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Comparative Study of Powdery Mildew (*Erysiphe polygoni*) Disease Severity and Its Effect on Yield and Yield Components of Field Pea (*Pisum sativum* L.) in the Southeastern Oromia, Ethiopia

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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 major pulse crop 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 find out the effect of Powdery mildew disease on field pea yield and yield components. Local field pea cultivar was used with a fungicide Benomyl at a rate of 2.5 kg/ha and four fungicide application schemes (spraying every 7 days, 14 days, 21 days and no fungicide spray) arranged in randomized complete block design (RCBD) with 3 replications. Logistic model (ln [y/ (1-y)]) was employed to analyze the Field experiment data using SAS procedure. The association between disease parameters and yield and yield components were assessed using regression and correlation techniques. ANOVA has shown significant difference ($p \le 0.05$) among treatments for disease severity. The highest diseases severity (41.98%) and Area Under Disease Progress Curve (AUDPC) (1458.33% days) and the lowest disease severity (13.89%) and AUDPC (471.15% days) were recorded from a plot with no fungicide treatment and plot sprayed every 7 days, respectively. Similarly, the highest disease progress rate (r) (0.044227 units-day^{-1}) and the lowest r (-0.006122 units-day^{-1}) were recorded from a plot with no fungicide treatment and plot sprayed every 7 days, respectively. Regarding the yield and yield related parameters; ANOVA has shown significant variations ($P \le 0.05$) between treatments for number of pods per plant, seeds per plant, TKW and grain yield. The highest number of pod per plant (21.75), seed per plant (89.5), TKW (189.81 g) and grain yield (2945.6 kg/ha) were recorded from plots sprayed every 7 days; while the lowest were from non-sprayed plots. On the other hand, the higher grain yield loss of 21.09% and the lowest loss (8.53%) were recorded from plots without fungicide spray and plot received spray at 7 days interval, respectively. The linear regression between powdery mildew severity index and grain yield revealed significant difference ($P \le 0.0001$) between treatments; and the estimated slope of the regression line obtained for Powdery mildew severity index was -34.16. Correlation analysis has shown that Powdery mildew disease severity have significantly strong negative correlation with grain yield ($r = -0.76120$, $P \le 0.01$). Similarly, grain yield has significant strong negative correlation ($r = -0.76298$, $P \le 0.0001$) with AUDPC.

Keywords: Field pea; Yield loss; Powdery mildew; Disease progress rate (r) and disease severity index

Introduction

Field pea or "dry pea" (*Pisum sativum* L.) is an annual cool-season food legume that grows worldwide [1]. In Ethiopia, it is among the major food legume crops produced ranking third in terms of area of production and yield next to Faba bean and chick pea [2]. It is important crop in providing quality vegetable protein in the diets of Ethiopians [3]. 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 Bale and Arsi, Ethiopia. In Ethiopia, the area of field pea production and yield per unit area is increasing from time to time, according to Central Statistical Authority of Ethiopia [4], in 2009/2010, out of 1,489,308 ha of land covered by pulses the area occupied by field pea was 226,533 ha and the annual production was estimated at about 235,872.10t with the average annual productivity of 1.041 t/ha. 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. Field pea, despite its importance, is very low in productivity which is far below its potential. This low productivity is mainly attributed to several yields limiting factors; among which, the inherent low yielding potential of the indigenous cultivars [5], diseases like Powdery mildew (*Erysiphe Polygoni*) and Ascochyta blight (*Mycosphaerella pinodes)* and some insect, pests are the major production constraints [5]. Powdery mildew caused by the obligate biotrophic fungus *Erysiphe polygoni* DC is an air-borne disease of worldwide distribution, being particularly important in climates with warm dry days and cool nights [6]. Even though it is severely damaging, the level of loss on field pea due to this disease is not known in Bale area. Therefore, this trial was initiated with the objective of quantifying the magnitude of loss caused by Powdery mildew on yield and yield components of Field pea.

