

Grain Yield and Yield Components of Field Pea (*Pisum sativum* L.): As Influenced by Ascochyta Blight (*Mycosphaerella pinodes*) Disease in the Highlands of Bale, Oromia

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Abstract

Field pea or “dry pea” (*Pisum sativum* L.) is an annual cool-season food legume which grows worldwide and is the second major pulse crop produced in the highlands of Bale next to Faba bean. The experiment was conducted for two consecutive cropping seasons; 2011/12 and 2012/13 at Sinana agricultural research center (SARC) on-station research site. The objective was to investigate the effect of Ascochyta Blight (*Mycosphaerella pinodes*) disease on field pea yield and yield components. Local field pea cultivar was used with a fungicide Benomyl at a rate of 2.5kg/ha and four application schemes (spraying at 7 days, 14 days and 21 days interval and no fungicide spray) arranged in RCB Design with 3 replications. The logistic model ($\ln[y/(1-y)]$) was employed for estimation of the disease progression and the data were analyzed using SAS procedure. The association of disease parameters with yield and yield components were assessed using Regression and correlation techniques. ANOVA for disease severity, AUDPC and disease progress rate (r) have shown significant difference ($P \leq 0.0001$) between treatments. The highest Ascochyta blight disease severity of 40.12% was recorded from non-treated plot; while the lowest severity of 12.96%, was recorded from plot sprayed at 7 days interval. Similarly, the highest AUDPC of 1432.41%-days and the lowest (434.25%-days) were recorded from non-treated and plot sprayed at 7 days interval, respectively.

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In the same way, the highest disease progress rate (r) of 0.036771 units-day⁻¹ and the lowest r of -0.007652 units-day⁻¹, respectively were recorded from non-treated plot and plot sprayed at every 7 days interval, respectively. ANOVA for yield and yield components have shown significant difference ($P \leq 0.05$) between treatments. For all of the parameters considered, the highest values were recorded from plots sprayed every 7 days interval; while the lowest were from none sprayed plot. The highest (195.81g) and the lowest (175.23g) TKW were recorded from plots sprayed at 7 days interval and none treated plots, respectively. While the highest (2945.6 kg/ha) and the lowest (1873.5 kg/ha) grain yield were recorded from plots sprayed at 7 days interval and none treated plots, respectively. The linear regression of disease severity with grain yield revealed that there was highly significant difference ($P \leq 0.0001$) between treatments. The estimated slope of the regression line obtained for Ascochyta blight disease severity was -39.08. Which indicates that, for every unit increase in Ascochyta blight disease severity there will be a reduction of 39.08 kg/ha in Field pea grain yield. Correlation analysis has shown that Ascochyta blight disease have highly significant strong negative correlation with grain yield ($r = -0.84400$, $P \leq 0.0001$). Similarly, grain yield have significant strong negative correlation ($r = -0.83841$, $P \leq 0.0001$) with AUDPC.

Key words: Field pea; Yield loss; Ascochyta blight; AUDPC; Disease progress rate (r); Disease severity index.

1. Introduction

Field pea or "dry pea" (*Pisum sativum* L.) is an annual cool-season food legume that grows worldwide [1]. Although cereal crops are the major crops cultivated in Bale highlands, food legumes are also one of the most important pulse crops produced by Bale farmers among which field pea is the one. In Ethiopia, it is among the major food legume crops produced, ranking second in terms of area of production and productivity next to Faba bean. It is important crop in providing quality vegetable protein in the diets of many Ethiopians [2]. It also plays an important role in soil fertility restoration and controlling disease epidemics as a suitable rotation and break crop where cereal mono-cropping is predominant at areas like Arsi and Bale, Ethiopia. Currently, the area of production and yield per unit area of field pea in Ethiopia is increasing, according to Central Statistical Authority [3], In 2009/2010, the area covered with field pea was 226,533 ha out of 1,489,308 ha of land covered by pulse crops and the annual production was estimated at about 235,872.10 tons with the average annual productivity of 1.041 t/ha. Field pea, despite its importance, is very low in productivity which is far below its potential. This low productivity is mainly attributed to several yield limiting factors; among which, the inherent low yielding potential of the indigenous cultivars [4], diseases like powdery mildew (*Erysiphe polygoni*) and Ascochyta blight (*Mycosphaerella pinodes*) [5] and some insect pests like green pea Aphids are the major production constraints. Currently, in the highlands of Bale, field pea production is increasing dramatically regardless of diseases challenges on its productivity. In this area until now, the effect of Ascochyta blight disease on Field pea is not studied. Therefore, this trial was conducted with the objective of quantifying the magnitude of loss caused by powdery Ascochyta blight on yield and yield components Field pea.

