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# Status and evaluation of released bread wheat varieties-fungicide interactions against the major rusts in the Western Hararghe Highlands

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## ABSTRACT

Bread wheat is a crucial crop that feeds billions of people worldwide. However, it is often affected by various stresses, including, wheat rust which can hinder its production and productivity. To evaluate the severity of this issue and the effectiveness of various treatments, a study was conducted in West Hararghe during the 2020 main cropping season. The survey covered a total of 125 cultivated fields, each of which was assessed for wheat rust prevalence. Four fungicides, including the unsprayed plot and five bread wheat varieties, were used as a treatment. The experiment was laid out in RCBD with three replicated plots. Among those fields, the disease was prevalent in 125 (100%) fields. Major wheat rust severity varies across locations. The maximum disease severity (22.5%) was recorded in the Gemechis district, while the lowest disease severity (11.0%) was recorded in the Tulo district. An incidence of 85.0% in the Gemechis and 61.5% in the Tulo districts were recorded. The effects of different fungicide interactions on wheat rust epidemics and the yield of bread wheat varying in reaction to the disease were studied in the major wheat growing district (Gemechis) of West Hararghe, Ethiopia. Generally, stripe, leaf, and stem rusts started to be observed from tillering to late after an ear head emergence. Fungicide spray treatments significantly reduced wheat rusts. Test fungicides revealed a comparable and better level of efficacy on wheat rust disease severity reduction compared to the unsprayed check. Thousand kernel weight reductions of up to 32.3% and 24.6% at Gemechis were recorded. Generally, Danda'a with Jeba and Shorima with progressive fungicide application provided better control of bread wheat rusts.

**Keywords**: Leaf rust, stem rust, pesticide, yellow rust, severity, varieties

## INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is one of the most important crops for consumption and feeds billions of people across the globe. It has been cultivated on approximately 225.62 million ha with an annual production of over 776.5 million metric tons in 2021/22 (World Atlas, 2020). World annual bread wheat, with a production of 772.6 million tons, is a staple food for more than 35% of the globe's population (Statista, 2021). Globally, China, India and Russia are the largest wheat producers, while South Africa and Ethiopia are the largest wheat producers in sub-Saharan Africa (SSA) (USDA, 2019).

Ethiopia's annual production is approximately 5.8 million tons with a mean productivity of 3 tons per hectare ($tha^{-1}$) (CSA, 2021), which is relatively lower than the attainable yield of the crop, reaching up to 5 $tha^{-1}$ (Zegeye, 2020). Wheat accounts for approximately 17% of the total grain production in Ethiopia, making it the third most important cereal crop after teff [*Eragrostis tef* (Zucc.) Trotter] and maize (*Zea mays* L.) (CSA, 2021). The most suitable altitude range for wheat production is between 1900 and 2700 meters above sea level (Hundie, 2000), and the Hararghe highland also shares this suitable range. The low yield of wheat is mainly related to biotic factors, and biotic factors are responsible for this low yield. Cultivation of unimproved low-yield varieties, insufficient and erratic rainfall, poor agronomic practices, disease and insect pests are among the most important constraints to wheat production in Ethiopia.

The major strategy for the management of wheat rust in Ethiopia focused on the development of resistant varieties and chemical options. These two principal methods of wheat rust management strategies have been implemented in most wheat-producing areas of the globe. To address this issue, several fungicides have been evaluated against rusts and are being used in wheat as rust management options. Evaluating released bread wheat variety fungicides against rust disease is important to sustain wheat production. Thus, the objectives of this study were (1) to assess the status of three wheat rusts (yellow, leaf and stem) in major wheat-producing districts of the zone and (2) to evaluate the efficacy of released bread wheat varieties with selected foliar fungicides for the control of wheat rusts and promote the economic and agronomic feasibility of fungicide-released bread wheat varieties.

