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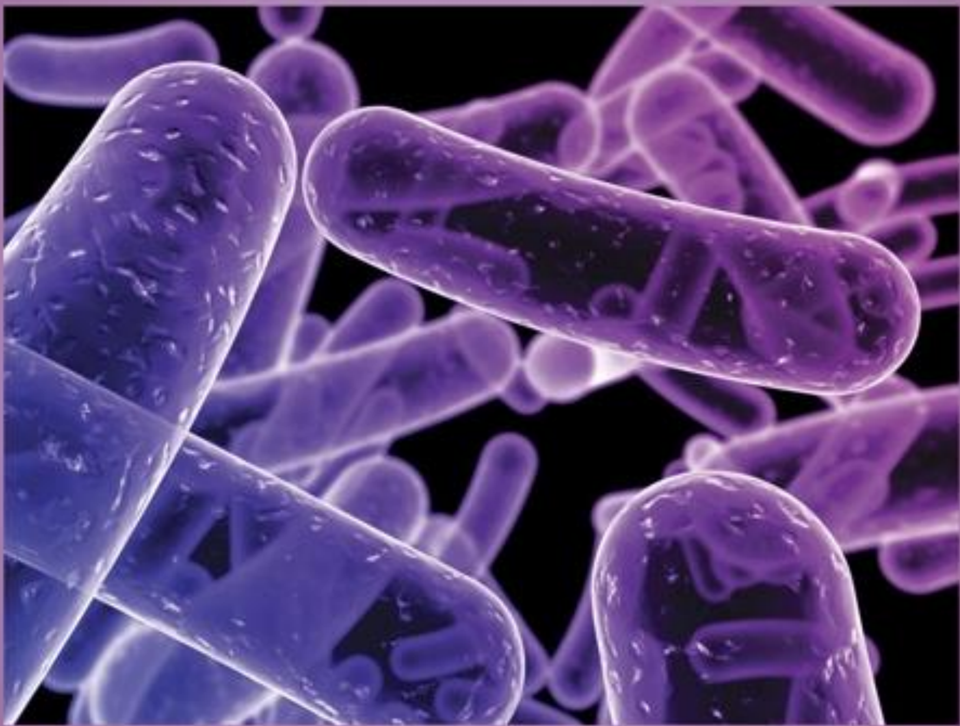

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Field Evaluation of Fungicides and Host Plant Resistance Against Spot Form of Net Blotch (*Pyrenophora Teres F. Maculata*) Disease of Barley in South Tigray, Ethiopia

Ftaneges Alem Teferi [1] and Kiros Meles Ayimut[2]

[1]Tigray Agricultural Research Institute, Alamata Agricultural Research Center, Alamata, Ethiopia.
[2]Department of Crop and Horticultural Science, Mekelle University, Mekelle, Ethiopia.
*E.Mail: fthaneges28@gmail.com

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ABSTRACT

Spot form net blotch (SFNB) disease has been seriously limiting barley production in Tigray. As a result, there is a need to enhance barley production through the development of management options that can be effectively used in combating the SFNB problem. This research was conducted to evaluate the effect of Thiram and propiconazole on the severity of SFNB of barley. The experiment was conducted using a split-plot design with three replications. The cultivars included: HB-1307, HB-42, Fetina, and saesea were used. The fungicides were thiram and propiconazole as main plots and varieties are the sup plots respectively. The data were subjected to ANOVA using GenStat version 2018 software. HB-42 was found resistant while saesea was susceptible. The highest area under the disease progress curve (AUDPC) was recorded in untreated saesea (1517.7). The minimum AUDPC of SFNB (536.9) was in HB-42 with the spray of fungicides. The highest yield was in Fetina with sprayed (4.02 ton/ha) and the lowest was untreated HB-42 (2.288 ton /ha). Fetina with a spray of Thiram and Propiconazole in comparison with the unsprayed offered 2383.42% of the marginal rate of return so Fetina with the spray of Thiram and Propiconazole is recommended for profitable production.

INTRODUCTION

Barley (*Hordeum vulgare* L.*)* is recognized as one of the most ancient food crops that have been first cultivated, along with wheat, peas, and lentils, with domestication centering in the Fertile Crescent about 10,000 years ago (Badr *et al*., 2000). Globally, barley ranks fourth among cereals after wheat, maize, and rice with a total area of 49.8 million hectares and 141.2 million Mt of production (FAOSTAT, 2018). The estimated area coverage of barley in the year 2017 in Ethiopia was 959,273.36 ha, with a total grain production of 202, 4921.676 tons, and 2.11 tons per hectare productivity. Morocco, Ethiopia, Algeria, Tunisia, and South Africa were the top five largest barley producers in Africa with an estimated production of approximately 2.1 million tons,1.7 million tons,1.3 million tons, 0.9 million tons, and 0.307 million tons, respectively (Central statistical agency, 2017).