2. Materials and methods

2.1. Description of experimental site

The experiment was conducted for two years; 2011/12 and 2012/13 during the main cropping season of Bale highlands at on-station research site of Sinana Agricultural Research Center (SARC), southeast Oromia, Ethiopia. SARC is located at 463 km far from the central city, Finfine to the southeast. It is situated at 07° 07' N latitude and 40° 10'E longitude with an elevation of 2400 m.a.s.l [6]. The dominant soil type is pellic vertisol which is slightly acidic. The location represents the major Field pea production areas of Bale with a characteristics of bimodal rain fall pattern where the first rainy season occurs from March to June “Ganna” (short season) and the second from August to December “Bona” (main cropping season), locally the two seasons are termed in line with the time of crop harvest. It receives the mean annual rainfall of 750 mm to 1000 mm and mean annual temperature of 9-21 °C ([6]. As a result, the area is hot spot for field pea diseases.

2.2. Treatments and design

The experiment was arranged in three replications of RCB Design. Local field pea cultivar was evaluated on 2 m x 1.2 m plot size with a total of 6 seeding rows. Between row, plot and replication spacing of 0.2m, 1m and 1.5m, respectively were maintained. The diseases infection gradient was created by spraying a fungicide Benomyl@2.5 kg/ha at a fixed spray interval of every 7, 14, and 21 days and a control plot receiving no fungicide spray (NS) was used for treatment comparison. Fungicide application was started immediately after the development of the first observable disease symptom and then the spray were made at a regular interval. Seed rate, fertilizer rate, weeding and other all agronomic packages were applied as per the recommendation for the crop. Disease scoring was conducted in a 1-9 diseases scoring scale [7]. The disease data recorded based on scale mentioned above was converted to percentage severity index (PSI) [8]:

$$PSI = \frac{\text{Sum of Numerical Ratings} \times 100}{\text{Number of Plants Scored} \times \text{Maximum Score on Scale}} \dots\dots\dots (1)$$

2.3. Data Management and Statistical Analysis

Field experiment data under different treatments were analyzed using logistic model, $\ln[y/(1-y)]$ [9] with the SAS Procedure [10]. The slop of the regression line estimated the diseases progress rate in different treatments. AUDPC values were calculated for each treatment using the standard formula [9]. ANOVA was performed for disease severity index [8], AUDPC [9], and rate of disease progress (r) according to SAS procedure. LSD technique at 5% probability level was used for treatments mean separation. Logistic model, $[\ln [(Y/1-Y)]]$, [11] was used for estimation of disease parameters from each treatment. These parameters were used in analysis of variance to compare the disease progress among the treatments.

$$AUDPC = \sum_{i=1}^{n-1} 0.5(x_{i+1} + x_i)(t_{i+1} - t_i) \dots\dots\dots (2)$$

Where, X_i = the PSI of disease at the i^{th} assessment

t_i = is the time of the i^{th} assessment in days from the first assessment date , n= total number of disease assessments

The association of Ascochyta blight disease severity with grain yield was analyzed through linear regression analysis by plotting yield data against Diseases severity. Correlation between grain yield and yield related parameters with the diseases parameters (AUDPC, Ascochyta blight disease severity and r (disease progress rate)) were assessed and correlation coefficient values were computed to establish their relationships.

2.4. Yield Loss Estimation

The relative losses in yield and yield components of each treatment were determined as a percentage of that of the protected plot. Losses were calculated separately for each of the treatment with different levels of disease severity, as:

$$RL (\%) = \frac{(Y_1 - Y_2)}{Y_1} \times 100 \dots\dots\dots (3)$$

Where, RL% = percentage of relative loss (reduction of the parameters; i.e. yield and yield component); Y_1 = Mean grain yield on the protected plot (plot with maximum protection), Y_2 = Mean grain yield on unprotected plot (i.e. unsprayed plot or sprayed plots with varying level of disease).

