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Research Article

Evaluation of newer fungicides for the management of wheat stem rust caused by (*Puccinia graminis* f. sp. *tritici*)

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Abstract:

Wheat is one of the important and third most consumed food crop world over. It is the most important staple food of about two billion people of the glove . Among all the biotic constraints stem rust is the most destructive disease of wheat. When crop resistance is failed it causes severe loss to wheat production. Chemical fungicides are an emergent tool for management of this disease. During cropping season 2020-21 & 2021-22, we evaluated some newer chemical fungicides against wheat stem rust with reduction in DI % & ACI and increase yield attributes. In this experiment four fungicides *viz.,* Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC, Pyraclostrobin 7% EC, Propiconazole 25% EC and Tebuconazole 50%EC were used @ 0.1% on two susceptible varieties. The fungicide Tebuconazole (50EC) reduces the DI % (disease incidence) up to 45.62 % after 7 days of spraying and 74.92 % after 14 days of spraying. It clearly indicates that this toxicant is exhibiting very excellent curative effect. Bio-efficacy potential of Propiconazole 25% EC is next to Tebuconazole 50% EC and difference between then is statistically insignificant. It is clear that Tebuconazole 50% EC drastically reduces the severity of stem rust to the level of 1.67 against check. Biological yield and grain yield is also comparatively best with Tebuconazole 50% EC. The grain yield increase percentage was very high *i.e.* 169.49 % with variety Agra local and 185.48 % with variety Local red as compare to check value *i.e.* zero.

Keywords: Stem rust, Wheat, Fungicides and Tebuconazole

1. Introduction:

Wheat is one of the most widely grown and most consumed food crops all over the world. The major wheat producing countries are China, India, Russia, USA, France, Canada, Germany, Pakistan and Australia. India is the second largest producer of wheat after China. During 2020-21 wheat was globally cultivated on 224.49 million hectare areas with 792.40 million tonnes production and 3530 kg/hectare productivity. In India it was cultivated on 31.58 million hectare areas with 108.75 million tonnes production and 3424 kg/ha productivity, (Annual Progress Report 2020-21, IIWBR, Karnal). Madhya Pradesh has produced wheat on 6.80 million hectare areas with 17.62 million tonnes production and 2760 kg/ha productivity (III Advance Estimates of 2020-21, Directorate of Economics and Statistics, Ministry of Agriculture and Farmers' Welfare).

There are three rust species reported to infect wheat are: *Puccinia triticina* (brown rust), *Puccinia striiformis* f. sp. *tritici* (yellow rust), and *Puccinia graminis* f. sp. *tritici* (stem or black rust). These are ubiquitous and considered most harmful wheat pathogens globally (Dean *et al.* 2012, Huerta- Espino *et al* 2014), Stem rust becomes most destructive under favorable conditions, and may cause

up to total yield losses to the susceptible varieties (Roelfs, 1985; Leonard and Szabo, 2005).

Roelfs *et al.* (1992).The symptoms of stem rust primarily appear on the stems but can also be observed on leaves, sheath, glumes, and awns even on seeds during the booting stage to three weeks before harvesting. Stem rust is favoured by hot days (25-30°C/ 77-86°F), mild nights (15-20°C/ 59-68°F), and wet leaves from rain or dew. Both aeciospores and urediniospores require free water for germination as do the other spore stages. Infections occur through stomata. More than 5 billion dollars are lost due to cereal rust each year (Figueroa *et al.* 2018). Wheat stem rust threatens to about 7 million hectares of Central and Peninsular in India (Bharadwaj *et al.* 2019).

Epidemics of the rust in India was reported in 1975 by Nagarajan and Joshi. In central province it was for the first time communicated during 1786 and subsequently in 1805, 1827, 1828-29, 1831- 32. Rust occurrence in main wheat belt of India that is in and around Delhi was during 1843 and during 1884 and 1895 from Allahabad, Banaras and Jhansi areas. Thereafter epidemic had occurred in Punjab and sub mountainous areas of Gorakhpur in 1905. Severe appearance of rust in the plains of Indo-Gangetic areas was recorded during 1910-1911.

