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Evaluation of fungicides efficacy against wheat yellow rust disease on bread wheat (*Triticum aestivum* L.) in the eastern part of Afghanistan

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Abstract
Wheat is one of the strategic cereal crops in Afghanistan in terms of the area of land allocated, volume produced and the number of farmers engaged in its production. However, the production and productivity of wheat is reduced by various biotic and abiotic stresses. Among the biotic stresses, wheat yellow rust caused by *Puccinia striiformis* f.sp. *tritici,* is the most feared wheat production bottlenecks. Field experiment was conducted to verify and evaluate the efficacy of fungicides against wheat yellow rust disease and recommend for registration. The trials was carried out at yellow rust hotspot location, Shisham Bagh research center during 2017-18 cropping season. Experimental design was randomized completely block, consisting of four fungicides with two numbers of applications, and three replicates. Treatments were: tebuconazole, trifoxystrobl + tebuconazole, thiophanate-methyle, propiconazole and a control treatment without fungicide application. Fungicides were applied at the phenological stage of: flowering when yellow rust was observed in field. Severity data were obtained based on percentage scores of leaf area with visible disease symptoms/signs according to Cobb's diagrammatic scale. Fungicide spray treatments significantly reduced yellow rust disease severity to the lowest level possible over the no application. There is highly significant difference ($p \leq 5\%$) in grain yield and thousand kernel weight between fungicide treatments and nil application of fungicide. The highest grain yield was obtained from tebuconazole sprayed plots while the lowest from thiophanate methyle and no application. Fungicide treatments also revealed significant yield advantage than thiophanate methyle and untreated plots.

Keywords: Bread wheat, disease severity, fungicide, puccinia striiformis f.sp. tritici, yellow rust.

Introduction
Bread wheat (*Triticum aestivum* L.) is one of the most widely grown and consumed food crop all over the world. It is the most important cereal crop in terms of area under cultivation and in importance followed by maize (*Zea mays* L.), barley (*Hordeum vulgare* L.) and sorghum (*Sorghum bicolor* L.) (FAO, 2009) [11]. Annually, wheat is produced on 224.53 million hectares of land with production and average productivity of 672.2 million metric tons and 2.99 tons /ha across the world (USDA, 2010) [24].
Wheat is the staple crop of Afghanistan, which has one of the highest average per capita consumption levels (over 186 kg/person/year) in the world (Persaud, 2012) [19]. Afghanistan's wheat production has always been short of its domestic demand. Wheat production in Afghanistan has been erratic mainly due to recurrent droughts of varying degrees especially during 2008, 2010 and 2011 in recent past. Afghanistan's best harvest has been 5.1 million tons in 2009 (FAO, 2012) [10]. Imports from neighboring countries have been required to meet local demands. Approximately, 45% of Afghanistan's area under wheat in a normal year is irrigated, and accounts for about 70 to 90% of total production. The remaining 55% relies on rainfall and at best provides the remaining 10 to 30% of domestic production. Among biotic stresses, rusts are the most important for wheat. Stripe or yellow rust of wheat, caused by *Puccinia striiformis* f. sp. *tritici*, is one of the most important disease inflecting high economic yield losses in most of the wheat growing areas of the world (Chen *et al*., 2014) [3]. This disease appears in the form of yellow stripes on leaves, causes substantial losses in yield through damaging the photosynthetic system, most importantly reducing grain weight and affecting its quality (Line, 2002; Chen, 2005) [16, 4]. In susceptible cultivars yield loss upto 100 per cent can be observed, if infection occurs at an early stage and continues to develop during the growing season (Afzal *et al*., 2007) [1]. Chen (2005) [4] has reported that depending upon the susceptibility of cultivar, earliness of initial infection, rate of disease development and duration of disease, the yield losses due to stripe rust may range between 10-70 per cent.

Afghanistan being strategically located in central Asia close to the natural habitat of alternate hosts for *Puccinia striiformis* f. sp. *tritici* (Jin *et al*., 2010) [12], offer ideal conditions for a Yellow rust incidence throughout the crop season. Hence, the disease control practices are required in order to prevent yield losses. Afghanistan has managed to ward off yield losses from rusts mainly be releasing and deploying rust resistant varieties and by removing susceptible ones from the seed chain.

Fungicides are one of the most important components of a disease management strategy in wheat production. Particularly when resistant cultivars are not available or when the resistance in the existing cultivars becomes ineffective due to the emergence of new pathogenic races or pathotypes, fungicidal intervention provides an effective and practical means of minimizing disease outbreaks (Chen, 2014; Selkakumar *et al*., 2014) [3, 22]. Chemical fungicides get first preference when susceptible varieties are grown, as they provide a rapid control of the disease. Triadimefon (Bayleton) has been widely used as foliar fungicide to control stripe rust which prevented multimillion dollar losses (Line, 2002) [16]. Different fungicides like Tilt (propiconazole), Evito (fluoxastrobin), Quadris (azoxystrobin), Prosaro (prothioconazole + tebuconazole), Stratego (propiconazole + trifloxystrobin), and Quilt (azoxystrobin + propiconazole) etc. have been registered for the control of wheat stripe rust worldwide (Chen, 2007) [5]. Further, as reported by Viljanen-Rollinson *et al*. (2002) [26] the efficacy of a fungicide depends partly on the growth stage of the crop and disease level at the time of application.

