

Evaluation and Verification of Fungicides for the control of Yellow rust (*Puccinia Striiformis f.s.tritici*) in Bread wheat, Arsi highlands of Ethiopia

Abstract

The present study was performed to meet objective of examining the efficacies of new fungicides against yellow (stripe) rust in dedicated hotspot disease screening site). Two new verification test fungicides namely Cayunis EC 325 (Bixafen 75g/L +Spiroxamine 150g/L + Trifloxystrobin 100g/L), and Tridium 70 WG (Mancozeb59.7%+Azoxystrobin 4.7%+Tebuconazole 5.6% WG and evaluated with standard checks called Nativo SC 300(trifloxystrobin 100 gm/lt + tebuconazol 200 gm/lt) were evaluated the efficacies in controlling the yellow (stripe) rust. The objective of the present study was to evaluate and verify the efficacy of new fungicides against yellow rust disease and recommend the effective for registration. The trial was conducted in non-replicated with replication of sites at Meraro and Bekoji substations of kulumsa agricultural research center and boru chilalo farmers' field. The result revealed that Bixafen 75g/L +Spiroxamine 150g/L + Trifloxystrobin 100g/L), and Mancozeb59.7%+Azoxystrobin 4.7%+Tebuconazole 5.6%WG fungicides were effective in controlling yellow rust disease and improving high grain yield than trifloxystrobin 100 gm/lt + tebuconazol 200 gm/lt and unsprayed control treatments in all tested experimental sites and recommended for registration -

Keywords: *Tridium 70 WG, Cayunis 325 EC, fungicide efficacy, yellow rust, disease severity, grain yield*

Introduction

stripe (yellow) rust is a serious wheat production problem at early growth stage and continue to develop during the developmental stage of the crop in highly prevalent with cool and wet weather conditions in all continents where wheat is grown (Afzal *et al.*, 2007-; Chen *et al.*, 2014).Currently, wheat stripe rust is the most economically important fungal disease caused with 100% yield loss (verify) and quality degradation particularly in susceptible cultivars (Milus *et*

Commented [z1]: Delete the phrase and begin with a short introduction for the study.

Commented [z2R1]:

Commented [z3]: Rephrase the objective of the study

Commented [z4]: include more results in the abstract like increase rate or decrease rate of effectiveness. The abstract must be consistent and improved.

Commented [z5]: (change the keys words)

Commented [z6]: Old references

Commented [z7]: Verify this information

al., 2008; Chen, 2015; Ayele and Muche, 2019). Newly, recurrent aggressive *Pst* races are adapted to higher temperature climate and have spread to wheat producing areas of the world that were perversely less affected by wheat stripe rust disease (Ali *et al.*, 2014).

Yellow rust (*Puccinia striiformis* sp. *tritici*) is one of the most important fungal diseases of wheat and the major production bottleneck in the major wheat growing regions of Ethiopia (Ayele *et al.*, 2008a). In Ethiopia, the rapid emergence of virulent pathotypes of *Pst* 11, 16 and 17 have overcome most of recently released cultivars which are best resistant previous manner and known yellow rust resistant differential lines. The countries wheat belt areas of Arsi and Bale highlands are the known hotspots for the epidemics of wheat stripe rust disease (Negassa, 1986, Denbel, 2014). Even though there is seasonal variability in the occurrence of stripe rust in Arsi and Bale highlands that the main and long rainy season is ideal for stripe rust development (Bekele *et al.*, 2002).

Yellow rust can cause yield losses of up to 96.7% on susceptible cultivars if infection occurs very early in the crop development stage and the disease continues to develop during the growing season (reformulate). Grain yield losses of 22.9 to 39.7 % on resistant varieties due to head infection, 48.7 to 56.5 % on moderately resistant varieties, 43.3 to 57.5% on moderately susceptible varieties and 91.5 to 96.7% have been recorded on susceptible bread wheat varieties with shrivelled and reduced germination ability and kernel weight by 65.7 and 15.4% respectively (Alemu and Getnet, 2019).

Commented [z8]: Reformulate this sentence

Commented [z9]: In which country and it is complex phrase please rewrite it.