## MATERIALS AND METHODS

### Descriptions of the study area

The research was conducted in five major wheat-producing districts (Oda bultum, Habro, Chiro, Tulo and Gemechis) of the West Hararghe zones of eastern Ethiopia during the 2020 cropping season. West Hararghe Zones are located 7°55′–9°33′N latitude and 40°01′–41°39′E longitude. All the districts differed in their ecological features, geographical location and mean weather variables. Habro found at latitude 8.8131°N and longitude 40.5203°E and an average altitude of 1814.38 Meters (5952.69 Feet) above sea level, and its temperature ranges from a maximum of 25–30 °C and a minimum of 7–20 °C, and annual rainfall ranges from 650-1000 mm. Oda Bultum is also located in the West Hararghe Zone. The capital town of the district is Badesa. Its altitudinal range is from 1600-2400 m.a.s.l, and the annual rainfall is 900–1100 mm. It has mean maximum and mean minimum temperatures of 28 and 25, respectively. From the total land area of the district, 60% is plain and 40% is steep slope. The maximum and minimum rainfalls are 1200 and 900 mm, respectively (Oda Bultum Agriculture Office, 2012). Gemechis district is again found in the West Hararghe zone, which is located 343 km east of Addis Ababa and approximately 17 km south of Chiro. The district is situated between 8° 40′0″ and 9° 04′0″ N and 4° 50′0″ and 41° 12′0″ E. The soil of the study area is dominantly loamy soil (Desalegn *et al*., 2016). Chiro district is located in the West Hararghe Zone at approximately 324 km east of Finfine. The capital town of the district is Chiro, which is also the capital town of the zone. Normally, the district is divided into three major agroecological zones. These are lowland with 22 kebeles, midland with 13 kebeles and highland altitude with 4 kebeles. Tullo district is located 370 km southeast of Addis Ababa. The altitude of the district is 1750 m above sea level with a mean annual rainfall of 1850 ml and a mean annual temperature of 23 °C.

### Assessment of major wheat rust disease intensity

A field survey of major rusts was carried out in the main growing season in the potential wheat-growing area of west Hararghe, Oromia Regional State, in the 2020 main cropping season. Based on the time of occurrence for major wheat rusts, different crop growing stages were selected for the survey. The selected fields of wheat were infested by leaf, yellow and stem rusts. Purposive sampling was used to select farm fields based on the growing potential of wheat. Every farm field was selected at intervals of 5–10 km based on vehicle odometers following the main roads and accessible routes.

A major wheat rust survey was conducted along the two diagonals in an ''×'' fashion. A total of five quadrants of 2 m × 2 m (4 $m^2$ quadrats) were selected at approximately 20–50 m distances from each other. In the study field, wheat crops within the quadrant were counted and recorded as diseased and healthy plants. To record the major rust severity, 10 plants per spot were counted, and the assessment was made on plant parts per plant. The average of the ten plants represented the rust severity. In each quadrant, visual rating was used to assess major wheat rusts. The prevalence, incidence and severity of the fields were calculated following methods developed by Bernier *et al.* (1985) and Ding *et al.* (1993). Disease prevalence (%) was calculated as the number of fields affected by major wheat rusts and the total number of fields assessed and expressed as percentages.

$$\text{Prevalence} = \frac{\text{No of infected fields}}{\text{Total no of fields assessed}} \times 100$$

Disease incidence was calculated as the percentage of infected plants to the total number of plants counted per spot.

$$\text{Incidence} = \frac{\text{Total number of diseased plants}}{\text{Total number of plants assessed}} \times 100$$

Disease severity (%) The severity of diseases was examined as the percentage of plant part (tissue) affected by visually observing the sampled plants within the quadrants and was recorded using the scoring scale severity disease as described by Peterson *et al.* (1948).

$$\text{Disease severity} = \frac{\text{Area of plant tissue affected by diseases}}{\text{Total area}} \times 100$$

$$\text{PSI} = \frac{\text{Sum of individual disease rating}}{(\text{Total No. plants})(\text{Maximum disease grade})} \times 100$$

**Field experiment**

For this experiment, four types of fungicides with five wheat varieties were used, forming twenty-five treatments with a control. Fungicides (Jeba, Progress, Natura 250 EW, and Dipcoron) were applied as per standard recommendations. Plots were sprayed every 14 days, and the first spray was applied at rust onset. A knapsack sprayer was used to apply the fungicides. Plastic sheets were used to separate the plot being sprayed from the adjacent plots to reduce fungicide drift.

