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# Evaluation of Fungicides for the Management of Tef Leaf Rust (*Uromyces eragrostidis*) in Tef at East and North Shoa, Ethiopia

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## ABSTRACT

Tef leaf rust disease caused by *Uromyces eragrostis* is the widely distributed tef disease. Currently, an evaluation of different fungicides for the control of tef leaf rust is very crucial to tackle and minimize yield loss caused by this pathogen. Therefore, the activity aimed to identify effective fungicide(s) for the control of tef leaf rust disease in the country. The experiment was conducted at Minjar substation and Debre Zeit on station from 2019 to 2020 main cropping seasons to test Rex Duo, Tilt, Nativo and Natura 250 EW fungicides against the disease. Due to heterogeneity of disease parameters data combined analysis was not done for the two locations. The application of different fungicides created significantly different levels of terminal tef leaf rust severity on tef variety Quncho. Quncho is susceptible to tef leaf rust and enabled the assessment of the effects of tef leaf rust disease on tef grain yield, shoot biomass and lodging index during the cropping seasons. The analysis of variance revealed that there was no significant difference among Rex Duo and Tilt fungicides at Minjar site for tef yield but the highest grain yield was obtained through the application of Rex Duo (3.9tha$^{-1}$). At this location application of Rex Duo (18.8tha$^{-1}$) was significantly different from Tilt application for shoot biomass and lodging index 74.3%. At Debre Zeit; the maximum tef yield of 2.4tha$^{-1}$ and shoot biomass of 14.5tha$^{-1}$ were obtained from treated plots through the application of Rex Duo. Tilt 250EC application showed the mean value of 2.2tha$^{-1}$ and 12.9tha$^{-1}$ grain yields and shoot biomass of Quncho tef varieties, respectively. Generally, disease parameters resulted the lowest mean value under the plots treated by Rex Duo at Minjar and Debre Zeit locations. *It is marked that, the fungicide Rex Duo control the leaf rust disease of tef effectively as compared to other fungicides used in this evaluation.* It is therefore recommended that the application of fungicide Rex Duo *is the best control option in controlling leaf rust disease of tef.*

**Keywords:** Tef; Fungicides; Yield; Shoot biomass; Tef leaf rust

## INTRODUCTION

Tef [*Eragrostis tef* (Zucc.) Trotter] is an indigenous staple cereal crop of Ethiopia. There is no doubt that tef is a very ancient crop in Ethiopia, where domestication took place before the birth of Christ. Tef is an important cereal crop in Ethiopia. In 2018/19, it was estimated that tef made up to 24.17% of all the cultivated area in Ethiopia, covering about 3.1 million hectares and grown by 7 million farmers (CSA 2018/19). Tef is grown in almost all regions of the country for home consumption since it is a preferred grain, and for the local market, since it fetches the highest grain price compared with other cereals and is used as a cash crop by farmers. Although the crop is dominantly cultivated as sole crop, it is also grown as an intercrop or mixed crop, relay crop, or in rotation with several types of crops [1,2]. The crop is grown both in belg (short rainy) and Meher (long rainy) seasons.

Tef leaf rust disease of tef caused by *Uromyces eragrostis* is the widely distributed tef disease in Ethiopia [3]. According to Tadesse [4] citing Castellani, et al. tef leaf rust causes an average yield loss of 10-25%. Leaf rust of tef can be managed by various means. Among which, early planting, the use of the genetic tolerance or resistant cultivars are the most effective, environmentally friendly, and sound methods. All the tef genotypes observed during the survey were showed the reaction from moderately susceptible to susceptible response against tef leaf rust disease [3]. Under such a scenario, fungicide interference is crucial to control this disease.

In Ethiopia, several fungicides were registered and recommended for the management of rust diseases of wheat and this has been reviewed by Yeshi [5] and Bekele [6] and a more recent review in this regard was by Ayele, et al. [7].

Though tilt fungicides were recommended for the control of tef

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leaf rust on tef based on the recommendation done for other crops like wheat, no attempt was made to integrate varieties and different fungicides applications in tef that is valuable for the integrated management of tef leaf rust.

