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Evaluation of Different Fungicides Efficacy Against Net Blotch (*Pyrenophorateres*) and Leaf Rust (*Pucciniahordei*) Diseases of Barley, South-Eastern Ethiopia

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Abstract: Barley (Hordeum vulgare L.) is one of the most important staple food crops in the highlands of Ethiopia. However, the production and productivity of barley are constrained by various a biotic and biotic stresses. Among the biotic stresses, barley net blotch and leaf rust are the most destructive diseases of barley. The field experiment was conducted at three locations (Sinana, Robe and Goba) for two consecutive years (2017 and 2018) crop growing seasons. The objective of this study was to evaluate the effectiveness of different fungicides for the management of barley net blotch and leaf rust diseases. Treatments were composed of one highly susceptible barley variety (Guta) to major barley diseases and seven systemic foliar fungicides (Tilt250EC (PropiconazoleEC), RexDuo (Epoxiconazole+Thiophanatemethyl), AmistarXtra280SC (Azoxystrodin+Cyproconazole), OperaMax (F500 (85G/L)) (Pyraclostrobin+Epoxiconazole), Natura250EC (Tebuconazole250EC), Nativo300SC (Tebuconazole50%+Trifloxystrobin75WG), Artea330EC (Propiconazole+Cyproconazole) and untreated plot (control) were arranged in a randomized complete block design with three replications. The present study revealed that Tilt 250 EC and Artea 330 EC fungicides provided significant grain yield increment over untreated plot (control) across the three sites. The highest grain yield obtained from plots treated by Tilt 250 EC (2778.9 kgha^{-1}) and Artea 330 EC (2538.9 kgha^{-1}), which was 40% and 35% higher than the untreated control, respectively. The most effective among all tested fungicides, Artea 330 EC and Tilt 250 EC applied at the rate of 0.5 litre per hectare which reached 98.63% and 94.54% efficacy in controlling barley rust disease, respectively. Likewise, Tilt 250 EC and Artea 330 EC also relatively reduced net blotch disease severity to the lowest level. Likely, Tilt 250 EC and Artea 330 EC revealed that 11.4 quintal ha^{-1} and 9 quintal ha^{-1} yield advantage over untreated plot (control). The highest net benefit obtained from the application of Tilt 250 EC followed by Artea 330 EC fungicides as compared to the untreated plot. The application of Tilt 250 EC and Artea 330 EC fungicides gave maximum economic profitability with an attractive acceptable return to control leaf rust and a net blotch of barley. One time application of Tilt 250 EC and Artea 330 EC fungicides is the most effective in controlling barley leaf rust and net blotch diseases at the time of disease appearance.

Keywords: Barley, Fungicide, Variety, Severity, Net Blotch, Leaf Rust

1. Introduction

Barley (*Hordeum vulgare* L.) is one of the oldest cultivated crops in the world, which has been cultivated for thousands of years [9]. It ranks fourth among most grown cereal worldwide following wheat, maize, and rice, with an area harvested of 46.9 million ha and a production total of 141.3 million tons in 2016 [7]. Barley is one of the most important staple food crops in the highlands of Ethiopia. Ethiopia is the second-largest barley producer in Africa, next to Morocco, accounting for about 25 percent of the total barley production in the continent [6]. Barley is a cool-season crop that is adapted to high altitudes. It is also a hardy crop grown in a wide range of agro-climatic regions under several production systems. In Ethiopia, barley is grown at altitudes between 1500 and 3500 m above sea level (a.s.l), but it is predominantly grown between altitudes of 2000 and 3000 m a.s.l and ranks fifth in area and production among the cereals in Ethiopia. Barley is produced mainly for human consumption and the most important staple food crops in Ethiopia [8]. Moreover, barley straw is a good source of animal feed especially during the dry season [8]. It is also useful material for thatching roofs of houses and uses as beddings [10] and [4]. Barley is affected by a range of diseases that are responsible for considerable damage and loss of yield and quality annually. These include net blotch caused by *Pyrenophora teres* (the net form caused by *P. teres* f. *teres* and the spot form caused by *P. teres* f. *maculate*), leaf scald or blotch caused by *Rhynchosporium* commune (formerly *R. secalis)* [19], leaf rust caused by *Puccinia hordei*, Powdery mildew caused by *Blumeria graminis* f. sp. *hordei* and stem rust caused by *Puccinia graminis*. In Ethiopia, the productivity of barley is very low (about 1.9 ton ha^{-1} compared with the world average of 2.4 ton ha^{-1}). This is primarily due to the low yielding ability of farmers' cultivars, the influence of several biotic and a biotic stresses and minimal promotion of improved barley production technologies. The most important biotic stresses include diseases such as scald, net blotch, spot blotch and rusts, which can reduce yields by up to 67%, and insect pests such as aphids and barley shoot fly, which can cause yield losses of 79% and 56%, respectively. Therefore, under epidemic conditions and non-availability of resistant varieties, the use of a fungicide is the only option in reducing barley foliar diseases as a component in integrated management of the disease. Timely and judicious use of effective fungicides for the management of barley foliar diseases will be profitable to the farmers. There is limited information available on the use of fungicide to control barley foliar diseases in the country. Hence, the objective of this study was to evaluate the effectiveness of different fungicides for the management of net blotch and leaf rust diseases of barley.