Wheat cultivars Hidase, Shorima, Wane, Limu and Danda'a, which react differently to leaf rust, yellow rust *(Puccinia striiformis* f.sp. *tritici* W) and stem rust *(Puccinia graminis* f.sp. *tritici)* diseases were planted at a major rust hot spot location in the Gemechis (farmer training center) district in the west Hararghe highlands. A seed rate of 150 kg/ha and a fertilizer rate of 41/46 kg/ha N/P2O5 were used. The test fungicides JEBA 25%, Progress, Natura 250EW and Dipcoron were sprayed at rates of 0.5, 0.6, 0.5 and 1 L/ha, respectively. Fungicides were applied at a 5% severity level of leaf and yellow rust (booting crop growth stage) and at a 2% severity level of stem rust. The fungicides were sprayed using a Knapsack sprayer delivering 250 litters of water/ha. Biomass and grain yield data were determined on the basis of crops harvested from 3 m × 3 m harvestable plot areas and converted to hectares. Rust severity was recorded as a percentage using the modified Cobb Scale (Peterson *et al*., 1948).

**Wheat rust disease assessment**

The rust severity was estimated as the proportion of the leaf and head infection of a plant affected by the disease. The disease severity was recorded weekly from the time of symptom appearance to physiological maturity of the crop by using the modified Cobb's scale (Peterson *et al*., 1948) from 10 randomly pre-tagged plants. The average severity from the 10 plants of each plot was used for analysis. During disease assessment, the growth stage of the crop was recorded to observe the onset and progress of the disease in relation to wheat phenology. Crop growth stage was assessed based on the decimalized key developed by Zadoks *et al*. (1974). Rust severity data were obtained based on percentage scores of leaf area with symptoms/signs. Fully formed pustules were considered those with abundant sporulation. Following the appearance of the first symptoms, five infected wheat leaves were sampled from each plot at weekly intervals up to the kernel hard dough stage.

**Data collection**

Data were collected on various parameters, including rust severity, AUDPC, and rate of disease infestation. Severity was assessed and recorded using the modified Cobb's scale (Peterson *et al.,* 1948) by assessing agronomic tillers per plant (total and fertile tillers were recorded), plant height (cm), number of grains per spike, thousand kernel weights, and grain yield (tonne) were subjected to analysis of variance as suggested by Gomez and Gomez using SAS software (Version, 2009). Least significant difference at LSD 5% was used to compare treatment means.

**Cost benefit analysis**

The cost and benefit of each treatment were analysed partially, and the marginal rate of return was computed by considering the variable cost available in the respective treatment. Variable costs included chemical costs and labor costs for fungicide application. Yield and economic data were collected to compare the advantages and costs of fungicides. Price of wheat crop (birr/ton) obtained from the local market and total sale from one hectare were computed. The price of the wheat at the local market (birr/ton) was 30,000. The price of fungicide progress, Jeba, Natura and Diprocon were Ethiopian birr (ETB) 300, 250, 400, 250, ETB/L, respectively, for each type of fungicide.

The cost of labor for fungicide application was 100 ETB per day. Based on the obtained data from the experimental site, cost–benefit analysis was performed using partial budget analysis. Partial budget analysis is a method of organizing data and information about the costs and benefits of various agricultural alternatives (CIMMYT, 1988). Partial budgeting is employed to assess the profitability of any new technologies (practices) to be imposed on the agricultural business. Marginal analysis is concerned with the process of making choices between alternative factor-product combinations considering small changes. The marginal rate of return is a criterion that measures the effect of additional capital invested on net returns using new management compared with the previous management (CIMMTY, 1988). It provides the value of benefit obtained per the amount of additional cost incurred percentage.