3. Result and discussion

The combined Analysis of variance over years have shown that there were statistically significant difference ($P \leq 0.0001$) between treatments for the disease related parameters such as Ascochyta blight disease severity, Area Under Disease Progress Curve (AUDPC) and Disease Progress Rate (r). Similarly, there were statistically significant difference ($p \leq 0.05$) between treatments for yield and yield related parameters such as No. of Pods per Plant, Seeds per plant, Thousand Kernel Weight (TKW) and Grain yield (Table 2). The highest and the lowest Ascochyta blight disease severity (40.12 % and 12.96 %) were recorded from a plot without fungicide spray and from a plot sprayed at every 7 days interval, respectively (Table 1).

Table 1: Effect of Fungicide application on Ascochyta blight Disease Severity (%), AUDPC (%-days), Disease Progress Rate (r) (units day⁻¹) and Percent Diseases Severity Reduction (%)

Treatment	AsDS (%)	AUDPC	Disease progress rate (r)	Percent Disease Severity Reduction (%)
At 7DI	12.96	434.25	-0.007652	67.70
At 14DI	29.01	1017.59	0.017915	27.69
At 21DI	33.95	1186.11	0.023528	15.38
No spray	40.12	1432.41	0.036771	-
CV (%)	8.80	9.74	34.94	
LSD _($p \leq 0.05$)	3.07	119.41	0.0074	

Note: DI= Days Interval of Spray; LSD=Least Significant Difference; CV=Coefficient of Variation

Similarly, the highest AUDPC (1432.41 %-days) and the lowest (434.25%-days) were recorded from non sprayed plot and plot sprayed at 7 days interval, respectively.

This result has supported with a finding of [12], when they found the highest AUDPC from control plot and the lowest from fully controlled plot. In the same way, the highest Disease progress rate ($0.036771 \text{ units-day}^{-1}$) and the lowest Disease progress rate ($-0.007652 \text{ units-day}^{-1}$) were recorded from non sprayed plot and plot sprayed at 7 days interval, respectively.

The highest and the lowest percentage of disease severity reduction were recorded from non treated plot and plot treated with fungicide at every 7 days interval, respectively. In general, the disease severity, AUDPC and the disease progress rate have shown a linearly increasing trend as the spray interval is increasing (Table 1 and Figure 1 A and B). This finding is supported by different studies in which fungicide spray have radically reduced Ascochyta blight disease severity [13,12].

The highest Ascochyta blight disease percent severity reduction of 67.70 % was obtained from plot received a fungicide application at a weekly interval; while the lowest Ascochyta blight disease severity reduction of 15.38% was recorded from a plot treated with a fungicide at 21 days interval.

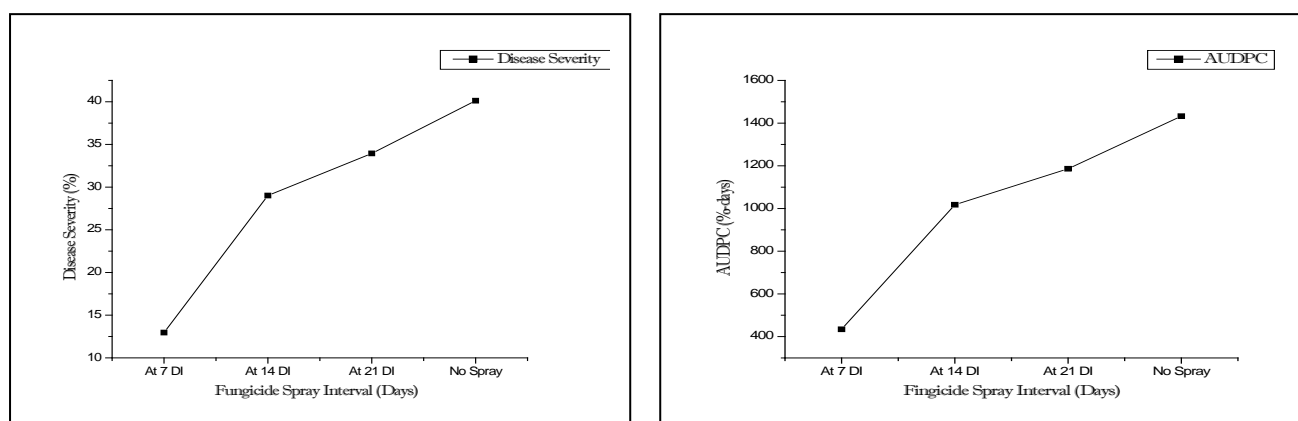


Figure 1: Influence of fungicide spray interval on Ascochyta blight disease severity (%) (A) and Area Under Disease Progress Curve (AUDPC) (B) at Sinana On-station

And a plot with a fungicide treatment at 14 days interval has reduced Ascochyta blight disease severity by 27.69% (Table 1).

