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Study on Fungicide Rate for the Management of Septoria Tritici Blotch (*Zymoseptoria tritici*) of Bread Wheat (*Triticum aestivum* L.) in Ethiopia

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Abstract: This research was conducted with the aim of determining the fungicide's rate (Tilt) on wheat varieties with different level of response to Zymoseptoria tritici blotch. From the result of this study, there is significant difference between bread wheat varieties with ZSTB reaction. The highest final disease severity (93% and 83.5%) and AUDPC (576.19% and 506.7%) value recorded on Pavon 76 & Alidoro Variety without fungicide application; whereas the lowest final disease severity (49.0% and 65.5%) and AUDPC (278.3% and 464.8%) value recorded on Alidoro and Pavon 76 variety sprayed with 0.75 lt/ha, respectively. There are significant differences between different Tilt fungicide rates with ZSTB reaction. Among all treatments there is significant difference on yield, thousand kernel weight and hector-liter weight. The highest yield (4.13t/ha and 3.58t/ha), recorded on rate-75%; whereas the lowest (2.97t/ha and 2.06t/ha) recorded on untreated plot from Alidoro and Pavon-76 varieties, respectively. Among fungicide spray dose there is highly significant difference between sprayed plots versus unsprayed plots regardless of spray rates. From this we have concluded that the interaction of Tilt 250 EC with Alidoro which is moderately resistant variety was very effective to manage wheat ZSTB disease.

Keywords: AUDPC, Bread Wheat, Net Benefit, Rate, Tilt, Zymoseptoria

1. Introduction

One of the most widely grown cereal crops is wheat (Triticum spp.), which is harvested annually in excess of 778.6 million metric tonnes. [11, 19]. About 20% of the calories consumed by humans come from bread wheat (Triticum aestivum L.), which also provides the most steady diet for 40% of people. [13]. Cereals occupied 82.19% (11, 538, 341.9 hectares) of the area used for grain crops. Of the grain crop area, wheat occupied 14.62% (1, 897, 405.05 hectares). Cereals made a production contribution 88.36% (about 30, 205, 426.06 tones) of the grain production; wheat contributed 16.91% (5, 780, 130.6 tones) of the grain production. The average grain yield of wheat is still low (3.05 t/ha), highly variable, and falls short of the global average (6.5 t/ha) despite increases in production and yield [7]. Wheat production and productivity are hindered globally by a number of issues, such as biotic and abiotic stressors and limited adoption of innovative agricultural technologies, despite its importance as a food and industrial crop [22]. The most significant biotic stressors limiting wheat productivity are fungus-caused conditions. All around the entire country, Septoria diseases, particularly Septoria tritici blotch (STB), are common [8]. These diseases include yellow rust (Puccinia striiformis f. sp. tritici), stem rust (P. graminis f. sp. tritici), leaf rust (P. triticina), and leaf rust (P. triticina). In areas where vulnerable wheat varieties are widely produced, the combination of mild temperatures and high humidity gives an ideal environment for the foliar wheat to spread quickly. Furthermore, wheat cultivars that are robust in one region of the world could show susceptibility in another. The development of wheat varieties with broad spectrum resistance is hampered, even within a single nation, by differences in pathogen virulence that may be linked to

fungal genetic variability [9]. In general, wheat foliar diseases (STB, wheat rusts) continue to be a major barrier to the production of wheat worldwide, including in Ethiopia. However, the disease's status varies every year due to environmental factors and racial differences. Therefore, evaluating the disease's state annually is vital. Determining the rate of fungicide (Tilt) on different wheat cultivars with different level of response to Zymoseptoria tritici blotch is the goal of this investigation.

2. Tools and Techniques

2.1. Description of the Study Areas

In 2022, the study was carried out at the Holetta Agricultural Research Centre in Ethiopia. The location's geographic coordinates are 090 04'N, 380 38'E, and 2390 m. a. s. l. It is located 29 km west of Addis Ababa. The region's maximum and minimum annual mean temperatures are 23.910°C and 6.750°C, respectively, with an average temperature of 15.33°C. The average annual rainfall ranges from 0.00 to 304.1mm. Luvisols, a form of clay soil, are the most common cultivar. Wheat production there is excellent for making bread, and ZSTB pressure is typically high during the rainy season. [12].

2.2. Experimental Design and Treatment

Highly susceptible improved bread wheat variety namely Pavon 76 and Moderately Resistant Alidoro used for the three replications of the study's Randomized Complete Block Design (RCBD). The area involved measured 1.2 m by 2.5 m (3 m^2) in size. To create different ZSTB epidemic levels, 4 levels (0lt/ha, 0.25lt/ha, 0.5t/ha & 0.75 lt/ha) of fungicides Tilt was used and applied during disease onset.