Currently, an evaluation of different fungicides for the control of tef leaf rust is very crucial to tackle this disease and minimize yield loss caused by this pathogen. Therefore, the activity aimed to identify effective fungicide(s) for the control of tef leaf rust disease in the country.

## MATERIALS AND METHODS

### Description of experimental areas

The experiment was conducted at two locations (Minjar sub-station and Debre Zeit on the station) for two years (2018/19 and 2019/20) main cropping seasons. The experiment was carried out at Debre Zeit Agricultural Research Centre (DZARC) located at latitude of 8°44 'N, longitude of 39°02' E. Debre Zeit is mid-highland with altitude of 1900 m.a.s.l. and characterized by moderate rainfall (851 mm total annual rainfall); average minimum temperature of 8.9°C and mean maximum temperature of 28.3°C. The soil is characterized as pellic vertisol. Minjar is located at latitude of 9°09′ 60.00″ N and longitude of 39°19′ 60.00″ E at an altitude of 1040 meter m.a.s.l. The soil type is slightly vertisol.

### Treatments and experimental design

The study was conducted by using experimental design of randomized complete block design with a factorial arrangement with three replications. The experiment contained five treatments (Nativo SC 300, Natura 250 EW, Rex Duo, Tilt 250 EC* and untreated plot). Each fungicide was applied at a recommended rate of company basis for the control of other cereal diseases like wheat rusts and others. During fungicides application, the plots that receive fungicides were sheltered with plastic sheet supported by four wooden poles to protect the drift of fungicide to the next plots.

Tef cultivar Quncho that was relatively vigor and show susceptible reaction to tef leaf rust was utilized. The trial was planted in 2.5 m plot length and 1.2 m width at each site. The recommended seed rate of 15 kg/ha was used during planting. The planting was done manually by hand drill at both sites. There was no artificial inoculation of Quncho variety to have high disease pressure and rather the trial was planted at hot spot areas for tef leaf rust disease. Four different fungicides having different active ingredients were applied for the control of tef leaf rust (Table 1).

The spray of fungicides was done once the disease observed on the trial. All plots received one-time fungicide spraying during the heading of tef crop. The check is left untreated for comparison.

### Data collection and analysis

Disease scoring was done using the modified Cobb's scale [8] and the reaction as recommended for other cereal by Roelfs, et al. but without having a resistant (R) type of response [3]. Three times disease scoring was done at ten days interval during the cropping season. The first scoring was done before the application of each fungicide and the rest two scoring were done after spraying of fungicides.

The average coefficient of infection (ACI) for the variety was computed as follows:

$$ACI = \frac{DS(\%)\ X\ \text{Constant value for each response}}{\text{Total number of observation}}$$

Where 'ACI' = Average Coefficient of Infection

DS= Disease severity percentage

The AUDPC is calculated using the midpoint rule method [9] as follows.

$$AUDPC = \frac{\sum_{i=1}^{n-1}\left(Yi + Y_{i+1}\right)}{2} x\left(ti + 1 - ti\right)$$

Where "y" is the percentage of affected tissue at each reading,

"t" is time in days of each reading and "n" is the number of readings.

The Area under Disease Progress Curve (AUDPC) and terminal severity data was used to compare treatments.

Data on terminal tef leaf rust severity (TRS), area under disease progress curve (AUDPC), the average coefficient of infection (ACI), Lodging index, shoot biomass and grain yield were subjected to analysis of variance using GLM procedure of the System Analysis Software (SAS, 2004) [10]. Least Significant Difference (LSD 0.05) was employed to compare treatment means. Data on disease parameters, shoot biomass, lodging index and yield were correlated using the Proc-Corr procedures of SAS, 2004 [10].

## RESULTS AND DISCUSSION

Due to heterogeneity of data over cropping years at each locations, combined analysis of terminal tef leaf rust severity, Area under disease progress curve (AUNDPC), Average coefficient of infection, grain yield, Shoot biomass and lodging Index were not done.