The formula is as follows:

$$\text{MRR} = \frac{\text{DIC}}{\text{DNI}}$$

Where MRR is the marginal rate of returns; DNI is the difference in net income compared with the

control; and DIC is the difference in input cost compared with the control.

The following points were considered during cost–benefit analysis using a partial budget.

- Cost of all agronomic practices and treatments within the site,
- Price of wheat per ton for each variety,
- The costs of fungicides and labor were taken based on the price in study areas.
- Costs return and benefit were calculated per hectare basis.
- It was assumed that the farmers produce these varieties using fungicide management when the varieties provide a 100% marginal rate of returns.

**Data analysis**

Analysis of variance (ANOVA) was performed using the SAS General Linear Model (GLM) procedure (SAS version 9.00, Inst. 2002), and mean comparisons were made among treatments using Duncan's multiple range test (DMRT) at 0.05 levels of significance, and descriptive statistics were used.

## RESULTS AND DISCUSSION

**Disease survey**

These results showed that wheat rusts were observed in all assessed fields. This finding is in line with the evidence of (MoARD, 2009), which states the regular occurrence of major rusts depending on weather conditions. However, the intensity of the disease varied among districts. A higher rust prevalence was recorded in the Gemechis districts (85%), followed by the Oda Bultum districts (63.8%) (Table 1). The survey results also indicated that there was high disease severity, incidence and prevalence in the study areas.

**Table 1**. Major wheat rust intensity during the 2020 main cropping season in West Hararghe

| District | No. of fields assessed | Leaf rust % | | | Yellow rust (%) | | | Stem rust (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | PR | IN | SV | PR | IN | SV | PR | IN | SV |
| Gemechis | 25 | 100 | 49.3 | 11.5 | 100 | 60.7 | 21.5 | 100 | 85.5 | 28.5 |
| Oda Bultum | 25 | 100 | 47.3 | 13.5 | 100 | 47.3 | 21.0 | 100 | 63.8 | 23.5 |
| Chiro | 25 | 100 | 58.3 | 22.5 | 100 | 59.0 | 11.0 | 100 | 61.5 | 22.5 |
| Tulo | 25 | 100 | 49.1 | 15.0 | 100 | 57.7 | 16.0 | 100 | 32.0 | 18.0 |
| Habro | 25 | 100 | 57.2 | 10.0 | 100 | 38.7 | 81.5 | 100 | 44.7 | 11.0 |

PR= prevalence; IN= Incidence ; SV= severity

The results showed that the incidence of major wheat rusts ranges from 10–100% (Table 1). The highest mean disease incidence and severity of 85.5 and 22.5%, respectively, were recorded in Gemechis district. The lowest mean disease incidence and severity were recorded in Tulo district, with means of 61.5 and 11.0%, respectively (Table 1).

In the present study, the status of major wheat rusts was assessed. The intensity of rusts differed from one district to another, as the obtained results indicate. The three rusts also differed across the agro ecologies of west Hararghe, which is consistent with the general concept of wheat rust epidemiology.

Disease intensity measurement for field experiment

Wheat rust epidemics, severity and reaction and yield vary in five different varieties treated with four fungicides and (unsprayed) bread wheat varieties. Wheat rusts were observed at the early tillering growth stage (45–60) of bread wheat at the experimental site. Under natural epidemics (no spray) at the Gemechis terminal, severity levels of yellow, leaf and stem rusts were observed at 13.8, 17.6 and 41.0%, respectively. Lower levels of yellow, leaf and stem rust severity were observed on the Danda'a variety with jeba fungicide application, while the highest yellow, leaf and stem rust levels were observed on the Hidase variety with nail application.