Table 1. *Lists of bread wheat varieties that were tested in the field.*

No.	Cultivars	Release year	Adaptation (M. A. S. L.)	Maturity dates	Response	Yield (t/ha)
1	Pavon 76	1982			HS	2.6-5.2
2	Alidoro	2007	2200-2900	118-180	MR	2.6-5.2

HS = Highly Susceptible, MS = Moderately Susceptible, and MR = Moderately Resistant.

2.3. Disease Details Gathered

The severity of zymoseptoria tritici blotch and spontaneous infections were factors in the field trial was assessed every seven days starting from the first occurrence of disease symptoms up to maturity of the crop. When evaluating the severity of zymoseptoria tritici blotch, Saari and Prescott's severity scale for wheat foliar diseases was modified to provide a double digit scoring scale (00-99)[15, 9]. The first digit (D1) indicates vertical disease progress on the plant and the second digit (D2) refers to severity measured as diseased leaf area.

The formula created by Sharma and Duveiller were used to determine the Area under Disease Progress Curve (AUDPC) values for each plot [17].

$$\text{AUDPC}= \sum_{i=1}^{Ni-1} \frac{(Xi+Xi+1)}{2} (ti + 1 - ti)$$

Where,

Xi= the cumulative disease severity expressed as a proportion at the i^{th} observation,

ti = the time (days after planting) at the i^{th} observation and n= total number of observations.

Given that the severity of the wheat Zymoseptoria tritici blotch was previously reported in percent and time (t) in days, AUDPC values can be expressed in percent – days [5]. Then AUDPC values are used in analysis of variance to compare amount of disease among different treatments.

2.4. Evaluation of the Yield and the Yield Components

On each experimental plot, all agronomic, yield-related, and yield-related data were recorded. Below is a list of these numbers and their specifics.

1) Thousand Kernel Weight (TKW) (g): For each experimental unit, a thousand grains were chosen at random and weighed in grammes.
2) Hectoliter weight (HLW) (Kg/hL): For each experimental unit, the grain weight of a one-liter volume (random sample) was determined using the normal approach, and the results were translated to Kg/hL. A 12.5% adjustment was made to the moisture content.
3) Grain yield (GY) (tones): Grain yield in g/plot were recorded and converted to t/hectare.

2.5. Benefit-Cost Analysis

The cost of wheat grains (60 Birr/kg) was calculated based on the local market in 2022, and the price of 100 kg (5500 Birr) was obtained from a hectare basis. Variable costs, such as fungicides (Tilt = 2,600 Birr/lt) and labour costs (70 Birr/LD) to apply the fungicide, were also noted and taken into consideration. These materials' total quantities (fungicides, seeds, labour, and water) were calculated, and their costs were converted. Prior to performing the economic analysis (partial budget), statistical analysis on the gathered data was carried out to compare the average yield between the treated and untreated treatments, respectively. The formula developed to determine the marginal rate of return by [6] was used to calculate the partial budget analysis. Economic data and the variations in treatments were used to do the following partial budget analysis:

$$\text{Cost Benefit Ratio (\%)} = \frac{\text{MB}}{\text{MC}} * 100$$

Sale Revenue (SR in B/ha) = wheat selling price*wheat grain yield (t/ha*1000kg/1t)

Net Benefit (Profit) (NB in B/ha) = Sale revenue - Total input and labor cost (TIC B/ha)

Marginal Benefit (MB in B/ha) = net Profit of the treatment - net profit of control plot

Marginal Cost (MC in B/ha) = Total input and labor cost of the treatment - Total cost of control

2.6. Data Evaluation

The SAS computer package version 9.3's general linear model was used for data analysis [16]. The Duncan's New Multiple Range Test was used to compare the means for the various treatments.