### Disease parameters

### Terminal stem rust severity

Mean terminal tef leaf rust severity on untreated unsprayed plots at Minjar site recorded the highest value of 41.7% (Table 2). Terminal tef leaf rust severity on treated plots by different fungicides varied

**Table 1:** Fungicides used for evaluation against leaf rust of tef and control at Debre Zeit on station and Minjar sub-station.

| Lists | Trade Name | Common Name | Application Rate |
|---|---|---|---|
| 1 | *Nativo SC 300* | *trifloxystrobin 100gm/lt + tebuconazol 200 gm/lt* | 0.9 l/ha |
| 2 | *Natura 250 EW* | *Ebuconazole* | *0.5 l/ha* |
| 3 | *Rex duo* | *Epoxiconazole + Thiophanatemethy* | *0.5 l/ha* |
| 4 | *Tilt 250 EC** | *Propiconazole* | *1 l/ha* |
| 5 | | *Untreated/ Check/Control* | |

between 10 and 17.5%. Tef leaf rust disease level was reduced significantly through the application of different fungicides (Nativo with mean value of 17.5%, Tilt with mean value of 16.7%, Natura *250EW* with mean value of 15% and Rex Duo with mean value of 10%), suggesting a significant reduction in tef leaf rust disease level as the result of fungicides sprayed (Table 2).

At Debre Zeit, the highest mean value of terminal leaf rust severity (45.7%) was recorded on unsprayed plots. At this location the terminal tef leaf rust severity was varied from 11.2 to 16.7 % under different fungicide treatments. The lowest terminal tef leaf rust was recorded on the plots treated by Rex Duo (11.2%) and followed by Natura (12%) and Tilt (15%) treated plots. Plots treated under Nativo showed the highest severity as compared to the three fungicides (Rex Duo, Natura and Tilt) as showed in Table 2.

Generally, the lowest mean value of terminal tef leaf rust was recorded at Minjar (10%) and Debre Zeit (11.2%) under the treatment Rex Duo. The Rex Duo fungicide application was thus considered the most effective as it led to the lowest terminal stem rust severity both locations (Table 2). This finding was similar with the finding of Stephen et al. which reported that application of fungicides effectively reduced disease severity. Mamdouh AA, et al. [11] also reported that the Tilt protected remained almost free from stem rust of wheat which is similar to these findings.

## Area under disease progress curve (AUDPC)

The Mean value of Area under Disease Progress Curve (AUDPC) on unsprayed plot showed the highest value of 336.3 (Table 2). AUDPC on treated plot by different fungicides varied between 79.2 and 177.2. The AUDPC was reduced significantly through the application of different fungicides (Nativo with mean value of 177.2, Tilt with mean value of 139.2, Natura with mean value of 134.8 and Rex Duo with mean value of 79.2), suggesting a significant reduction in tef leaf rust disease level as the result of fungicides sprayed.

At Debre Zeit, the highest mean value of area under disease progress curve (357.9) was recorded on unsprayed plots. At Debre Zeit location the mean value of area under disease progress curve for treated plots were varied from 62.7 to 149.8 under different fungicide treatments. For this disease parameter the lowest was recorded on the plots treated by Rex Duo (62.7) and followed by Natura (108.5 and Tilt (130.7) treated plots. Plots treated under Nativo showed the highest area under disease progress curve (AUDPC) as compared to the three fungicides (Rex Duo, Natura and Tilt) (Table 2).

Generally, at both locations (Minjar and Debre Zeit) the lowest area under disease progress curve was recorded under the application of Rex Duo (*Epoxiconazole + Thiophanatemethy) and followed by fungicide Natura 250EW (Ebuconazole).*

## Average coefficient of infection

At Minjar sub-station average coefficient of infection on unsprayed plot accounts for about 26.7% and it was highly significantly different from other treated plots by different fungicides. The lowest average coefficient of infection was recorded through the application of fungicide Natura 250EW as compared to other treatments having the mean value of 6.7% and followed by Rex Duo accounting 6.8% (Table 2). Generally, the lowest disease parameters were recorded under different fungicides application as compared to unsprayed plot.