In 1965-66 a severe toll of wheat stem rust was reported from Khandwa, Khargone and few surrounding villages of Hoshangabad district on local varieties especially on Safad pisi, Bansi and Jalaliya wheat. Late on it was also reported from Sagar, Damoh, Datiya, Vidisha, Jabalpur, Narsinghpur, Khandwa, Mandsour, Dhar, Chhatarpur, Tikamgarh and Raisen districts of Madhya Pradesh on local and few improved wheat varieties during 1967-68. In Hoshangabad districts a heavy toll of rusts was observed in Pipariya tehsil, on local wheat varieties. Powarkheda area of Hoshangabad was also severely attacked by stem rust on the then prevailing varieties viz. DL 34, NP 839, HY 65, C 330, Sonara- 63 and Sonara 64 (Mishra and Singh 1969). Extensive Stem rust occurrence on local wheat genotypes i.e. Pissi and Malwi local during 1978-79 in Narmada valley of Madhya Pradesh was first time reported by Joshi, *et al* (1985),

The Host resistance invariably plays a very important role in disease management particularly in case of obligate pathogen. Selecting resistant varieties are most physibles and sustainable means wheat stem rust management. However it is clear from the literature that over time the varieties that were initially resistant became susceptible. This is because of evolution of new races of ever evolving pathogen and emergence of potential new races. Therefore researchers need to have a better understanding of chemicals effective against stem rust pathogen, so that suitable and effective toxicant can be recommended when chemical fungicide management is urgently needed. Hence considering all above it is worthwhile to evaluate comparative efficacy of newer available fungicides it is necessary to know about best suitable fungicide.

2. Material and methods

Two bread wheat varieties, namely Agra local and Local red were used. They differ in reactions to stem rust. For instance Agra Local is slow rusting type while Local red is fast rusting susceptible varieties to stem rust of wheat (*Puccinia graminis* f.sp. *tritici*). Seeds of both bread wheat varieties were sown on 06/12/2020 during crop season 2020-21 and 07/12/2021 during 2021-22 in total 10 treatments and three replications keeping plot size 2.5 m x 5 row using recommended dose of seed & fertilizers.

2.1 Inoculation and observation on disease incidence & Average coefficient of Infection (disease severity)

At forty days crop age inoculation schedule were applied. Inoculum of stem rust causing organism *Puccinia graminis* f. sp. *tritici* race mixture (urediniospores suspension) was sprayed using hand sprayer on both wheat varieties. It was repeated after seven days interval & observed disease incidence and Average coefficient of infection (disease severity). Fungicides spray schedule was applied at level of disease incidence and ACI% (disease severity). Fungicides were applied manually using knapsack sprayer delivering 250 litre of water/ha.

2.2 Test fungicides

The bio-efficacy of fungicides trial was conducted during the wheat season 2020-21 and 2021-22. Under this four newer fungicides like Azoxystrobin (18.2% ww) + Difenoconazole (11.4% ww), Pyraclostrobin (7% EC), Propiconazole (25% EC) and Tebuconazole (50% EC) were used for foliar application @ 0.1% on two susceptible wheat varieties at mean disease incidence range 56.39 % to 58.01% in Agra local and 56.64% to 59.47% in Local red and Mean Average coefficient Infection (disease severity) range from 46.67 to 53.33 in Agra local and Local red during crop season 2020-21.The spray schedule

was applied at mean disease incidence range 57.03 % to 60.38% in Agra local and 57.41% to 61.51% in Local red and Mean Average coefficient Infection (disease severity) range from 46.67 to 53.33 in Agra local and Local red in 2021-22 in different treatment combination and distilled water was sprayed on checks. During sprays, plastic sheets were used to separate the plot & unwanted splash of fungicides. Treatment details are as under

1. T1 Agra local + (Azoxystrobin 18.2%w/w + Difenoconazole 11.4% w/w SC)
2. T2 Agra local + (Pyraclostrobin 7% EC)
3. T3 Agra local + (Propiconazole 25% EC)
4. T4 Agra local + (Tebuconazole 50% EC)
5. T5 Agra local + (No chemical (Check-1)
6. T6 Local red + (Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC)
7. T7 Local red + (Pyraclostrobin 7% EC)
8. T8 Local red + (Propiconazole 25% EC)
9. T9 Local red + (Tebuconazole 50% EC) and
10. T10 Local red + (No chemical (Check-2)

2.3 Disease assessment, Crop yield and thousand grain weight

During both crop seasons after fungicides spray disease incidence and average coefficient Infection (disease severity) were observed at 0 day, 7th day and 14th day of spraying. At harvest the biological yield qt/ha., grain yield qt/ha and 1000 grain weight in grams was calculate. Disease severity was recorded in percentage using modified Cobb Scale (Peterson *et al*., 1948).