Materials and Methods

Description of experimental site

The experiment was conducted for two years; in 2011/12 and 2012/13 at Sinana Agricultural Research Center (SARC) research site. The location represents the major Field pea production area of Bale highlands and is a hot spot for the development of Powdery mildew. The area is characterized by bimodal rain-fall pattern where the first rainy season occurs from March to June called "Ganna" (short season) and the second is from August to December which is called "Bona" (main

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season), the two seasons are locally termed in line with the time of crop harvest. SARC is situated at 07° 07' N latitude and 40° 10'E longitude with an elevation of 2400 m.a.s.l. The area receives 750 mm to 1000 mm high mean annual rain fall and have mean annual temperature of 9°C to 21°C. The area is dominantly characterized by a soil type which have a pellic vertisol character and is slightly acidic.

Treatments and design

The experiment was arranged in three replications of RCB Design. Local field pea cultivar was evaluated on plot size of 2 m × 1.2 m with between row, plot and replication spacing of 0.2 m, 1 m and 1.5 m, respectively. Powdery mildew disease development was initiated through natural infection and the disease 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 was included for treatment comparison. A Fungicide was applied using knapsack sprayer with spray volume of 60.6 ml per 2.4 m^2 plot. Fungicide application was started immediately after the development of the first observable disease symptom. Seed rate, fertilizer rate, weeding and other all agronomic packages were done as per the recommendation for the crop. Disease scoring was conducted in a 1-9 disease scoring scale [7]. The disease data recorded based on scale mentioned above was converted to percentage severity index (PSI) according to Wheeler [8]:

$$PSI = \frac{\text{Sum of Numerical Ratings X100}}{\text{Number of Plants Scored X Maximum Score on Scale}}$$

Data management and statistical analysis

Variables for 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 disease progress rate in different treatments. AUDPC values were calculated for each treatment using the standard formula [9]. ANOVA was performed for disease severity index, AUDPC [9], and rate of disease progress (r) according to SAS procedure. LSD technique at the 5% probability level was used for treatments mean separation. Logistic model, [ln [(Y/1-Y)], (Vander Plank, [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.

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

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 Powdery mildew disease severity with grain yield was analyzed using linear regression analysis by plotting yield data against Diseases severity. Correlation between grain yield and yield related parameters with the disease parameters (AUDPC, Powdery mildew disease severity and r (disease progress rare)) were assessed and correlation coefficient values were computed to establish their relationships.

Yield loss estimation

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

Y1 = mean grain yield on the protected plots (plots with maximum protection)

Y2 = mean grain yield on unprotected plots (i.e. unsprayed plots or sprayed plots with varying level of disease).

Results and Discussions

The combined analysis of variance over years has shown that there was statistically significant difference ($p \leq 0.05$) between treatments for parameters such as Powdery mildew disease severity, AUDPC, Disease Progress Rate (r), Number of pods per plant, Number of seeds per plant, Thousand Kernel Weight (TKW) and Grain yield (Table 1). In contrast, for the parameters such as Plant height and Total biomass the difference was not statistically significant ($p \leq 0.05$). The highest Powdery mildew disease severity (41.98%) was recorded from a plot without fungicide treatment, while lowest disease severity of 13.89% was recorded from plot sprayed at 7 days interval (Table 1 and Figure 1). In general, both the disease severity and AUDPC has shown a linearly increasing trend as the spray interval is increasing (Table 1 and Figure 1). This finding is supported by different studies that fungicides have dramatically reduced Powdery mildew disease severity [12,13].

