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Efficacy of fungicides in managing yellow rust of wheat

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Abstract

Eleven fungicides were evaluated as two foliar sprays for the management of yellow rust (*Puccinia striiformis*) at CSKHPKV, RWRC, Malan. Seven fungicides were tested during both the cropping seasons whereas, two each were evaluated during 2015-16 and 2016-17. Tebuconazole 25 EC @ 0.1% was the most effective with mean disease severity (MDS) of 1.84 % and mean disease control (MDC) of 99.64% over the unsprayed check (48.39%) followed by Nativo 75WG@0.05%, Amistar 250 SC, Propiconazole and Amistar Top 325 SC @ 0.1%. The highest mean grain yield of 32.24 q/ha was recorded in two sprays of Azoxystrobin 20%+Difenconazole 12.5% SC @0.1% with mean increase in yield of 56.73% over check with corresponding net profit of Rs. 14815 and cost: benefit ratio of 1: 2.93. It was followed by 32.10, 31.47, 31.18 and 29.65 q/ha yield in Tebuconazole 25% EC, Azoxystrobin 23.1%SC, Tebuconazole 50%+ Trifloxystrobin 25% w/w 75WG and Propiconazole 25%EC, with mean yield increase of 11.54, 10.91, 10.62 and 9.08 q/ha with 56.08, 53.01, 51.60 and 44.14 % over the unsprayed check with net profit of Rs. 16705, 13187, 13384 and 13479 and with corresponding cost: benefit ratio of 1: 4.03, 1:2.68, 1:2.89 and 1:4.36, respectively. On the basis of one year data, the highest grain yield of 37.08 and 32.24 q/ha was recorded in Score 250 EC and Opera @0.1% with 64.80 and 72.96% increase in yield over check with cost: benefit ratio of 1: 3.53 and 5.38 respectively. Duncan's Multiple Range Test (DMRT) implied that effect of years on disease severity was non-significant, all the test fungicides resulted in significant reduction in disease severity and treatments Tebuconazole 25% EC, Tebuconazole 50%+ Trifloxystrobin 25% w/w 75WG, Azoxystrobin 20%+Difenconazole 12.5% SC and Azoxystrobin 23.1%SC showed significantly more yield than the other fungicides. These fungicides may be used against this disease as a short-term alternative of resistant varieties.

Keywords: Stripe rust, wheat, fungicides, management, *Puccinia striiformis* f sp. *tritici.*

1. Introduction

Wheat is a major cereal staple food grown worldwide. It is inflicted by a large number of diseases, among which yellow rust caused by *P. striiformis* f.sp. *tritici* (Pst) is a major threat to wheat production in cooler and wetter regions (Reiss and Jørgensen, 2017; Ali *et al.,* 2017). It has emerged as an important disease in the North India, especially in the North Western Plain Zone and North Hill Zone including Himachal Pradesh. It may cause 10-70 percent losses (Chen, 2005) losses upto 70 percent have been recorded in India (Nagarajan and Joshi, 1975). Cultivation

of resistant cultivars is an eco-friendly, practically feasible, cost effective and sometimes the only means to manage this disease. Hence, the disease has been a major focus for research and breeding due to the ability of the fungi to overcome race-specific resistance genes within a short time of its commercial cultivation causing major changes in pattern of epidemics and subsequent yield losses (Reiss and Jørgensen, 2017). Under such conditions, outbreaks of the disease can be managed by the application of available fungicides (Khanfri et al., 2018) especially in the high value seed crop where in addition to yields, quality of grains is equally important. In India, more than 90% commercially grown varieties in the epidemiologically important NWPZ and NHZ are susceptible to YR (https://www.aicrpwheatbarley.org/wp-content/ uploads/ 2019/ 08/Crop-Protection-Report-2018-19-1-rev.pdf pp 17-18). In this context, efficacy of some commercially available fungicides and fungicidal mixtures was determined for the management of this important disease.