3. The Findings and Discussion

3.1. Disease Severity and the Area Under the Curve of the Disease

3.1.1. Severity

ZSTB severity varies significantly across varieties and Fungicide levels during every assessment date in 2022 cropping years (Table 2). Disease parameters were subjected to an analysis of variance (severity for each plot) and for each assessment date, yield related, and yield related components (yield, thousand-kernel weight, and hectoliter), the area under the disease progress curve was calculated. At every assessment date Alidoro variety showed much less severe disease, while Pavan-76 was also vary significantly from each other in 2022 cropping year (Table 2). At every assessment, by far the greatest severity was recorded on 0lt/ha sprayed plots also other fungicide levels was vary significantly from each other (Table 2). Regarding to this results, ZSTB severity developed rapidly on Pavon-76 whereas, the disease developed slowly on Alidoro. From our experiment there is significant difference between 0.25lt/ha, 0.5lt/ha and 0.75lt/ha for the management of ZSTB. This demonstrated that the level of fungicide application or improvement in varietal resistance to ZSTB as a result of fungicide spray had a significant impact on the level of disease development revealed how crop resistance levels affected the latent time of STB pathogens and the rate at which diseases developed [9]. In 2022, the impacts of the fungicide application levels (0.25lt/ha, 0.5lt/ha, and 0.75lt/ha) on the severity of the illness varied considerably (p 0.05) from all assessment dates (Table 2). Furthermore, wheat cultivars that are resistant in one region of the country may show vulnerability in another, showing that there is no universal response. This can be attributable to changing pathogen populations or current weather patterns that may have an impact on host tolerance to the disease. ZSTB was the only tested variety. ZSTB was generally severe at Holetta; this may have been a result of the more hospitable environmental circumstances present during crop growth seasons, i e., with rainy, cold, and acceptable average monthly maximum temperature range of 19oC - 27oC throughout crop growing season. Temperatures between 20 and 25 degrees Celsius, along with a rainy and overcast sky, can best favour Zymoseptoria tritici infection. [9].

The current high yielding wheat variety Pavan-76, according to the study's findings, was the most vulnerable to ZSTB, indicating the necessity of prioritising the use of resistant genes. For resource-constrained farmers in impoverished nations, using resistant varieties is the greatest way to reduce fungal diseases in general and Zymoseptoria tritici blotch in particular. It is also the most profitable and environmentally benign method for commercial farmers [21]. Alternately, fungicide treatments can be used to this variety to reduce ZSTB development. Additionally, recent findings suggested that spraying wheat fields might be a useful strategy for lowering ZSTB levels, even on vulnerable kinds. The producer's level of risk tolerance must be taken into consideration while determining the rate and frequency of fungicide application [4].

ZSTB severity assessments were conducted up to five times before being halted due to the presence of leaves. This accelerated premature leaf senses and moisture stress from low or no rainfall during the crop's later growth stage may have a deleterious effect on ZSTB [20]. Spraying Tilt fungicide often at the proper rates greatly decreased the severity level on all kinds, even if complete control of ZSTB growth was not accomplished and the extent of control varies across varieties. The inability of fungicide to completely eliminate ZSTB can be caused by the environment's favourable conditions for ZSTB development during the growing season, particularly enough rain and a comfortable temperature. The establishment of ZSTB is favoured by sufficient rainfall, which also it might reduce the efficiency of fungicide.

3.1.2. Area Under the Curve of Disease Progress

The results reveled that, high values of AUDPC were recorded across varieties with AUDPC%-days fluctuating between 576.5 to 464.8 in Pavon 76 variety and 506.5 to 278.0 in Alidoro variety respectively (Table 2). The findings showed that high AUDPC values were seen throughout kinds, with AUDPC%-days ranging from 506.5 to 278.0 in the Alidoro variety and 576.5 to 464.8 in the Pavon 76 variety, respectively (Table 2).

The current study's findings demonstrated significantly significant (p 0.001) variations in AUDPC between the two varieties Alidoro and Pavon-76.

The highest value ever reported on Pavan-76 was 576.5. The AUDPC summarises plant disease epidemics very conveniently by taking into account the beginning intensity, the rate parameter, and the length of the epidemic, which determines the ultimate disease intensity. [13]. significantly the highest AUDPC was noted on plots that weren't sprayed. and other fungicide levels was vary significantly from each other in both Alidoro and Pavon-76 (Table 2). The highest value ever reported on Pavan-76 was 576.5. While Alidoro, a wheat cultivar, had the smallest (278.0) AUDPC in% days. Comparing the treated plots to the untreated ones, the

AUDPC has decreased at all fungicide spray levels, although did not significantly affected AUDPC value among levels in cropping years. This is consistent with what [1, 2, 23] observed for the highest AUDPC values (3879%-days) from untreated plots.

