Plant
2023; 11(2): 60-67
http://www.sciencepublishinggroup.com/j/plant
doi: 10.11648/j.plant.20231102.13
ISSN: 2331-0669 (Print); ISSN: 2331-0677 (Online)

Yield Loss Assessment and Fungicides Valuation for the Control of Head Smudge (*Helmintosporium miyakei*) Disease of Tef in West Arsi Zone, Ethiopia

Ashenafi Gemechu Degete

Ethiopian Institute of Agricultural Research, Debre Zeit Agricultural Research Center, Debre Zeit, Ethiopia

Email address:
gemechuashenafi@gmail.com

To cite this article:
Ashenafi Gemechu Degete. Yield Loss Assessment and Fungicides Valuation for the Control of Head Smudge (*Helmintosporium miyakei*) Disease of Tef in West Arsi Zone, Ethiopia. *Plant*. Vol. 11, No. 2, 2023, pp. 60-67. doi: 10.11648/j.plant.20231102.13

Received: May 12, 2023; **Accepted**: June 8, 2023; **Published**: June 27, 2023

Abstract: Tef head smudge disease caused by *Helmintosporium miyakei* is among the widely distributed tef disease in Ethiopia. Currently, an evaluation of different fungicides for the control of tef head smudge and yield loss quantification is very crucial. Therefore, this study aimed to identify effective fungicide(s) for the control of head smudge disease and quantify yield loss caused by this pathogen in the country. The experiment was conducted at the Negelle Arsi on farmers' field from the 2020 to 2021 short rainy seasons. The application of different fungicides created significantly different levels of severity of head smudge disease on tef varieties Boset and Tesfa. The two varieties are susceptible to head smudge and enabled the assessment of the effects of head smudge disease on tef grain yield, severity of the disease, and yield loss during the short rainy seasons. The analysis of variance revealed that there was no statistically significant difference among the Rex Duo and Nativo 300 SC fungicides for tef yield but the highest grain yield was obtained through the application of Rex Duo (2431.2 kg ha^{-1}). The fungicide efficacy of 77.1 and 60.9% were obtained through the application of Rex Duo and Nativo 300 SC fungicides, respectively. The result revealed that the maximum yield loss of 55.8 and 50% was prevented through the application of the fungicides Rex Duo and Nativo 300 SC, respectively. It is recommended that based on the availability in the market and cost of fungicide Rex Duo and Nativo 300 SC the farmers can apply either Rex Duo or Nativo 300 SC in controlling head smudge disease of tef.

Keywords: Tef, Fungicides, Yield Loss, Head Smudge

1. Introduction

Tef is endemic to Ethiopia and its major diversity is found only in this country, but the exact date and location for its domestication, as is the case with several other crops, is not known. However, there is no doubt that it is a very ancient crop in Ethiopia, where domestication took place before the birth of Christ. Tef is an important cereal crop in Ethiopia. The area under tef cultivation is over three million hectares each year. In 2020/21, it was estimated that tef made up to 28% of all the cultivated area under cereals in Ethiopia, covering about 2.93 million hectares and grown by 6.87 million farmers [6]. Tef is grown in almost all regions of the country for home consumption since it is a preferred grain, and for 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 [7, 15]. The crop is grown both in *Belg* (short rainy season) and *Meher* (long rainy season).

Tef head smudge disease caused by *Helmintosporium miyakei* is the widely distributed tef disease in Ethiopia [2]. Head smudge disease of tef can be managed by various means among which, using clean seed, crop rotation, stubble management, the use of the genetic tolerance or resistant cultivars are the most effective, environmentally friendly, and sound methods. Most of the tef genotypes and released varieties observed during the survey were showed the reaction from moderately susceptible to susceptible response against tef head smudge disease [2]. Under such a scenario, fungicide interference is crucial to control this disease.

In Ethiopia, several fungicides were registered and

recommended for the management of wheat fungal diseases and this has been reviewed [4, 17] and a recent review in this regard was by Ayele, B. et al. [3].

So far no fungicides were recommended for the control of head smudge disease and yield loss due to this disease is not quantified. No attempt was made to integrate varieties and different fungicides applications in tef that is valuable for the integrated management of tef head smudge disease.