2. Materials and methods

The experiment was conducted at the hot spot location CSKHPKV, Rice and Wheat Research Centre (RWRC), Malan during the cropping season of 2015-16 and 2016-17 using susceptible variety HS 240. Eleven fungicides (Table 1) were applied as foliar applications against yellow rust. The cultivar was sown in plots of 8 m2 following recommended agronomical practices under irrigated conditions in randomized block design with three replications (http://www.hillagric.ac.in/extension/dee/pdf_files/Rabi_28-8-09.PDF). The disease appeared as natural epiphytotic however, to avoid escape artificial epiphytotics were created by spraying the uredosporic suspension of *P. striiformis* inoculums ($1x10^6$ uredospores/ml of water) yellow rust mixture (47S102, 46S103, 70S69 46S119 and 78S84) 48h prior to spray of fungicides, on the plots of var. HS 240. The fungicides (Table 1) were applied as two foliar sprays. The first spray was applied with the appearance of disease in the field and was repeated at fifteen days interval. The data were recorded on disease severity using the modified Cobb's scale as per Peterson et al., (1948) on 25 randomly selected plants and the mean disease severity was used to explain the results.

The data on plot yield were also recorded after harvesting of the crop and was presented as yield q/ha. The data were subjected to analysis of variance using computer program CPCS 1 and statistical online packages.

The data were also analyzed using Factorial Randomized Block Design (FRBD) to determine the effect of years, treatments and their interaction taking into consideration 2 levels of factors i.e. years (i.e. 2015-16 and 2016-17) and 8 levels of factor treatments i.e. Tilt 25 EC, Folicur 25 EC, Nativo 75 WG, Merger 80 WP, Amistar Top 325 SC, Amistar 250 SC, CF 110 and no spray control. Means between years & treatments and their interaction on percent disease intensity and yield were compared using Duncan's Multiple Range Test using IBM SPSS Statistics 22 software.

Table 1: List of the fungicides used in this study along with their Trade name, technical name and dosage

S.no.	Trade name (%)	Technical name	Concentration(%)
1	Tilt 25 EC	Propiconazole 25% EC	0.1%
2	Amistar Top 325 SC	Azoxystrobin 20 %+ Difenconazole 12.5% SC	0.1%
3	Nativo 75 WG	Tebuconazole 50%+ Trifloxystrobin 25% w/w 75WG	0.05%
4	Opera	Pyraclostrobin 13.3% + Epoxyconazole 5% SE	0.1%
5	Folicur 25 EC	Tebuconazole 25% EC	0.1%
6	Amistar 250 SC	Azoxystrobin 23.1%SC	0.1%
7	Taqat 75 WP	Hexaconazole 5% + Captan 70%WP	0.1%
8	Merger 80 WP	Tricyclazole 18 % + Mancozeb 62 % WP	0.1%
9	CF 110	Hexaconazole 68% + Zineb 4%WP	0.1%
10	Eregon 44.3 SC	Kresoxim methyl 44.3% SC	0.1%
11	Score 250 EC	Difenoconazole 25%EC	0.1%

3. Results and Discussion

All the fungicides resulted in significantly less disease severity as compared with the unsprayed check i.e. 56.81 and 39.97% during 2015-16 and 2016-17, respectively.

Among the seven fungicides evaluated during both the years, the least MDS (1.81%) was recorded in two foliar sprays of Folicur 25 EC @ 0.1% with mean disease control of 99.64% over the unsprayed check plots (Table 2). It resulted in mean yield of 32.10 q/ha with 56.08 per cent increase in yield over the unsprayed check (20.57 q/ha, Table 3). It was followed by Nativo 75WG @0.05%, Amistar 250 SC, Tilt 25EC and Amistar Top 325 SC @ 0.1% resulting in % MDS of 2.51, 4.61, 5.03 and 6.02 with 99.26, 98.43, 97.70 and 97.40 per cent MDC over check with the corresponding mean yield of 31.18, 31.47, 29.65 and 32.24 q/ha, respectively (Table 2). The treatments resulted in an increase of 6.72-14.58 q/ha in mean grain yields over the unsprayed check (Table 2).

Among the test fungicides, seven treatments were common during both the years and effect of years, treatments and their interactions on per cent disease severity and yield (q/ha) are given in Table 4. Duncan's Multiple Range Test (DMRT) was applied to compare the MDS and yield q/ha between the years, treatments and their interactions. MDS of 11.65 % and 10.56% was recorded during the years 2015-16 and 2016-17, respectively and effect of years on disease severity was non-significant (Table 4). All the treatments showed significantly less mean disease severity as compared with no spray check (48.39%) but were significantly at par with each other (Table 2). The interaction of years and treatment was significant indicating that effect of the treatments varied over the years. The effect of years on yield was significant and all the treatments resulted in significantly more yield than the unsprayed control. The treatments Folicur 25 EC, Nativo 75 WG, Amistar Top 325 SC and Amistar 250 SC out yielded significantly i.e. 32.10, 31.18, 32.24 and 31.47 q/ha than the plots treated with other fungicides but these were at par with each other. It was followed by Tilt 25 EC and Merger 80 WP having yield i.e. 29.65 and 29.58, respectively and was at par with treatments Folicur 25 EC, Nativo 75 WG, Amistar Top 325 SC and Amistar 250 SC. In case of yield, years and treatment interaction was found to be non-significant.