2. Materials and Methods

2.1. Experimental Site

The study was conducted at three districts (Sinana, Robe and Goba) of Bale zone during 2017 and 2018 cropping seasons. Sinana Agricultural Research Center (SARC) is located in the highlands of Bale. It is located at 07°07' N and 40°10' E and 2400 meters above sea level. SARC is characterized by bi-modal rainfall forming two wheat-growing seasons in a year. The two seasons are locally named after the time of crop harvest. The main season locally called *Bonaa* (extends from August to December) and the other season called *Ganna* (extends from March to July). The annual rainfall ranges from 750 to 1000 mm (average 776.29 mm). The main growing season receives 270 to 550 mm rainfall, while the short growing season receives from 250 to 560 mm. The average annual maximum temperature is 21°C and the minimum temperature is 9°C. The soil type is dominated by pellic vertisols and slightly acidic. Robe is located 33 km from Sinana in the southeast direction. Goba is located 47 km from Sinana and about 14 km from Robe in the southwest direction.

2.2. Experimental Design, Treatment and Field Management

The experiment was arranged in randomized complete block design in three replications. The trial composed eight treatments (Tilt 250 EC, Rex Duo, AmistarXtra 280 SC, Opera max (F500 (85 G/L), Natura 250 EC, Nativo 300 SC, Artea 330 EC, and untreated plot). The fungicides were applied at recommended rate (Table 1). One food barley variety (Guta) was used in this study which is highly susceptible to major barley diseases. Plots were set to 2.5 m long and 1.6 m wide with 8 rows and 0.2 m spacing between rows. Distance between plots and blocks were 1m and 1.5m, respectively. Recommended seed rate 125 kg ha^{-1} and fertilizer DAP 100 kg ha^{-1} were used. Plots were sown manually in rows. Land preparation and weeding were done manually as recommended for barley. Fungicides were applied mixing with 250 litre per hectare water using knapsack sprayer.

Table 1. *Detail description of fungicides used in the study.*

S/N	Trade name	Active Ingredient	Company	Rate (l/ha)
1	Rex Duo	Epoxiconazole + Thiophanate-methyl	BASF	0.5
2	Tilt 250 EC	Propiconazole EC	Syngenta	0.5
3	AmistraXtra 280 SC	Azoxystrodin + Cyproconazole	Syngenta	0.65
4	OperaMax (F500 (85G/L))	Pyraclostrobin + Epoxiconazole	BASF	1
5	Natura 250 EC	Tebuconazole 250 EW	Suzhou Eagro limited	0.65
6	Nativo 300 SC	Tebuconazole50%+Trifloxystrobin75WG	Bayer Crop Science	500g
7	Artea 330 EC	Propiconazole+Cyproconazole	Syngenta	0.5

Disease assessments

Leaf rust (Puccinia hordei) severity was assessed in percentage by estimating the approximate percentage of the whole plant affected by using a modified Cobb scale [13] on a plot basis. Net blotch (Pyrenophora teres) severity was recorded on a double-digit scale (00-99).