At Debre Zeit location, the highest average coefficient of infection on untreated plot was recorded having the mean value of 33.7%. On the other hand; the entire treated plot showed lowest average coefficient of infection as compared to untreated plot having different mean value. The lowest mean value of average coefficient of infection (6.1%) was recorded on plots treated by Rex Duo fungicide and followed by Natura 250EW having the mean value of 8.2% (Table 2).

Generally, Rex Duo and Natura 250EW showed the lowest average coefficient of infection at both locations (Minjar and Debre Zeit) as compared to other fungicides.

## Grain Yield, shoot biomass and Lodging index

## Grain Yield of Tef

Estimating yield loss by disease is a prerequisite to develop strategies for disease control particularly through breeding objectives for disease resistance or tolerance [12]. At Minjar Sub-station, the yield on untreated plots accounted for about 2.7tha$^{-1}$ on the variety Quncho. The yield varied from fungicide to fungicides. In all the cases the treated plots give higher tef yield than the untreated plots (Table 3).

The maximum tef yield of 3.9 tha$^{-1}$ was obtained from treated plots through the application of Rex Duo and followed by Tilt having the mean value of 3.4 tha$^{-1}$ from Quncho tef varieties; whilst grain yields of 3.3tha$^{-1}$ was obtained from fungicide treated plot by Natura 250 EW (Table 3). As compared to the three fungicides the lowest tef yield was obtained under the application of Nativo fungicide at Minjar location (Table 3). Results suggest the effect of fungicides

**Table 2:** Effect of different fungicides on TRS, ACI and AUDPC mean values of tef rust on Quncho variety treated with different fungicides.

| | Minjar Sub-Station | | | Debre Zeit On-Station | | |
|---|---|---|---|---|---|---|
| Treatments | TRS. | ACI | AUDPC | TRS. | ACI | AUDPC |
| No spray | 41.7$^{a}$ | 26.7$_{b}$ | 336.3$_{b}$ | 45.6$^{a}$ | 33.7$^{a}$ | 357.9$^{a}$ |
| Nativo | 17.5$_{b}$ | 14.7$_{b}$ | 177.2$_{bc}$ | 16.7$^{b}$ | 11.9$^{b}$ | 149.8$^{b}$ |
| Tilt | 16.7$_{b}$ | 12$_{b}$ | 139.2$_{bc}$ | 15$^{b}$ | 10.9$^{b}$ | 130.7$^{b}$ |
| Natura | 15$_{b}$ | 6.7$_{b}$ | 134.8$_{c}$ | 12.5$^{b}$ | 8.2$^{b}$ | 108.5$^{cb}$ |
| Rex duo | 10 | 6.8 | 79.2 | 11.2$^{b}$ | 6.1$^{b}$ | 62.7$^{c}$ |
| Mean | 20.2 | 15.9 | 173.3 | 19.4 | 14.2 | 161.9 |
| CV(%) | 32.6 | 31.6 | 27.1 | 32.5 | 57.5 | 29.6 |

**TRS:** Terminal Rust Severity; **ACI:** Average Coefficient of Infection; **AUDPC**: Area Under Disease Progress Curve

**Table 3:** Effect of different fungicides on yield, shoot biomass and lodging index values of tef rust on Quncho variety treated with different fungicides.

| | Minjar Sub-Station | | | Debre Zeit On-Station | | |
|---|---|---|---|---|---|---|
| **Treatments** | **Yield (t/ha)** | **SBM t/ha** | **LI** | **Yield (t/ha)** | **SBM t/ha** | **LI** |
| No spray | $2.7^{b}$ | $14.8^{c}$ | $90.7^{a}$ | $1.5^{c}$ | $7.3^{d}$ | $95.2^{a}$ |
| Nativo | $3.4^{a}$ | $16.3^{b}$ | $83^{b}$ | $2^{b}$ | $9.7^{c}$ | $78^{b}$ |
| Tilt | $3.4^{a}$ | $17.4^{b}$ | $81.8^{b}$ | $2.2^{b}$ | $12.9^{b}$ | $73.3^{c}$ |
| Natura | $3.3^{ab}$ | $17.1^{b}$ | $85.7^{ab}$ | $2.1^{b}$ | $11.9^{b}$ | $73.5^{c}$ |
| Rex duo | $3.9^{a}$ | $18.8^{a}$ | $74.3^{c}$ | $2.4^{a}$ | $14.5^{a}$ | $69.5^{c}$ |
| Mean | 3.3 | 16.9 | 83.1 | 2 | 11.3 | 77.9 |
| CV(%) | 13.4 | 5.6 | 4.6 | 7.8 | 10.3 | 3.7 |

