

Participatory Evaluation and Selection of Fungicide Efficacy Against Wheat Rust Diseases on Bread Wheat (*Triticum aestival* L.) at Highland Area of Guji Zone

Seyoum Alemu^{*}, Girma Teshome, Kabna Asefa

Bore Agricultural Research Center, Bore, Ethiopia

Email address:

seyoum23@gmail.com (Seyoum Alemu)

^{*}Corresponding author

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Abstract: Bread wheat (*Triticum aestivum* L.) is an important cereal grown in the highlands of Ethiopia. Various biotic and abiotic stresses affected the production and productivity of wheat. From biotic stresses, yellow rust and stem rust disease of wheat that caused by *Puccinia striiformis* f. sp. *tritici* and *Puccinia graminis* f. sp. *tritici* are among the devastating and wheat production bottlenecks. Therefore, a field experiment was done at two highland of Guji zone (Bore and Ana Sora) under rain-fed condition during the 2019/20 main cropping season to evaluate effects of different fungicides on wheat rust diseases, yield and yield components of bread wheat. The treatments consisted of five fungicides including standard check and nil application using bread wheat variety Kubsa. A randomized complete block design with three replications was used to conduct up the experiment. The partial budget analysis was carried out to assess financial profitability of fungicide application for the management of rusts. Analysis of the results revealed that the application of fungicides significantly affected rust diseases, growth parameters and yield attributes except date to heading and date maturity. Fungicide spray treatments significantly reduced both rusts (yellow and stem) rust diseases severity to the lowest level and increment of yield over the nil application. The minimum yellow rust and stem rust diseases severity recorded from the test fungicide Take-Off 293% SC while maximum yellow rust and stem rust diseases severity were recorded at unsprayed plot. There was significant difference ($p < 5\%$) in grain yield, biomass yield, thousand seed weight, plant height, spike length and rust (yellow and stem) between fungicide treatments and control/nil application. The highest grain yield (2738 kg/ha) was obtained from Take-Off 293% SC sprayed plots while the lowest (987 kg/ha) was from nil application. Take-Off 293% SC revealed better grain yield advantage than the standard Check fungicide and control by about 5.6 and 63.95, respectively. Moreover, all fungicide applications showed a considerable production advantage over untreated plots. Take-Off 293% SC controlled effectively both rusts (yellow and stem) diseases of wheat by increasing yield of wheat. Therefore, based on partial budget analysis, yield and rust disease control, using of Take-Off 293% SC fungicide which leads to the optimum yield of bread wheat by decreasing rusts and can be recommended for the study area and other areas with similar agro-ecologies.

Keywords: Bread Wheat, Disease Severity, Fungicide, Stem Rust, Yellow Rust

1. Introduction

Bread wheat (*Triticum aestivum* L.) is one of the most important cereal crops in terms of area and production in the world. It produced 659 million tons of grain with an average productivity of 3160 kg ha⁻¹ in the 2014–2015 cropping season on more than 216 million ha of land than any other

crop [5]. During the Meher season of 2016–17, Ethiopia produced 42.1 million quintals of wheat on an area of 1.7 million ha, with a yield average of 26.75 kg ha⁻¹ [4]. Though the country ranked second in area of production (1.7million ha) next to Morocco (2.9million ha) and third in total production (42.1 million quintals) next to Egypt (92.7 million quintals and Morocco (51.1 million quintals), but stood sixth

in yield in Africa next to Zambia, Namibia, Egypt, Mali, and South Africa that takes the rank 1 to 5, respectively (FAO, 2017); Indicating that Ethiopia increasing the area of farming with low productivity.

Many biotic and abiotic influences reduce wheat production and productivity. Among the biotic factors, wheat rust diseases are the most devastating and wheat production as bottleneck. Guji highlands are among hot spot for wheat rusts where new virulent races evolve and spread to other parts of the country and to the world and it is where the periodic epidemics cause significant yield losses and reduction [6].

Both yellow and stem rusts of wheat caused by *Puccinia striiformis* f. sp. *tritici* and *Puccinia graminis* f. sp. *tritici*, respectively are the most important diseases on bread wheat in the world and in Ethiopia [12]. In the highlands Guji, bread wheat yield loss up to 71% due to yellow rust was recorded [8]. However, 100% yield loss was recorded in severe cases on the highly susceptible varieties due to yellow rust (BoARC Progress report). Similarly, Stem rust is also an aggressive an important wheat disease in Guji. Currently, most of popular bread wheat varieties grown in Guji are susceptible to virulent stem rust races, Ug99 (TTKSK) and its derivatives. Moreover, in 2018/19 main cropping season a new stem rust race (TTKTT) was detected on popular bread wheat varieties (Huluka, Sanate, Shorima, Ogolcho, Hidasie, Danda'a etc) (Hei *et al.*, [6]. The most popular disease control strategies for wheat are sources of rust resistance. Several efforts were made towards resistant cultivars development in Ethiopia and several bread wheat cultivars with various levels were released for production. But many of them are attacked due to development of these new races. Thus it is important to use the other option like fungicide to sustain production and productivity of bread wheat.