Currently, an evaluation of different fungicides for the control of tef head smudge disease 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 head smudge disease and to quantify yield loss caused by this disease in the country.

2. Materials and Methods

2.1. Description of Experimental Areas

The experiment was conducted at Negele Arsi for two years (2020 and 2021) during short rainy seasons. The experiment was carried out at Negele Arsi in the West Arsi Zone of the Oromia Region and Negele Arsi has a latitude of 7°21`N, longitude 38°42`E, and an elevation of 1899 meters above sea level. The annual average temperature varies between 10°C and 25°C while the annual rain fall varies between 500 and 1000 mm. The soil type is slightly vertisol.

2.2. Treatments and Experimental Design

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

Tef cultivars Boset and Tesfa were utilized due to susceptible reaction to head smudge and mostly planted in short rainy seasons especially because Boset is early type and Tesfa is the most susceptible because of the compacted nature of the variety. The trial was planted in 2.5 m plot length and 1.2 m width at each year. The recommended seed rate of 15 kg/ha was used during planting. The planting was done by hand drill during both seasons. There was no artificial inoculation of Tesfa and Boset varieties to have high disease pressure and rather the trial was planted at hot spot area for tef head smudge disease. Four different fungicides, with different active ingredients, were applied for the control of tef head smudge (Table 1).

Table 1. *Fungicides used for evaluation against head smudge of tef and control Negelle Arsi on farm.*

Lists	Trade Name	Common Name	Application Rate
1	Nativo 300SC	trifloxystrobin 100gm/lt + tebuconazol 200 gm/lt	0.75 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	0.5 l/ha
5	Untreated/ Check/Control		

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

2.3. Data Collection and Analysis

The severity was visually estimated by considering the number of infected panicles per plot and International Rice Research Institute (IRRI, 2013) and the scoring of the disease is based on 1-9 scale adopted from fusarium head blight of wheat disease. Where 1 < 5%, 2 = 5–17%, 3 = 18–30%, 4 = 31–43%, 5 = 44–56%, 6 = 57–69%, 7 = 70–82%, 8 = 83–95% and 9 > 95% of the spikelet's with FHB symptoms.

Two times disease scoring was done at ten days interval during the cropping seasons. The first scoring was done before the application of each fungicide and the rest scoring was done after spraying of fungicides.

Relative yield loss (%): Potential reduction of grain yield loss (in the absence of foliar spray of fungicides) was calculated as yield difference between fungicides sprayed and control treatment expressed in percentage of the sprayed plots, in other word, yield increase over the change of yield increase to untreated plots [13] as follows;

$$\text{Relative yield Loss (\%)} = \frac{(YP-YuS)}{\text{YP}} \text{x } 100$$

Where L = relative percent yield loss, YP = yield from the maximum protected plot (fungicide sprayed plots) and YuS = yield from fungicide unsprayed plots.

Fungicide Efficac*y*: The fungicide efficacy (FE) was calculated as stated below,

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

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

Data on final severity (FS) and grain yield were subjected to analysis of variance using GLM procedure of the System Analysis Software [10]. Tukey test and the (0.05) was employed to compare treatment means.

Due to heterogeneity of variance over cropping years, combined analysis of terminal final head smudge severity and grain yield were not done.

3. Results and Discussion

Untreated (Boset Variety) Treated with Rex Duo (Boset Variety)

Figure 1. *Pictorial comparison of Boset and Tesfa varieties treated by fungicide Rex Duo and untreated during the evaluated season.*

Untreated (Tesfa Variety) Treated with Rex Duo (Tesfa Variety)

Figure 2. *Pictorial comparison of treated and untreated plots after threshing of the Tef Boset.*

3.1. Disease Parameter, Efficacy (%), and Yield

3.1.1. Final Head Smudge Severity

From the analysis of variance there was no significant effect of variety by fungicide interaction ($p > 0.05$). From the analysis of variance there was a highly significant ($p > 0.001$) difference among treatments and varieties (Table 2).

In both seasons, head smudge disease severity level was reduced significantly ($p < 0.05$) through the application of fungicides relative to the unsprayed plots. There was highly significant ($p<0.001$) different among varieties and treatments evaluated during the cropping seasons.