Grain yield and yield components

Data on the yield and yield components were recorded from the six central rows for each treatment. The average height of ten random plants from each plot was measured from the ground level including the ear at maturity in cm. The number of seed per spike was counted from ten randomly selected spikes from each plot at maturity. The spike length was measured from ten randomly selected plants from each plot in cm. Biomass yield was used from four central rows of 4m length excluding the borders on both sides from each plot at harvest in grams per plot (gm/plot). Grain yield was determined from the four central rows of 4m length from each plot in gram per plot (g/plot) and converted to kgha^{-1}. After harvesting, the grain yield was adjusted to a moisture content of 12.5% and the weight of 1000-kernels was measured in (g).

2.3. Fungicide Efficacy

Fungicide efficacy (EF) was calculated using Abbott's formula [1]:

$$\text{EF (\%)} = \frac{X-Y}{X} \text{x}100$$

Where,
X – Disease severity in control
Y – Disease severity in treated plots

2.4. Economic Analysis

Economic data were collected to assess the costs and benefits associated with each treatment. The partial budget technique as described by CIMMYT [5] was applied to the yield results. These included variable input costs and prevailing market prices of fungicides, labor and barley yield dominance analysis procedure as in CIMMYT [5] was used to select potentially profitable treatments from the range that was tested using the equation.

$$\text{MRR} = \frac{Change\ NI}{Change\ TVC}\ x\ 100$$

Where: NI= change in net income, TVC= change in total variable cost, MRR= Marginal rate of return.

An economic evaluation of the effect of fungicides and labor was performed on the grain yield partial budget was estimated for the average yield of the different treatments. Fungicides, barley grain, and labor current price were used in the study.

2.5. Statistical Analysis

The effects of fungicide treatments on disease severity, yield, and yield-related traits were subjected to analysis of variance (ANOVA) using the Statistical Analysis System (SAS) version 9.1 [15]. Data on disease severity were transformed using logistic transformation before statistical analysis. Means comparisons for the significantly different variables were made among treatments using Least Significant Differences (LSD) test at 0.05 levels of significance.

3. Results and Discussion

3.1. Weather Conditions

Seasonal precipitation and temperatures recorded at weather stations near the experimental sites were shown in Table 2. The seasonal weather conditions showed different meteorological trends from planting to harvesting (June to November). The two years growing seasons were marked by mild temperatures and moderate rainfall which made a conducive environment to the development of barley net blotch and leaf rust diseases across all locations. However, the disease severity of net blotch and leaf rust of barley was differed from year to year and location to location during the crop growing seasons.

Table 2. *Mean temperatures and rainfall experienced during the evaluation period of (2017- 2018) at Sinana.*

Growing season	June	July	August	September	October	November
2017						
Min. Temp °C (mean)	13.2	14.1	14.7	13	13.6	12.8
Max. Temp °C (mean)	27.3	24.1	22.3	21.3	20.6	20.6
Mean rainfall (mm)	0.9	1.4	3.2	5.7	2.5	1.8
2018						
Min. Temp °C (mean)	12	11	11.7	11.7	11.4	11.6
Max. Temp °C (mean)	22.3	22.8	22.9	22.2	21.2	21.5
Mean rainfall (mm)	4.3	0.3	3.6	3.3	2.7	1.6

Min=Minimum, Max=Maximum, Temp. =Temperature, mm=Millimetres.

3.2. Disease Development

The onset of barley net blotch disease was early in the growing seasons at all locations in 2017 and 2018. The highest infection of 83 at (GS 41-49) was recorded in the untreated plots at two locations (Sinana and Robe) whereas the lowest infection was recorded at Goba in the same years. The occurrence of leaf rust disease was relatively late at all locations as compared to net blotch disease. The highest mean leaf rust severity was recorded in the untreated plot at Robe, but the lowest infection was recorded at Sinana and Goba (Tables 3, 4 and 5). Leaf rust severity at Robe and Goba was moderate in 2018 whereas low leaf rust severity was recorded at Sinana in the same year.

3.3. Effect of Fungicides on Barley Net Blotch Severity

The statistical analysis revealed that there was no significant effect observed among fungicide treatments and untreated plot (control) in reducing net blotch severity at Sinana and Goba (Tables 3 and 5). However, there was a significant difference observed among fungicide treatments and untreated plots in controlling net blotch severity at Robe (Table 4). Similarly, in 2018, there was a significant effect observed among fungicide treatments and untreated plot in reducing net blotch severity at Sinana and Robe (Tables 6 and 7). There was no significant effect observed among fungicide treatments and untreated plot in reducing net blotch severity at Goba (Table 8). One time application of Tilt 250 EC and Artea 330 EC fungicides significantly reduced net blotch severity as compared to untreated plot (control) across the three locations. These current findings are in agreement with the investigation of Bekele et al. [2] who reported that 57.5-83.82% net blotch disease of barley variety reduction over untreated check using a different fungicide. Similar results were reported by Wubishet et al. [17] that at least one-time fungicide application at GS39-41 provided effective net blotch management.