Objective

- 1) To evaluate fungicides efficacy against rust diseases on bread wheat through participatory
- 2) To determine economically appropriate fungicides for wheat production

2. Materials and Methods

2.1. Treatments and Experimental Design

Treatments consist of five fungicides (Jeba, Diprocon, Orozole and Take-Off 293% SC) and one standard check (Rex Duo) with fungicide 0.5 litres/ha for each fungicide and unsprayed will be included as control. The treatments were arranged in randomized completed block design with three replications for mother trial (MT) (planted on station) and farmers were used as replication for baby trials (BT). In order to achieve this, one farmer field was utilized as a replication for the baby trials, with the two non-replicated trials being planted in the other host farmer's fields. The plot sized 5.0 x 5.0 meters. The row spacing, spacing between plots and blocks was 20 cm, 1.0 m and 1.5 m, respectively. One row from both sides was excluded from data collection that

avoids effect of border. Wheat variety, Kubsa which is susceptible to rusts especially yellow rust and stem rust was used. Blended NPS fertilizer was applied at the rate of 121 kg ha⁻¹ and mixed thoroughly with soil to avoid direct contact with the seeds. The fungicide was tank mixed and applied as soon as the disease appeared and then at two weeks interval. All the other management was applied as recommended for the crop for the area.

2.2. Data Collection

Data was collected in two ways: agronomic data & farmer's data. For agronomic data phenological, growth, yield and its component were collected following their own principles. Rust severity was recorded using the modified Cobb's scale [7].

2.3. Data Analysis

Data collected from mother trials was subjected to 'GenStat' software (version 18) to evaluate the variability of the tested fungicides. To do this, analysis of variance was computed for each character studied using the Gomez and Gomez method (1984). The probability level of = 0.05 was utilized to compare treatment mean differences using Fisher protected Least Significant Difference (LSD). For data collected from baby trials, matrix ranking suggested by De Boef *et al.*, [3] was employed.

2.4. Partial Budget Analysis

The economic analysis was calculated using the technique outlined in CIMMYT [2], utilizing the market prices that were in effect at the time of planting and harvest for the inputs and outputs, respectively. All required costs for production and benefits obtained were calculated in birr on hectare basis. The price of chemicals/fungicides, gross benefit (GB) ha⁻¹ and mean grain yield of each treatment were concepts used in the partial budget analysis. The benefit of straw yield was not included in the calculation of the benefit since the farmers in the area do not use it. Marginal rate of return, which refers to net income obtained by incurring a unit cost of fungicides, was calculated by dividing the net increase in yield of bread wheat due to the application of each fungicide. Using the formula $NB = (GY \times P) - TCV$, the net benefit (NB) was calculated as the difference between the gross benefit and the total cost that varies (TCV), [2]. Where $GY \times P$ = Gross Field Benefit (GFB), GY = Adjusted Grain yield per hectare and P = Field price per unit of the crop.

The yield obtained was adjusted downward by 10%. This is to show the difference between the experimental yield and the farmers yield from the same treatment.

3. Results and Discussions

3.1. Diseases

The pressure of both rusts (yellow and stem) disease was very high and significant difference among treatments across

all test locations in highlands of Guji zone 2019/20. There were high variation disease pressure among fungicides and nil application on both yellow rust and stem rust. Fungicide spray treatments (test and check fungicides) significantly reduced both yellow rust and stem rust diseases severity over the nil application (Table 1). Take-Off 293% SC reduced yellow rust disease severity to the lowest level compared to the standard check fungicides and unsprayed by about 23.35 and 90.96% respectively. It also reduced stem rust diseases severity by about 63.96 and 72.98% as compared to standard check and unsprayed plot respectively. Similarly, from visual field observation, Take-Off 293% SC also showed more level of efficacy in controlling both yellow rust and stem rust diseases than the standard check, Rex Duo even though it is not statistically different. In general, yellow rust range 7.68% - 85.03% whereas stem rust ranges from 5.00% - 18.51% under test fungicides and control/unsprayed treatment respectively. Similar findings were reported by Ahmed *et al*, [10] and Ayele *et al* [13].