3.1. Economics of fungicidal spray

All the test fungicides were effective against yellow rust in reducing the disease severity and increasing the yield as compared with the unsprayed check during both the years. The mean yield data during both the years were used to work out economics of fungicidal application. It was observed that the highest mean grain yield of 32.24 q/ha was recorded in two sprays of Amistar Top 325 SC @0.1% (Table 2) with 11.67 q/ha mean increase in yield i.e. 56.73% over check. It resulted in net profit Rs. 14815 with cost: benefit ratio of 1: 2.93 (Table 3). It was followed by 32.10, 31.47, 31.18, 29.65, 29.58 and 27.29 q/ha yield in two foliar sprays of Folicur 250EC, Amistar 250 SC@0.1%, Nativo 75WG @0.05%, Tilt 25EC @0.1%, Merger 80WP @0.1% and CF 40 @0.1% (Table 2) with mean yield increase of 11.54, 10.91, 10.62, 9.08, 9.01 and 6.72 q/ha i.e. 56.08, 53.01, 51.60, 44.14, 43.80 and 32.67 % over the unsprayed check with net profit of Rs. 16705, 13187, 13384, 13479, 13709 and 9136 with corresponding cost: benefit ratio of 1:4.03, 1:2.68, 1:2.89, 1:4.36, 1:4.77, 1:4.77 and 1:3.40, respectively (Table 3). On the basis of one year data, the highest grain yield of 37.08 and 32.24 q/ha was recorded in two sprays of Score 250 EC and Opera @0.1% (Table 2) with 14.58 and 13.60 q/ha increase in yield i.e. 64.80 and 72.96% over the check. It resulted in net profit of Rs. 20117 and 21321 with cost: benefit ratio of 1: 3.53 and 1:5.38, respectively (Table 3). In the present study, DMRT showed that, effect of years on disease severity was found to be non-significant. Fungicides Tilt 25 EC, Folicur 25 EC, Nativo 75 WG, Merger 80 WP, Amistar Top 325 SC, Amistar 250 SC, CF 110 resulted in significantly less mean disease severity as compared with the no spray check but these were significantly at par with each other according to DMRT. These fungicides have different modes of action against the fungus i.e. demethylation inhibitors (DMI) group containing triazole & imidazoles chemical families, succinate dehydrogenase inhibitors (SDHI) containing oxanthiins & carboxamide families and quinine outside inhibitors (QoI) group having strobilurins family (Mueller *et al.,* 2013; Joshi *et al.,* 2017). These may be used alternatively to avoid development of resistance. Moreover, Folicur 25 EC, Nativo 75 WG, Amistar Top 325 SC and Amistar 250 SC resulted in significantly more yield than the other fungicides and with no spray control. Fungicides are the easily available effective alternatives on susceptible cultivars, grown on succumbing the resistant varieties to new races and provide a practical, rapid-response solution to manage stripe rust. However, fungicide application has become more and more common in developing countries where

Table 2: Efficacy of foliar application of fungicides on stripe rust severity (%) and yield (q/ha) at Malan during 2015-16 and 2016-17 on var. HS 240