3.4. Effect of Fungicides on Leaf Rust Severity

In 2017, there was no significant difference observed among fungicide treatments and untreated plots in reducing leaf rust severity at Sinana and Robe (Tables 3 and 4). However, there was a significant effect observed among fungicide treatments and untreated in controlling leaf rust severity at Goba (Table 5). The result revealed that there was a significant effect observed among fungicide treatments and untreated plot in reducing leaf rust severity across the three locations (Tables 6, 7and 8). Similarly, Milos et al. [12] reported that a mixture of fungicide pyraclostrobin + epxiconazole resulted in the lowest disease severity. Tilt 250 EC and Artea 330 EC fungicide applications significantly reduced leaf rust severity as compared to the untreated plot. These findings are in line with Bhardwaj et al. [3] reported that for controlling the initial load of inoculums or under the high incidence of barley rust diseases, fungicides belonging to triazole group such as Azoxystrobin 25% EC (Amistar), Bayleton 25%EC (Triadimefon), Difenoconazole 25% EC (Score), Propiconazole 25% EC (Tilt) and Tebuconazole 25% EC (Folicur) have been found effective at the rate of 0.1 percent i.e. 1ml in 1litre of water.

3.5. Effect of Fungicides on Grain Yield and Yield Component

3.5.1. Plant Height

The statistical analysis showed that there was a significant effect observed among fungicide treatments and untreated plots on plant height at Sinana and Goba in 2017 and 2018 crop growing seasons, respectively (Tables 3 and 8). However, there was a non-significant effect observed among fungicide treatments and untreated plots on plant height at Robe and Goba (Tables 4 and 5). Likewise, there was a non-significant effect also observed among fungicide treatments and untreated plots on plant height at Sinana and Robe (Tables 6 and 7).

3.5.2. Spike Length Per Plant

The result showed that there was a significant effect observed among the fungicide treatments and untreated plot on spike length at Sinana, Robe and Goba (Tables 3, 4, 7 and 8). However, there was no significant effect observed among the fungicide treatments and untreated plot on spike length at Sinana and Goba (Tables 5 and 6). The highest spike length (10.00 cm) recorded from the Rex Duo fungicide application whereas the lowest spike length (8.00 cm) recorded from the untreated plot, respectively (Table 8).

3.5.3. Number of Seed Per Spike

The statistical analysis showed that there was a significant effect observed among the fungicide treatments and untreated plots on a number of seed per spike at Robe and Goba (Tables 4, 5 and 8). However, there was a non-significant difference observed among fungicide treatments and untreated plots on seed per spike at Sinana and Robe (Tables 3, 6 and 7).

3.5.4. Biomass Yield

There was a non-significant effect observed among the fungicide treatments and untreated plot on grain biomass across the three locations (Tables 3, 4 and 5). Similarly, in 2018, there was also a non-significant effect observed among the fungicide treatments and untreated plot on grain biomass at Sinana and Goba (Tables 6 and 8). However, there was a significant effect observed among the fungicide treatments and untreated plot on grain biomass at Robe (Table 7).

3.5.5. Grain Yield

The statistical analysis revealed that there was no significant effect observed among the fungicide treatments and untreated plot for the increment of grain yield at two test sites (Sinana and Robe). This data revealed that the test fungicides showed almost equal response for yield at these sites (Tables 3 and 7). However, there was a significant effect observed among the fungicide treatments and untreated plots for the increment of grain yield at both locations (Robe and Goba) (Tables 4 and 5). Likewise, in 2018, there was a significant effect observed among the fungicide treatments and untreated plots for grain yield increment at both locations (Sinana and Goba) (Tables 6 and 8). Tilt 250 EC and Artea 330 EC fungicides provided significant grain yield increment over untreated plot (control) across the three testing sites. These current findings are in agreement with the investigation of Mark et al. [11] who reported that foliar fungicide application significantly reduced net blotch severity, increased grain yield up to 23% and improved grain quality. The mean grain yield among the treatments ranged from 1550.7 $kgha^{-1}$ to 2778.9 $kgha^{-1}$. The highest grain yield was obtained from Tilt 250 EC (2778.9 $kgha^{-1}$) followed by Artea 330 EC (2538.9 $kgha^{-1}$), which was 40% and 35% higher than the untreated control. Similarly, Wanyera et al. [18] reported a 50% higher yield of wheat crop from fungicide treated as compared to the untreated plot.