Released bread wheat varieties interaction Fungicide application significantly reduced (leaf, yellow and stem rusts) disease severity over the nil application of susceptible varieties. Similarly, it was reported by Jonaviciene (2014) that tebuconazole fungicide reduced the disease intensity of wheat stem rust by 71.5% relative to untreated plots. However, there was no statistically significant difference among the Danda'a variety with jeba fungicide application, Limu variety with progress fungicide application and Shorima variety with natura fungicide application in reducing leaf, yellow rust and stem rust disease severity (Table 1).

As shown in Table 1, tested fungicides and varieties, Danda'a with jeba, Lime with progress and Shorima with natura significantly reduced leaf rust, yellow rust and stem rust disease severity to the lowest level possible over the nil application. The tested fungicides and varieties, Danda'a with jeba, Lime with progress and Shorima with natura, significantly reduced yellow rust, leaf rust and stem rust disease severity by approximately 0.500, 1.133 and 1.267%, respectively, compared to the unsprayed plot.

It is evident from visual field observations and Table 1 data analysis results that the test fungicides, Jeba25% EC and Progress, showed comparable levels of efficacy on leaf rust, yellow rust and stem rust

disease severity reduction compared to the standard check. Diprocon and Natura showed better levels of efficacy on leaf rust, yellow rust and stem rust disease severity reduction compared to the standard check. Therefore, Jeba 25% EC, Progress, Diprocon and Natura can be recommended for the control of wheat rust diseases (leaf rust, yellow rust and stem rust).

**Table 2**. Effect of released bread wheat variety-fungicide interaction against yellow, leaf and stem rusts

| Treatments | Yellow rust | | Stem rust | | Leaf rust | |
|---|---|---|---|---|---|---|
| | Severity | Incidence | Severity | Incidence | Severity | Incidence |
| V2F3 | 1.87 | 31.44 | 1.47 | 30.02 | 2.51 | 31.95 |
| V2F1 | 10.90 | 37.25 | 21.79 | 62.51 | 13.33 | 55.22 |
| V5F5 | 1.40 | 36.66 | 1.20 | 30.06 | 2.50 | 32.26 |
| V3F5 | 4.90 | 42.19 | 4.33 | 40.05 | 8.66 | 48.82 |
| V3F1 | 9.50 | 43.48 | 29.00 | 56.22 | 13.50 | 54.94 |
| V3F4 | 3.00 | 32.67 | 13.33 | 51.42 | 5.33 | 39.36 |
| V4F5 | 1.26 | 30.23 | 1.23 | 37.41 | 2.40 | 25.37 |
| V1F1 | 12.00 | 40.37 | 41.00 | 38.16 | 17.66 | 55.81 |
| V1F5 | 6.90 | 31.12 | 15.20 | 52.76 | 10.00 | 38.53 |
| V1F3 | 8.00 | 50.37 | 6.50 | 43.22 | 10.00 | 44.29 |
| V3F2 | 6.10 | 36.08 | 14.46 | 36.68 | 8.00 | 45.52 |
| V3F3 | 8.16 | 38.76 | 16.50 | 40.98 | 9.67 | 47.69 |
| V4F1 | 10.10 | 49.28 | 29.70 | 50.98 | 12.80 | 40.48 |
| V2F5 | 1.33 | 31.13 | 1.81 | 44.16 | 2.96 | 27.46 |
| V4F4 | 0.50 | 21.92 | 1.26 | 19.57 | 1.13 | 23.57 |
| V4F2 | 3.63 | 17.50 | 2.48 | 22.54 | 3.26 | 24.70 |
| V5F4 | 1.53 | 34.04 | 1.00 | 32.83 | 2.36 | 32.73 |
| V1F2 | 6.10 | 43.62 | 15.10 | 33.88 | 7.33 | 53.69 |
| V5F1 | 13.87 | 48.72 | 11.57 | 46.53 | 16.97 | 56.31 |
| V5F3 | 2.76 | 34.11 | 2.03 | 39.29 | 4.13 | 33.29 |
| V2F2 | 2.83 | 33.78 | 2.23 | 29.77 | 3.60 | 28.30 |
| V5F2 | 1.16 | 26.77 | 1.06 | 27.17 | 2.22 | 22.77 |
| V4F3 | 1.40 | 23.56 | 1.13 | 25.23 | 1.56 | 30.02 |
| V1F4 | 12.36 | 29.36 | 19.11 | 31.74 | 13.33 | 44.88 |
| V2F4 | 0.90 | 26.15 | 2.50 | 25.05 | 1.70 | 32.97 |
| LSD 5% | 1.16 | 5.24 | 1.04 | 7.49 | 1.45 | 5.42 |
| CV% | 28.67 | 26.59 | 20.85 | 25.03 | 26.28 | 24.62 |