Sno.	Treatment		No. of Sprays	Mean Disease Severity (%)			% disease control over check			Yield (q/ha)			increase over check q/ha		
		Technical name		2015-16	2016-17	mean	2015-16	2016-17	mean	2015-16	2016-17	mean	2015-16	2016-17	mean
1	Tilt 25 EC	Propiconazole 25% EC	2	0.28 (3.05)	2.33 (7.01)	1.30 (5.03)	99.6	94.62	97.70	26.38	32.92	29.65	7.74	10.42	9.08
2	Amistar Top 325SC	Azoxystrobin 20 %+ Difenconazole 12.5%SC	2	0.28 (3.05)	2.67 (8.99)	1.47 (6.02)	99.6	93.8	97.40	30.73	33.75	32.24	12.09	11.25	11.67
3	Nativo 75 WG	Tebuconazole 50%+ Trifloxystrobin 25% w/w 75WG	2	0.17 (2.29)	0.67 (2.7)	0.42 (2.51)	99.7	98.5	99.26	29.04	33.33	31.18	10.40	10.83	10.62
4	Folicur 25 EC	Tebuconazole 25% EC	2	0.41 (3.63)	0 (0)	0.20 (1.81)	99.3	100	99.64	28.79	35.42	32.10	10.15	12.92	11.54
5	Amistar 250 SC	Azoxystrobin 23.1%SC	2	0.11 (1.82)	1.67 (7.39)	0.89 (4.61)	99.9	96.2	98.43	30.45	32.5	31.47	11.81	10.00	10.91
6	Merger 80 WP	Tricyclazole 18 % + Mancozeb 62 % WP	2	2.94 (9.82)	4.17 (11.64)	3.55 (10.73)	97.1	90.4	93.73	27.08	32.08	29.58	8.44	9.58	9.01
7	CF 110	Hexaconazole 68% + Zineb 4%WP	2	4.93 (12.72)	1.4 (6.78)	3.16 (9.75)	99.6	96.8	94.41	24.58	30.00	27.29	5.94	7.50	6.72
8	Opera	Pyraclostrobin 13.3% + Epoxyconazole 5% SE	2	0.18 (2.41)	-	0.18 (2.41)	99.8	-	99.8	32.24	-	32.24	13.60	-	13.60*
9	Taqat 75 WP	Hexaconazole 5% + Captan 70%WP	2	3.72 (11.01)	-	3.72 (11.01)	95.4	-	95.4	27.23	-	27.23	8.59	-	8.59*
10	Eregon 44.3 SC	Kresoxim methyl 44.3% SC	2	-	4.17 (11.64)	4.17 (11.64)	-	90.4	90.4	-	32.92	32.92	-	10.42	10.42*
11	Score 250 EC	Difenoconazole 25%EC	2	-	1.83 (7.76)	1.83 (7.76)	-	95.8	95.8	-	37.08	37.08	-	14.58	14.58*
12	Control			70 (56.81)	43.33 (39.97)	56.66 (48.39)				18.64	22.5	20.57			
	CD (5%)			2.38	11.84					5.32	2.73	4.025			

Based on data of one year, - data not recorded, (figures within the parenthesis are arc sign transformed values)

Table 3: Economics of fungicidal management of rust on rust on var. HS 240 Malan during 2015-16 and 2016-17.

Sno.	Treatment		No. of Sprays	% increase in yield			Total profit	Expenditure	Net profit	*C:B ratio
		Technical name		2015-16	2016-17	mean				
1	Tilt 25 EC	Propiconazole 25% EC	2	41.52	46.31	44.14	17479	4000	13479	4.36
2	Amistar Top 325 SC	Azoxystrobin 20 %+ Difenconazole 12.5% SC	2	64.86	50.00	56.73	22465	7650	14815	2.93
3	Nativo 75 WG	Tebuconazole 50%+ Trifloxystrobin 25% w/w 75WG	2	55.79	48.13	51.60	20434	7050	13384	2.89
4	Folicur 25 EC	Tebuconazole 25% EC	2	54.45	57.42	56.08	22205	5500	16705	4.03
5	Amistar 250 SC	Azoxystrobin 23.1%SC	2	63.36	44.44	53.01	20992	7805	13187	2.68
6	Merger 80 WP	Tricyclazole 18 % + Mancozeb 62 % WP	2	45.28	42.58	43.80	17344	3635	13709	4.77
7	CF 110	Hexaconazole 68% + Zineb 4%WP	2	31.87	33.33	32.67	12936	3800	9136	3.40
8	Opera	Pyraclostrobin 13.3% + Epoxyconazole 5% SE	2	72.96	-	72.96	26180	4859	21321	5.38*
9	Taqat 75 WP	Hexaconazole 5% + Captan 70%WP	2	46.08	-	46.08	16536	3930	12606	4.20*
10	Eregon 44.3 SC	Kresoxim methyl 44.3% SC	2	-	46.31	46.31	20059	8150	11909	2.46*
11	Score 250 EC	Difenoconazole 25%EC	2	-	64.80	64.80	28067	7950	20117	3.53*

Labour cost= @ Rs. 260/ man day and 5 man days are required for one hectare, MSP wheat @ Rs.= 1925, *C:B= cost: benefit ratio, Rate of Tilt @ Rs. 1400/litre, Folicur @ 2900, Nativo @ 8900, Merger @ 1035, Amistar top @ 5050, Eregon @ 5550, Amistar @ 5205, Score @ 5350, CF110 @ 1200, Taqat @ 1330, Contaf @ 600, Opera @ 2259.