Cereal production and marketing are the means of livelihood for millions of households in Ethiopia and is the single largest sub-sector within Ethiopia's agriculture, far exceeding all others in terms of its share in rural employment, agricultural land use, calorie intake, and contribution to national income (Shahidur, 2010). Ethiopia is the first-largest barley producer in Africa, accounting for about 2,024,922 tonnes of the total barley production in the continent (FAOSTAT, 2018). In Tigray, northern Ethiopia, the estimated area coverage, the total annual volume of grain production, and the productivity of barley per hectare were 95,462.96 ha, 1, 695, 72.54 Tons, and 1.78 ton/ha, respectively (Central statistical agency, 2017).

The low productivity of the crop is associated with multidimensional abiotic and biotic factors, among those diseases are the most important in barley (Yitbarek *et al*., 1996). Powdery mildew (*Blumeria graminis* f. sphordei), spot form of net blotch (SFNB) *(Pyrenophora teres* f. maculata), spot blotch (*Cochliobolus sativus*), and scald (*Rhynchosporium secalis*) pose a serious threat to sustainable barley production (El-Yousfi and Ezzahiri, 2002). Net blotch disease barely had a limited distribution before the year 1984 in Ethiopia (Eshetu, 1985) while a decade later the disease expanded to most parts of the highlands of the country, where barley is important, and reached an ever-endemic status (Yitbarek *et al*., 1996). The disease causes substantial yield loss ranging from 27% to 34% (Yitbarek and Wudneh, 1985, Bekele *et al*., 2001). Though the use of spot form net blotch-resistant barley varieties has been most successful in reducing the impact of the disease elsewhere in the country, none of the barley varieties cultivated in the Southern Zone of Tigray were resistant to the disease. Yield losses due to barley diseases are variable but spot form net blotch causes a substantial yield loss, 27% on average, and up to 34% when it is severe (Yitbarek and Wudneh, 1985). Yitbarek *et al*. (1996), reported that the disease expanded and reached an ever-endemic status in most parts of the highlands of the country, where barley is important. On the other hand, Bekele *et al.* (2001) reported due to net blotch farm average yield loss of 28-29%.

The use of resistant lines is an important part of an effective disease management program for a net form of net blotch disease (NFNB) Cultivars of barley currently used throughout the world vary significantly in their resistance to the pathogen, ranging from highly resistant to highly susceptible (Douiyssi *et al.,* 1998). Although resistance sources have been identified the level of resistance in popular varieties is still not sufficient to avoid losses in yield and quality of seed (Singah *et al.*, 2008). Fungicide applications are known to suppress net blotch infections by suppressing infection rates (Kavita *et al*., 2017). In South Tigray, the spot form net blotch was not quantified by the management options but an assessment was done in 2014. The assessment reached on the net blotch disease has been prevalent in barley fields in Enda -Mokoni woredas with about 73% prevalence rate (Teklay *et al*., 2014) and the distribution of net blotch reached 40%. Hence, an integrated approach combining the use of fungicide application and host plant resistance would help to improve barley production. Therefore, this study aimed to evaluate the combined use of host plant resistance and fungicide application on spot form net blotch disease development and yield of barley in the main rainy season at Enda-Mokoni, Tigray, Ethiopia.

MATERIALS AND METHODS

Description of the Study Area:

The experiment was conducted in the 2018 main cropping season (June-October) in the Enda-Mokoni district, Southern Tigray, Ethiopia (Figure 1). The district has experienced bimodal rainy supply year-round and they are known as the "*Kiremt*" and "*Belg*". The "Kiremt" is the main summer season, beginning mostly from the 2nd week of June to the last week of August. However, the 2nd season is the "*Belg*," and it is the short rainy season ranging from the 2nd week of February to March (Kidane *et al*., 2016). Enda Mokoni woreda is located 660 km north of Addis Ababa and about 120 km south of Tigray Regional state capital of Mekelle. The woreda is geographically located at 390 32'N latitude and 120 47'E longitudes. It is located south of the Tigray region, north of Ofla woreda, west of Raya Azebo woreda, east of Amhara region, and south of Alaje wereda. The altitude in the woreda ranges from 1800 to 3250 meters above sea level (m.a.s.l), but most of the woreda is found at about 2200 m.a.s.l and the mean annual temperature varies from 12^0c to 18.5^oc. The climate of the woreda is classified into three agro-climatological zones: High land representing 65%, midland (weynadega) 30%, and low land 5%. Enda-Mekhoni district has also similar dominant soil types Haplic leptosos 89%, haplic Vertisols 7%, and the rest soils are Haplic Cambisols, Haplic Cambisols (Eutric), Leptic Cambisols, Vertic Cambisols, Leptic Regosols, Calcic Vertisols and, Haplic Vertisols (Eutric). The average annual rainfall of the woreda ranges from 600 to 800mm (Central statistical agency, 2017). Mixed farming is dominantly practiced in the district, where the livelihood of the rural community depends both on livestock and crop farming system. The dominant livestock reared in the area is cattle, sheep, goats, and horses, in that order. Livestock production is a major component of the livelihood system and provides draught power, food, and income (Kidane *et al*., 2016). The main crops are grown in the district including barley (*Hordeum vulgare* L.*)*, wheat (*Triticum* spp.*)*, field pea (*Pisum sativum*), faba bean (*Vicia faba*), lentil, sorghum (*Sorghum bicolor*), and maize (*Zea mays*) (Kidane *et al*., 2016). Geographically, the research site is located at Mekan Tabia is found at an altitude of 2530m.a.s.l, with an average annual rainfall of 750mm and average minimum and maximum temperatures ranging from 10 °C to 20 °C, respectively (Central statistical agency, 2013).

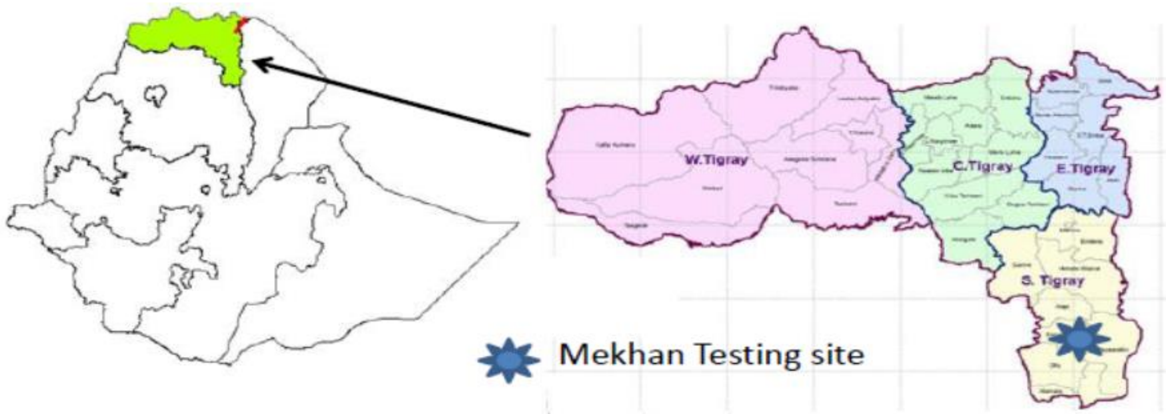

Fig. 1: Map of the study area where the field experiment was conducted.

Experimental Design and Treatments:

A split-plot design with three replications was used and the total treatment combinations were 16 (Table 1). DAP was used as standard fertilizer and applied in rows at a rate of 100 kg/ha at planting as recommended by Tigray Agricultural Research Institute and urea was side dressed at a rate of 100 kg/ha at early planting and plant growth stage (GS) of 40. Other agricultural practices such as weeding and chemical application were conducted as necessary. All plots, including the control, were sprayed once with dimethoate 40% EC at a rate of 1 liter per ha (1l/ha) at 80 days after planting for control of Eplachena smiles and other insects.

Table 1: Treatment setup and their combinations

Treatment number	Treatment combination
1	HB13-07
2	HB13-07 +Thiram
3	HB13-07+ Propiconazole
4	HB13-07+Thiram + Propiconazole
5	HB-42
6	HB-42+Thiram
7	HB-42+ Propiconazole
8	HB-42 + Thiram + Propiconazole
9	Fetina
10	Fetina + Thiram
11	Fetina + Propiconazole
12	Fetina + Thiram + Propiconazole
13	saesea
14	Saesea + Thiram
15	saesea + Propiconazole
16	Saesea + Thiram + Propiconazole