3.2. Analysis of Variance for Phenology, Agronomic and Yield Data

Statistically non-significant variation observed for days to

heading and maturity. The effect of Fungicides significantly ($P < 0.05$) influenced plant height (Table 1). The result show that plant height increased as rust diseases controlled, even though there was no statistically different among test fungicides (Table 1). The tallest plant (79.94 cm) was recorded from plot treated with Take-Off 293% SC while the shortest plant (68.55 cm) was obtained at untreated/control plot. This is because of the vital role of fungicides in controlling rusts which favor vegetative growth and resulted for significant influence on plant height. The result of this study in line with the finding of Yared *et al* [8] where they reported significant effect of fungicides on height of bread wheat.

The analysis of result indicated significant ($P < 0.05$) effect of fungicides on the spike length of bread wheat (Table 1). The result showed that using of fungicides increased spike length. Thus, the longest spike (8.99 cm) was recorded at Take-Off 293% SC application and this was statically at par with other fungicides (Table 1). The increase in spike length by using fungicides might have resulted from improved root growth and increased uptake of nutrients and better growth favored due to control of rust diseases.

Table 1. Effect of Fungicides Against Bread Wheat Rusts, Yield Component and Yield of Bread Wheat at Highlands of Guji Zone.

Fungicides	Yellow Rust severity (%)	Stem Rust severity (%)	Days to heading	Days to maturity	Plant height (cm)	Spike length (cm)	Thousand kernels weight (g)	Grain yield (kg/ha)	Biomass (t/ha)
Diprocon 30 EC	15.06 bc	11.7 ab	72.67	141.7	78 a	7.663 a	28.8 a	2486 a	5.629 ab
Jeba 25 EC	18.44 b	13.38 ab	72	141.7	79.33 a	7.993 a	28 a	1730 b	3.673 c
Untreated	85.03 a	18.51 a	72.33	141	68.55 b	5.777 b	18.4 b	987 c	2.937 c
Take-Off 293% SC	7.68 d	5.00b	72.33	142	79.94 a	8.997 a	28.27 a	2738 a	5.821 a
Orozole 25EC	15.06 bc	16.75 a	72.67	141.3	77.89 a	8.387 a	27.47 a	2055 b	4.816 b
Rex Duo	10.02 cd	6.67 b	72.33	142	76.16 a	8.33 a	28.13 a	2587 a	5.411 ab
Mean	25.21	12.00	72.39	141.61	76.65	7.86	26.51	2097.12	4.71
LSD (0.05)	6.05	8.60	NS	NS	6.26	1.66	6.05	327.44	0.915
CV (%)	13.2	39.4	1.8	0.3	4.5	11.2	12.6	8.6	10.7

CV (%) = Coefficient of variation, NS= non-significant, LSD= Least Significant Difference at 5% level

Application of fungicides significantly ($P < 0.05$) affected thousand kernels weight of wheat (Table 1). Thousand kernels weight of bread wheat was increased due to application fungicides. But, there was no statistically significant difference between fungicides (Table 1). The highest thousand kernels weight (28.8 g) was obtained at application of Diprocon 30 EC followed by Take-Off 293% SC. But, the minimum thousand kernel weight (18.14 g) was obtained at nil application/control treatment. Thousand kernels weight obtained from the overall treated plots were significantly higher than thousand seed weight from the unsprayed plot/control. This might be due to the improvement of seed quality and size due to control of rust diseases. In agreement with this result, Wubishet and Tamene (2016) reported significant thousand kernels weight for bread wheat.

Application of fungicide significantly ($P < 0.05$) influenced above ground dry biomass of wheat (Table 1).

The maximum above ground dry biomass (5.82 t ha⁻¹) was recorded at Take-Off 293% SC whereas the lowest (2.937 t ha⁻¹) from unsprayed plot (Table 1). This finding agreed with that of Wubishet and Tamene [9] reported increased above ground dry biomass of wheat by up to 34.78% as compared to control, which indicate the benefit of fungicide.

The analysis of the result showed that the effects of fungicides significantly ($P < 0.01$) affected the grain yield of bread wheat (Table 1). Using of fungicides significantly increased grain yields of wheat than unsprayed/control. The highest grain yield (2738 kg ha⁻¹) was recorded at application Take-Off 293% SC and it was statistically at par with Rex Duo with grain yield of 2587 kg ha⁻¹ whereas the lowest grain yield (987 kg ha⁻¹) was recorded at control/unsprayed plot (Table 1). In general, grain yield obtained from Take-off 293% SC applied plots was 63.95% greater than yield from the unsprayed plot.

This finding agrees with that of Wubishet and Tamene [9]

and Nagaraja *et al* [11] who reported increment of grain yield of bread wheat through application of fungicides. Similarly, Yared *et al.* [8] also reported significant effect of fungicides on grain yield of bread wheat. Wanyera *et al* [14] also reported 50% yield advantage due to application of fungicide over unsprayed/control treatment. Like ways Wegulo *et al.* [15] and Kelley *et al.* [16] reported 42% and 77% yield increment due to fungicide application as compared to control.