*Based on data of one year, - data not recorded, (figures within the parenthesis are arc sign transformed values)

Table 4. Efficacy of different treatments during the years 2015-16 and 2016-17 on severity of yellow rust and yield of var. HS 240

Sno.	Treatments	Disease severity			Yield		
		Years		Mean	Years		Mean
		2015-16	2016-17	Treatments	2015-16	2016-17	Treatments
1	Tilt 25 EC	0.28 (3.05)	2.33 (7.01)	1.31[a] (5.03)	26.38	32.91	29.64[bc]
2	Folicur 25 EC	0.41 (3.63)	0.00 (0.00)	0.20[a] (1.81)	28.78	35.41	32.10[c]
3	Nativo 75 WG	0.17 (2.29)	.67 (2.70)	0.42[a] (2.50)	29.04	33.33	31.18[c]
4	Merger 80 WP	2.94 (9.82)	4.17 (11.64)	3.55[a] (10.73)	27.08	32.08	29.58[bc]
5	Amistar Top 325 SC .	28 (3.05)	2.67 (8.99)	1.47[a] (6.02)	30.72	33.75	32.23[c]
6	Amistar 250 SC	0.11 (1.82)	1.67 (7.39)	0.88[a] (4.61)	30.45	32.50	31.47[c]
7	CF 110	4.93 (12.72)	1.40 (6.78)	3.16[a] (9.75)	24.58	30.00	27.29[b]
8	Control	70.00 (56.81)	43.33 (39.97)	56.66[b] (48.39)	18.65	22.50	20.57[a]
	Mean (Years)	9.89 (11.65)	7.02 (10.56)	8.45	26.96	31.56	29.26
	LSD (0.05)						
	Years	NS				1.47	
	Treatments	6.44				2.94	
	Years X Treatment	9.12				NS	

Means within a column having the same letters are not significantly different according to Duncan,s Multiple Range Test, (figures within the parenthesis are arc sign transformed values)

wheat is a major source of national food security. As has been reported in the present studies, Goel et al., (1975) and Woods *et al.,* (1983) have also reported that propiconazole effectively reduced the stripe rust when applied as foliar spray. In the past studies, difenconazole, propiconazole and tebuconazole have also been reported to be effective against this disease (Chen and Woods, 2002; Covarelli and Orfei, 2005). The high efficacy of fungicides i.e. Folicur 250EC, Tilt 25EC and Score 250 EC @0.1 % were also supported by Basandrai *et al.,* (2013) who reported that propiconazole was effective against powdery mildew leaf rust and yellow rust. Similarly, Singh *et al.,* (2016) reported that minimum mean disease severity 1.22 percent was found in case of Amistar @1% followed by Score @ 1%. The studies of Boualem *et al.,* (2017), reporting the efficacy of Azoxystrobin and propiconazole in reduction of powdery mildew, yellow rust and brown rust severity to the tune of 63.33, 91.66 and 87.5%, respectively, and also supported the present study. Jørgensen *et al.,* (2018) also reported the efficacy of tebuconazole to yellow rust and brown rust across Europe. The use of DMI fungicides for decades have led to the emergence of strains with decreased sensitivity or even resistance in populations of *Puccinia striiformis f.* sp. *tritici* in the United Kingdom and the United States (Bayles *et al.,* 2000; Kang *et al.,* 2019). As has been observed by earlier workers (Waterhouse and Semar, 2012; Fleitas *et al.,* 2018a, b) the carboxamides (SDHIs), triazole (DIMs) and strobilurin (QoIs) mixture have shown better control against foliar pathogens in wheat. Moreover, Sharma *et al.,* (2016) reported that lower concentration of Opus (0.5 l/ha and 1.0 l/ha), Platoon (0.5 l/ha and 1.0 l/ha) and Opera (0.75 l/ha and 1.5 l/ha) resulted in less stripe rust severity and increase in grain yield. In the present study, it was found that the fungicides-Folicur, Amistar, Score and fungicidal mixtures-Opera, Nativo, and Amistar top are highly effective against yellow rust in reducing the disease severity and increasing the yield. These fungicides may be used against this disease as a short-term alternative of resistant varieties for the multiple disease control.

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