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Evaluation of Different Fungicides for the Management of Stem Rust (*Puccinia graminis* Pers. *tritici* Erikss. & Henn.) of Wheat

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Wheat (*Triticum aestivum* L.) is the most important cereal crop. It belongs to genus *Triticum* of the family *Poaceae*. The most prevalent pathogens on wheat are the three rusts *viz.,* black/stem rust (*Puccinia graminis* Pers. *tritici* Erikss. and Henn.), leaf/brown rust (*Puccinia recondita* Rob. Ex.

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Desm. f. sp. *tritici*) and yellow/stripe rust (*Puccinia striiformis* West), which pose serious threat on its production. The present investigations were carried out at Department of Plant Pathology, C. P. College of Agriculture, and Agronomy Instructional Farm, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat during *Rabi* 2021-22 and 2022-23. The minimum disease severity (21.60 & 22.34%) was recorded in propiconazole 25 EC with maximum (49.01 & 47.28%) disease reduction over control followed by tebuconazole 50% + trifloxystrobin 25% WG during 2021-22 and 2022-23, respectively. The maximum 2727 kg/ha grain yield and 3135 kg/ha straw yield were obtained from the plots treated with propiconazole 25 EC which was followed by tebuconazole 50% + trifloxystrobin 25% WG (2434 kg/ha & 2776 kg/ha), respectively.

Keywords: Fungicide; poaceae; Puccinia graminis; Puccinia recondite; Puccinia striiformis, Triticum aestivum.

1. INTRODUCTION

"Wheat (*Triticum aestivum* L.) is the most important cereal crop for the majority of world's population. Wheat belongs to genus *Triticum* of the family *Poaceae*. It is the third largest cereal produced in the world after corn and rice and is most widely consumed as stable food in the world. In India, wheat is the second most important crop next to rice exclusively in the *Rabi* season. Three species of wheat namely, *T. aestivum* L. (Bread wheat), *T. durum* (Macroni or Durum wheat) and *T. dicoccum* Schrank. (Emmer wheat), are commonly cultivated in India. Wheat is a major ingredient in foods such as bread, porridge, crackers, biscuits, muesli, pancakes, pies, pastries, cakes, cookies, muffins, rolls, doughnuts, gravy, beer, vodka, boza (a fermented beverage) and breakfast cereals" (Loughman et al., 2005).

"The rusts are responsible for the considerable damage to the wheat crop. The losses caused due to rusts vary from region to region. Stripe rust or yellow rust is confined to cooler parts of the country comprising of the hilly mountains and foot hills of Himalayas, Nilgiri and Pulney, State of Himachal Pradesh, Punjab, Hariyana, Uttar Pradesh and parts of Rajasthan. It is totally absent from south India except in Nilgiri and Pulney hills of Tamil Nadu. Black stem rust though prevalent all over the country, normally appears in epidemic form only in southern, central and eastern parts of India, where normally high temperatures prevail during the crop season" (Wanyera et al., 2009; Loughman et al., 2005).

The most notorious, shifty enemies and prevalent pathogens on wheat are the three rusts *viz.*, black/stem rust (*Puccinia graminis* (Pers.) *tritici* Eriks. and Henn.), leaf/brown rust (*Puccinia recondita* Rob. Ex. Desm. f.sp. *tritici*) and yellow/stripe rust (*Puccinia striiformis* West), which pose serious threat to the stability of its production. The rusts are the worldwide distributed diseases of wheat. An overview of global crop losses caused by the three wheat rusts indicated varying regional significances. Stripe rust assumed more importance in West Asia, Southern Africa, the Far East (China), South America and Northern Europe. Leaf rust caused more serious losses in South Asia, North Africa, Southeast Asia and South America. Stem rust has traditionally been important in North America, Australasia, Northern Africa, South Africa and to some extent, Europe.

2. MATERIALS AND METHODS

2.1 Management of Black Rust of Wheat under Field Condition

Experiments on the present investigations entitled, "Studies on stem rust of wheat caused by *Puccinia graminis* Pers. *tritici* Erikss. & Henn. were conducted on Agronomy Instructional Farm and department of Plant Pathology, C. P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat during the year of 2021-22 and 2022-23. The materials used and methodology followed for the present investigations on management of stem rust through different fungicides under field condition.

❖ **Information about workplace**

1. Location

Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Dantiwada, Gujarat, where the present investigations were undertaken is situated at 21.5° North latitude and 70.5° East longitude and has an elevation of 82.92 meters above the mean sea level.