Similarly, the highest AUDPC of 1458.33% day was calculated from a plot with no fungicide treatment; while the lowest AUDPC (471.15% day) was calculated from a plot with a fungicide treatment at every 7 days. This result has supported with a finding of [13], when they found the highest AUDPC from control plot and the lowest from fully

Treatment	PmDS (%)	AUDPC (% days)	Disease Progress Rate (r)	Diseases Severity Reduction (%)
@ 7DI	13.89	471.15	-0.006122	66.91
@ 14DI	28.40	985.19	0.013149	32.35
@ 21DI	34.88	1205.55	0.020656	16.91
No spray	41.98	1458.33	0.044227	-
CV (%)	3.35	122.88	0.0082	
$LSD_{(p \leq 0.05)}$	9.35	9.90	37.96	

Note: DI=Days Interval of Spray; LSD=Least Significant Difference; CV=Coefficient of Variation; PmDS=Powdery Mildew Disease Severity

Table 1: Effect of Fungicide application on powdery mildew disease severity (%), AUDPC (%-days), disease progress rate (r) and percent disease severity reduction (%).

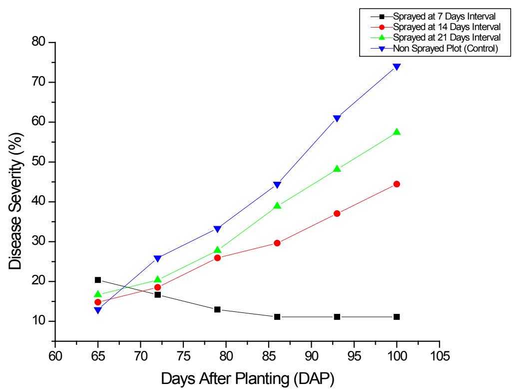

Figure 1: Influence of fungicide spray on powdery mildew disease severity (%).

controlled plot. Whereas, Disease progress rate (r) of -0.006122 units day^{-1}, 0.013149 units day^{-1}, 0.020656 units day^{-1} and 0.044227 units day^{-1} were calculated from plots sprayed every 7, 14, 21 days and No fungicide spray, respectively.

The highest percent disease severity reduction of 66.91% was obtained from plot received a fungicide application at a weekly interval; whereas, the lowest powdery mildew disease severity reduction (16.91%) was recorded from a plot treated with a fungicide at 21 days interval. This result supported the result of [14] that four sprays of Karathane (0.1%) at weekly interval gave effective control of powdery mildew. And the plot with a fungicide treatment at 14 days interval has reduced the powdery mildew disease severity by 32.25% (Table 1). Similarly, this result agrees with [12], they found that the highest disease severity reduction from fully controlled plot while the lowest disease reduction was from a plot with no fungicide spray.

With regard to yield related traits, the maximum number of pods per plant (21.75) was recorded from the plot with fungicide sprays at 7 days interval while the lowest (14.88) was from the plot with no fungicide spray.

This result is exactly in agreement with [13] result when they found the highest number of pods/plant from treated plot while the least number of pods/plant was recorded from Control plot. In case of seeds per plant, the maximum number (89.5) was recorded from the plot sprayed a 7 days interval and the lowest (57.23) was obtained from a plot with no fungicide treatment. The current result is supported by the finding of different scholars; the disease have the potential to reduce total yield biomass, number of pods per plant, number of seeds per pod, plant height and number of nodes [15]. Similarly, ANOVA for TKW and grain yield has shown statistically significant ($p \leq 0.05$) variations between treatments. The Maximum TKW (189.81 g) was recorded from plot which has received a fungicide treatment at 7 days interval where the smallest TKW of 175.23 g 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 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 Shah et al. [16]. They found the maximum grain yield from a plot where the Powdery mildew was fully controlled and the minimum yield was from a plot with no treatment for the disease. Similarly, it was reported that the disease can cause 25% to 50% yield losses, reducing total yield biomass, number of pods per plant, number of seeds per pod, plant height and number of nodes and the disease also affects green pea quality [17].

