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Yield and Profitability Analysis of Fungicides against Yellow Rust in Bread Wheat

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Abstract

Recent adaptation of yellow rust (Pst) to warmer climates poses an increasing threat to wheat production. Therefore, wheat needs to be treated with fungicide to protect the flag leaf and save severe yield losses. A field experiment was conducted during 2014-15 and 2015-16 to compare the efficacy of fungicides and spray timing for reducing yellow rust yield losses in wheat. Both years these trials were conducted at two yellow rust hot spot locations i.e., Cereal Crops Research Institute (CCRI) Nowshera and Crop Diseases Research Institute (CDRI) Islamabad.

Three fungicides i.e., Folicur (tebuconazole) @300 mL/ha, Nativo (tebuconazole + trifloxystrobin) @300 g/ha and Tilt (propiconazole) @ 500 mL/ha were used in this study. In a double split plot design with two replications, one set of plots were treated with single spray at ZS-3 (stem elongation and jointing) stage and other set of plots were treated with two sprays (first at ZS-3 and second at ZS-4.3 to 5.5). All three fungicides significantly (P=0.05) reduced wheat yield losses as compared to control plots and returned a significant profit as well. However, there were no significant efficacy differences among these fungicides, nor in the spray timing/doses. By gaining 2.36 t/ha yield and 126.78 US $/ha marginal return, Folicur proved to be best choice against yellow rust. There was no significant differences for grain yield efficacy between the two studied spray timings, however, with 113.53 US $/ha marginal return single spray at ZS-3 (stem elongation and jointing) seemed to be appropriate stage for reducing cost effective wheat yield losses.

Keywords: Bread wheat; Fungicides; Spray timing; Yellow rust

Introduction

Wheat yellow rust is caused by *Puccinia striiformis f.sp. tritici* and is one of the most devastating diseases of wheat. In most wheat producing countries yield losses caused by yellow rust ranges from 10%-70% depending upon the susceptibility of cultivar, earliness of the initial infection, rate of disease development and duration of the disease [1,2]. Nearly 88% of the world's wheat varieties are susceptible to Pst and annual global losses inflicted by the disease are around US$ 1 billion [3,4]. In Asia, yellow rust can infest 46% wheat area which is around 43 million ha. Wheat is grown on almost 9 m ha in Pakistan and covers around 33% of the cultivated area of the country. 70% of the wheat grown area in Pakistan is vulnerable to yellow rust and has suffered several times from yellow rust major epidemics (1973-2005) and has lost billions of rupees [5]. A loss of Rs. 2 billion in Pakistan was reported during the year 1997 [6]. It has been reported that Pakistani farmers were growing 8-10 years old wheat varieties in 2014 compared to 6-8 years old in 1997 [7]. Earlier studies on wheat diversity, mostly using biochemical (SDS55 PAGE) and molecular (DNA) analyses indicated a very close kinship of commonly grown varieties [8].

Although the single most economical solution against wheat rusts is growing resistant varieties, the appearance of new virulent races outpaces the breeding and subsequent deployment process of new varieties [9]. Thus, the rapidly evolving pathogen pose continues threat of substantial yield losses and a backup plan in the form of fungicides is needed. Fungicides are cost-effective means of plant pathogen control in many crops and positive net monetary returns from fungicides have been reported by several studies [6,7]. Morgounov and team found a 31.3% yield gain in resistant varieties, using fungicides [10]. They also reported 28.5%, 36.0% and 69.5% yield gain for, MR, MS, and S groups, respectively. To be optimum effective fungicides need to be applied at right growth stage. Fungicides are most effective when applied at flag leaf emergence or immediately after first appearance of disease. Cook et al. have also explained that epidemics of foliar disease started before flag leaf emergence had the greatest impact on yield. Since there is a lack of empirical data in Pakistan on the use of efficacious fungicides and their profitability in managing yellow rust, our study aims to answer the question. In addition, we also explored wheat growth stage which is more economical in managing yellow rust [11].