Table 2. *Analysis of variance for grain yield of tef.*

Source	Sum of DF	Squares	Mean Square	F Value	Pr > F
Model	29	26513231.22	914249.35	5.19	<.0001
Error	30	5286308.68	176210.29		
Corrected Total	59	31799539.89			

Table 3. *Analysis of variance of variety, variety interaction with fungicides.*

Source	DF	SS	Mean Square	F Value	Pr > F
Block	2	106431.251	53215.625	0.30	0.7416
Trt	4	4394879.156	1098719.789	6.24	0.0009
Var	1	3144246.723	3144246.723	17.84	0.0002
Year	1	9523220.800	9523220.800	54.04	<.0001
Var*Trt	4	366137.011	91534.253	0.52	0.7220
Trt*Year	4	1410395.822	352598.956	2.00	0.1198
Var*Year	1	6057797.834	6057797.834	34.38	<.0001

Final tef head smudge severity on treated plots by different fungicides varied between 15.7 and 65.5%, suggesting a significant reduction in head smudge disease severity level as the result of fungicides sprayed (Table 4).

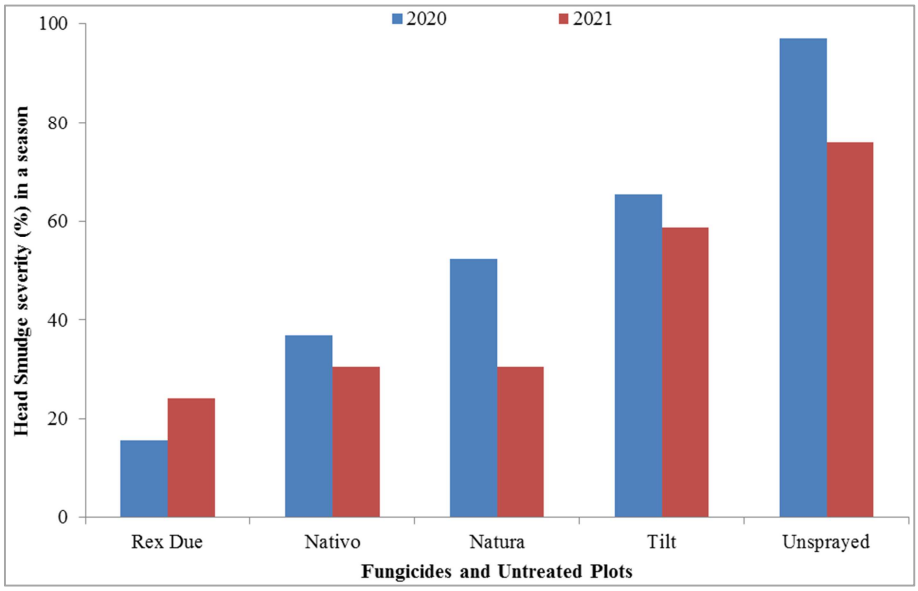

Figure 3. *The mean of head smudge disease severity during 2020-2021 across each fungicide.*

The mean value of head smudge severity on unsprayed plots recorded the highest value of 97% during the 2020 the Belg cropping season (Figure 3). The lowest final head smudge disease severity was recorded on the treated plots by Rex Duo, followed by Nativo 300 SC, and Natura (Figure 3). In 2020 cropping season; Rex Duo reduced six times head smudge severity than the control plots whereas Nativo 300 SC reduced three times as compared to untreated plots (Figure 3). The overall mean value of head smudge severity for Rex Duo treated plots during both seasons was 19.85% followed by Nativo 300 SC with the mean severity value of 33.75%. In 2020 short rainy season, Tilt fungicide showed the weakest control of tef head smudge disease as compared to other evaluated fungicides this might be due to nature of the disease. Similar to the 2020 season, in 2021 short rainy season, tefs that were treated with Rex Duo had the lowest head smudge disease severity while untreated tef plots had the highest severity (figure 3).

In general, the lowest mean value of final head smudge disease severity was recorded in during cropping season of 2020 (15.7%) and 2021 (24%) under the treatment Rex Duo.