This result has confirmed the result of [14]; as he found four sprays of Karathane (0.1%) at weekly interval gave effective control of the disease and highly reduced the disease severity. Similarly our result agrees with the finding of [13], they found that the highest disease severity reduction from fully controlled plot while the lowest disease severity reduction was from a plot with no fungicide spray.

Table 2: Field pea Grain Yield and Yield Components as influenced by the fungicide treatment against Ascochyta blight

Treatment	No. of Pod/plant	No. of Seed/plant	TKW (gm)	Grain yield (kg/ha)
At 7DI	21.75	89.50	195.81	2945.6
At 14DI	19.16	80.01	187.87	2511.7
At 21DI	17.89	75.33	183.07	2049.4
No spray	14.87	57.02	175.23	1873.5
CV (%)	14.98	27.30	5.22	10.91
LSD ($P<0.05$)	3.32	24.81	11.65	308.03

Note: TKW-Thousand Kernel Weight.

With regard to yield related traits, the maximum number of pods per plant (21.75) was recorded from a plot treated with a fungicide spray of at 7 days interval while the lowest (14.87) was from a plot with no fungicide spray. This result is exactly in agreement with [12] result when they found the highest number of pods/plant from treated plot while the least number of pods/plant was recorded from negative control/untreated plot. In case of seeds per plant, the maximum number (89.5) was recorded from a plot sprayed at 7 days interval and the lowest (57.02) was obtained from a plot with no fungicide treatment. Similarly ANOVA for TKW and grain yield have shown statistically significant ($p \leq 0.05$) variations between treatments. The Maximum TKW (195.81g) was recorded from plot which has received a fungicide treatment at 7 days interval where as the smallest TKW of 175.23g was recorded from unsprayed plot. With regard to grain yield, the maximum grain yield (2945.6 kg/ha) was obtained from a plot which has received a fungicide spray at 7 days interval where as the smallest grain yield of 1873.5 kg/ha was recorded from a plot with no fungicide spray (Table 2). This result is supported by [15] finding; they found the maximum grain yield from a plot where the disease was fully controlled and the minimum yield was from a plot with no treatment for the disease.

3.1. Yield loss estimation

Losses in grain yield and yield related traits as a function of Ascochyta blight disease infection was assessed from fungicide treated and untreated plots aside. The highest loss in number of pods per plant (14.53 %) was recorded from a plot with no fungicide spray while the lowest loss (5.47 %) was from a plot treated with a fungicide at 14 days interval. This result is similar with [16] findings where they found the losses in pod number/plant from 100% infected crop were estimated to 21-31%. Similarly, the highest loss in number of seeds per plant (8.56 %) was from no fungicide treated plot while the lowest (2.5 %) was from a plot treated with a fungicide at 14 days interval. In the same manner, the maximum loss in grain yield (25.93 %) was recorded from a plot without any fungicide treatment; while the lowest loss of 10.49 % was recorded from a plot received a fungicide treatment at every 14 days interval; where loss of 21.67 % was recorded from a plot treated with a fungicide at an interval of 21 day (Table 3). The result from this study supports the finding of different scholars; it was reported that the disease can cause 25–50 % yield losses, through reducing total biomass yield, number of pods per plant, number of seeds per pod, plant height and number of fertile nodes and the disease also found to

affect green pea quality [17,16,13,18], which is in agreement with the result of this study. A finding from [19] also supports our result, he found that from a heavily infested plot with the disease and with no any treatment; the pathogen has caused up to 50% yield losses and reduced pod quality significantly.