Fungicides are the main strategy to control rust in Western Europe although efforts are in progress to reduce reliance on these compounds. Fungicides can be an important control option when rust epidemics are severe, however, their use results in significantly increased production costs for the farmers (Hodson, 2011). In developed countries of Europe, Australia and the Americas, fungicides, at times used on a large scale as a key part of the national food security strategy (ICARDA, 2011). In Canada, use of fungicides for disease management is employed by farmers (McCallum *et al.*, 2007a).

Commented [z10]: old references

Foliar fungicides have been widely used to control stripe rust which prevented multimillion dollar losses and significantly reducing crop loss. Cooper and Dobson (2007) testified, proper and frequent application of fungicides upon the disease onset gives benefits in the effort to

increase crop productivity and quality of the grain. Hailu and Fininsa (2007) also reported a relatively better yield for sprayed plots as compared to unsprayed plots under experimental condition and the spray interval is reported to be a significant factor in the disease severity and rate of epidemic development.

In Ethiopia, Ayele *et al* (2019) reported grain yield increment on susceptible varieties had increased 823.8 to 1863% and 1086.8 to 2883% with proper application of Tilt and Rex® Duo sprayed fungicides respectively. So, the objective of the present study was to evaluate and verify the efficacy of Cayunis 325 EC (Bixafen 75g/L + Spiroxamine 150g/L + Trifloxystrobin 100g/L), and Tridium 70 WG (Mancozeb 59.7% + Azoxystrobin 4.7% + Tebuconazole 5.6% WG fungicides against yellow rust disease and recommend the effective for registration.

Commented [z11]: This part covers a lot of details but would benefit from clarification regarding Ethiopia's unique challenges

Commented [z12]: The study's objective is clear, but rephrasing for conciseness would improve readability.

MATERIALS AND METHODS

Description of Experimental Site (

The trial was implemented at kulumsa agricultural research center sub-stations of Bekoji which is located at 7° 32' 27" North (N), 39°, 15', 21" East (E) with altitude range of 2780 meters above sea level while Meraro is located 7° 24' 27" North, 39°, 14', 56" East (E) with altitude range of 2990 meters above sea level. Monthly maximum and minimum temperature of the Meraro and Bekoji experimental sites have received 5.7 and 18.1°C, and 7.9 and 18.6°C with annual rainfall of 1196 and 102 millimetres respectively. Both locations represent best screening and hotspot areas to yellow rust and characterized in receiving extended rainfall and bimodal cropping systems for major wheat production potential agro ecologies.

Cayunis EC 325 (Bixafen 75g/L + Spiroxamine 150g/L + Trifloxystrobin 100g/L) and Tridium (Mancozeb 59.7% + Azoxystrobin 4.7% + Tebuconazole 5.6% WG) were verified with 0.9lit/ha and 2kg/ha recommended rate and standard checks Nativo 300SC (trifloxystrobin 100 gm/lit + tebuconazol 200 gm/lit and Rex® Duo (187g/l Epoxiconazole + 310g/l Thiophanate-methyl) with 0.75 lit/ha and 0.5 lit/ha with 250lit/ha water using knapsack spray as sole or integrated disease management options on wheat respectively (Table 1).

Experimental Materials

Table 1. Common name, Trade name, Formulation and manufacturers of fungicides against yellow rust in wheat, 2021

Common name	Trade name (commercial name)	Formulation and manufacturer (active compounds)	recommended rate
Bixafen+ Spiroxamine+Trifloxystrobin	Cayunis 325 EC	Bixafen 75g/L + Spiroxamine 150g/L + Trifloxystrobin 100g/L	0.9lit/ha
Mancozeb+Azoxystrobin+Tebuconazole	Tridium 70 WG	Mancozeb59.7%+Azoxystrobin 4.7%+Tebuconazole 5.6%WG	2kg/ha
trifloxystrobin+ tebuconazol	Nativo	trifloxystrobin 100 gm/lt + tebuconazol 200 gm/lt	0.75lit/ha
Epoxiconazole + Thiophanate-methyl	Rex® Duo	187g/lEpoxiconazole + 310g/l Thiophanate-methyl	0.5lit/ha
Nil	-	-	-

Formatted: Font color: Red

Commented [z13]: Recommended dose

Experimental Design and Management

The experiment was laid out in simple non replicated plot design with site as replications. The plot size used was 10m x 10m consisting of 50 rows. All other agronomic practices, such as weeding, fertilizer application and cultivation were implemented as per recommendation for bread wheat production

Commented [z14]: Clarify if this means that each location served as a replicate, and specify if there were any within-site replications to enhance statistical reliability.