Overall the final tef head smudge severity was varied from 19.85 to 62% under different fungicides treatment. The mean value for the untreated plots for both seasons was 86.5%. This result was in lines with Tamene Mideksa et al. [12] who reported that fungicide treatments significantly reduced wheat stripe rust disease severity over the unsprayed plots.

Of the fungicides tested against head smudge disease the highest mean value of head smudge disease severity (62%) was recoded for Tilt fungicide for both seasons. Plots treated under Rex Duo showed the lowest severity as compared to the three fungicides (Nativo 300 SC, Natura, and Tilt) (Figure 3). This indicates that the Rex Duo fungicide application was considered the most effective as it coped to the lowest head smudge severity in both Belg seasons. This finding was similar to the finding [16] which reported that the application of fungicides effectively reduced disease severity. Mamdouh A. A et al. [9] also reported that Tilt sprayed wheat remained almost free from stem rust of wheat which is not similar to these findings. Tilt was the least to control tef head smudge disease as compared to other fungicides and this might be due to the nature of pathogen.

3.1.2. Grain Yield of Tef Varieties and Yield Loss (%)

In 2020 the yield difference of 1633.4 kg/ha obtained under the fungicide application of the Rex Duo over the untreated plots (Figure 4). The highest tef grain yield was obtained from the plots treated by Rex Duo with the mean value of 2020.8 kg/ha followed by Nativo 300 SC with 1739.8 kg/ha. Statistically there is no difference between Rex Duo and Nativo 300 SC fungicides but Rex Duo is significantly different from the remaining fungicides used in this study (Table 4). Estimating yield loss by disease is a prerequisite to develop strategies for disease control particularly through breeding objectives for disease resistance or tolerance [14].

The yield of Boset and Tesfa varieties on untreated plots accounted 1070.4 and 1078 kg ha^{-1}, respectively (Figure 4). In all the cases, the treated plots gave higher grain yield for both varieties than the untreated plots (Figure 4). Similar work was conducted by the author [8] who reported that significant variation in yield parameters were observed among fungicide applications under different environment.

The maximum tef grain yield was obtained from treated plots of Boset and Tesfa varieties through the application of Rex Duo. The Rex Duo fungicide treated plots gave two and half times higher grain yield over the untreated plots for Boset variety and two folds higher grain yield over the untreated plots of Tesfa tef variety (Figure 4). Application of Nativo 300 SC fungicide gave the mean value of 2359.5 kg ha^{-1} and for Boset and Tesfa tef varieties, respectively (Figure 4). As compared to the three fungicides the lowest tef yield was obtained under the application of Tilt fungicide however it is significantly different from the untreated plots (Table 4). This result suggests that the effect of fungicides have improved the yield performance of susceptible tef varieties Boset and Tesfa. From this study up to 55.8% yield loss was prevented through the application of fungicide Rex Duo followed by Nativo 300 SC which prevent 50% of yield loss caused by tef head smudge disease. Woubit D. [16] showed that up to 42% yield loss was prevented by applying foliar fungicides to winter wheat. The fungicide treatments significantly ($p<0.05$) reduced tef head smudge disease severity over the unsprayed check. This is in line with the author [5] who reported that the fungicide treatments resulted in an increase in mean grain yields of wheat over the unsprayed check.

Besides Rex Duo, relatively the highest yield was obtained from Nativo 300 SC fungicide (Table 4). Statistically there is no significant difference between fungicides Rex Duo and Nativo 300 SC but numerically the Rex Duo fungicide gives the difference of grain yield of 378 kg ha^{-1} over the Nativo 300 SC fungicide (Table 4).