Materials and Methods

This experiment was designed to study the yield loss estimates due

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to stripe rust, efficacy of three fungicides and to prepare the general recommendations for the fungicide application as an alternate strategy to combat stripe rust in Pakistan. Two hot spots for the stripe rust were chosen for the study: Islamabad and Nowshera for this purpose. The fungicide trial was conducted at Crop Disease Research Institute, Islamabad, and Cereal Crops Research Institute, Nowshera during 2014-15 and 2015-16 cropping seasons respectively. The experiment was carried out in a split-split plot design with two replications. Size of an individual plot was 8 m2.

Wheat varieties and fungicide used in the experiment

Three wheat varieties-Pirsabak-13 a resistant (R) varieties to yellow rust, Pirsabak-04 (during 2014-15) and Inqilab-91 (during 2015-16) as a moderately susceptible varieties and Morocco as a universal susceptible check and spreader were used in the experiment. Three fungicides-Folicur (tebuconazole), Nativo (tebuconazole + trifloxystrobin) and Tilt (propiconazole) were sprayed on one set of plots one time at Zadok's scale 3 [12], (ZS-3) while other set of plots were sprayed two times, first at ZS-3 and second time at ZS-4.3 to 5.5, on susceptible varieties. No spray was applied to Pirsabak-13 (resistant variety) and was kept as control plot for comparing gross returns through grain yield gains between treated and non-treated plots. The quantity of fungicides used per spray was 300 ml/ha for Folicur, 300 g/ha for Nativo and 500 ml/ha for Tilt.

Data collection and analysis

The crop was harvested in the first week of May both years. At maturity, individual plots were harvested discarding two border rows on both sides of the plot. Grain yield (t/ha) was calculated for each of the treatment in the experiment. The experimental design was split-split-plot, however for data analysis, since the experiment involved many factors with different levels data was analyzed using unbalanced factorial model through SAS package for combined over locations for both years separately. The effects of all factors and their possible interactions were investigated using the model, as:

$y = \mu+V \times F\times S \times L+\varepsilon$ Where, μ: the overall mean; V: variety; F: fungicide; S: spray; L: Location; ε: the error component. Type-III SS were used for statistical significance and interpretation of results. Adjusting this model (ANOVA) allowed for an interpretation and statistical justification to determine the existence of significant characteristics of varieties. Data was analyzed using SAS package for combined over locations for both years separately. As the results were inconsistent both the years, combined over years and over locations ANOVA was also carried out. To draw a conclusion, means of all three factors (Variety, Fungicides and Spray schedule/doses) were compared using LSD (0.05) test from combined over years data of both locationsGrain yield loss from the control plots was calculated and expressed in percentage using the following equation [12]. Reduction (%)=(Ysp-Ynsp/Ysp)*100 where, Ysp is grain yield of sprayed plot and Ynsp indicatesb grain yield from control plot. Economic return was obtained by subtracting gross return (dollars/ha) of control plots from fungicide sprayed plots applied treatments. Variable cost in the experiment was that of fungicides application, as well as cost of spraying it (dollars/ha). Prices and cost of applying a fungicide (rented spray pumps) were averaged of several markets and farmer localities. Yellow rust resistant variety Pirsabak-13 was excluded from analysis however, we have discussed its mean yield performance in order to show the yield and economic advantage of using rust resistant varieties.

Results and Discussion

The study primarily focused on three important factors that included varieties, fungicides, and spray times. During 2014-15 wheat varieties differed significantly ($P<0.01$) for grain yield. In case of Morocco (universal susceptible check), single spray (ZS-3 growth stage) of Tilt produced 63.1% extra yield over its non-sprayed plots, followed by two sprays (ZS 4.3-5.5.) of Folicur which saved 34.7% grain yield as compared to its control plots. Table 1 during the first year we could not find significant difference in the efficacy of fungicides, spray schedules and their interactions except variety and location. Fungicides and spray schedules (single and double) did not show significant difference in producing extra yield and income. Due to frequent rains during first year at both locations, timely (Feb-March) sprays were not possible, and it caused fungicides not to be optimal effective. Fungicides at inappropriate time may not provide optimal efficacy [13]. The highest marginal return (117 U.S $/ha) was achieved by applying single spray of Tilt, followed by two sprays of Folicur (34.85 US $/ha). As there was no significant difference among fungicides and doses, we pooled response of both varieties across all treatments. This revealed that yield gain (20.7%) of Morocco was higher than Pirsabak-04 which was 4%. Similarly, the marginal return (averaged over all treatments) of Morocco (16.7 $/ha) was higher (0.5 $/ha) than Pirsabak-04. This is because Morocco responded positively to fungicides and produced significant yield advantage over its control plots whereas there was less difference in yield of protected vs. control plots of MSS varieties. Susceptible wheat cultivars to common foliar diseases are more likely to generate positive returns when treated with fungicides [14,15].