Disease Assessment

Wheat yellow rust incidence and severity was assessed on weekly basis by counting the number of plants visibly diseased (for incidence), and by estimating the percentage of leaf area affected (for severity) from the plot based plants

Commented [z15]: Please mention the scale that you used for the Disease severity

~~Disease incidence:~~ Disease incidence was assessed when symptoms appear for the first time and calculated with the following formula;

Disease incidence = No. of infected plants from the samples taken/total No. of plants assessed (100)

Result and Discussion

Disease Severity

Where is the result section.

In 2021 main cropping season yellow rust was very high disease epidemics to the level of creating significant difference among treatments and across all test locations. Fungicide spray new test treatments and standard check significantly reduced yellow rust disease severity over the nil application. Under natural epidemics and without artificial inoculation of the pathogen on check treatment, the terminal yellow rust severities of about 90s, 70s and 60s for Cayunis 325 EC treatments and 80s, 60s and 50s for Tridium 70WG tested treatments were recorded on unsprayed plots at Meraro, Kulumsa and Boru Chilalo respectively (Table 2).

The terminal yellow rust severity after once spray of Nativo was recorded by 20s, 20s and 20s at Meraro, Kulumsa and Boru Chilalo while Cayunis 323EC was scored respectively. However, the terminal yellow rust severity at Meraro, Kulumsa and Boru Chilalo recorded uniform 20% was recorded on Cayunis EC 325 fungicide sprayed plots (Table 1). The highest disease severity (90 and 70%) was recorded in unsprayed plots at Meraro and Kulumsa on the unsprayed check plots and the lowest yellow rust disease severity 20mr were recorded on Cayunis EC 325 and Nativo sprayed plots at Kulumsa, Boru Chilalo and Meraro sprayed plots on respectively.

Among the foliar applications fungicides, Tridium 70WG, Cayunis EC 325 and Nativo 300SC were found most effective against rust and it gave the highest disease control over the untreated control (Table 2).

Conversely, there were no statically significant differences between the tests and standard check fungicides in reducing yellow rust disease severity (Table 1). However, from visual field observation the test fungicides, Tridium 70WG and Cayunis EC 325 showed comparable level of efficacy in controlling yellow rust disease with the standard check, Nativo and Rex® Duo.

Commented [z16]: Consider organizing this section more clearly, starting with an overview of the severity trends observed across locations and treatments, followed by specific details on each fungicide's performance.

Commented [z17]: Replace ambiguous terms like "90s, 70s, 60s" with "90%, 70%, 60%" to clearly indicate percentages. Additionally, specify whether these values represent averages, ranges, or single-point observations for each location.

Therefore, Cayunis EC 325 and Tridium 70WG can be recommended for the control of wheat yellow rust disease (Table 2).

Table 2. Effect of fungicides on yellow rust disease severity of bread wheat

Treatment	Meraro		Kulumsa		Boru Chilalo	
	Before spraying	After spraying	Before spraying	After spraying	Before spraying	After spraying
Nativo	20s	20mr	25s	20mr	20s	20mr
Cayunis	20s	20mr	25s	20mr	20s	20mr
Untreated	20s	90s	25s	70s	20s	60s
Tridium	20s	20mr	10s	10mr	15s	15mr
Rex® Duo	20s	20mr	10s	10mr	15s	15mr
Untreated	20s	80s	10s	60s	15s	50s

Grain Yield and Yield Components

At Kulumsa grain yield were 6031 kg ha⁻¹, 5861 kg ha⁻¹ and, 1861 kg ha⁻¹ on Nativo, Cayunis EC 325 and unsprayed check plots respectively (Table 3). At Boru chilalo Grain yield were recorded 5822 kg ha⁻¹, 5398 kg ha⁻¹ and, 4013 kg ha⁻¹ on Nativo, Cayunis EC 325 sprayed and unsprayed check plots, whereas at Meraro grain yield were not harvested due to favourable environment to the yellow rust in the cropping season and spike of the treatments was infected on Nativo, Cayunis EC 325 and unsprayed check plots due to high yellow rust pressure and long moisture duration that needs additional fungicide application to reduce late coming rust appearance.