Table 2. *The impact of different bread wheat cultivars and fungicide rates on AUDPC and Zymoseptoria tritici blotch severity in 2022.*

Treatments Disease severity (%)							
Varieties	**Fungicide rates**	**1st**	**2nd**	**3rd**	**4th**	**5th**	**AUDPC**
Pavon-76	untreated	11.5^{e}	67.5^{a}	85.5A	86.5^{A}	93.0^{A}	576.5^{A}
	0.25 lt/ha	13.5^{de}	14.0^{d}	64.5^{B}	69.5^{BC}	90.5^{A}	471.3^{B}
	0.5 lt/ha	16.5^{cd}	48.0^{b}	51.5^{C}	68.0^{BC}	91.5^{A}	504.3^{AB}
	0.75 lt/ha	21.0^{a}	37.5^{c}	48.5^{C}	65.5^{C}	83.5^{A}	464.8^{B}
Alidoro	untreated	17.5^{bc}	35.5^{c}	68.5^{B}	80.5^{AB}	87.0^{A}	506.5^{AB}
	0.25 lt/ha	19.0^{abc}	11.5^{d}	22.5^{D}	21.0^{DE}	62.5^{C}	387.8^{D}
	0.5 lt/ha	12.5^{e}	17.0^{d}	27.5^{D}	28.0^{E}	57.5^{B}	286.3^{C}
	0.75 lt/ha	20.0^{ab}	16.5^{d}	27.0^{D}	43.0^{D}	49.0^{BC}	278.0^{CD}
	Mean	16.437	30.937	49.437	57.750	72.812	409.406
	CV	8.736	13.323	10.578	10.946	11.077	9.296
	LSD (5%)	3.1	9.2	11.68	14.94	19.12	91.08

The Duncan multiple range test indicates that the means in a column that are separated by the same letters are not substantially different.

3.2. Yield as well as Yield parameters

3.2.1. Output of Grains

The difference in grain yield between different kinds was statistically significant (p 0.05) (Table 3). The greatest yield (4.13 t/ha) was observed on Alidoro variety in which is treated with 0.75 l/ha fungicide application level in 2022 cropping season. Whereas the smallest grain yield was (2.07 t/ha) recorded from the untreated plots of Pavon-76 variety. There was significant difference between yields of Pavan-76 and the resistance variety Alidoro (Table 3). This result is in agreement with [2], who found that the best yield was obtained from 0.75l/ha sprayed plots and the lowest yield was obtained from untreated plots. Compared to treated plots, untreated plots had lower qualitative and quantitative grain yields [1]. Compared to the moderately resistant Alidoro variety, the susceptible Pavan-76 cultivar produced less quantitative grain yields [1]. Compared to the moderately resistant Alidoro variety, the vulnerable Pavan-76 cultivar produced less.

3.2.2. Weight in Thousands of Kernels

According to analysis of variance (ANOVA), there were significant variations between the fungicide application level and the weight of the thousand kernels (Table 3). The largest weight of the thousand kernels (48.27) was taken from Alidoro which is treated with 0.75l/ha whereas the smallest weight of the thousand kernels (40.25) was recorded on untreated plots of Pavon -76 varieties in 2022 cropping season. With respect to Pavon 76 in the 2022 harvest year, Alidoro variety had significantly higher weight of the thousand kernels (Table 2). Regardless of the two varieties, varying fungicide levels typically resulted in considerable differences in the weight of a thousand kernels.

3.2.3. Weight in Hectoliters

The result revealed that the largest weight in hectoliter (82.46 kg/hl) was taken from variety Alidoro; whereas, the smallest weight in hectoliter (79.2 kg/hl) was recorded on untreated plots of Pavon -76 in 2022 cropping season (Table 3).

Table 3. *The impact of fungicide rates and bread wheat cultivars on wheat yield and yield-related characteristics in 2022.*

Treatments	Yield and Yield Components					
varieties	**Fungicide rates**	**PH**	**S L**	**TKW**	**HLW**	**YLD (t/ha)**
Alidoro	untreated	83.75^{C}	7.00^{C}	40.10^{C}	82.46^{A}	2.17^{AB}
	0.25 lt/ha	82.50^{C}	6.25^{C}	41.20^{C}	82.72^{A}	3.24^{AB}
	0.5 lt/ha	90.63^{BC}	6.25^{C}	41.56^{BC}	82.76^{A}	3.83^{AB}
	0.75 lt/ha	89.63^{BC}	7.50^{BC}	48.27^{BC}	83.54^{A}	4.13^{A}
Pavon -76	untreated	93.13^{AB}	8.50^{AB}	40.25^{ABC}	79.20^{B}	2.07^{AB}
	0.25 lt/ha	93.75^{AB}	8.75^{AB}	45.03^{AB}	79.21^{B}	2.97^{B}
	0.5 lt/ha	100.38^{A}	9.50^{A}	45.06^{AB}	79.25^{B}	3.19^{B}
	0.75 lt/ha	94.25^{AB}	8.63^{AB}	47.93^{A}	79.3^{B}	3.58^{AB}
	Mean	91	7.79	43.13	81.03	3.51
	CV	4.6	7.8	4.042	0.69	9.93
	LSD (5%)	9.1	1.4	3.9	1.2	0.9

The Duncan multiple range test indicates that the means in a column that are separated by the same letters are not substantially different.