The four varieties of barley were as subplots and fungicides as main plots and the varieties were released by the Ethiopian Institute of agricultural research (EIAR) and Mekelle University, which were evaluated along with the susceptible check and resistant check for spot form net blotch at the experimental site (Table 2). The varieties tested include local (variety Saesea, a susceptible check) and improved types (HB13-07, HB-42 (Resistant check), and Fetina). The fungicides used were Thiram, as pre-seed treatment at a rate of 2.5g/kg of barley grain, and Propiconazole as a foliar spray at a recommended rate of 0.5 l/ha **(**Table 3**).** Thiram was applied as seed treatment before planting the seed and Propiconazole was applied naturally in the field after planting the barley and Propiconazole was applied twice, first when 10% of the plants showed disease symptoms and second at the booting stage of the crop (Table 3). Fungicides and varieties were assigned as main plots and sub-plots respectively. There were 8 rows per plot and the plot size was 1.6m x 3m. The spacing was 1.5 m, 1 m, and 0.2m between the block, plot, and row, respectively. The total area becomes (26.7*15) m^2.

Table 2: varieties with released institutions.

S. N	Varieties	Released by	Maturity days	Yield potential q/ha	Altitude	Rainfall	Year of release
1.	Saesea (SC)	farmers	-	-	-	-	-
2.	HB-42(RC)	EIAR	145	3.0	NA (not available)	800-1400	1985
3.	Fetina	Mekelle university	133	4.50	2000-3500	700-1200	2012
4.	HB-1307	EIAR	137	4.78	2000-3000	700 – 1000	2006

Table 3: Fungicides with their information.

S. N	Fungicides		Type of application	Approved Uses	Rate
	Common name	Trade Name			
1	Propiconazole	Tilt 5% EC*	Foliar application	For the control of fungus spp. On teff wheat and barley.	0.5l/ha
2	thiram 80%	WP Thiram Granuflo 80 WP*	Seed treatment	For the control of seed decay and damping-off disease; on maize and sorghum and other crops	2.5g/kg

Field Evaluation of Varieties against SFNB Disease of Barley:

Disease incidence and severity were recorded from the assessment of 10 pre-tagged plants in the middle 6 rows of each plot (to avoid border effects). Disease incidence was recorded every 10 days starting from the first 10% disease appearance by taking the percentage of plants showing symptoms of net blotch and spot blotch. Four assessments were done during the experiment and disease severity was recorded by estimating the percentage of leaf area and disease incidence was estimated as the number of infected plants expressed in percentages and also, the severity was recorded on a scale of 0 – 9, corresponding to free of disease (0: no visible infection on leaves) to highly susceptible (9: all barley leaves dry due to infection by the diseases). (Couture, 1980; Mathre,1982).

Data on days to heading and maturity, plant height, grain yield, thousand seed weight (g), percent incidence, severity, and AUDPC (area under disease progress curve) were collected. Yield losses were estimated and Partial budget analysis was computed. The average percentage severity index (PSI) for each field was calculated (Couture L, 1980).

$$\text{PSI (\%)} = \frac{\sum(\text{disease grade x number of plants in each grade})}{(\text{total number of plants x highest disease grade})} \text{x}100 \text{ ------------------------- (eq. 1)}$$

The area under the disease progress curve (AUDPC) was used to quantify disease intensity over time according to the trapezoidal method, as described by (Wilcoxson et al., 1975) and (Madden et al., 2007). using the following function; it is expressed in % days (i.e., the accumulation of daily percent infection values).

$$\text{AUDPC} = \sum_{i=1}^{n} [0.5(x_{i+1} + x_i)] [t_{i+1} - t_i] \text{ --- (eq. 2)}$$

Where x_i is the cumulative disease severity expressed as a proportion at the i^{th} observation, t_i is the time (days after planting) at the i^{th} observation, and n is a total number of observations.

Yield Loss Estimation*:*

The relative losses in yield of each treatment were determined as the percentage of that of the protected plots of the experiment according to CIMMYT (1988):

$$\text{RL (\%)} = \frac{(\text{YP}-\text{YT})}{(\text{YP})} x100 \quad \text{..........................eq.3}$$

Where, RL: Relative Loss (reduction of the yield parameter), YP: Mean Yield of the Protected Plots (plots with maximum protection - from fungicide sprayed at weekly intervals), and YT: Mean Yield in Unprotected Plots (i.e. unsprayed plots or sprayed plots with varying level of disease).