At Kulumsa thousand seed weight were 35.32gram, 34.3 gram and, 31.37gram kg ha⁻¹ on Nativo, Cayunis EC 325 and unsprayed check plots whereas at Boru chilalo Grain yield were recorded 36.28 gram, 36.06 gram and, 34.56 gram on Nativo, Cayunis EC 325 sprayed and unsprayed check plots respectively (Table 2).

At Kulumsa hectolitre weight were 42 kg ha⁻¹, 39 kg ha⁻¹ and, 33 kg ha⁻¹ on Nativo, Cayunis EC 325 and unsprayed check plots and at Boru chilalo hectolitre weight were recorded 52 kg ha⁻¹, 50 kg ha⁻¹ and, 42 kg ha⁻¹ on Nativo, Cayunis EC 325 sprayed and unsprayed check plots

Commented [z18]: Correct all the units in the text

Formatted: Font color: Red

Formatted: Font color: Red, Superscript

Formatted: Font color: Red

Commented [z19]: Replace gram to "g". replace it in the whole text

Commented [z20]: Ensure that all data presented in this section align with Table 3 and cross-reference the table as needed (e.g., "As shown in Table 3, grain yield at Kulumsa...").

respectively whereas at Meraro hectolitre weight were not recorded on Nativo, Cayunis EC 325 and unsprayed check plots, due to shrivelling of wheat kernels that indicates reduced flour yield which indicated that stripe rust affected grains resulted in lower dough strength (the physical strength to resist extension), which in turn, could affect baking quality.

The numerical analysis showed that there was no significant difference between the test fungicides and the standard check fungicide in grain yield, thousand kernel weight and hectoliter weight (Table 3). Even though there was no numerical significant difference in grain yield, thousand kernel weight and hectoliter weight between test fungicide Cayunis EC 325 and Nativo, relatively higher grain yield, thousand kernel weight and hectoliter weight was obtained from Cayunis EC 325 and Nativo sprayed treatments but the difference is insignificant to differentiate the effect of the test fungicide and standard chemical. Test and standard check fungicides revealed numerically significant yield advantage over unsprayed plot.

Table 3. Effect of fungicides application on grain yield, TKW, HLW of bread wheat

Treatments	Grain yield(kg/ha)			HLW(kg/hl)			TKW(gram)		
	KU	MR	BC	KU	MR	BC	KU	MR	BC
Nativo 300 SC	6031	5983	5822	35.32	34.9	36.3	42	41	52
Cayunis 325 EC	5861	6428	5398	34.3	35.2	36.1	39	45	50
Untreated	1861	50	4013	31.37	15.3	33	34.6	11	42

In 2020 main cropping season yellow (stripe) rust disease pressure was very high and excellent disease epidemics developed to the level of creating significant difference among treatments across all test locations in Arsi zone. Fungicide spray treatments (test and standard check fungicide) significantly reduced yellow rust diseases severity over the nil application. Under natural epidemics (no spray) on check treatment, the terminal yellow rust severities of about 90%, 60% and 50% was recorded on unsprayed plots at Meraro, Kulumsa and Boru Chilalo respectively.

The terminal yellow rust severity after once spray of Rex® Duo was recorded by 20%, 10% and 15% at Meraro, Kulumsa and Boru Chilalo respectively whereas, the terminal yellow rust severity at Meraro, Kulumsa and Boru Chilalo recorded 20%, 10% and 15% was recorded on Tridium fungicide sprayed plots respectively (Table 2). The highest disease severity (90 and

60%) was recorded in unsprayed plots at Meraro and Kulumsa on the unsprayed check plots and the lowest yellow rust disease severity 10% and 15% were recorded on Tridium and Rexit Duo sprayed plots at Kulumsa and Boru Chilalo respectively as well as 20% at Meraro which the Rexit Duo and Tridium sprayed plots. Among the fungicides foliar spray application of Rexit Duo and Tridium were found most effective against rust and it gave the highest disease control over the untreated control (Table 4).