**t/ha:** Ton per hectare; **SHB:** Shoot biomass; **LI:** Lodging index

**Table 4a:** Correlation analysis of disease parameters, Lodging, yield and Shoot biomass at Minjar site.

| Parameters | Trs | LI | GY | SHB | AUDPC | ACI |
|---|---|---|---|---|---|---|
| Trs | 1.00 | | | | | |
| LI | 0.45** | 1.00 | | | | |
| GY | -0.60*** | -0.42** | 1.00 | | | |
| SHB | -0.25 | -0.01 | 0.57*** | 1.00 | | |
| AUDPC | 0.89*** | 0.34* | -0.64*** | -0.29 | 1.00 | |
| ACI | 0.85*** | 0.31 | -0.56** | -0.17 | 0.98*** | 1.00 |

Trs= Terminal rust severity, LI= Lodging Index; GY= Grain Yield; SHB= Shoot Biomass;
AUDPC= Area Under disease progress curve; ACI= Average Coefficient of Infection
**= Significant at 5%, ***= Highly Significant at 1%

**Table 4b:** Correlation analysis of disease parameters, Lodging, yield and Shoot biomass at Debre Zeit on station.

| | Trs | LI | GY | SBM | AUDPC | ACI |
|---|---|---|---|---|---|---|
| Trs | 1.00 | | | | | |
| LI | 0.81*** | 1.00 | | | | |
| GY | -0.68*** | -0.69*** | 1.00 | | | |
| SBM | -0.51** | -0.70*** | 0.83*** | 1.00 | | |
| AUDPC | 0.98*** | 0.82*** | -0.69*** | -0.54** | 1.00 | |
| ACI | 0.97*** | 0.80*** | -0.70*** | -0.51** | 0.96*** | 1.00 |

Trs= Terminal rust severity, LI= Lodging Index; GY= Grain Yield; SHB= Shoot Biomass;
AUDPC= Area Under disease progress curve; ACI= Average Coefficient of Infection
**= Significant at 5%, ***= Highly Significant at 1%

may have in improving the yield performance of susceptible tef varieties.

At Debre Zeit location the lowest tef yield (1.5tha$^{-1}$) was also obtained from unsprayed plot. When comparing the four fungicides the highest tef yield was obtained under the application of fungicide Rex Duo with the mean value of 2.4tha$^{-1}$ at this location. Beside Rex Duo relatively the highest yield was obtained from plot treated by Tilt fungicide having the mean value of 2.2tha$^{-1}$ (Table 3). Generally, the higher yield of tef was obtained from Minjar than Debre Zeit, this due to environmental factors; disease pressure was lower as compared to Debre Zeit or soil factors might be the problem.

## Shoot biomass

At Minjar location the lowest shoot biomass was recorded on untreated plots having the mean value of 14.8tha$^{-1}$ and this showed that the pathogen is obligate and it procures all the nutrients from the host. Rex Duo was highly significantly different from other treatments.

The highest shoot biomass was recorded on the treated plot by Rex Duo having the mean value of 18.8tha$^{-1}$ which is significantly different from other evaluated fungicides for the control of tef leaf rust (Table 3). On the other hand Tilt treated plots gave the highest shoot biomass (17.1tha$^{-1}$) as compared to Natura and Nativo fungicides at Minjar location.

At Debre Zeit location; the lowest shoot biomass (straw) (7.3tha$^{-1}$) was obtained from unsprayed plot. The highest mean value of shoot biomass (14.5 tha$^{-1}$) was obtained from Rex Duo sprayed plots and followed by Tilt treated plot having the mean value of 12.9 tha$^{-1}$. Natura also gave good shoot biomass (straw) (11.9 tha$^{-1}$) as compared to Nativo (9.7 tha$^{-1}$) and untreated plots (Table 3).