Partial Budget Analysis:

Before doing the economic analysis (partial budget), statistical analysis was done on the collected data to compare the average yields between treatments. Where there is a difference between treatment means, the obtained economic data were subjected to analysis using the partial budget analysis method of CIMMYT (1988). Economic analysis would be done using the prevailing market prices for inputs at planting and outputs (yield) when the crop was harvested. All costs and benefits were calculated on a per-hectare basis in Ethiopian Birr (ETB ha^{-1}). The price of barley seed was determined from the local market and the price of the fungicides from the supplier.

The following concepts were used in the partial budget analysis (PBA):

combined mean grain yield is the average yield (kg ha^{-1}) of each treatment, the sale revenue (SR) ha^{-1} is the product of the market price of barely and the adjusted mean yield (research yield*0.9, to represent the yield under farm/farmers condition) for each treatment, The marginal cost (MC) of fungicides is the product of the quantity required by each treatment ha^{-1} and the price of fungicides plus fungicides application (man-days x wage rate), and the net benefit/income (NI) is the difference between the sale revenue and marginal costs (SR – MC). To measure the increase in net return associated with each additional unit of cost (marginal cost), the marginal rate of return (MRR) will be calculated using the formula $MRR(\%) = \frac{\Delta NI}{\Delta IC} *100$, where, ΔNI is changed in net income compared with control, and ΔIC is changed in input cost compared with control.

Data Analysis:

The collected agronomic data (yield and yield components) and Disease parameters (disease severity, disease incidence, PSI, and AUDPC) were subjected to analysis of variance (ANOVA) using GenStat version 2018 software and the mean separation was compared by Duncan's multiple range tests 0.05 LSD level of significance.

RESULTS AND DISCUSSION

The Severity of Spot Form Net Blotch (SFNB) Disease of Barley:

Percentage Severity Index (PSI) of SFNB Disease:

Disease assessment was done 42 days after planting. The PSI of SFNB disease development showed a highly significant difference among varieties while there was a non-significant difference among fungicides and their interaction effects (Fig. 2). The local variety (Saesea, susceptible check) had a significantly higher PSI value (PSI = 19.35) than all remaining varieties while the minimum PSI was recorded in HB-42(12.5). However, the disease assessments on the 52, 62, and 72 days after planting the statistical analysis at (p=0.5) of the percentage severity index show a highly significant difference among variety by fungicide interactions. On the 52 days after planting, HB-42 had the lowest PSI value across all fungicide treatments, as well as the untreated HB-42. Whereas on the 62 days after planting, HB-42 treated with propiconazole + thiram had a lower PSI value than the rest of the treatments, though statistically similar to HB-42 treated with either propiconazole or thiram (Fig. 2). 72 days after planting, HB-42 treated with propiconazole + thiram had the lowest PSI of the rest of the treatment combinations (Fig. 2).

Singah *et al.*, (2007) reported that the seed treatment of a newly developed fungicidal formulation Vitavax 200 WS (Carboxin + Thiram 1:1) gave good results in reducing the severity index, the incidence of foliar diseases spot form net blotch and the result in figure 2 argues with the finding as the application of seed treatment reduces the spot form net blotch disease. The result supports the idea McLean *et al.* (2016) reported that applications of propiconazole one or more times throughout the growing season significantly reduced spot form net blotch in Australia. The result in Figure 3 argues with the idea of McLean *et al.*, (2010) were reported that the Cultivation of resistant varieties of barley is potentially an effective method for control of spot form net blotch in Victoria. BARC (2002) reported that only using the barley variety such as HB 42, HB 52, A-HOR 880/61, HB 120, Ardu 12-60B, and 'Shege' enough was effective for the control of spot form net blotch disease but the present studies contradict as the use of both variety and fungicides decrease the PSI of spot form net blotch disease (Fig. 2).