Table 3: Percent (%) losses in grain yield and yield related traits of field pea as a function of Ascochyta blight disease infection

Treatment	No. of Pod/plant	No. of Seed/plant	TKW (gm)	Grain yield (kg/ha)
At 7DI	-	-	-	-
At 14DI	5.47	2.50	1.63	10.49
At 21DI	8.15	3.73	2.62	21.67
No spray	14.53	8.56	4.23	25.93

Note- 7DI- sprays at seven days interval; 14DI- sprays at fourteen days interval and 21DI- sprays at twenty one days interval;

Simple linear regression model was employed to assess the relationship between Ascochyta blight disease severity with number of pods per plant, number of seeds per plant, TKW (Thousand kernel weight) and grain yield. The simple linear regression depicted that the relationship of Ascochyta blight disease severity with number of pods per plant ($P < 0.001$), number of seeds per plant ($P < 0.025$), TKW ($P < 0.001$) and grain yield ($P < 0.0001$) have revealed significant difference between treatments. The estimated slope of the regression line obtained for Ascochyta blight disease severity was -39.08 which implies that for each unit increase in percent severity of Ascochyta blight disease, there was a Field pea grain yield loss of 39.08 kg/ha and in similar fashion the relationship between disease severity and the other yield related parameters were calculated (Figure 2 A, B, C & D). Based on the coefficient of determination (R^2) value calculated, the equation explained that about 71.23 % of loss in the field pea grain yield was occurred due to Ascochyta blight disease and the F-statistics calculated have shown a strongly very high significance ($P < 0.0001$) of the over all probability of the equation (Figure 2 A, B, C & D). Similarly, pair wise Pearson correlation analysis was employed to assess the relationship between disease parameters and yield and yield related traits. Ascochyta blight disease severity have significant negative correlation with number of pods per plant ($r = -0.67776$, $P \leq 0.0001$). Number of seeds per plant and TKW (g) have significant negative correlation with Ascochyta blight disease severity ($r = -0.48562$, $P \leq 0.001$; $r = -0.63482$, $P \leq 0.0001$), respectively. Likewise, Ascochyta blight disease severity was found to be negatively strongly significantly correlated with field pea grain yield ($r = -0.84400$, $P \leq 0.0001$, respectively) (Table 4). On the same way, AUDPC have significant very strong positive correlation with Ascochyta blight disease severity and disease progress rate ($r = 0.99872$, $P < 0.001$; $r = 0.97901$, $P \leq 0.0001$), respectively. Similarly, significant negative correlations were found ($r = -0.68281$, $P \leq 0.0001$; $r = -0.47527$, $P \leq 0.001$; $r = -0.62944$, $P \leq 0.0001$) between AUDPC and number of pods per plant, number of seeds per plant and TKW (g), respectively. AUDPC has strong negatively significant correlation ($r = -0.83841$, $P < 0.0001$) with grain yield. Disease progress rate (r) have significant negative correlation with number of pods per plant ($r = -0.66069$, $P \leq 0.0001$) and TKW ($r = -0.61705$, $P \leq 0.0001$). Likewise, r have strongly significant negative correlation ($r = -0.79800$, $P \leq 0.0001$) with grain yield (Table 4). With regard to the association between grain yield and some yield related parameters;

grain yield have significantly strong positive correlation ($r = 0.70565$, $P \leq 0.0001$; $r = 0.51163$, $P \leq 0.001$) with number of pods per plant and seeds per plant, respectively. Similarly, grain yield have significant positive correlation ($r = 0.61770$, $P \leq 0.0001$) with Thousand Kernel Weight (TKW).