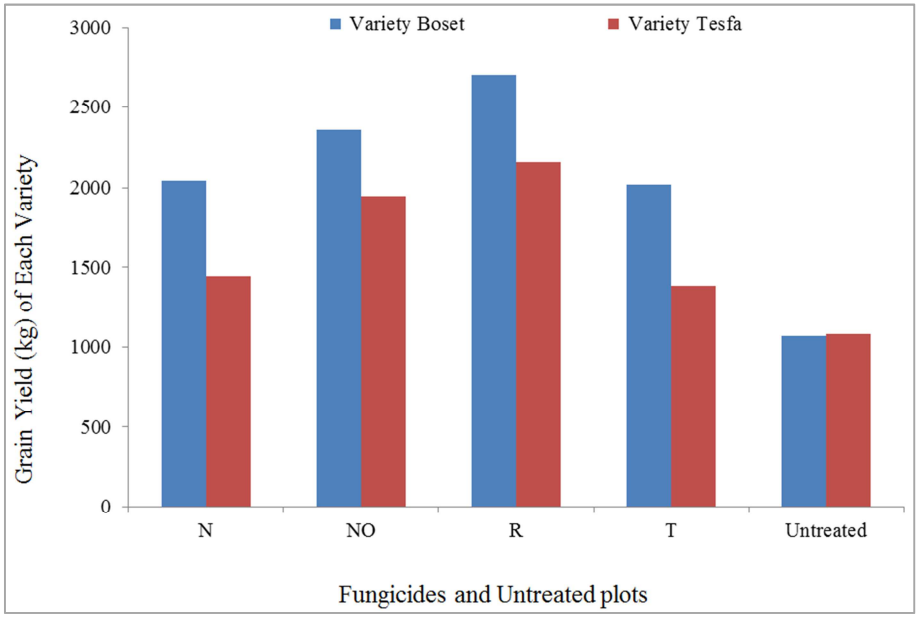

Figure 4. *Effect of different Fungicides on Grain Yield of Tef Varieties Boset and Tesfa during 2020-2021 cropping seasons.*

Table 4. *The overall effect of different fungicides on yield and head smudge severity of each fungicide.*

Treatment	Yield kg/ha	Yield loss	Final Severity
Rex Duo	2431.2[a]	55.8	19.8[a]
Nativo 300 SC	2153.2[a]	50.1	33.8[ab]
Natura	1743.3[b]	38.4	41.3[b]
Tilt	1701.4[b]	36.8	62.1[c]
Unsprayed	1074.6[c]	0	86.5[d]
Mean	1820.8		48.7
CV (%)	22.3		42.4

3.2. Grain Yield of Tef Varieties in the Evaluated Seasons (2020-2021)

In 2020 Belg season the lowest tef yield was obtained from unsprayed plot followed by plots treated by Natura fungicide. When comparing the four fungicides the highest tef yield was obtained under the application of fungicide Rex Duo during 2020 Belg season, followed by fungicide Nativo 300 SC and the lowest a mean grain yield of tef obtained under the application of fungicide Natura in the same season (Figure 5). In 2020 cropping season the Rex Duo fungicide treated plots gave 1634 kg ha^{-1} grain yield than the untreated plots whereas Nativo 300 SC treated plots gave 1359 kg ha^{-1} over the untreated plots (Figure 5).

In 2021 Belg cropping season, the highest tef grain yield obtained through the application of fungicide Rex Duo, followed by Nativo 300 SC (Figure 5). This aids in increasing the production of tef through controlling the effect of head smudge disease of tef. Thus, the application of fungicides showed a positive contribution in controlling the head smudge problems by keeping the health of the crop from this hemibiotrophic pathogens like head smudge disease of tef.

In both Belg cropping seasons, the highest tef grain yield was obtained under the application of fungicide Rex Duo. This result was also similar to the finding [1] which reported that the application fungicide Rex Duo reduced tef leaf rust severity.

Basically, the higher yield of tef was obtained during 2020 Belg cropping season than 2021 Belg cropping season, this is due to environmental factors; disease pressure was lower as compared to 2021 cropping season.

In general, the mean value of tef yield in both cropping season under the fungicide Rex Duo protection was 2431.5 kg ha^{-1} whereas the untreated plots gave the mean value of 1074.5 kg ha^{-1} which was much lower than the treated plots by the Rex Duo fungicide. There was the difference of tef grain yield of 1356.5 kg ha^{-1} between the Rex Duo treated plots and untreated plots.