**Effect of fungicide and vulnerability interaction on yield components**

Tiller Number: The effects of bread wheat variety fungicide application on the number of tillers showed statistically significant differences ($P \leq 0.01$) among the treatments (Table 3). The results showed that the highest number of tillers was recorded in the treated plots, whereas the lowest number of tillers was recorded in the unsprayed check. The higher number of tillers recorded in the plot treated with jeba fungicide might be due to the greater effectiveness of jeba fungicide and the ability of the Danda'a variety to resist stem rust on wheat tillers. Wheat rust resulted in lower infection, thus increasing the number of tillers.

Spike length: The effect of fungicide treatments on spike length was significant ($P \leq 0.01$). The highest spike length was recorded in Danda'a with jeba fungicide, followed by Shorima with natura, whereas the lowest spike length was recorded in the Hidase variety with nail application. The data revealed that the application of fungicides increased grains per spike compared with the unsprayed check in of grains per spike.

Plant Height: There was a significant difference ($P \leq 0.01$) in plant height among the released bread wheat-fungicide interaction and control application treatments. However, there was no significant difference among Limu with Natura, Limu with Dipcoron, Shorima with Dipcoron and Danda'a with Jeba. Even though there was no statistically significant difference among treatments, there was better plant height obtained from Danda'a with Jeba and other tested fungicide sprayed plots, while the lowest plant height was obtained from the nil application with the Hidase variety. All test fungicides resulted in a longer plant height than the Hidase variety with nail application.

Kernel Height: The effect of bread wheat variety–fungicide on kernel height showed a statistically significant difference ($P \leq 0.05$). The highest length of kernels was recorded in Danda'a with jeba fungicide application, followed by Shorima with natura fungicide application, whereas the lowest was recorded in the Hidase variety with nail application. The analysed data revealed that the application of fungicides with the Danda'a variety increased kernel height compared with the unsprayed control. This

result is in agreement with the work of Hailu and Fininsa (2007), who reported a relatively better yield for sprayed plots than for unsprayed plots under experimental conditions.

**Table 3**. Grain yield, thousand kernels, and grain corresponding relative losses due to wheat rust under different fungicide sprays at Gemechis in the 2020 main season in eastern Oromia, Ethiopia