2. Climate

The region has a subtropical climate with an average rainfall ranging from 402-694 mm. The monsoon is warm and moderately humid. It commences between the end of July and end of October. Monsoon in this area is often erratic and uncertain, both in respect of total rainfall and its distribution. Winter is fairly cool and dry, while summer is quite hot, where the temperature ranges from 30 to 42 °C.

This experiment was conducted in Randomized Block Design under field condition. Each plot contains ten rows. Among these six rows sown with stem rust susceptible variety (Lok-1) and other two rows of both side of plot were sown with susceptible infectors. The infector rows were inoculated with freshly collected uredospore at boot leaf stage by syringe inoculation method for uniform spread of inoculum. Eight different fungicides (Two systemic fungicides and six combination fungicides) were selected and compared with untreated check. The fungicides were applied two times with an interval of 15 days starting after the appearance of stem rust symptoms. Observations on black rust were recorded periodically.

2.2 Disease Severity

First spray of the fungicides carried out done immediately after the initial appearance of disease symptoms and control plot was sprayed by water. “Twenty plants were selected randomly in each plot and observations on disease severity were recorded using the modified Cobbs scale” (Peterson et al*.,* 1948). The per cent disease reduction (PDR) was calculated based on per cent disease severity of control and treatment after final spray.

PDR = PDS of control – PDS of treatment / PDS of control × 100

2.3 Grain Yield

Grain yield in gram per plot was recorded and converted on hectare basis. Only six internal rows of the plots were harvested for yield estimation. Grain yield of sprayed plots were compared with check.

2.4 Straw Yield

Straw yield was obtained by subtracting the grain yield from the weight of total produce of each plot and recorded on the hectare basis.

The per cent increase in grain yield and straw yield over control was calculated by using following formula:

Per cent increase in yield = Yield of treated plot – Yield of control plot / Yield of treated plot × 100

3. RESULTS AND DISCUSSION

The experiment was laid out at Agronomy Instructional Farm, S. D. Agricultural University, SDAU in randomized block design with three replications. Total eight fungicides and a control were adopted as mentioned in material and methods. Total two sprays were given at 15 days interval. The data on per cent disease severity of stem rust was recorded before first fungicidal spray to after second fungicidal spray along with grain yield and straw yield.

3.1 Disease Severity (2021-22)

Perusal of data presented in Table 1 revealed that all the fungicides tested in field condition were significantly reduced stem rust disease severity as compared to control. The significantly minimum disease severity (21.60%) was recorded in propiconazole 25 EC with maximum (49.01%) disease reduction over control followed by tebuconazole 50% + trifloxystrobin 25% WG recorded (23.84%) disease severity with 43.74 per cent disease reduction over control. These fungicides were statistically at par with each other. The next best fungicides in merit in relation to per cent disease severity were pyraclostrobin 133 g/l + epoxiconazole 50 g/l SE, picoxystrobin 7.05% + propiconazole 11.7% SC, tebuconazole 25 EC, azoxystrobin 18.2% w/w + cyproconazole 7.3% w/w SC, azoxystrobin 11% w/w + tebuconazole 18.3% w/w SC and azoxystrobin 18.2% w/w + difenoconazole 11.4% w/w SC with 25.97, 27.84, 29.30, 30.80, 31.67 and 33.47 per cent disease severity and 38.71, 34.30, 30.84, 27.30, 25.25 and 21.00 per cent disease reduction, respectively. Maximum per cent disease severity (42.37%) recorded in control.

3.2 Disease Severity (2022-23)

Perusal of data presented in Table 2 revealed that all the fungicides tested in field condition were significantly reduced stem rust disease severity as compared to control. The significantly minimum disease severity (22.34%) was recorded in propiconazole 25 EC with maximum (47.28%) disease reduction over control followed by tebuconazole 50% + trifloxystrobin 25% WG recorded (24.50%) disease severity with 42.17 per cent disease reduction over control. These fungicides were statistically at par with each other. The next best fungicides in merit in relation to per cent disease severity were pyraclostrobin 133 g/l + epoxiconazole 50 g/l SE, picoxystrobin 7.05% + propiconazole 11.7% SC, tebuconazole 25 EC, azoxystrobin 18.2% w/w + cyproconazole 7.3% w/w SC, azoxystrobin 11% w/w + tebuconazole 18.3% w/w SC and azoxystrobin 18.2% w/w + difenoconazole 11.4% w/w SC with 26.70, 28.60, 30.17, 31.40, 32.34 and 34.50 per cent disease severity and 36.98, 32.50, 28.80, 25.88, 23.68 and 18.57 per cent disease reduction, respectively. Maximum per cent disease severity (42.40%) recorded in control.