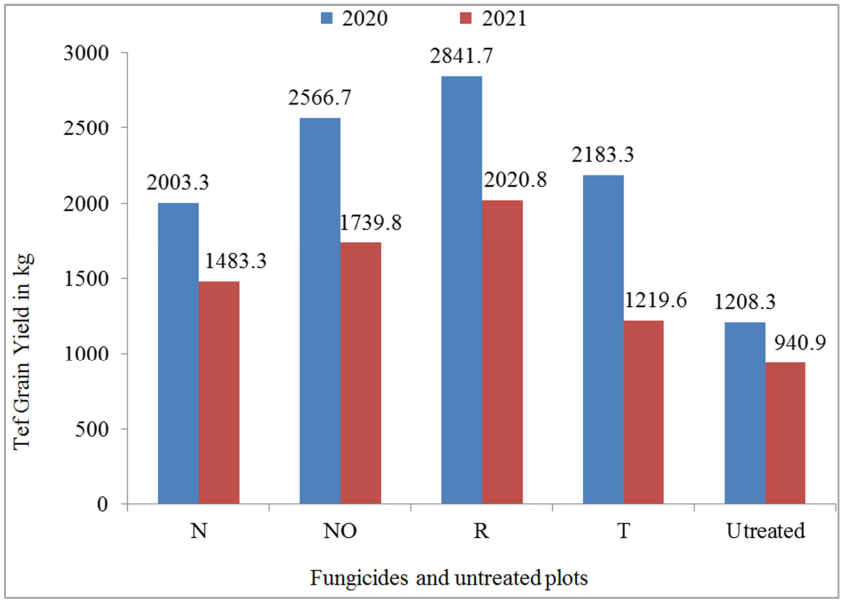

Figure 5. *The mean of tef grain yield under different fungicides and untreated plots during 2020 and 2021 cropping seasons.*

3.3. Efficacy of the Evaluated Fungicides During 2020-2021

In 2020 and 2021 cropping seasons the lowest efficacy was recorded under fungicide Tilt (Table 5). The highest efficacy of fungicide observed under fungicide Rex Duo in 2020 and 2021 cropping seasons with the percentage of 83.8 and 68.4%, respectively. The efficacy of the fungicide varied from season to season this is may be due to mechanical error or environmental factors. In 2020, Nativo 300 SC fungicide showed the efficacy of 61.9%. However, in 2021 the efficacy of fungicide Nativo 300 SC was similar with fungicide Natura with the efficacy percentage of 59.9.

The evaluated fungicides increased grain yield of tef through reducing the effect of tef head smudge disease. Results revealed that the Rex Duo fungicide significantly reduced head smudge disease and showed good level of efficacy as compared to other fungicides. These findings are similar with the work of Tadesse, K. et al. [11] who reported that application of fungicide was found to be the best

treatment in reducing stem rust infection of wheat and producing the higher grain yield compared to unsprayed treatment in wheat crop. The overall grain yield of tef under fungicide sprayed plots of Boset and Tesfa varieties showed 2281.5 and 1733.1 kg ha^{-1}, respectively (Figure 6). There was the difference between sprayed and unsprayed with the value of 1211.1 kg ha^{-1} for Boset variety and Tesfa showed the difference of 654.3 kg ha^{-1} between sprayed and unsprayed plots (Figure 6).

Table 5. *The efficacy of each fungicides during 2020 and 2021 cropping seasons on the severity of head smudges disease at Negelle Arsi on farm.*

Trt	Year (2020)			Year (2021)		
	yield (kg/ha)	Final Severity	Efficacy (%)	yield (kg/ha)	Final Severity	Efficacy (%)
N	2003.3	52.2	46.2	1483.3	30.5	59.9
NO	2566.7	37	61.9	1739.8	30.5	59.9
R	2841.7	15.7	83.8	2020.8	24	68.4
T	2183.3	65.5	32.5	1219.6	58.7	22.8
Unsprayed	1208.3	97	0	940.9	76	0.0