2.4 Statistical analysis

Data on stem rust severity and incidence, increase yield and yield components were analyzed statistically (CV) coefficient of variation and Means with the same letter within a column are not significant difference using Randomized Block Design (RBD).

3. Results and discussion

3.1 Effect on disease incidence

Bio-efficacy of four different newer fungicides were assessed using parameters like average disease incidence, average coefficient of infection, grain and biomass yield and thousand kernel weight (TKW). The spray schedule was followed at about 50% disease incidence and comparative incidence recorded at 0 day, 7 day and 14 day of spray. If compare the curative Potential of fungicides. It is very much clear from (Table: 1) that Tebuconazole @ 50% EC had drastically reduced the disease incidence from 57.14 % to 23.31% after 7 days of spray and it was shown to have even better performance after 14 days of spray *i.e.* 3.94% as against unsprayed checks T5 and T10 where corresponding black rust incidence was 78.86% and 80.38% respectively. The second best performing fungicide was Propiconazole 25% EC @ 1ml/L. Although all the test fungicides were statically superior over checks, treatment T1 and T3 were not significantly differ from each other but significantly superior over other. Treatment T2 and T4 was significantly differ from each check. This trend of result was almost similar with both the varieties *i.e.* Agra local and Local red in both the cropping years cropping year (2020-21 and 2021-22), evident from the data in (Table: 1 & 2).

3.2 Effect on Average Coefficient of infection

Average coefficient of infection was the next important parameter to observe the comparative Bio- efficacy of foliar spray of newer fungicides clearly indicates that the average coefficient of infection at the time of spraying was more than 50% when the spraying schedule was started. After 7days of spraying the disease score was recorded and was calculated ACI value of treatment T4 (Tebuconazole 50% EC) was lowest *e. i.* 13.33 with variety Agra local, on another variety of wheat *e. i.* Local red (T9) too, the same fungicide has shown best efficacy with ACI value 10.00 .Toxicant Tebuconazole has even further reduced the ACI up to 1.67 at 14 day of spraying. Considering ACI value it is stated that fungicides, Propiconazole numerically rank second after Tebuconazole and efficacy did not differ significantly from each other on both the varieties. All fungicides are statistically superior over check. The chemical Pyraclostrobin was proved to be least effective on both the varieties viz., Agra local and Local red with slight variation the trend of result was almost similar in both the years, evident from data in (Table: 1 & 2).

3.3 Effect on biological Yield

Effect of different fungicides on biological yield of wheat on stem rust management summarized data in (Table: 1 & 2). Significant effect of different fungicides recorded on biological yield of wheat. All the treatments

are significantly superior over check but the maximum average biological yield qt/ha was recorded in treatment (T4) 62.50 followed by (T3) 55.80 & (T1) 55.30. This trend of result was almost similar with both the varieties & in both the years.

3.4 Effect on grain Yield

The effect of fungicides on avoidable yield loss in terms of grain yield/ha was drastically high as compare to both the checks data evident in (Table 1 & 2). All the treatments were significantly and drastically superior over check. Grain yield qt/ha, best in Tebuconazole 50% EC sprayed plot (T4) 15.90 followed by Propiconazole 25% EC sprayed plot (T3) 14.20 as compared to checks that is T5 (water sprayed plots) where average grain yield qt/ha was 5.90. Similar trend of observation was also there with another susceptible variety *i.e.* Local red and with same chemicals. One thing which is very appeals is the result of Propiconazole 25% EC and Tebuconazole 50% EC was differing significantly from each other. But this was not the case with other parameters. The % increase yield in grain during 2020-21 was 185.48% (T9) and 171.77% (T8) as compared to Local red and Agra local varieties respectively.