3.5.6. Thousand Kernel Weight

The statistical analysis revealed that there was a non-significant effect observed among the fungicide treatments and untreated plot on 1000-kernel weight at Sinana and Goba (Tables 3 and 5). However, there was a significant effect observed among the fungicide treatments and untreated plot on 1000-kernel weight at Robe (Table 4). In 2018, there was a non-significant effect observed among the fungicide treatments and untreated plot on 1000-kernel weight at Sinana (Table 6). However, there was a significant effect observed among the fungicide treatments and untreated plot on 1000-kernel weight at Robe and Goba (Tables 7 and 8). The result revealed that Tilt 250 EC and Artea 330 EC fungicide applications significantly increased 1000-kernel weight compared to the untreated plot (Table 3). All test fungicides significantly increased thousand kernel weight compared to control (Table 4). These current findings are in agreement with the work by Wubishet Alemu and Tamene Mideksa [16] that highly significant effect observed among test fungicides and nil application for the increment of thousand kernel weights. The highest thousand kernel weight obtained from Artea 330 EC (47.03g) followed by Tilt 250 EC (46.46g) and Nativo 300 SC (46.30g) application whereas the lowest obtained from untreated plot (35.23g) application (Table 7). Similarly, it was previously reported that the fungicide treatments had a strong impact on the control of infection of P. teres and increased kernel yield in variable disease infection conditions [14].

Table 3. *Effect of different fungicides on barley diseases severity, yield and yield related traits at Sinana in 2017 cropping season.*

Treatments		PH	SL	S/S	BY	GY (kg/ha)	TKW	NB (%)	LR (%)
Variety	Fungicide	(cm)	(cm)		(ton/ha)		(g)	Severity	Severity
Guta	Tilt	86.13ab	7.70ab	50.20	2.33	1898.3	40.03a	78.33	0.53
Guta	Rex Duo	89.40ab	7.60ab	45.13	2.30	1906.9	37.76ab	82.00	0.27
Guta	AmistarXtra	90.60b	7.80ab	49.93	2.62	2060.3	37.20b	81.33	0.53
Guta	Opera Max	90.20a	8.46a	49.87	2.20	1852.4	37.73ab	81.67	1.33
Guta	Natura	91.47a	7.53ab	47.93	2.30	1889.9	38.96ab	81.67	1.87
Guta	Native	88.53ab	8.20a	45.53	2.43	1841.4	37.63ab	78.00	0.53
Guta	Artea	90.93a	8.13ab	42.13	2.42	1984.4	40.63a	77.67	0.53
Guta	Control	81.47b	7.10b	40.53	2.43	1631.3	36.10b	83.00	0.27
Mean		88.59	7.82	46.4	2.38	1869.38	38.13	80.45	1.03
CV (%)		5.2	7.8	12.2	13.7	13.6	4.9	4.6	43.6
LSD (5%)		**	**	ns	ns	ns	**	ns	ns

PH= plant height, SL= spike length, SS= seed per spike, BY= biomass yield, GY= grain yield, TKW= thousand kernel weight, NB= net blotch, LR= leaf rust, **= significant difference at P<0.05, ns= non-significant difference at P<0.05, CV=coefficient of variation, LSD= least significant difference.

Table 4. *Effect of different fungicides on barley diseases severity, yield and yield related traits at Robe in 2017 cropping season.*