However, there was no numerically significant difference between the test and standard check fungicide in reducing yellow rust disease severity (Table 4). However, from visual field observation the test fungicide, Tridium showed comparable level of efficacy in controlling yellow rust disease with the standard check, Rexit Duo. It is evident from visual field observation and table 1 data result is that the test fungicide, Tridium showed comparable level of efficacy on yellow rust disease severity reduction compared to the standard check. Therefore, Tridium can be recommended for the control of wheat yellow rust disease.

Such outcomes could be attributed to the fungicides' efficacy in combating wheat against stripe rust diseases on bread wheat. This research result finding similar to with Wubishet A., et al., 2016 report. Wegulo et al (2009) revealed that up to 42% yield loss was prevented by application of foliar fungicides to winter wheat. Similarly, Kelley (2001) found that over a six-year period, the fungicide propiconazole significantly boosted winter wheat yield by 77%. Furthermore, Vamshidhar Puppala, VP., et al. 1998 reported significant yield increases from fungicide application to control the disease complex of leaf rust, tan spot and Septoria tritici blotch in wheat. In general, the current study also clearly shows that in Ethiopia, it is impossible to grow susceptible to moderately susceptible wheat varieties without application fungicides in areas where wheat rust diseases are a major problem especially, in Arsi and Bale highlands.

Table 4. Effect of fungicides application on grain yield, TKW, HLW of bread wheat

Treatments	Grain yield(kg/ha)			HLW(kg/hl)			TKW(gram)		
	KU	MR	BC	KU	MR	BC	KU	MR	BC
Tridium 7WG	2832	579.5	3221	35.10	36.8	35.8	26.5	24.5	25.7
Rexit Duo	2878	603.5	3224	36.08	35.1	36.5	28.6	30	26.6
Untreated	1550	90.7	1986	34.08	20	35.9	12.9	12.5	22

CONCLUSION AND RECOMMENDATION

Cayunis EC 325 and Tridium 70WG test fungicides did not differ statically from the standard check Nativo 300SC and Rex® Duo in controlling wheat yellow rust disease and provided better grain yield, thousand kernel weight and hectoliter weight than unsprayed check treatments. Among the four fungicides, foliar application of Cayunis EC 325 and Tridium 70WG were found the most effective against yellow rust at Meraro which was highest disease pressure and hotspot area and it gave the highest disease control (77.9%). Moreover, the test fungicides reduced yellow rust disease severity to the lowest level disease management and revealed grain yield advantage better than the standard checks and nil fungicide application untreated checks. After all assessment and evaluation result, the newly verified fungicides are found to be very effective in controlling yellow rust disease for improving wheat yield. Thus, Cayunis EC 325 (Bixafen 75g/L +Spiroxamine 150g/L + Trifloxystrobin 100g/L) and Tridium (Mancozeb 59.7%+Azoxystrobin 4.7%+Tebuconazole 5.6%WG) are recommended for registration as an alternative fungicide for the control of wheat yellow rust disease at rate of 0.9lit/ha and 2kg/ha with 250lit/ha water using knapsack spray as sole or integrated disease management options on wheat. (don't mention the results in the conclusion)

Reference

- Ayele, B., Fehrmann, H. and Yahyaoui, A., 2008a. Status of wheat stripe rust (*Puccinia striiformis*) races and their virulence in major wheat growing areas of Ethiopia. Pest Management Journal of Ethiopia 12: 1-7.
- Bekele Hundie, Shambel Kumbi and Dereje Hailu, 2002. Seasonal variations in the occurrence of wheat stripe rust in Bale highlands. Pest Management Journal of Ethiopia 6: 65-72
- Cooper J, Dobson H., 2007. The benefits of pesticides to mankind and the environment. Crop prot. 26:1337-1348.