3.5 Effect on thousand grain weight

The average thousand grain weight in all the treatments were significantly and drastically higher over both the checks, except T2 & T7 treatment. The average thousand grain weight was maximum in Tebuconazole 50% EC sprayed plot (T9) 33.67g followed by Propiconazole 25% EC sprayed plot (T8) 30g but not significantly differ from each other. The minimum average thousand grain weight in treatment (T10) 21.67g and it was statistically at par from treatment (T7) 22.67g. The similar trend was observed with another susceptible variety Agra local, data summarized in (Table 1). This Trend of result was also observed in crop season 2021-22 data evident in (Table 2).

Table 1. Effect of fungicides on Disease incidence, Average coefficient Index (Disease severity) of stem rust (*Puccinia graminis* f. sp. *tritici*) and wheat yield parameters (2020-21)

Treatments	*DI %			* ACI %			* Yield			% increased yield	% Avoidable yield loss
	0 day spray	After 7 day spray	After 14 day spray	0 day spray	After 7 day spray	After 14 day spray	Bio. Yield (Qt./ ha.)	Yield (Qt/ ha)	1000 grain wt (g)		
T1 - Agra local + Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC	58.01	33.41	7.06	53.33	26.67	13.33	55.30	13.60	29.67	130.51	56.62
T2 - Agra local + (Pyraclostrobin 7% EC)	56.39	39.02	13.35	46.67	40.00	20.00	51.40	12.10	24.33	105.08	51.24
T3 - Agra local + (Propiconazole 25%EC)	56.72	32.40	5.73	53.33	20.00	6.67	55.80	14.20	29.00	140.68	58.45
T4 - Agra local + (Tebuconazole 50% EC)	57.14	23.31	3.94	53.33	13.33	1.67	62.50	15.90	32.67	169.49	62.89
T5 - Agra local + (No chemical (Check -1)	56.99	68.93	78.86	53.33	60.00	66.67	33.80	5.90	22.33	0	0
T6 – Local red + Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC	56.69	33.10	8.06	53.33	33.33	13.33	50.20	16.40	28.33	164.52	62.2

T7 - Local red + (Pyraclostrobin 7% EC)	57.24	38.21	12.17	53.33	40.00	8.33	44.10	14.70	22.67	137.1	57.82
T8 - Local red + (Propiconazole 25% EC)	57.69	31.98	5.19	53.33	16.67	6.67	54.30	16.85	30.00	171.77	63.2
T9 - Local red + (Tebuconazole 50% EC)	59.47	24.04	4.13	53.33	10.00	1.67	61.60	17.70	33.67	185.48	64.97
T10 -Local red + (No chemical (Check -2)	56.64	67.67	80.38	46.67	60.00	66.67	28.40	6.20	21.67	0	0
S.Em (±)	**-**	**2.5**	**1.63**	**-**	4.89	3.31	3.1	0.77	1.91	-	-
CD at (5 %)	-	5.25	3.42	-	10.27	6.95	6.51	1.62	4.01	-	-
CV	-	7.81	9.12	-	18.73	19.75	7.63	7.04	8.52	-	-

*DI % = Mean value of disease incidence

*ACI % = Mean value of average coefficient of infection

*Yield = Mean value of yield

Table 2. Effect of fungicides on Disease incidence and Disease severity of wheat stem rust (*Puccinia graminis* f. sp. *tritici*) and yield parameters (2021-22)