Treatments		PH	SL	S/S	BY	GY (kg/ha)	TKW	NB (%)	LR (%)
Variety	Fungicide	(cm)	(cm)		(ton/ha)		(g)	Severity	Severity
Guta	Tilt	94.27	6.35a	41.87ab	2.12	2010.0a	40.00a	81.00b	13.33
Guta	Rex Duo	93.07	6.23ab	36.47bc	2.07	1931.1ab	40.66a	83.00ab	12.00
Guta	AmistarXtra	93.47	5.80ab	42.73a	1.93	1952.2a	40.66a	83.33ab	13.33
Guta	Opera Max	94.87	5.80ab	35.13c	1.80	1818.9ab	42.00a	83.33ab	9.33
Guta	Natura	88.87	5.96ab	35.87bc	1.65	1692.2ab	41.33a	83.00ab	12.00
Guta	Native	93.53	6.00ab	35.40c	1.72	1825.6ab	40.00a	82.33ab	9.33
Guta	Artea	90.73	5.46b	33.47c	1.60	1947.8a	42.00a	81.66b	14.66
Guta	Control	92.87	4.56c	31.07c	1.53	1157.8b	30.33b	83.66a	16.00
Mean		92.71	5.77	36.50	1.80	1724.44	39.62	82.92	12.50
CV (%)		4.7	7.8	9.5	31.4	25.70	5.4	1.2	34.8
LSD (5%)		ns	**	***	ns	**	**	**	ns

PH= plant height, SL= spike length, SS= seed per spike, BY= biomass yield, GY= grain yield, TKW= thousand kernel weight, NB= net blotch, LR= leaf rust, **= significant difference at P<0.05, ns= non-significant difference at P<0.05 CV=coefficient of variation, LSD= least significant difference.

Table 5. *Effect of different fungicides on barley diseases severity, yield and yield related traits at Goba in 2017 cropping season.*

Treatments		PH	SL	S/S	BY	GY	TKW	NB (%)	LR (%)
Variety	Fungicide	(cm)	(cm)		(ton/ha)	(kg/ha)	(g)	Severity	Severity
Guta	Tilt	93.6	6.10	41.00a	2.80	2778.9a	45.3	47.67	0.80c
Guta	Rex Duo	89.7	5.83	36.33ab	2.26	1947.8ab	46.0	47.33	2.60bc
Guta	AmistarXtra	93.7	6.03	36.66ab	2.26	2128.9ab	44.6	44.33	2.73bc
Guta	Opera Max	88.8	5.70	37.80ab	2.66	2375.6ab	42.6	54.67	4.06bc
Guta	Natura	92.2	5.53	34.53ab	2.66	2324.4ab	42.6	47.67	8.00b
Guta	Native	94.5	5.93	32.66b	2.08	1901.1ab	43.3	51.00	2.66bc
Guta	Artea	93.3	6.23	40.13ab	2.76	2538.9a	44.0	47.67	0.20c
Guta	Control	92.7	6.13	35.13ab	2.35	1637.8b	39.3	57.67	14.66a
Mean		92.3	5.94	36.78	2.49	2154.16	44.3	49.8	4.22
CV (%)		4.7	7.5	12.9	17.3	26.45	4.9	29.1	71.43
LSD (5%)		ns	ns	**	ns	**	ns	ns	***

PH= plant height, SL= spike length, SS= seed per spike, BY= biomass yield, GY= grain yield, TKW= thousand kernel weight, NB= net blotch, LR= leaf rust, **= significant difference at P<0.05, ns= non-significant difference at P<0.05, CV=coefficient of variation, LSD= least significant difference.

Table 6. *Effect of different fungicides on barley diseases severity, yield and yield related traits at Sinana in 2018 cropping season.*

Treatments		PH	SL	S/S	BY	GY (kg/ha)	TKW	NB (%)	LR (%)
Variety	Fungicide	(cm)	(cm)		(ton/ha)		(g)	Severity	Severity
Guta	Tilt	103.3	8.66	50.00a	2.91	2620.2a	38.76	82.00b	0.80b
Guta	Rex Duo	106.3	8.66	45.66ab	2.50	2188.7abc	37.03	83.00a	2.93ab
Guta	AmistarXtra	104.6	8.33	50.33a	2.50	2367.2ab	37.71	83.00a	5.60ab
Guta	Opera Max	105.6	8.00	52.33a	3.00	2182.3abc	36.98	82.66ab	6.93a
Guta	Natura	105.0	8.66	46.66ab	2.75	1734.7c	38.16	82.66ab	2.93ab
Guta	Native	105.6	8.33	52.00a	2.66	2197.3abc	34.84	82.00b	5.60ab
Guta	Artea	106.0	8.66	51.33a	2.58	2587.3a	37.35	82.03b	0.80b
Guta	Control	106.0	7.33	42.00b	2.03	1792.7c	33.36	83.00a	6.93a
Mean		105.33	8.33	48.79	2.71	2206	36.40	82.54	3.95
CV (%)		3.02	9.39	8.84	16.60	12.25	7.61	0.61	78.7
LSD (5%)		ns	ns	**	ns	**	ns	**	**

PH= plant height, SL= spike length, SS= seed per spike, BY= biomass yield, GY= grain yield, TKW= thousand kernel weight, NB= net blotch, LR= leaf rust, **= significant difference at P<0.05, ns= non-significant difference at P<0.05, CV=coefficient of variation, LSD= least significant difference.