Although the marginal return from the susceptible check was high from moderately susceptible varieties, their gross and return after deducting cost of fungicides, was significantly higher than the susceptible check (Table 1). The rapidly expanding threats of yellow rust made it necessary to evaluate the economic analysis of fungicides which can compensate sever losses during rust attacks. Single spray of Folicur resulted in maximum yield advantage (3.14 tons/ha) for Pirsabak-04 over its control plots. A nearly same result (3.11 tons/ha) was achieved by applying two sprays of Folicur to Pirsabak-04, however the net marginal return from two sprays of Folicur was less due to extra cost and no significant yield benefit. The economic return (29.45 US $/ha) from single spray of Tilt was also promising, as it's cost per ha was less, thus it gave considerable economic benefit even with less yield advantage (2.96 tons/ha). Single spray of nativo also produced same results (2.99 tons/ha), but its net return (14.7 $) was less than Tilt as its per ha cost was higher. The highest marginal return (890.5 US $) was obtained from resistant variety Pirsabak-13 (data not shown here). This is due to producing maximum grain yield (3.59 tons/ha) without any cost of application of fungicides.

Second year results

Contrary to the first-year results, plots treated with fungicides had significant yield advantage due to variety × spray interaction. Significant ($P \leq 0.01$) yield advantages were also achieved due to variety, location × fungicide and location × variety × fungicide interaction. LSD (0.05) ranking showed that fungicides had significant positive effect for yield gain over control (between the groups), however there was no significant difference among the fungicides (among the group) (Table 2).

Variety and treatment	Grain yield (ton/ha)	% Increase in yield over control	Gross revenue ($)	Cost of spray $/ha	Income after deducting cost of spray $/ha	Marginal return over unsprayed ($)
Morocco						
Control	0.85		210.02			
Tilt, single spray	1.38	63.1	342.55	15.5	327.05	117.02
Tilt, two sprays	0.92	8.49	227.85	31	196.85	-13.17
Folicur, single spray	0.8	-5.9	197.62	19	178.625	-31.4
Folicur, two sprays	1.14	34.69	282.87	38	244.87	34.85
Nativo, single spray	0.93	10.33	231.72	19	212.72	2.7
Nativo, two sprays	0.96	13.28	237.92	38	199.92	-10.1
Pirsabak-04						
Control	2.78		688.97			
Tilt, single spray	2.96	6.52	733.92	15.5	718.42	29.45
Tilt, two sprays	2.67	-3.94	661.85	31	630.85	-58.12
Folicur, single spray	3.14	13.16	779.65	19	760.65	71.67
Folicur, two sprays	3.11	12.04	771.9	38	733.9	44.92
Nativo, single spray	2.45	-11.7	608.37	19	589.37	-99.6
Nativo, two sprays	2.99	7.65	741.67	38	703.67	14.7

Table 1: Fungicide's efficacy and economic return from its use during 2014-2015.

Treatment and variety	Grain yield (ton/ha)	% Increase in yield over control	Gross revenue ($)	Cost of spray $/ha	Income after deducting cost of spray $/ha	Marginal return over unsprayed ($)
Morocco						
Control	1.44		356.75			
Tilt, single spray	2.25	56.18	557.17	15.5	541.67	184.92
Tilt, two sprays	2.08	44.82	516.67	31	485.67	128.91
Folicur, single spray	2.33	62.05	578.12	19	559.12	202.36
Folicur, two sprays	2.47	71.47	611.73	38	573.73	216.98
Nativo, single spray	2.32	60.99	574.35	19	555.35	198.6
Nativo, two sprays	2.2	52.68	544.68	38	506.68	149.93
Inqilab-91						
Control	1.51		374.98			
Tilt, single spray	2.35	55.17	581.86	15.5	566.36	191.39
Tilt, two sprays	2.46	62.89	610.8	31	579.8	204.82
Folicur, single spray	2.22	47.05	551.39	19	532.39	157.41
Folicur, two sprays	2.42	59.88	599.5	38	561.5	186.52
Nativo, single spray	2.34	54.91	580.87	19	561.87	186.9
Nativo, two sprays	2.48	64.32	616.14	38	578.14	203.17