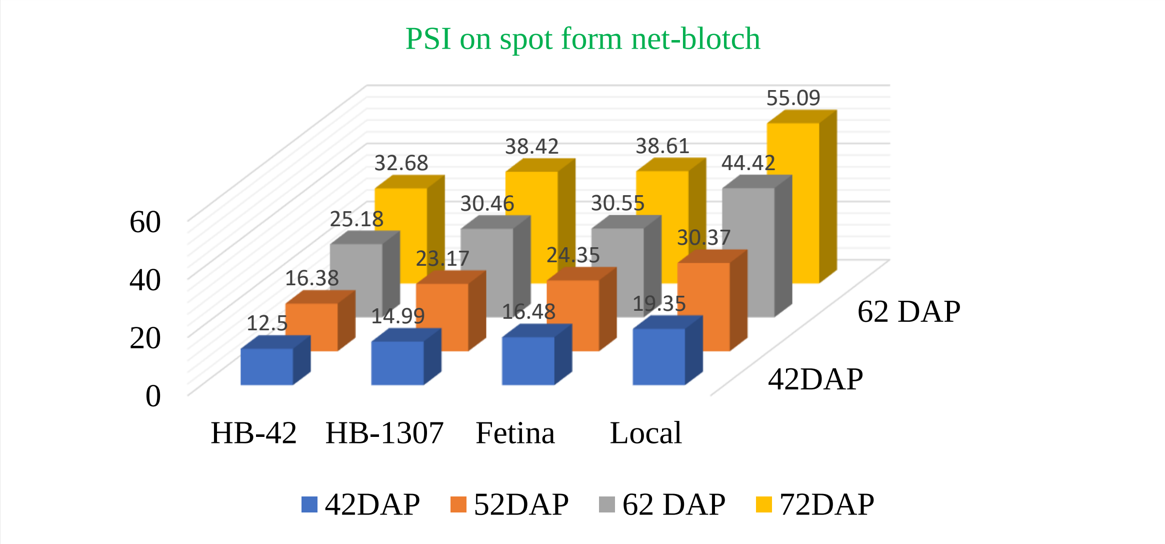

Fig. 2: Percentage severity index on spot form net blotch disease of barley (DAP- days after planting).

The Area Under the Disease Progress Curve of Spot Form Net Blotch:

The AUDPC of SFNB disease development showed a highly significant difference among varieties by fungicide interactions, where higher AUDPC value was recorded in the untreated local variety (Saesea, susceptible check) (AUDPC = 1517.7) (Table 4). The least AUDPC value (536.9) was recorded in the HB-42 treated with Thiram + Propiconazole. The present study argues with the idea of De Viedma and Kohli (1998) reported that the application of the Triazole group (Tebuconazole and Propiconazole) had proven to be very effective against spot form net blotch disease.

The application of propiconazole and thiram on HB-42, Fetina, and HB-1307, decreases highly the development of SFNB disease (Table 4). Even though the application of Thiram and propiconazole singly did not result in a significant difference in AUDPC within each variety (Table 4). Wallwork (2011) observed that the use of Seed treatment fungicides could provide multiple benefits to farmers when managing spot form of net blotch diseases (SFNB). The present study argues with Sharma *et al*. (2005) reported that seed treatment with vitavax (thiram 200B and carbendazim) and the Triazole group (e.g.- Tebuconazole and Propiconazole) especially has proven to be very effective against spot form net blotch disease.

Table 4: Variety x fungicide interaction effect on AUDPC of SFNB disease of barley at Mekan, 2018/19.

Barley variety	**Fungicides**			
	Propiconazole	**Thiram**	**Thiram + Propiconazole**	**Control**
Saesea	998.0[f]	1005.4[f]	959.1[f]	1517.7[g]
HB-42	651.7[bc]	635.0[b]	536.9[a]	742.5[cde]
HB-1307	770.2[de]	796.2[e]	683.2[bcd]	964.0[f]
Fetina	751.7[cde]	807.3[e]	736.9[cde]	1001.7[f]
Grand mean	847.3			
LSD (5%)	93.28			
CV	6.6			

NB: Values with the same letter are not significantly different at= 0.05.

Agronomic Parameters:

As is shown in Table 5, only the application of fungicides showed a significant difference and the highest biomass yield (4.9 t/ha) was obtained from plots treated with Thiram + Propiconazole and the lowest was recorded in the untreated plots (3.7 t/ha). Similarly, only the application of fungicides showed a significant difference in thousand seed weight where plots treated with Thiram + Propiconazole had significantly higher seed weight than the untreated plots, and sole thiram and sole propiconazole applications. Propiconazole-treated plots had seed weight that was significantly higher than the fungicide untreated and Thiram-treated plots. The present study (Table 5) in line with Singh *et al.*, (2014) reported that seed treatment with Thiram and two sprays of Propiconazole gains the highest average of thousand-grain weight. The result in Table 5 argues that the finding of Shivam Kumar (2018) reported that it is evident that the application of fungicides increases on a thousand seed weight in the current study.

Table 5: Main effect on agronomic data of barley variety

Treatment name	BM(t/ha)	TSW(g)
Thiram- Propiconazole	4.92[a]	162.5[a]
Thiram	4.20[b]	138.8[c]
Propiconazole	4.20[b]	151.0[b]
Untreated control	3.72[c]	133.0[c]
Grand Mean	4.26	146.33
LSD (5%)	0.42	6.970
CV	6.9	5.4

NB: BM= Biomass yield, TSW= Thousand seed weight, values with the same letter are not significantly different at= 0.05.