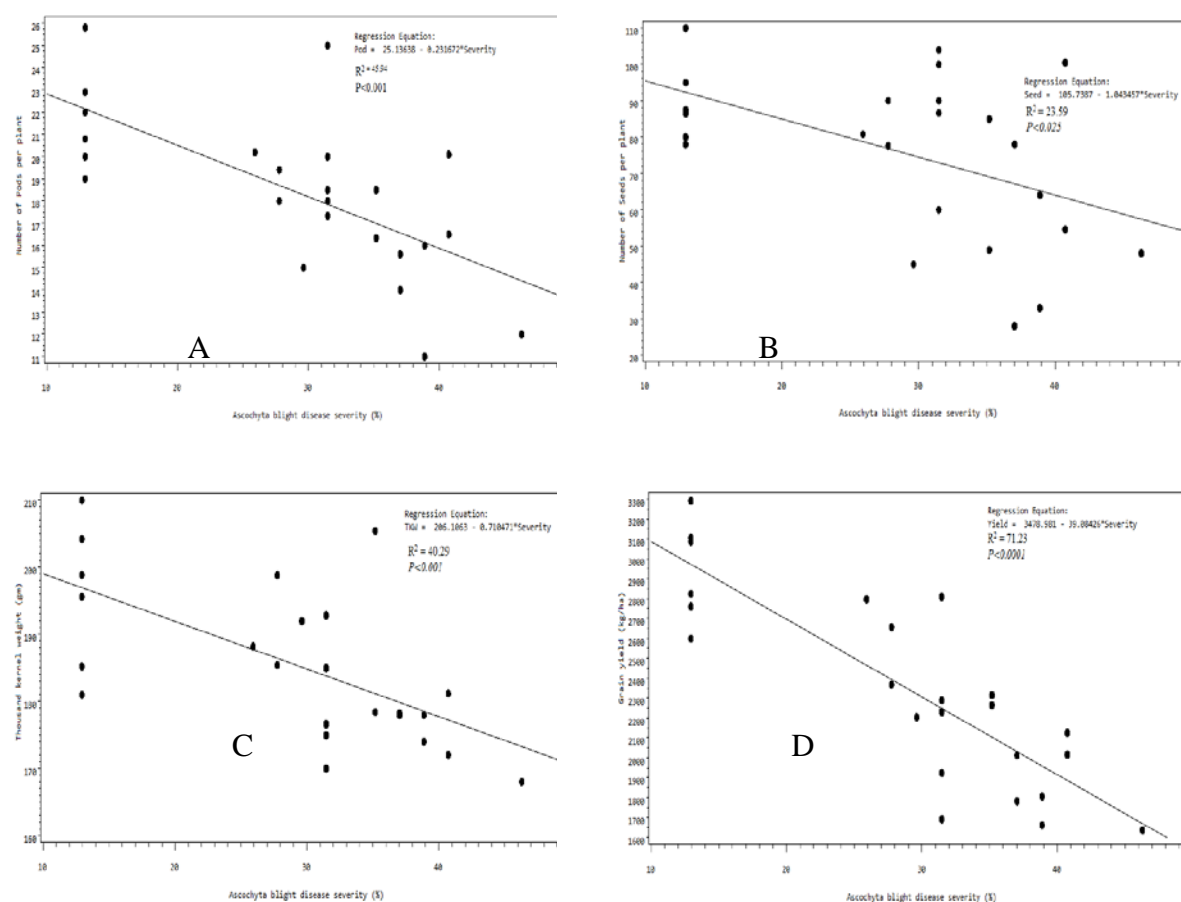


Figure 2: Estimated relationship between Ascochyta blight disease severity and losses in Field pea number pods per plant (A), number of seeds per plant (B), TKW (C) and grain yield (D) at Sinana

Table 4: Pair wise Pearson correlation coefficient among disease parameters, yield and yield related traits of Field pea

	AsDS	r	AUDPC	#pod/plant	#Seed/plant	TKW (gm)	G.yield kg/ha
AsDS							
r	0.97151***						
AUDPC	0.99872**	0.97901***					
pod/plant	-0.67776***	-0.66069***	-0.68281***				
Seed/plant	-0.48562**	-0.40659*	-0.47527**	0.72195***			
TKW (gm)	-0.63482***	-0.61705***	-0.62944***	0.27480 ^{NS}	0.16206 ^{NS}		
G.yield kg/ha	-0.84400***	-0.79800***	-0.83841***	0.70565***	0.51163***	0.61770***	

Note: AsDS-Ascochyta blight Disease Severity, r-Disease Progress Rate, and AUDPC-Area Under Disease Progress Curve (%-days)

4. Conclusion and Recommendation

Field pea is the major pulse crop grown in the highlands of Bale next to Faba bean. However, some diseases like Ascochyta blight (*Mycosphaerella pinodes*) and Powdery mildew (*Erysiphe pisi* var. *pisi*) have put its productivity under question in the highlands of Bale. This study will better contribute towards the management of field pea diseases, particularly of Ascochyta blight, which is the most important disease of field pea next to Powdery mildew in the highlands Bale, Ethiopia. The fungicide spray frequencies against this disease have made a statistically justifiable difference on field pea productivity. The highest grain yield of 2945.6 kg/ha was recorded from plot sprayed at 7 days interval; While the lowest grain yield (1873.5 kg/ha) was recorded from a plot with no fungicide spray. Whereas the highest and the lowest grains yield loss of 25.93 % and 10.49 %, respectively were recorded from plot without fungicide spray and a plot sprayed with a fungicide at 7 days interval. Therefore, for the management of Field pea Ascochyta blight disease, from the result of the current study; based on disease pressure and the prevailing environmental condition 2-3 times spray of a fungicide Benomyl at a rate of 2.5 kg/ha at 7-10 days interval is recommended.

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