| Treatments | PH | NT | TSW | NK | KH | SPL | GY |
|---|---|---|---|---|---|---|---|
| V2F3 | 65.98 | 4.73 | 3.95 | 50.27 | 9.73 | 7.57 | 11.83 |
| V2F1 | 64.14 | 4.17 | 2.40 | 38.30 | 6.27 | 7.00 | 13.93 |
| V5F5 | 67.80 | 4.87 | 3.56 | 49.98 | 7.34 | 6.80 | 16.26 |
| V3F5 | 65.40 | 4.73 | 3.86 | 45.94 | 9.17 | 7.30 | 15.31 |
| V3F1 | 56.25 | 3.25 | 2.54 | 36.03 | 9.10 | 6.15 | 9.13 |
| V3F4 | 65.13 | 4.70 | 3.85 | 35.91 | 8.90 | 7.90 | 15.37 |
| V4F5 | 74.46 | 4.73 | 4.34 | 51.62 | 9.80 | 7.57 | 18.80 |
| V1F1 | 57.80 | 4.57 | 3.47 | 44.33 | 9.50 | 5.80 | 7.22 |
| V1F5 | 59.10 | 4.73 | 4.12 | 35.85 | 10.00 | 5.93 | 9.86 |
| V1F3 | 75.55 | 5.50 | 3.18 | 41.33 | 9.60 | 9.90 | 22.58 |
| V3F2 | 72.46 | 4.73 | 2.72 | 50.81 | 8.40 | 8.73 | 21.17 |
| V3F3 | 65.76 | 4.73 | 2.73 | 34.85 | 8.23 | 7.27 | 15.66 |
| V4F1 | 73.46 | 4.97 | 3.67 | 40.88 | 8.20 | 8.03 | 13.76 |
| V2F5 | 65.26 | 4.57 | 3.34 | 48.11 | 9.27 | 6.63 | 12.38 |
| V4F4 | 71.76 | 4.33 | 4.11 | 64.87 | 8.83 | 7.63 | 29.16 |
| V4F2 | 73.56 | 5.70 | 3.22 | 60.17 | 8.27 | 7.30 | 15.61 |
| V5F4 | 63.76 | 5.57 | 3.93 | 34.33 | 10.20 | 6.87 | 11.140 |
| V1F2 | 52.66 | 3.93 | 3.82 | 38.10 | 8.30 | 5.47 | 8.83 |
| V5F1 | 62.90 | 4.32 | 3.01 | 36.48 | 8.75 | 6.87 | 11.05 |
| V5F3 | 64.60 | 4.03 | 3.35 | 43.98 | 9.47 | 6.60 | 25.33 |
| V2F2 | 60.70 | 3.80 | 3.39 | 42.78 | 7.67 | 7.17 | 10.28 |
| V5F2 | 61.40 | 4.43 | 3.69 | 54.56 | 8.63 | 7.20 | 12.46 |
| V4F3 | 66.63 | 4.56 | 3.95 | 59.59 | 8.50 | 8.13 | 14.40 |
| V1F4 | 66.26 | 4.43 | 3.64 | 51.84 | 8.07 | 7.33 | 14.09 |
| V2F4 | 66.90 | 5.03 | 3.50 | 69.92 | 8.80 | 8.567 | 13.43 |
| LSD 5% | 3.02 | 0.60 | 0.32 | 6.76 | 0.8 | 0.61 | 2.34 |
| CV% | 8.09 | 22.99 | 15.93 | 25.55 | 15.97 | 14.89 | 30.09 |

CV=coefficient of variation, PH= plant height (cm), NT= number of tillers, SPL= spike length (cm), KH = kernel height, TSW= thousand seed weight (g), GY/ha=grain yield per hectare (kg)

**Effect of fungicide and variety interaction on yield**

Results revealed that there was a statistically significant difference ($P \leq 0.01$) in grain yield among the bread wheat varieties treated with fungicides. The yield of varieties ranges from 882 kg/ha to 2916 kg/ha with a mean value of 1899 kg/ha. The highest grain yield was recorded in Danda'a applied with jeba fungicide (2916 kg/ha), followed by Shorima applied with natura fungicide (2533 kg/ha). The lowest grain yield was recorded from the Hidase variety applied with nails (882 kg/ha). This result is in line with the result of Ransom and McMullen (2008) who reported that within an environment and across wheat cultivars, fungicides improved yields. Tadesse, Amare, and Ayalew (2010) also reported that the application of fungicides was found to be the best treatment in reducing stem rust infection and producing a higher grain yield compared to unsprayed treatment in wheat crops. All tested fungicides showed better grain yield advantages over the unsprayed plot. Different studies from different areas have demonstrated yield increases in wheat due to fungicide application and resistant varieties (Table 3).