Table 6, indicated that the interaction of variety X fungicides, sole variety, and fungicides showed a significant difference in the treatments. The highest grain yield was recorded in treated Fetina with a yield of 4.02 t/ ha and the lowest grain yield recorded in untreated HB-42 was 2.28 ton /ha. The present study in Table 6 in line with Singh *et al.,* (2014) reported that seed treatment with thiram and two sprays of Propiconazole gains the highest average grain yields (4.28 t/ha). The present study in Table 6 is in concordance with the finding of Singh *et al.,* (2014) reported that seed treatment with Vitavax (thiram and carboxin) Power @0.25% and two sprays of Tilt @0.1%, and the highest average grain yields (4.28 t/ha) in the present study was recorded in Fetina treated with Propiconazole and Thiram. The result in Table 5 argues with the finding of Singh *et al.,* (2008) reported that the foliar application of Propiconazole 0.1% after the appearance of the disease significantly reduces the spot form net blotch and increases yield tested over several locations. The result in Table 6 contradicts the idea of BARC (2002) were concluded that the completely resistant variety provided the best control and had no reduction in grain yield or quality, in the present study only using a resistant variety was not enough rather additional management would be taken such as seed treatment and foliar applications to control the spot form net blotch disease.

Table 6: Interaction effect of grain yield of barley and fungicide combinations tons/ hectare.

	Fungicides			
Barley variety	**Propiconazole**	**Thiram**	**Thiram + Propiconazole**	**Control**
Saesea	2.724[bc]	2.693[bc]	2.824[bc]	2.688[bc]
HB-42	2.754[bc]	2.551[ab]	2.830[bc]	2.288[a]
HB-1307	3.278[ef]	3.120[de]	3.421[f]	2.897[cd]
Ftina	3.695[g]	3.367[ef]	4.026[h]	2.945[cd]
Grand Mean	3.01			
LSD (5%)	0.26			
CV	12.5			

NB: Values with the same letter are not significantly different at= 0.05.

Association of Disease Parameters and Yield of Barley:

Spot form net blotch AUDPC was negatively correlated to yield with a correlation coefficient r = -0.220 at 0.05 level indicating that spot form net blotch had a substantial negative effect on the yield of barley (Table 7). Spot form net blotch AUDPC was negatively correlated to TSW with the correlation coefficient r= 0.593 at 0.05 level indicating a substantial negative effect of net blotch on the Thousand seed weight of barley (Table 7). Khan (1989) also similarly reported the predominance of negative correlations between disease spot form net blotch and yield and stressed that multiple correlations between yield and disease at various growth stages accounted for the greatest proportion of yield variation.

Table 7: Main effects of correlations coefficients (r) for yield, biomass, thousand seed weight and AUDPC in the application of fungicides for management of spot form net blotch of barley.

	BMY	**TSW**	**GY**	**SFNB AUDPC severity**
TSW	0.347* 0.016			
GY	0.318* 0.027	0.517*** 0.000		
SFNB AUDPC severity	-0.510*** 0.000	-0.593*** 0.000	-0.220 NS 0.134	
SFNB AUDPC incidence	-0.558*** 0.000	-0.646*** 0.000	-0.235 NS 0.108	0.893*** 0.000

Yield Loss Estimation:

The variation in grain yield losses was observed between the treatments. In untreated plots, the mean of grain yield losses was distinctly higher than in protected plots, reduced with the application of fungicide relative to untreated plots**.** In the present study as shown in Tables 8 and 9, the application of Thiram, propiconazole, and both propiconazole + thiram reduces the highest relative yield loss in Fetina by 12.53%, 20.3%, and 26.85% respectively and in Saesea application of Thiram, propiconazole and both propiconazole + thiram decreases relative yield loss by the mean of 0.19%, 1.18%, and 4.68% respectively (Table 9). Thomas *et al.* (1989) reported that the untreated plots with propiconazole can cause a substantial yield loss happened by net blotch disease which ranges from 31 to 60 % worldwide and 25% in Ethiopia over untreated plots.

Table 8: Yield loss estimation of barley by the application of Thiram and Propiconazole separately.

	Thiram			Propiconazole		
Variety	**Treated**	**Untreated**	**RL (%)**	**Treated**	**Untreated**	**RL (%)**
HB-42	2.551	2.288	10.31	2.75	2.288	16.80
Fetina	3.367	2.945	12.53	3.695	2.945	20.30
Saesea	2.693	2.688	0.19	2.72	2.688	1.18
HB-1307	3.12	2.897	7.15	3.27	2.897	11.41

RL% = Decreases the yield loss by x percent as applying the seed treatment and foliar application.