3.3 Grain and Straw Yield (2021-22)

The data presented in Table 3 revealed that all the treatments were found significantly superior in relation to grain and straw yield as compared to control. The maximum 2628 kg/ha grain and 3022 kg/ha straw yield was obtained from plots treated with propiconazole 25 EC which was followed by tebuconazole 50% + trifloxystrobin 25% WG with 2354 kg/ha grain and 2681 kg/ha straw yield. The nest best treatment in merits were pyraclostrobin 133 g/l + epoxiconazole 50 g/l SE, picoxystrobin 7.05% + propiconazole 11.7% SC, tebuconazole 25 EC, azoxystrobin 18.2% w/w + cyproconazole 7.3% w/w SC and azoxystrobin 11% w/w + tebuconazole 18.3% w/w SC with 2335, 2209, 2112, 2027 and 1901 kg/ha grain yield and 2586, 2475, 2395, 2231 and 2186 kg/ha straw yield, respectively. The significantly minimum 1893 kg/ha grain yield and 2110 kg/ha straw yield was recorded in azoxystrobin 18.2% w/w + difenoconazole 11.4% w/w SC as compared to control 1619 kg/ha grain yield and 1861 kg/ha straw yield.

3.4 Grain and Straw Yield (2022-23)

The data presented in Table 3 revealed that all the treatments were found significantly superior in relation to grain and straw yield as compared to control. The maximum 2825 kg/ha grain and 3248 kg/ha straw yield was obtained from plots

Table 1. Effect of different fungicides on stem rust severity during 2021-22

Sr. No.	Treatments	Con. (ml/lit)	Disease severity (%)			PDC after final spray
			Before spray	After 1st spray	After 2nd spray	
1.	Picoxystrobin 7.05% + Propiconazole 11.7% SC	1.5	29.82* (24.36)**abcd	30.23 (25.47)bcd	31.94 (27.84)cde	34.30
2.	Pyraclostrobin 133 g/l + Epoxiconazole 50 g/l SE	1.5	28.74 (22.77)bcd	29.14 (23.70)cde	30.82 (25.97)de	38.71
3.	Tebuconazole 50% + Trifloxystrobin 25% WG	1.5	28.23 (22.17)cd	27.92 (21.74)de	29.41 (23.84)ef	43.74
4.	Azoxystrobin 18.2% w/w + Cyproconazole 7.3%w/w SC	1.5	30.22 (24.97)abc	31.20 (27.04)bc	33.92 (30.80)bc	27.30
5.	Azoxystrobin 18.2%w/w + Difenoconazole 11.4% w/w SC	1.5	32.09 (27.87)ab	32.09 (28.67)b	35.51 (33.47)b	21.00
6.	Azoxystrobin 11%w/w + Tebuconazole 18.3% w/wSC	1.5	30.66 (25.60)abc	31.48 (27.70)bc	34.37 (31.67)bc	25.25
7.	Propiconazole 25 EC	1.5	26.25 (19.34)d	27.08 (20.50)e	27.96 (21.60)f	49.01
8.	Tebuconazole 25 EC	1.5	30.04 (24.80)abc	30.83 (26.37)bc	32.79 (29.30)bcd	30.84
9.	Control	-	32.94 (29.57)a	37.28 (36.54)a	40.86 (42.37)a	-
S.Em.±			1.56	1.25	1.25	-
C.D. at 5%			NS	3.75	3.74	-
C.V.%			9.07	7.03	6.53	-

**Figures outside of parentheses are arc sin transformed values*
***Figures in the parentheses are original values*
Treatment means with common letter/letters are not significant by Duncan's New Multiple Range Test at 5% level of significance