The statistical analysis showed that there was no significant difference among the tested wheat varieties with Danda'a, Limu and Shorima interaction fungicides and the standard check fungicide in grain yield, thousand kernel, spike length plant height, tillering number and kernel length. Moreover, there was no significant difference among the test fungicides for the abovementioned agronomic parameters. Although there was no statistically significant difference in grain yield, thousand kernel, spike length plant height, tillering number and kernel length among these treatments and Danda'a with jeba fungicide application, relatively higher grain yield, thousand kernel, spike length plant height, tillering number and kernel length were obtained. However, the difference is insignificant to differentiate the effect of the chemicals and varieties. This statement agrees with the report of Wubishet Alemu and Tamene Mideksa (2016) stated that there was a non-significant difference among different fungicides on the thousand grain weight of wheat infected by rust disease. There was a highly significant difference in grain yield, thousand kernels, spike length, plant height, tillering number and kernel length between fungicide treatments and the Hidase variety with no application. All test varieties with fungicide application revealed better grain yield advantages

than the standard unsprayed plots. Test and check fungicides also revealed a significant yield advantage over unsprayed plots.

**Cost benefit analysis**

Differences in net benefit were obtained among the treatments. Only the wheat grain yield was considered for sale. The wheat grain yield, sales, costs incurred due to the use of fungicides and the net benefit relative to the benefits obtained from the untreated control plot were calculated (Table 4).

The cost of water was assumed to be zero. The wheat grain yield was based on the average west Hararghe zone gate price of wheat between March and April 2021 obtained from personal communication with the west Hararghe zone finance department. Among the treated plots, the calculated value for the partial cost benefit showed that the maximum total gross yield benefit (55, 9500 ETB /ha) was obtained from plots that received fungicide progress, followed by plots that received the fungicide Natura (466500 ETB/ha) (Table 4). However, lower gross yield benefits (341400 ETB/ha) and (29400 ETB/ha) were obtained from plots that received Dipcoron. However, these plots had higher gross yields than the untreated control (223500 ETB/ha) plot. Generally, plots treated with fungicide progress resulted in the highest gross yield benefit, followed by plots treated with the fungicide Natura relative to plots treated with the fungicides Jeba and Dipcoron (Table 4).

**Table 4**. Results of partial budget analysis for the management of stem wheat rust disease

| Fungicide | Natura | Jeba | Diprocon | Progress | Control | Mean |
|---|---|---|---|---|---|---|
| Yield ($tha^{-1}$) | 13.93 | 29.16 | 11.83 | 15.31 | 7.22 | 15.49 |
| Price ($ETBqt^{-1}$) | 2000 | 2000 | 2000 | 2000 | 2000 | 2000 |
| Sale revenue(1x 2) | 27860 | 58320 | 23660 | 30620 | 14440 | 30980 |
| Marginal cost($ETBha^{-1}$) | 3549 | 3549 | 3549 | 3549 | 0 | 2957.5 |
| Net profit(3-4) ($ETBha^{-1}$) | 24311 | 54771 | 20111 | 27,071 | 14440 | 28022.5 |
| Marginal benefit ($ETBha^{-1}$) | 24014 | 6794 | 20819 | 33209 | 0 | 16079.28 |
| Marginal rate of return (7/5 (%) | 4198 | 1188 | 5751 | 4247 | 0 | 2375.57 |

## CONCLUSIONS

A field survey on major wheat rusts was conducted in west Hararghe to identify the intensity of leaf, yellow and stem rusts. The highest and lowest wheat rust incidences were recorded in the Gemechis and Tulo districts, with values of 85.5 and 32.0%, respectively. Similarly, the highest and lowest wheat rust severity was recorded in the Gemechis and Tulo districts, with values of 28.5 and 11.0%, respectively. Of the three major rusts, stem rust is the most severe disease of wheat in all locations under study, with an incidence of 85.5% and a severity of 28.5%. A field experiment was conducted to evaluate the interaction of some selected foliar fungicides with released bread wheat varieties. From the evaluated fungicides and bread wheat varieties, Danda'a with jeba and Shorima with progress were the most effective in controlling the three major wheat rusts.

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