Table 7. *Effect of different fungicides on barley diseases severity, yield and yield related traits at Robe in 2018 cropping season.*

Treatments		PH	SL	S/S	BY	GY	TKW	NB (%)	LR (%)
Variety	Fungicide	(cm)	(cm)		(ton/ha)	(kg/ha)	(g)	Severity	Severity
Guta	Tilt	109.0	7.00a	45.66	2.53a	2042.6	46.46a	82.00b	0.80c
Guta	Rex Duo	106.0	7.00a	47.00	2.50a	1594.3	45.56ab	83.00ab	2.93bc
Guta	AmistarXtra	104.6	7.00a	40.66	2.16ab	1550.7	46.26ab	83.00ab	5.60ab
Guta	Opera Max	108.6	6.33ab	47.33	2.56a	1774.6	44.96ab	82.67ab	6.93ab
Guta	Natura	104.0	6.50ab	43.33	2.66a	1870.7	38.03b	82.67ab	2.93bc
Guta	Native	105.6	7.00a	44.00	2.16ab	1519.2	46.30a	83.00ab	5.60ab
Guta	Artea	106.0	7.00a	40.66	2.16ab	2022.4	47.03a	82.33b	0.80c
Guta	Control	101.6	5.33b	34.33	1.66b	1204.7	35.23b	83.67a	10.66a
Mean		105.7	6.64	42.9	2.30	1659.88	45.05	82.67	4.80
CV (%)		5.43	11.76	18.5	19.66	28.41	10.48	0.7	63.2
LSD (5%)		ns	**	ns	**	ns	**	**	**

PH= plant height, SL= spike length, SS= seed per spike, BY= biomass yield, GY= grain yield, TKW= thousand kernel weight, NB= net blotch, LR= leaf rust, **= significant difference at P<0.05, ns= non-significant difference at P<0.05, CV=coefficient of variation, LSD= least significant difference.

Table 8. *Effect of different fungicides on barley diseases severity, yield and yield related traits at Goba in 2018 cropping season.*

Treatments		PH	SL	S/S	BY	GY (kg/ha)	TKW	NB (%)	LR (%)
Variety	Fungicide	(cm)	(cm)		(ton/ha)		(g)	Severity	Severity
Guta	Tilt	68.33ab	8.00b	41.33a	2.36	2470.0a	48.40a	41.33	1.46b
Guta	Rex Duo	72.00a	10.00a	39.00ab	2.31	2480.0a	48.66a	34.33	1.60b
Guta	AmistarXtra	67.33ab	8.33b	30.00cd	1.63	2186.7ab	49.33a	31.00	4.00b
Guta	Opera Max	67.67ab	8.66ab	33.00bc	2.00	2105.6ab	47.33ab	31.33	5.33b
Guta	Natura	70.00a	8.33b	27.33cd	2.03	2030.0ab	48.00a	27.66	3.60b
Guta	Native	65.67ab	8.00b	24.33d	1.43	2022.2ab	46.00ab	31.00	2.73b
Guta	Artea	64.67b	8.33b	31.00cd	1.80	2440.0a	48.00a	21.00	1.46b
Guta	Control	67.00ab	8.00b	31.00cd	1.43	1035.6b	42.33b	31.00	11.66a
Mean		67.83	8.50	32.12	1.87	2026.25	46.95	31.12	3.98
CV (%)		4.9	9.73	13.22	16.4	37.72	6.46	38.49	58.16
LSD (5%)		**	**	**	ns	**	**	ns	**

PH= plant height, SL= spike length, SS= seed per spike, BY= biomass yield, GY= grain yield, TKW= thousand kernel weight, NB= net blotch, LR= leaf rust, **= significant difference at P<0.05, ns= non-significant difference at P<0.05, CV=coefficient of variation, LSD= least significant difference.