Treatments	*DI %			* ACI %			* Yield			% increased yield	% Avoidable yield loss
	0 day spray	After 7 day spray	After 14 day spray	0 day spray	After 7 day spray	After 14 day spray	Bio. Yield (Qt/ ha.)	Yield (Qt/ ha.)	1000 grain wt (g)		
T1 - Agra local + Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC	60.94	40.40	7.47	53.33	33.33	16.67	56.60	14.20	31.00	118.46	54.23
T2 - Agra local + (Pyraclostrobin 7% EC)	57.03	41.92	11.03	53.33	40.00	20.00	50.40	12.65	23.67	94.62	48.62
T3 - Agra local + (Propiconazole 25% EC)	59.35	27.56	6.14	46.67	13.33	8.33	58.80	14.80	31.33	127.69	56.08
T4 - Agra local + (Tebuconazole 50% EC)	60.38	20.80	3.41	53.33	10.00	3.33	62.40	16.10	34.00	147.69	59.63
T5 - Agra local + (No chemical (Check-1)	58.29	68.56	79.19	46.67	60.00	73.33	33.60	6.50	22.00	0	0
T6 – Local red + Azoxystrobin 18.2% w/w + Difenoconazole 11.4% w/w SC	58.75	37.58	9.95	53.33	33.33	10.00	47.40	15.80	30.00	119.44	54.43
T7 - Local red + (Pyraclostrobin 7% EC)	57.41	41.85	15.43	46.67	40.00	20.00	43.50	14.50	23.33	101.39	50.34
T8 - Local red + (Propiconazole 25% EC)	59.97	28.65	5.54	53.33	16.67	10.00	49.20	16.40	30.33	127.78	56.1
T9 - Local red + (Tebuconazole 50% EC)	61.51	18.37	4.98	53.33	8.33	3.33	51.90	17.30	34.00	140.28	58.38
T10 -Local red + (No chemical (Check -2)	57.74	69.06	78.08	46.67	60.00	73.33	29.50	7.20	20.00	0	0

S.Em (±)	-	**2.34**	**1.29**	-	**4.03**	**3.69**	**2.78**	**0.91**	**1.97**	-
CD at (5 %)	-	**4.92**	**2.71**	-	**8.47**	**7.75**	**5.84**	**1.91**	**4.14**	-
CV	-	**7.26**	**7.15**	-	**15.67**	**18.98**	**7.06**	**8.24**	**8.63**	-

*DI % = Mean value of disease incidence

*ACI % = Mean value of average coefficient of infection

*Yield = Mean value of yield

Experiment was basically conceptualized to know the comparative efficacy of fungicides even when the management, application was started after disease occurrence so that curative potential of toxicant and its further impact on yield and yield attributes may be compared over two years (2020-21 & 2021-22). Field trials exhibited that Tebuconazole was found most effective not only in controlling stem rust disease incidence and ACI. But it has very positive result on yield and thousand kernel weight.

The fungicide Tebuconazole 50% EC reduces the disease incidence up to 45.62 % after 7 days of spraying and 74.92 % after 14 days of spraying. It clearly indicates that this toxicant is exhibiting very excellent curative effect. Relative efficacy of Propiconazole is next to Tebuconazole and differs between then is statistically insignificant if we compare the ACI value of treatment T4 with check. It is very much clear that Tebuconazole 50% EC has drastically reduces the severity of stem rust to the level of 1.67 against check that is 66.67.

Biological yield, Grain yield is also comparatively best with Tebuconazole 50% EC. The grain yield increase percentage was very high *i.e.* 169.49 % with variety Agra local and 185.48 % with variety Local red as compare to check value *i.e.* zero.

The performance of next best fungicide was Propiconazole 25% EC is insignificantly differ from Tebuconazole 50%EC in all parameters except Biological yield & Grain yield it means Tebuconazole 50% EC has positive impact on thousand grain weight and grain yield. Our findings are in corroboration with previous work done by Lopeg *et al.* 2014 and Singh *et al.,* 2016. They reported that Azole and Strobin group of fungicides increased the grain yield and quality.

The performance/bio-efficacy of Tebuconazole was found best in other folior disease of wheat (Mahapatra and Das 2013).

North Central regional Committee on management of small grain diseases has also rated that Tebuconazole (38.7%) has excellent stem rust management potential.

Conclusion

Therefore, it can be concluded that fungicide Tebuconazole 50% EC @ 0.1% may be recommended for stem rust management. Because it not only substantially decreases the DI and ACI, but it also increases the yield attributes. The Propiconazole 25% EC stand next to it in its performance followed by Azoxystrobin 18.2% w/w+ Difenoconazole 11.4% w/w SC @ 0.1 %

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Author's contribution

Field experiment conduction and Manuscript preparation: DKB. Supervision, correction and edition: VKY and KKM.

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