Note: Trt= Treatment; N=Natura; NO= Nativo 300 SC; R= Rex Duo; T= Tilt

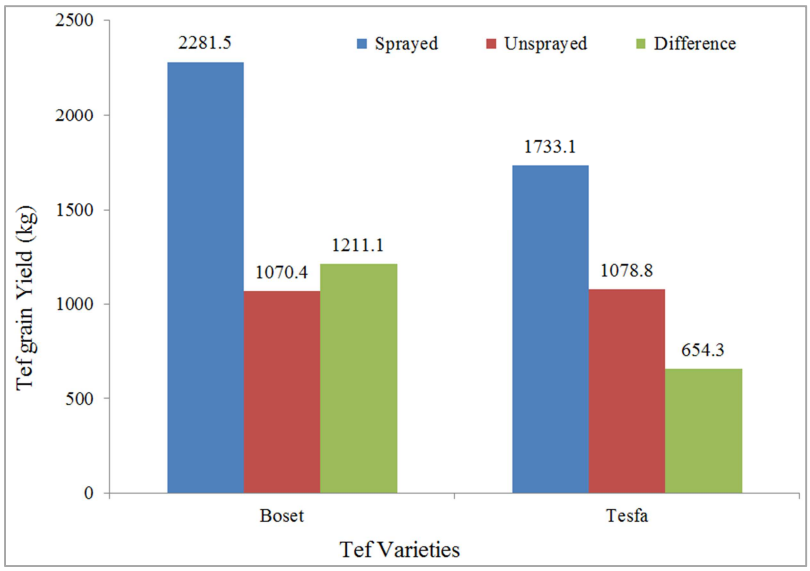

Figure 6. *The overall grain yield of Tef varieties Boset and Tesfa under sprayed, unsprayed, and the difference.*

4. Conclusion

Tef head smudge disease resulted in significant reduction in yield and increase final severity of the disease of tef during the cropping seasons of 2020 and 2021 when left untreated. However, application of fungicides significantly reduced terminal tef final head smudge severity and there by significantly improved tef grain yield and quality. In general, the analysis of variance revealed significant differences among fungicide treated and untreated plots in tef gain yield and final head smudge severity in 2020 and 2021 cropping season at Negele Arsi location. The results confirmed the economic importance of tef head smudge for its effect on grain yield of tef and quality of tef in Ethiopia. Application of fungicides also plays a great role in minimizing yield loss caused by this pathogen by keeping the health of the tef crop.

Current results not only demonstrated the negative impact of tef head smudge disease on grain yield of tef, but also the role of fungicides application which reduce tef final head smudge severity and hence it was possible to improve grain yield and quality of the produce. This study also quantified that the maximum yield loss of 55.8 and 50% was prevented through the application of the fungicide Rex Duo and Nativo 300 SC, respectively. This increase the production and productivity of tef yield in the country.

The results confirmed that the evaluated fungicides Rex Duo and Nativo 300 SC are the best in control of tef head smudge and hence the farmers can use one of these fungicide to minimize grain quality and yield loss caused due to this pathogen.

Therefore, it is recommended that, statistically there was no significant difference among the fungicides Rex Duo and Nativo 300 SC in controlling the head smudge disease of tef effectively as compared to other fungicides used in this evaluation. Based on the availability and cost of the fungicides Rex Duo and Nativo 300 SC in the market, the farmers can use either Rex Duo or Nativo 300 SC fungicide in the control of tef head smudge disease in the country.

Acknowledgements

I would like to thank the integrated tef project for financial support and tef research team of Debre Zeit Agricultural

Research Center for rendering valuable encouragement and technical support during the whole period of the study and the technicians Mrs. Nugusu Husen and Behailu Abera for their support from field work to laboratory works.

References

[1] Ashenafi Gemechu Degete (2021) Evaluation of Fungicides for the Management of Tef Leaf Rust (Uromyces eragrostidis) in Tef at East and North Shoa, Ethiopia. J Plant Pathol Microbiol 12: 569.

[2] Ashenafi Gemechu Degete. Distribution of Head Smudge (Helminthosporium Miyakei) of Tef Disease During Short Rainy and Main Cropping Seasons in Some Parts of Oromia and Southern Nation Nationality and People Regions of Ethiopia. 2021, 3 (3) OAJBS. ID. 000289. DOI: 10.38125/OAJBS.000289.

[3] Ayele, B., Eshetu, B., Bekele, Bekele H, B., Degefu, M., Asnaketch Tekalign, A., Ayalew, M. Ayalew, A., Meles, K. and Abebe, F. 2008. Review of two decades of research on diseases of small cereals crops. *In*: Abraham Tadesse (ed.) Increasing Crop Production through Improved Plant Protection Vol. 1. Proceedings of the 14th Annual Conference of the Plant Protection Society of Ethiopia (PPSE), 19-22 December 2006, Addis Ababa, Ethiopia, pp. 375-429.

