR = Marginal rate of return.

The highest (ETB 233.7) marginal rate of return was obtained from Mosisa when it was treated with Mancozeb at weekly interval for seven times, followed by local (ETB 222.4) treated with Mancozeb at 21 days

interval for two times. In other words, for every ETB 1.00 investment in Mancozeb cost and spraying, there was a gain of ETB 2.337 for the faba bean variety Mosisa and ETB 2.22 for the local variety. Nevertheless, the treatment effect was non-significant with dominance analysis; the marginal rate of return calculated from the plots sown with varieties of Mosisa and Walki sprayed with fungicide at 21 days interval was negative (Table 5).

Generally the highest faba bean grain yield, highest marginal benefit, and marginal rate of return were obtained from the moderately resistant faba bean variety Mosisa as compared to the other treatment combinations. But the variety Walki, have high grain yield, high marginal benefit but have low marginal rate of returns. The variety local sprayed with Mancozeb fungicide at weekly, every 14 and 21 days interval provided higher marginal rate of return than the other two faba bean (Shalo and Walki) varieties even if it provides lower marginal benefits. So from the economic point of view, production of moderately resistant varieties Mosisa and Walki under Mancozeb-spraying practices is the most profitable with other integrated management options against chocolate spot at the current faba bean market prices.

4. Conclusion

Faba bean is botanically known as Vicia faba L.; with the common names including broad bean, horse bean, tic bean and field bean. It is one of the earliest domesticated food legumes in the world, probably in the late Neolithic period (Metayer, 2004). Ethiopian farmers are also aware of the role of legumes in general and faba bean in particular in improving soil health by fixing atmospheric nitrogen, and widely use them in rotation with cereals (Sahile et al., 2008a). Ethiopia, the average yield of faba bean under small-holder farmers is not more than 1.8t ha^{-1} (CSA, 2014), despite the availability of high yielding varieties (> 2 t/ha) (MA, 2011). The low productivity of the crop is attributed to susceptibility to biotic and abiotic stresses (Sahile et al., 2008; Mussa et al., 2008). In the Maghreb region (Libya, Tunisia, Algeria, Morocco), yield losses due to chocolate spot diseases can reach 60-80% on susceptible cultivars (Bouhassan et al., 2004). Chocolate spot is a major limiting factor in the main faba bean growing regions of Ethiopia, and yield losses vary from 34.1 to 61.2% (Dereje and Yaynu, 2001). According to a survey conducted, this disease was prevalent in all the faba bean growing areas with a range of 1950-2400 m.a.s.l, including Sinana (Dereje et al., 1988). Overall yield loss of 45% on the local and 42.4% on Shallo (SARC, 2004).

The maximum relative grain yield losses of 47.8% and 46.7% were recorded due to chocolate spot severity on the varieties Mosisa and local, respectively. On Shalo and Walki, chocolate spot resulted in relative grain yield loss of 30.4% and 29.1% respectively. Losse in hundred seed weight was greater on the local that had maximum weight loss of 16%. The maximum loss in biomass was recorded on the variety Walki and followed by the variety Shalo. The disease resulted in 38% and 37% loss in biomass the varieties Walki and Shalo, respectively. Partial budget analysis of marginal cost and marginal benefit depicted the highest (ETB 32022.9 ha^{-1}) marginal benefit that was obtained from the variety Mosisa sprayed with Mancozeb at weekly intervals, followed by Walki (ETB 23870.7 ha^{-1}) and the lowest (ETB 12732.3 ha^{-1}) was obtained from unsprayed local variety. Generally the highest faba bean grain yield, highest marginal benefit, and marginal rate of return were obtained from the moderately resistant faba bean variety Mosisa as compared to the other treatment combinations. Host resistance integrated with other cultural practices applicable in the area should be given due attention to provide other alternatives for effective, efficient and sustainable chocolate spot management options.

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