3.3. Farmer's Selection Criteria's

In this instance, farmers were given the freedom to judge the fungicides by their own standards. They innovate despite the fact that they lack a control treatment for comparison and statistical tools to test the hypothesis because they have a broad knowledge base about their environments, crops, and diseases that has been accumulated over many years and because they conduct their own experiments [1]. Farmers

were advised to establish criteria for choosing the best fungicide for their location based on this theory before making their choice. The farmers, who included senior individuals, women, and men, were engaged in group discussions to achieve this. After establishing the criteria, students were told to order the criteria in accordance with their interests. Farmers get to choose fungicides by assigning their own values as a result of this. Farmers have thus specified criteria such as grain yield, seed infection, stand of the crop, infections on the leaves, diseases on the stems, diseases on the heads/head infection, etc. The evaluators gave the tested fungicides different ratings based on predetermined criteria (farmers). In this regard, the control of bread wheat rust diseases was shown to be more effective using Take-Off 293% SC fungicide and Rex Duo (table 2). The Take-Off 293% SC and Rex Duo fungicides were chosen by farmers as a result of their capacity to control the disease among the fungicides that were studied.

Table 2. Farmers' Preference Scores And Ranking For Baby Trial.

Fungicides name	Farmers selection criteria						Total	Average	Rank
	1	2	3	4	5	6			
Diprocon 30 EC	3.5	3.3	3.4	3.9	4.7	4.2	23	3.8	3
Jeba 25 EC	2.3	1.5	2.2	3.1	3.3	3.6	16	2.7	5
Untreated	1.2	1.0	1.3	1.0	1.5	1.0	7	1.2	6
Take-Off 293% SC	5.0	4.8	3.9	5.0	5.0	4.9	28.6	4.8	1
Orozole 25EC	2.7	1.9	2.7	3.2	3.4	3.3	17.2	2.9	4
Rex Duo	4.8	3.9	3.6	4.7	5.0	4.5	26.5	4.4	2

Keys: 1=grain yield, 2=disease on leaves, 3= disease on stem, 4= disease on head/head infection, 5=stand of the crop, 6=seed infection

3.4. Partial Budget Analysis

Table 2 provides an analysis of the marginal rate of return, total varying costs, and net benefits. Before using technology innovation, farmers must understand the costs and advantages of treatments. The study assessed the treatments' financial benefits in order to generate suggestions from the agronomic data. This helps the farmers in the study area choosing the best combination of resources. The study's findings showed that applying fungicides had greater net advantages than using no spray or control treatments (Table 3).

The partial budget analysis, as shown in Table 3, revealed that the application of Take-Off 293% SC gave the largest

net benefit (43383.91 Birr ha⁻¹), followed by Rex Duo (40318.48 Birr ha⁻¹), and the lowest net benefit (from control treatment). The minimum acceptable rate of return should range from 50% to 100% when using the marginal rate of return (MRR%) as the foundation for fungicide recommendations [2]. The Take-Off 293% SC application in this study produced the most economic benefit (43383.91ha⁻¹) at a marginal rate of return (9857.82%). Hence, using Take-Off 293% SC would be the most advantageous and cost-effective option, and it is advised for bread wheat production in the research area and other places with comparable agro-ecological circumstances. Similar result was reported by Yared *et al* [8].

Table 3. Partial Budget Analysis For Participatory Fungicide Selection.

Treatments (Fungicides)	Adjusted grain yield downwards by 10% (kg ha ⁻¹)	Gross Benefit (Birr ha ⁻¹)	Total variable cost (Birr ha ⁻¹)	Net return (Birr ha ⁻¹)	MRR (%)
Control	874.02	15732.31	0.00	15732.31	0.00
Diprocon 30 EC	2160.00	38880.00	425	38455.00	1314.402
Jeba 25 EC	1557.39	28033.04	375	27658.04	3180.195
Take-Off 293% SC	2435.22	43833.91	450	43383.91	9857.826
Orozole 25EC	1866.52	33597.39	400	33197.39	22157.39
Rex Duo	2281.30	41063.48	745	40318.48	D

4. Conclusions and Recommendations

It is crucial to move quickly to establish suitable research

methodologies in regions like Southern Oromia's Guji Zone that are a hotspot for bread wheat diseases. The data analysis also showed that the use of fungicides increases yield by reducing wheat rust infections. When compared to control

(unsprayed) and standard check, the application of Take-Off 293% SC resulted in yield advantages of 63.95% and 5.85%, respectively. Thus, based on a partial budget analysis, the research region and other locations with comparable agro-ecologies are advised to use the fungicide Take-Off 293% SC, which reduces rusts and leads to the best production of bread wheat.

Conflict of Interest

The authors declare there are no conflicts of interest.

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