Table 9: Yield loss estimation of barley by the application of Thiram and Propiconazole separately.

Thiram and propiconazole			
Variety	**Treated**	**Untreated**	**RL (%)**
HB-42	2.83	2.29	19.5
Fetina	4.03	2.95	26.85
Saesea	2.82	2.69	4.68
HB-1307	3.24	2.90	10.61

Partial Budget Analysis:

Among the 16 treatment combinations tested in Mekan, 8 treatments were dominated and excluded from the marginal analysis (Table 10). The application of fungicides to the Saesea, HB 42, and HB-13-07 treatments were dominant because of their non-profitability to the farmers. Fetina with the application of Thiram and Propiconazole in comparison with the control treatment (Saesea with no application of fungicide), offered 2383.42% of the MRR (Table 11). In contrast, the unsprayed plot, however, indicates that fungicide application is more profitable than untreated with both fungicides in Mekan. Furthermore, this indicates a gain of 23.83 Birr extra return by investing 1 Birr in both Thiram and Propiconazole in sprayed plots. The present study argues with Abera Takele *et al.* (2015) reported that minimum variable costs were observed in untreated plots. Nevertheless, the highest gross return was obtained (53450) from fungicide-treated plots.

Table 10: Partial budget analysis on the application of fungicides on barley variety.

Treatment name	Yield (ton/ha)	10%yield (ton/ha)	ADGY (ton/ha)	VC (ETB/ha)	GB(ETB/ha)	NB(ETB/ha)
Untreated HB-42	2.28	0.22	2.0592	0	24710.4	24710.4
Untreated Saesea	2.68	0.26	2.4192	0	29030.4	29030.4
Untreated HB-1307	2.89	0.28	2.6073	0	31287.6	31287.6
Untreated Fetina	2.94	0.29	2.6505	0	31806	31806
Thiram HB-42	2.55	0.25	2.2959	150	27550.8D	27400.8
Thiram Local	2.69	0.26	2.4237	150	29084.4D	28934.4
Thiram HB-1307	3.12	0.31	2.808	150	33696	33546
Thiram Fetina	3.36	0.33	3.03	150	36363.6	36213.6
Propiconazole Saesea	2.72	0.27	2.45	750	29419.2D	28669.2
Propiconazole HB-42	2.75	0.27	2.47	750	29743.2D	28993.2
Propiconazole HB-1307	3.27	0.32	2.95	750	35402.4D	34652.4
Propiconazole Fetina	3.69	0.36	3.32	750	39906	39156
Thiram- PropiconazoleSaesea	2.82	0.28	2.54	900	30499.2D	29599.2
Thiram- Propiconazole HB-42	2.83	0.28	2.54	900	30564D	29664
Thiram- Propiconazole HB-1307	3.42	0.34	3.07	900	36946.8D	36046.8
Thiram- PropiconazoleFetina	4.02	0.40	3.62	900	43480.8	42580.8

Table 11: Partial budget analysis with their marginal return rate with the non-dominance variable

Treatment name	TVC (ETB/ha)	NB (ETB/ha)	MRR (%)
Untreated HB-42	0	24710.4	
Untreated Saesea	0	29030.4	0
Untreated HB-1307	0	31287.6	0
Utreated Fetina	0	31806	0
Thiram HB-1307	150	33696	1260
Thiram Fetina	150	36363.6	0
PropiconazoleFetina	750	39906	590.4
Thiram- PropiconazoleFetina	900	43480.8	2383.2

TVC – Total variable cost, NB - Net benefit, MRR - Marginal rate return, ADGY- Adjusted yield, VB - Variable cost, D – Dominance.

Conclusion

The analysis of variance of AUDPC of spot form net blotch severity showed a significant ($P<0.05$) difference among the variety by fungicide application and their interactions. The highest AUDPC was recorded in untreated Saesea and the minimum was recorded in treated HB-42 and grain yield showed significant differences among the varieties by fungicide application and their interactions. The highest grain yields were recorded in the treated Fetina variety and the lowest in untreated HB-42. Spot form net blotch AUDPC was negatively correlated to yield and TSW, the cost-benefit analysis treated Fetina in comparison with control, offering 2383.42% of the MRR were profitable to the farmers. Instead of using several fungicides indiscriminately, the use of fungicides in combination can substantially control the disease.

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