Table 2: Fungicide's efficacy and economic return from them during 2015-16.

Previous studies have shown that wheat yield response to fungicides against yellow rust is dependent on multiple factors, such as type of fungicide, application timing, number of applications, predominant Pst races, wheat variety's degree of susceptibility to yellow rust, environmental variables, and application technology, to mention a few [16].

However, it was clear that in all cases in which epidemics of yellow rust occurred, the impact of fungicides was significant, allowing to reduce or avoid losses and generate income. In our study, Morocco with two sprays (ZS 4.3-5.5.) of Folicur had maximum economic return (216.98 US $/ha) followed by pre rust emergence spray (ZS-3) of Folicur (202.36 US $/ha). Nativo single spray (ZS-3) also resulted in a good marginal return of 198.60 US $/ha. In case of Inqilab-91 two sprays of Tilt showed highest economic return of 204.8 US $/ha, followed by Nativo two sprays with 203.17 US $/ha net return. With 191.39 US $/ha, first spray of Tilt also had significant yield and economic advantage over its control plots with 3.3 t/ha grain yield, Pirsabak-13 (resistant variety) provided highest marginal return of 818 US $ per hectare (Table 2).

To reach to a conclusion for recommending choices of varieties, fungicides, and spray times, all the three factors were analyzed for averaged over both years and locations and were ranked based on LSD (0.05) (Table 3).

Factor	Yield (t/ha)	Marginal return (US $/ha)
Variety		
Inqilab-91, Pirsabak-04 (MS-S)	2.85[a]	121.3[a]
Morocco (s)	1.58[b]	100.3[a]
Fungicide	580.87	580.87
Folicur	2.36[a]	126.78[a]
Tilt	2.26[a]	108.65[a]
Nativo	2.24[a]	96.97[a]
Control	1.73[b]	
Sprays		
Single	2.26[a]	113.53[a]
Two sprays	2.31[a]	108.08[a]
Fisher's least significant difference test at P=0.05; MS-S: moderately susceptible to susceptible; S: susceptible		

Table 3: Fisher's LSD test (0.05) for mean performance of Varieties, Fungicides and Spray schedule.

It is clear from the two years pooled data (over years and locations), and based on Fisher's least significant difference, that fungicides application had significant positive effect on wheat yield and net return as compared to control plots. There were no significant differences among the fungicides in controlling yield losses and net returns. However, Folicur (tebuconazole) was more profitable than other fungicides by providing maximum return of 126.78 $/ha averaged over two years. Results from earlier studies have indicated that fungicides applications were profitable in moderate to high disease severity situations [16]. On average positive net return can be achieved by using fungicides, but they show huge variability. Although there was no significant efficacy difference between spray times frequency (single vs. double spray), the single spray at Zadok's cale (ZS) 3 stages was more profitable. This was due to its timely rust control and low cost of fungicide as compared to two sprays. The cost of second spray (sprayed two times) applied at ZS 4.3 to 4.5 was more costly and with only 2.2% non-significant grain yield advantage.

Conclusion and Recommendation

Based on two years results we conclude that all three fungicides are effective in controlling yellow rust with a significant profit. Although there was non-significant difference among the performance of fungicides, all three fungicides, however, reduced yield losses significantly when compared to control plots. Our study also revealed that there is no significant difference between single spray and two sprays. However, we recommend that farmers need to be vigilant during the ZS 3 stage (stem elongation and jointing stage), where they should apply first spray as a protectant or due to first appearance of the yellow rust. Single spray at this stage will be more profitable as compared to two sprays (extra cost and no substantial yield advantage).

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