Yield loss estimation

Losses in yield and yield related traits as a function of Powdery mildew disease infection was assessed as a comparison of the control

Treatment	#Pod/plant	#Seed/plant	Plant height (cm)	TKW (gm)	Grain yield (kg/ha)
7DI	21.75	89.50	121.86	189.81	2945.6
@ 14DI	19.16	80.01	118.53	187.87	2511.7
@ 21DI	17.89	75.33	116.01	183.07	2049.4
No spray	14.88	57.02	114.22	175.23	1873.5
$LSD_{(p<0.05)}$	3.32	24.81	NS	11.65	303.03
CV (%)	14.98	27.30	20.99	5.27	10.91

Note: DI=Days Interval of Spray; LSD=Least Significant Difference; CV=Coefficient of Variation; PmDS=Powdery Mildew Disease Severity

Table 2: Field pea yield and yield components as influenced by fungicide treatment against powdery mildew.

Treatment	#Pod/plant (%)	#Seed/plant (%)	Plant height (%)	TKW (%)	Grain yield (%)
7DI	-	-	-	-	-
14DI	11.91	10.60	2.73	1.02	8.53
21DI	17.75	15.83	4.80	3.55	17.61
No spray	31.59	36.29	6.27	7.68	21.09

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

Table 3: Percent (%) losses in yield and yield related traits of field pea as a function of powdery mildew disease infection.

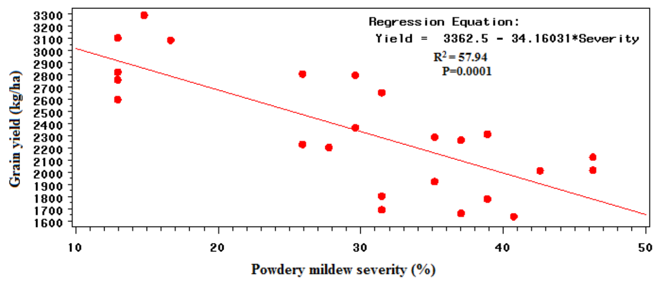

Figure 2: Estimated relationship between powdery mildew severity index and field pea grain yield loss at Sinana.

(Unsprayed) plot and the plot sprayed at 7 days interval. The plot sprayed at 7 days interval is considered as fully controlled plot and losses in yield and yield components is calculated based on this treatment. The highest loss in number of pod per plant (31.59%) was recorded from plot with no fungicide spray while the lowest loss (11.91%) was from plots treated with fungicides at 7 days interval. This result is similar with [18] findings who have recorded the losses in number of pods/plant from 100% infected crops were estimated to about 21% to 31%. Similarly, the highest loss in number of seeds per plant (36.29%) was from a plot without fungicide treatment; while the lowest (10.60%) was from plot treated with a fungicide at 14 days interval. In the same manner, the maximum loss in grain yield (21.09%) was obtained from plots without any fungicide treatment while the lowest loss of 8.53% was recorded from plot received a fungicide treatment at every 14 days interval; where loss of 17.61% was recorded from plot treated with a fungicide at an interval of 21 days (Table 3).

The result from this study supports the finding from different experiments; the disease can cause 25% to 50% yield losses [12,18-20], A finding from (Dixon, [20]) also supports our result, he found from his study that from a heavily infested plot with powdery mildew disease and with no any treatment; the pathogen has caused up to 50% yield losses and reduced pod quality significantly.

Simple linear regression model was employed to assess the relationship between Powdery mildew severity at a weekly interval as predictor variable and yield as a dependent variable. The linear regression between powdery mildew severity index and grain yield revealed there was significant difference ($P \leq 0.0001$) between treatments. The estimated slope of the regression line obtained for Powdery mildew severity index was -34.16. The estimate showed that for each unit increase in percent severity index of Powdery mildew, there was a Field pea grain yield loss of 34.16 kg/ha (Figure 2). Based on coefficient of determination (R^2) value, the equations explained about 57.94% of losses in grain yield was occurred due to Powdery mildew severity. F-statistics calculated showed very highly significance ($P \leq 0.0001$) of the over-all probability of the equation (Figure 2).