Table 2. Effect of different fungicides on stem rust severity during 2022-23

Sr. No.	Treatments	Con. (ml/lit)	Disease severity (%)			PDC after final spray
			Before spray	After 1st spray	After 2nd spray	
1.	Picoxystrobin 7.05% + Propiconazole 11.7% SC	1.5	30.57* (25.42)**ab	31.39 (27.20)bcd	32.39 (28.60)cde	32.50
2.	Pyraclostrobin 133 g/l + Epoxiconazole 50 g/l SE	1.5	29.58 (23.94)bc	30.41 (25.40)cde	31.26 (26.70)de	36.98
3.	Tebuconazole 50% + Trifloxystrobin 25% WG	1.5	28.72 (22.87)bc	29.29 (23.60)de	29.84 (24.50)ef	42.17
4.	Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC	1.5	30.69 (25.64)ab	32.72 (29.24)bc	34.27 (31.40)bc	25.88
5.	Azoxystrobin 18.2%w/w + Difenoconazole 11.4% w/w SC	1.5	31.70 (27.24)ab	33.79 (31.10)ab	36.10 (34.50)b	18.57
6.	Azoxystrobin 11%w/w + Tebuconazole 18.3% w/w SC	1.5	31.18 (26.37)ab	33.51 (30.74)b	34.75 (32.34)bc	23.68
7.	Propiconazole 25 EC	1.5	26.90 (20.14)c	27.85 (21.54)e	28.42 (22.34)f	47.28
8.	Tebuconazole 25 EC	1.5	30.52 (25.47)ab	32.39 (28.70)bc	33.29 (30.17)bcd	28.80
9.	Control	-	33.49 (30.34)a	36.82 (35.74)a	40.87 (42.40)a	-
S.Em.±			1.53	1.40	1.30	-
C.D. at 5%			NS	4.18	3.89	-
C.V.%			8.73	7.55	6.71	-

**Figures outside of parentheses are arc sin transformed values*
***Figures in the parentheses are original value*
Treatment means with common letter/letters are not significant by Duncan's New Multiple Range Test at 5% level of significance

treated with propiconazole 25 EC which was followed by tebuconazole 50% + trifloxystrobin 25% WG with 2514 kg/ha grain and 2872 kg/ha straw yield. The nest best treatment in merits were, pyraclostrobin 133 g/l + epoxiconazole 50 g/l SE, picoxystrobin 7.05% + propiconazole 11.7% SC, tebuconazole 25 EC, azoxystrobin 18.2% w/w + cyproconazole 7.3% w/w SC and azoxystrobin 11% w/w + tebuconazole 18.3% w/w SC with 2402, 2360, 2221, 2182 and 2150 kg/ha grain yield and 2802, 2730, 2583, 2510 and 2472 kg/ha straw yield, respectively. The significantly minimum 2123 kg/ha grain yield and 2324 kg/ha straw yield was recorded in azoxystrobin 18.2% w/w + difenoconazole 11.4% w/w SC as compared to control 1550 kg/ha grain yield and 1782 kg/ha straw yield.

3.5 Grain and Straw Yield (Pooled)

All the treatments were found significantly superior as compared to control. The maximum 2726.17 kg/ha grain yield and 3135.09 kg/ha straw yield were obtained from the plots treated with propiconazole 25 EC which was followed by tebuconazole 50% + trifloxystrobin 25% WG recorded 2434 kg/ha grain yield and 2776 kg/ha straw yield. The nest best treatment in merits were, pyraclostrobin 133 g/l + epoxiconazole 50 g/l SE, picoxystrobin 7.05% + propiconazole 11.7% SC, tebuconazole 25 EC, azoxystrobin 18.2% w/w + cyproconazole 7.3% w/w SC and azoxystrobin 11% w/w + tebuconazole 18.3% w/w SC with 2369, 2285, 2166, 2105 and 2025 kg/ha grain yield and 2694, 2602, 2489, 2370 and 2329 kg/ha straw yield, respectively. The significantly minimum 2008 kg/ha grain yield and 2217 kg/ha straw yield was recorded in azoxystrobin 18.2% w/w + difenoconazole 11.4% w/w SC as compared to control 1584 kg/ha grain yield and 1822 kg/ha straw yield.

Iqbal et al*.* (2015) reported that the propiconazole recorded the highest disease control (22.5%) compared to all rest of the treatments. The highest grain yield was recorded by propiconazole (3.41 t/ha) followed by sulphur (3.23 t/ha), metiram (3.07 t/ha).

Table 3. Effect of different fungicides on yield components during 2021-22 and 2022-23