Commented [z21]: •Summarize the overall yield advantages observed with the fungicide treatments, even if statistically insignificant. For example, "Although the differences were not statistically significant, treated plots consistently produced higher yields, thousand-kernel weights, and hectoliter weights than untreated plots."
If recommending specific treatments, explicitly tie these recommendations back to observed yield or yield component benefits

Commented [z22]: Replace the old references with recent others and verify the references in the text

- Hailu D, Fininsa C., 2007. Epidemics of stripe rust (*puccinia striiformis*) on common wheat (*triticum aestivum*) in the highlands of bale, southeastern Ethiopia. *Crop Prot.* 26:1209-1218.
- Hodson DP, 2011. Shifting boundaries: challenges for rust monitoring. *Euphytica* 179:93–104.
- ICARDA, 2011. Strategies to reduce the emerging wheat stripe rust disease. Synthesis of a dialog between policy makers and scientists from 31 countries In: International wheat stripe rust symposium, Aleppo, Syria.
- McCallum, B.D., Fetch, T. and Chong J. 2007a. Cereal rust control in Canada. *Australian Journal of Agricultural Research.* 58, 639-647.
- Negassa M. (1986). Estimates of phenotypic diversity and breeding potential of Ethiopian wheats. *Hereditas* 104: 41-48.
- Vamshidhar, P., Herrman, T. J., Bockus, W. W. and Loughin, T. M. 1998. Quality response of twelve hard red winter wheat cultivars to foliar disease across four locations in central Kansas. *Cereal Chemistry*, Vol. 75 No. 1 (January 1998), pp. 94-99, ISSN 0009-0352.
- Wubishet Alemu & Tamene Mideksa. 2016. *International Journal of Research Studies in Agricultural Sciences (IJRSAS)* Volume 2, Issue 9, 2016, PP 35-40
- Kelley, K. W. 2001. Planting date and foliar fungicide effects on yield components and grain traits of winter wheat. *Agronomy Journal*, Vol. 93, No. 2, (March 2001) pp. 380-389, ISSN 0002-1962.
- Worku Denbel. 2014. Epidemics of *Puccinia striiformis* f. sp. *tritici* in Arsi and West Arsi Zones of Ethiopia in 2010 and identification of effective resistance genes. *J. Nat. Sci. Res.* 4, pp. 33-39.
- Ayele A. and Muche G. (2019): Yield loss assessment in bread wheat varieties caused by yellow rust (*Puccinia striiformis* f. sp. *tritici*) in Arsi Highlands of South Eastern Ethiopia. *American Journal of BioScience*, 7:104-112
- Chen, Y.-E., Cui, J.-M., Yang, J. C., Zhang, Z. W., Yuan, M., Song, C., et al., 2015. Biomonitoring heavy metal contaminations by moss visible parameters. *J. Hazard. Mater.* 296, 201–209. doi: 10.1016/j.jhazmat.2015.04.060
- Wanquan Chen, Colin Wellings, Xianming Chen, Zhengsheng Kang And Taiguo Liu, 2014. Wheat stripe (yellow) rust caused by *Puccinia striiformis* f. sp. *Tritici*. *Molecular Plant Pathology* (2014) 15(5), 433–446. DOI: 10.1111/mpp.12116.

- Ali S, Gladieux P, Leconte M, Gautier A, Justesen AF, et al. (2014) Origin, Migration Routes and Worldwide Population Genetic Structure of the Wheat Yellow Rust Pathogen *Puccinia striiformis* f.sp. *tritici*. *PLoS Pathog* 10(1): e1003903. doi:10.1371/journal.ppat.1003903
- Syed Nadeem Afzal, M.I. Haque, M.S. Ahmedani, Samina Bashir and Atiq Ur Rahman Rattu, 2007. Assessment of Yield Losses Caused by *Puccinia Striiformis* Triggering Stripe Rust in the most Common Wheat Varieties. *Pak. J. Bot.*, 39(6): 2127-2134, 2007.
- Mogens S. Hovmøller, Amor H. Yahyaoui, Eugene A. Milus and Annemarie F. Justesen, 2008 Blackwell Publishing Ltd Rapid Global Spread of Two Aggressive Strains of A Wheat Rust Fungus. *Molecular Ecology* (2008) 17, 3818–3826 doi: 10.1111/j.1365-294X.2008.03886.
- Wegulo *et al.* , 2009 • S. N. Wegulo, J. A. Breathnach, and P. S. Baenziger, Effect of growth stage on the relationship between tan spot and spot blotch severity and yield in winter wheat, *Crop Prot.* 28 (2009), pp. 696–702