Generally, the lowest shoot biomass (straw) was obtained from Debre Zeit location this is due to the problems listed under tef grain yield.

## Lodging Index

At Minjar location the highest lodging index was recorded on the unsprayed plot having the mean value of 90.7%. Lodging index

was reduced through the application of fungicides in general but the lowest mean value was recorded through the application of Rex Duo fungicide as compared to other fungicides having the mean value of 74.3% and followed by fungicide Tilt having the mean value of 81.5% of shoot biomass. There was no significant difference between plot treated by Natura 250EW and unsprayed plot but quantitative difference exist between the two at minjar location.

At Debre Zeit location; the highest lodging index was recorded on unsprayed plots having the mean value of 95.2% and the lowest mean value of lodging index (69.5%) was recorded under the fungicide Rex Duo application.

This may supplement the most challenging task in the tef improvement program by minimizing the lodging problem of tef. So, application of fungicides showed a positive contribution in minimizing lodging problems by keeping the health of the crop from obligate pathogen like tef leaf rust.

**Correlation between disease parameters, Yield, Lodging and shoot biomass at Minjar and Debre Zeit locations**

Correlation analysis among terminal tef leaf rust severity, the area under disease progress curve, the average coefficient of infection, and yield revealed the negative impact of tef leaf rust on grain yield and SHB. On the other hand, lodging index was positively influenced by tef leaf rust disease.

Grain yield was negatively correlated with all of the three disease parameters (terminal tef leaf rust severity, the average coefficient of infection, and AUDPC) and the correlation was highly significant while the correlation between disease parameters and SHB was negative but non-significant at Minjar location (Table 4a). This implies that as the disease pressure increase or severe the shoot biomass decreased due to the effect of this obligate pathogen and vice versa.

At Debre Zeit there was strong negative correlation between disease parameters, tef yield and shoot biomass but there was strong positive correlation with lodging index of tef at Debre Zeit (Table 4b).

Generally, Grain yield was negatively correlated with all of the three disease parameters (terminal tef leaf rust severity, the average coefficient of infection, and AUDPC) and the correlation was highly significant at both locations (Tables 4a and 4b). Ashenafi G and Alemayehu Ch [13] also reported that durum wheat yield was correlated strongly with the area under disease progress curve and the average coefficient of infection.

## CONCLUSION AND RECOMMENDATIONS

Tef leaf rust disease resulted in significant reduction in yield and shoot biomass and also disease parameters of tef during the main cropping season of 2019 and 2020 when left untreated. It can also increase the lodging index of the crop become weak and weak. However, application of fungicides significantly reduced terminal tef leaf rust severity, area under disease progress curve, average coefficient of infection and there by significantly improved tef grain yield. In general, the analysis of variance revealed significant differences among fungicide treated and untreated plots in area under disease progress curve, terminal leaf rust severity, average coefficient of infection, yield, shoot biomass and lodging index at Minjar and Debre Zeit locations. The results confirmed the economic importance of tef leaf rust for its effect on grain yield of tef and shoot biomass (straw) tef in Ethiopia. Application of fungicides also plays a great role in minimizing lodging of tef by keeping the health of the tef crops.

The current study also revealed highly negative correlation of terminal tef leaf rust severity with grain yield and weak negative correlation with shoot biomass. For lodging index, which showed a highly significantly ($r = 0.45^{**}$) positive correlation with final tef leaf rust severity during the cropping years.

Current results not only demonstrated the negative impact of tef leaf rust on grain yield and shoot biomass of tef, but also the role of fungicides application which reduce tef leaf rust severity and hence it was possible to improve grain yield, lodging index and shoot biomass of the produce.

*It is marked that, the fungicide Rex Duo control the leaf rust disease of tef effectively as compared to other fungicides used in this evaluation.* The results confirmed that of the evaluated fungicides Rex Duo is the best in control of tef leaf rust and hence the farmers can use this fungicide to minimize yield and shoot biomass loss occurred due to this pathogen and also minimize to some extent the lodging of tef by keeping the health of the crop from this obligate pathogens which procure nutrients fully from its hosts.

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