3.5.7. Fungicide Efficacy

The fungicide efficacy was calculated using Abbott's formula for two crop growing years (2017-2018). The most effective among all tested fungicides; Artea 330 EC and Tilt 250 EC applied at the rate of 0.5 litre per hectare, which reached 98.63% and 94.54% efficacy in controlling barley leaf rust disease, respectively (Table 5). Likewise, Tilt 250 EC and Artea 330 EC also relatively reduced net blotch disease severity (3.1%) and (2.39%), respectively. Tilt 250 EC and Artea 330 EC fungicides significant yield advantage over untreated plot applications. Likely, Tilt 250 EC and Artea 330 EC revealed that 1141.1 kgha^{-1} (11.4 quintal ha^{-1}) and 901.1 kgha^{-1} (9 quintal ha^{-1}) yield advantages over untreated plot (Table 5).

3.5.8. Economic Analysis

The partial budget analysis was used for economic analysis of grain yield data and fungicide application. The average yield was adjusted by 12.5% moisture content to reflect the farmers' field yield as described by CIMMYT [5]. Two years of average market grain price of barley (8 birrs/kg). To estimate the total costs, the average current prices of fungicides (800 birrs/bottle) and daily laborer (100 birrs/ha) were used at the time of application. All costs and benefits were calculated on hectares basis in Ethiopian birr/ha (Table 9). The economic analysis showed that the highest net benefit was obtained from the application of Tilt 250 EC (28,028.18 birrs/ha) followed by Artea 330 EC (27,257.66 birrs/ha) fungicides whereas the lowest net benefit obtained from the untreated plot (19,750.34 birrs/ha). The economic analysis revealed that the application of Tilt 250 EC and Artea 330 EC fungicides gave profitable yield response with positive marginal rate of the return (MRR) of 6, 568.8 and 1,808.6, respectively (Table 9). Therefore, the application of Tilt 250 EC and Artea 330 EC fungicide is recommended as the best with an attractive acceptable return to control barley net blotch and leaf rust in the highlands of Bale.

Table 9. *Partial budget analysis of different fungicides to control barley net blotch and leaf rust at Sinana, Robe and Goba districts, 2017-2018.*

Treatment	TC	MC	NB	MB	MRR
Untreated (control)	0	0	19,750.34	0	0
Artea 330 EC	415.09	415.09	27,257.66	7,507.32	1,808.6
Tilt 250 EC	426.82	11.73	28,028.18	7,700.52	6,568.8

TC=total cost, MC=marginal cost, NB=net benefit, MB=marginal benefit, MRR=marginal rate of return

4. Conclusion and Recommendations

The two growing year’s data revealed that the effect of fungicide application in the management of barley net blotch and leaf rust were well described at the three locations. Significant differences were found among fungicide treatments in their ability to reduce disease development and protected crop reduction. The application of Artea 330 EC and Tilt 250 EC fungicides significantly reduced barley leaf rust and net blotch diseases as compared to untreated plots. The highest grain yield obtained plot treated from Tilt 250 EC and Artea 330 EC whereas the lowest obtained from the untreated plot (control). Tilt 250 EC and Artea 330 EC revealed that 1141.1kgha^{-1} (11.4 quintal ha^{-1}) and 501.1 kgha^{-1} (5 quintal ha^{-1}) yield advantages over untreated plot. The most effective among all tested fungicides were Artea 330 EC and Tilt 250 EC applied at the rate of 0.5 litre per hectare which reached 98.63% and 94.54% efficacy in controlling barley rust disease, respectively. Likewise, Tilt 250 EC and Artea 330 EC also relatively reduced net blotch disease severity to the lowest level. The economic analysis revealed that the application of Tilt 250 EC and Artea 330 EC fungicides gave profitable yield response with positive marginal rate of the return (MRR) of 6, 568.8 and 1,808.6, respectively. The application of Tilt 250 EC and Artea 330 EC fungicide is recommended as the best with an attractive acceptable return to control barley net blotch and leaf rust. Therefore, one-time application of Tilt 250 EC and Artea 330 EC fungicides (0.5 litre ha^{-1}) rate at the time of disease appearance should be recommended for barley leaf rust and net blotch management for barley production in the highlands of Ethiopia.

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Conflict of Interest

All authors have no conflict of interest.

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