Sr. No.	Treatments	Con. (ml/lit)	Grain yield (Kg/ha)			Straw yield (Kg/ha)			Per cent increase over control (%)	
			2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	Grain yield	Straw yield
1.	Picoxystrobin 7.05% + Propiconazole 11.7% SC	1.5	2209[bc]	2360[ab]	2285[ab]	2475[bcd]	2730[bc]	2602[bcd]	32.17	30.00
2.	Pyraclostrobin 133 g/l + Epoxiconazole 50 g/l SE	1.5	2335[ab]	2402[ab]	2369[ab]	2586[bc]	2802[b]	2694[bc]	33.12	32.37
3.	Tebuconazole 50% + Trifloxystrobin 25% WG	1.5	2354[ab]	2514[ab]	2434[ab]	2681[ab]	2872[ab]	2776[ab]	34.92	34.38
4.	Azoxystrobin 18.2% w/w + Cyproconazole 7.3% w/w SC	1.5	2027[bc]	2182[b]	2105[b]	2231[cde]	2510[bc]	2370[bcd]	24.73	23.14
5.	Azoxystrobin 18.2% + Difenoconazole 11.4% w/w SC	1.5	1893[cd]	2123[b]	2008[b]	2110[de]	2324[c]	2217[d]	21.09	17.82
6.	Azoxystrobin 11% + Tebuconazole 18.3% w/w SC	1.5	1901[cd]	2150[b]	2025[b]	2186[de]	2472[bc]	2329[cd]	21.79	21.79
7.	Propiconazole 25 EC	1.5	2628[a]	2825[a]	2726[a]	3022[a]	3248[a]	3135[a]	41.89	41.89
8.	Tebuconazole 25 EC	1.5	2112[bc]	2221[b]	2166[b]	2395[bcd]	2583[bc]	2489[bcd]	26.88	26.81
9.	Control	-	1619[d]	1550[c]	1584[c]	1861[e]	1782[d]	1822[e]	-	-
S.Em. ±			121.28	141.64	131.46	115.09	125.03	120.06	-	-
C.D. at 5%			364	425	394	345	375	360	-	-
C.V.%			9.91	10.86	10.38	8.33	8.36	8.34	-	-

Treatment means with common letter/letters are not significant by Duncan's New Multiple Range Test at 5% level of significant

Tesfaye et al*.,* (2018) reported that minimum terminal strip rust severity with highest grain yield was observed in plot treated with Tilt 250 EC followed by Natura 250 EW and Bayletone 25 WP in comparison to unsprayed plots.

Among the tested fungicides Trifloxystrobin+ Tebuconazole @ 0.1% was found best with minimum disease (8.08 PDS) along with highest yield (56.50 q/ha.). It was followed by Tebuconazole @ 0.1% (9.43 PDS), Trifloxystrobin+Tebuconazole @ 0.05 %, (10.35 PDS) and Tebuconazole @ 0.05% (11.68 PDS). The yield performance of Tebuconazole @ 0.1% (42.33 PDS) and Trifloxystrobin+Tebuconazole @ 0.05 % (54.90 q/ha) were at par with Trifloxystrobin +Tebuconazole @ 0.1 (56.59 q/ha) (Kanwar et al*.,* 2018). Gad et al*.,* (2019) reported that the application of Tilt® 25% EC at rate 0.1%, recorded the minimum disease severity (1.67%) compared with untreated plots (86.67%).

Ali et al*.* (2022) reported that the highest controlled disease severity was observed in propiconazole (21.6%) in first crop season and (20.5%) in second growing season. The sulphur controlled the disease severity by 20.7 per cent in the first crop season and 19.9 per cent in the second crop season followed by metiram as compared to the control. Grain yield was significantly increased with the foliar application of fungicides during both successive years.

Abdissa et al*.* (2024) reported that "significantly (P ≤ 0.05) the lowest yellow and stem rusts incidences were recorded from plots treated with propiconazole on Kubsa (3.8 and 1.3%) and Hidase (0 and 1.7%) varieties, respectively. Similarly, significantly (P ≤ 0.05) the lowest yellow (3.8 and 0.0%) and stem (1.3 and 1.7) rusts severity were also noted from plots treated with propiconazole, respectively, on Kubsa and Hidase varieties. Significantly, the highest yields of 5.7 t/ha from Hidase and 4.6 t/ha from Kubsa varieties were also observed from plots sprayed with propiconazole as compared to other treatments".

Bajoriya et al*.* (2023) reported that "the fungicide Tebuconazole reduces the DI % (disease incidence) up to 45.62 % after 7 days of spraying and 74.92 % after 14 days of spraying. Bio-efficacy potential of Propiconazole 25% EC is next to Tebuconazole 50% EC and difference between then is statistically insignificant".

4. CONCLUSION

Out of eight fungicides sprays, first spray of the respective fungicides was done immediately after the initial appearance of disease symptoms and control plot was sprayed by water. Thus it can be concluded that the stem rust of wheat effectively managed by two foliar sprays at 15 days interval starting from initiation of disease with propiconazole 25 EC or tebuconazole 50% + trifloxystrobin 25% WG.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Model (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of the manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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