3.3. Cost Benefit Evaluation

The results of a partial budget study showed that the unsprayed plots had the lowest cost of the two varieties, while the 100% fungicide spray level had the highest total cost (Table 4). However, a partial budget study revealed that

all fungicide spray level applied to the two varieties provided excellent gross field benefits and a marginal rate of return. In Holetta, the variety Alidoro, the partial cost-benefit analysis revealed that plots with a 75% fungicide spray level yield had the highest total gross yield benefit of 114180 Ethiopian Birr per hectare. Even though plots of the Pavan-76 variety with a 10% fungicide spray level produced lower gross yield advantages in the 2022 crop year, this fungicide spray level produced higher gross yield benefits than the control. A different net benefit has been seen from the two cultivar. At the study area variety, Alidoro had the highest marginal rate of return (MRR), 3338.59%, and 75% spray level, with a net profit of 236130 Ethiopian Birr per hectare. As a result, reasonable benefits in the fungicide sprayed amounts were attained. According to [18], it's important to consider a crop's ability to pay application costs, which depends on its prospective yield, when evaluating it for risk. Fungicides are employed because they offer dependable disease control, can be administered safely, and deliver production in the form of crop yield and quality at an affordable price [14]. Farmers wouldn't use fungicides, though, unless they were profitable and effective.

Table 4. *Analysis of the partial budget for the control of Zymoseptoria tritici blotch in wheat at Holetta major cropping season of 2022's.*

Varieties	Fungicide rates	YLD (t/ha)	WSP (B/Kg)	SR (B/ha)	TIC (B/ha)	MC (B/ha)	NB (B/ha)	MB (B/ha)	MRR (%)
Pavon-76	untreated	2.17	60	130200	8250	0	121950	0	0
	0.25 lt/ha	3.24	60	194400	9380	1130	185020	63070	5581.41
	0.5 lt/ha	3.83	60	229800	10510	2260	219290	97340	4307.07
	0.75 lt/ha	4.13	60	247800	11670	3420	236130	114180	3338.59
Alidoro	untreated	2.07	60	124200	8250	0	115950	0	0
	0.25 lt/ha	2.97	60	178200	9380	1130	168820	52870	4678.76
	0.5 lt/ha	3.19	60	191400	10510	2260	180890	64940	2873.45
	0.75 lt/ha	3.58	60	214800	11670	3420	203130	87180	2549.12

Wheat selling price for WSP, sales revenue for SR, MRR stands for marginal rate of return, TIC for total input cost, MC for marginal cost, NB for net benefit, MB for marginal benefit, Holetta Agricultural Research Centre is known as HARC.

4. Conclusion and Suggestions

There is significant difference between bread wheat varieties with ZSTB reaction. The highest final disease severity (93.0%) and AUDPC (576.5%) value recorded on Pavon 76 Variety, and statistically significantly different from Alidoro variety, which is moderately resistance; whereas the lowest final disease severity (49.0%) and AUDPC (278.0%) value recorded on Alidoro variety with 75% fungicide application level in 2022 cropping season. There are significant differences between different Tilt 250 EC fungicide rates with ZSTB reaction. The highest final disease severity (90.7% and 93.8%) and AUDPC (576.5 %) value recorded on 0% rate of the fungicide plots from Pavon-76; whereas the lowest final disease severity (43.0%) was value recorded on 75% of the fungicide rate from Alidoro in 2022 cropping years. From our experiment there is significant difference between 25%, 50% and 75% of Tilt 250 EC fungicide for the management of ZSTB in 2022 cropping years. Among all treatments there is significant difference on yield, thousand kernel weight and hector-liter weight in 2022 cropping years, but no significant difference on hector-liter weight in 2022 cropping year. The largest yield (4.13t/ha), taken on rate-75% from Alidoro and whereas the lowest (2.07t/ha) recorded on 0% plot from Pavon-76 in 2022, respectively. Among fungicide spray dose there is highly significant difference between sprayed pots versus unsprayed plots regardless of spray rates. From this we have concluded that 75% of Tilt 250 EC and Alidoro which is moderately resistant variety were very effective to manage wheat ZSTB disease.

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