[4] Bekele Hundie. 2003. Short report on stripe rust and stem rust. In Bedada Girma (ed.). Pp. 67-68. BADE. 2003. Bale Agricultural Development Enterprise. Proceedings of the Agronomy Workshop. Addis Ababa, Ethiopia.

[5] Basandrai, A. K., Mehta, A., Rathee, V. K., Basandrai, D., and Sharma, B. K., 2020. Efficacy of fungicides in managing yellow rust of wheat. *Journal of Cereal Research*, *12* (2), pp. 103-108.

[6] CSA (Central Statistical Agency) (2021). Agricultural Sample Survey for 2013/14 EC: Report on Area and Production of Major Crops for Private Peasant Holdings, Meher Season. Statistical Bulletin No 532, Addis Ababa, Ethiopia.

[7] Fufa, H., Bogale, T, Tefera, H., Assefa, K. and Kefyalew, T.. 2001. Agronomy Research in Tef,. *In*: Tefera, H., Belay, G. abd Sorrells, M. (eds.), Narrowing the Rift: Tef Research and Development, Proceedings of the International Workshop on Tef Geneticsand Improvement, Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia, pp: 167-176.

[8] Foster, A. J., Lollato, R., Vandeveer, M. and De Wolf, E. D., 2017. Value of fungicide application in wheat production in Southwest Kansas. Kansas Agricultural Experiment Station Research Reports, 3 (5), p. 3.

[9] Mamdouh A. A, Walid, M. El-Orabey, M. N. 2013. Effect of stem rust infection on grain yield and yield components of some wheat cultivars in Egypt Shahin ESci Journal of Plant Pathology. 02 (03): 171-178.

[10] Statistical Analysis Software (SAS). 2004. SAS Institute Inc. Cary, North Carolina. First printing, January 2004. SAS Publishing provides. 513pp.

[11] Tadesse, K., Amare, A. and Ayalew, B. 2010. Effect of fungicide on the development of wheat stem rust and yield of wheat varieties in highlands of Ethiopia. African Crop Science Journal. 18 (1): 23-33.

[12] Tamene Mideksa, Zerihun Eshetu. Verification of Comet Plus 475 G/L EC Fungicide Against Wheat Stripe Rust (Puccinia striiformis f.sp. tritici) Disease on Bread Wheat in Bale, Southeastern Ethiopia. Advances in Applied Physiology. Vol. 6, No. 2, 2021, pp. 30-32. doi: 10.11648/j.aap.20210602.11.

[13] Sharma, RC; Kumarse, N; Amir, A; Zafar, Z; Anwar, UJ. 2016. Reduction of winter wheat yield losses caused by stripe rust through fungicide management. *J Phytopathol*. 164: 671–677.

[14] Waleligne, W. 2004. Maize tef relay intercropping as affected by maize planting pattern and leaf removal in southern Ethiopia. African Crop Science Journal 12 (4): 358-367.

[15] Wegulo, S. N., Breathnach, J. A. and Baenziger, P. S. 2009. Effect of growth stage on the relationship between tan spot and spot blotch severity and yield in winter wheat. *Crop Protection,* Vol. 28, No. 8, (May 2009), pp. 696-702, ISSN 0261-2194.

[16] Woubit D., & Yeshi A., (2010). The study of fungicides application and sowing date, resistance, and maturity of *Eragrostis tef* for the management of teff rust [*Uromyces eragrostidis*] Canadian Journal of Plant Pathology Volume 27, Pages 521-527 | Accepted 02 Aug 2005, Published online: 01 Apr 2010.

[17] Yeshi Andnew. 1988. A review of chemical disease control research on wheat in Ethiopia. In: The 5th Regional Wheat Workshop for Eastern, Central and Southern Africa and the Indian Ocean. Antsirbe, Madagascar, October 5-10, 1987. Ginkel, M. V. and Tanner, D. G. (eds.). Mexico, D. F.: CIMMYT. pp. 251-255.