Similarly, pair wise Pearson correlation analysis was employed

	PMDS	AUDPC	r	#Pod/plant	#Seed/plant	Plant height	BMS (kg)	TKW (gm)	G. yield kg/ha
PMDS									
AUDPC	0.99776***								
r	0.91023***	0.90333***							
pod/plant	-0.58854**	-0.57610**	-0.66069***						
Seed/plant	-0.43624*	-0.44545*	-0.40659*	0.72195***					
Plant height	-0.26985NS	-0.25347NS	-0.14546NS	-0.12064NS	-0.23672NS				
BMS (kg)	-0.24653NS	-0.25570NS	-0.39367NS	0.47339*	0.46309*	-0.76925***			
TKW (gm)	-0.56522**	-0.55550**	-0.61705**	0.27480NS	0.16206NS	0.02598NS	0.34566NS		
G. yield kg/ha	-0.76120***	-0.76298***	-0.79800***	0.70565***	0.51163*	-0.33647NS	0.73066***	0.61770**	

Note: PMDS- Powdery Mildew Disease Severity (%), AUDPC- Area Under Disease Progress Curve (%-days), r-Disease Progress Rate, #pod/plant-number of pod per plant, #Seed/plant-Number of Seed per Plant, BMS-Biomass Yield, TKW-Thousand Kernel Weight and G. yield -Grain yield

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

to assess the relationship of disease parameters with yield and yield components. Powdery mildew disease severity has significant negative correlation with number of pods per plant (r= -0.58854, P ≤ 0.1). Similarly, number of seeds per plant and TKW (g) have significant negative correlation (r= -0.43624, P ≤ 0.05; r= -0.56522, P ≤ 0.01), respectively with powdery mildew disease severity. Likewise, Powdery mildew disease severity was found to be significantly strongly negatively correlated with field pea grain yield (r= -0.76120, P ≤ 0.01) (Table 4). On the same way, AUDPC have significant very strong positive correlation with Powdery mildew severity and disease progress rate (r) (r=0.99776, P<0.0001; r=0.91023, P<0.0001). Significant negative correlation was also found (r= -0.57610, P ≤ 0.01; r= -0.44545, P ≤ 0.05; and r= -0.55550, P ≤ 0.01) between AUDPC and number of pods per plant, number of seeds per plant and TKW (g), respectively. AUDPC have strong negative correlation (r= -0.76298, P ≤ 0.0001) with grain yield. Disease progress rate (r) has significant negative correlation with number of pods per plant (r= -0.66069, P ≤ 0.0001) and TKW (r= -0.61705, P ≤ 0.001) and have strongly significant positive correlation (r=0.91023, P ≤ 0.0001; r= 0.90333, P ≤ 0.0001) with Powdery mildew diseases severity and AUDPC. Likewise, disease progress rate (r) has strongly significant negative correlation (r= -0.76298, P ≤ 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 ≤ 0.0001; r=0.73066, P ≤ 0.0001) with number of pods per plant and Biomass yield, respectively. Similarly, grain yield has significant positive correlation (r=0.51163, P ≤ 0.001; r=0.61770, P ≤ 0.001) with number of seeds per pod and thousand kernel weight (TKW), respectively.

Conclusion

Field pea is the major pulse crop grown in the highlands of Bale next to Faba bean. However, some diseases like Powdery mildew (*Erysiphe polygoni*) and Ascochyta blight (*Mycosphaerella pinodes)* have put its productivity under question. This study will better contribute towards the management of field pea diseases, particularly of Powdery mildew, which is most important disease of field pea at highlands Bale, Ethiopia. The fungicide spray frequency has made a statistically significant difference on field pea productivity. The highest grain yield of 2945.6 kg/ha was recorded from plot sprayed at 7 days interval. Whereas the highest grains yield loss of 21.09% was recorded from plot without fungicide treatment. Therefore, for the management of field pea Powdery mildew disease, 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 within 7-10 days interval after the disease development is recommended from the result of the current study.

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