Rust resistance source is the most preferred diseases management option in wheat. Several efforts were made towards resistant cultivars development in Afghanistan and several bread wheat cultivars with various levels of rust resistance have been released for production. Moreover, once adopted farmers also like to popularize and keep high yielding susceptible cultivars in production for some years. Resistance breeding and use of chemical options are the two principal strategies adopted for wheat rust management in most of the wheat producing areas of the world. However, chemical options are not well exploited by most of Afghanistan farmers. To cope up with this, some fungicides have been evaluated, verified and registered against rusts and is being used in wheat as sole or integrated rusts management options. Hence, to maximize availability of more number of fungicide options in the market and to identify effective fungicides, frequent verification and evaluation of new fungicides against wheat rust disease is important to sustain wheat production and productivity. Thus, the objective of this study is to evaluate and verify the efficacy of fungicides against wheat rust disease and recommend for registration.

2. Materials and Methods

Wheat cultivar Marako, highly susceptible to yellow rust *(Puccinia striiformis* f.sp. *tritici*) disease was planted at yellow rust hot spot location, Shisham Bagh research station in 2017/18 main cropping season. Experimental design was randomized completely block, consisting of five treatments (four fungicides with two numbers of applications each) including the control plot without fungicide application.with three replications each. Seed rate of 110 kg/ha and a fertilizers rate of DAP 125 kg/ha and UREA 75 kg/ha were used. The whole rate of fertilizer was applied at planting. Test fungicides, Folicur 250 EW (Tebuconazole), Nativo 75 WG (25%Trifoxystrobl + 50%Tebuconazole), Thiophanate methyl 70% WP, Propiconazole 25% EC were sprayed with the rates of 1, 1, 0.5 and 0.5 lit/ha, respectively. Fungicide treatments were applied at 5% severity level of yellow rust (flowering crop growth stage) manually using Knapsack sprayer delivering 20 liter of water. Grain yield data were determined on the basis of crop harvested from 1 m x 2 m harvestable plot area and converted to hectare base. Rust severity was recorded in percentage using modified Cobb Scale (Peterson *et al*., 1948) [20].

2.1. Data Analysis

Analysis of Variance (ANOVA) was done by using SAS GLM Procedure (SAS version 9.00, Inst. 2002) and means comparisons for the significantly different variables were made among treatments using Least Significant Differences (LSD) test at 0.05 levels of significance.

3. Results and Discussion

3.1 Disease Epidemics

In 2017/18 main cropping season yellow/stripe rust pressure was very high and excellent disease epidemics developed upto the level of creating significant difference among treatments in Eastern part of Afghanistan. Fungicide sprayin treatments significantly reduced yellow rust disease severity over the control (Table 1). As it is evident from table 1 that Folicur 250 EW and Nativo 75 WG, Propiconazole 25% EC and Thiophanate methyl 70% WP significantly reduced yellow rust severity to the lowest level possible. Even though there was no statistically significant difference between the among test fungicides, relatively Folicur 250 EW and Nativo 75 WG reduced yellow rust severity to the lowest level compared to, Propiconazole 25% EC and Thiophanate methyl 70% WP. There was significant difference between Propiconazole 25% EC and Thiophante Methyl and as well as significant difference with Folicur and Nativo fungicide (Table 1). Folicur 250 EW and Nativo 75 WG showed comparable efficacy in controlling yellow disease with the test fungicides, Propiconazole 25% EC and Thiophanate methyl 70% WP. Folicur 250 EW reduced yellow rust disease severity by 95.8%, followed by Nativo 75 WG (94.2%) further followed by Propiconazole 25% EC (79.2%) and Thiophanate methyl 70% WP methyl (58.4%) when compared to unsprayed plot.

Test fungicides, Folicur 250 EW and Nativo 75 WG showed comparable level of efficacy on yellow rust disease severity reduction compared to the Propiconazole 25% EC and Thiophanate methyl 70% WP. Whereas Propiconazole 25% EC showed higher efficacy as compared to the Thiophanate methyl 70% WP. Therefore, Folicur 250 EW and Nativo 75 WG and Propiconazole 25% EC can be recommended for the control of wheat yellow rust disease.

3.2 Yield and Yield Components

The statistical analysis showed significant difference between the test fungicides in grain yield and thousand kernel weight (Table 1). Relatively higher grain yield and thousand kernel weight was obtained from Folicur 250 EW and Nativo 75 WG sprayed treatments and the difference is significant to differentiate the effect of the chemicals, Folicur 250 EW and Nativo 75 WG with Propiconazole 25% EC. But the difference in insignificant to differentiate Thiophanate methyl 70% WP between unsprayed plot. There is highly significant difference in grain yield and thousand kernel weight between fungicide treatments (test fungicides) with Thiophanate methyl 70% WP and no application (unsprayed plot). Significant difference in grain yield and thousand kernel weight was observed between the test fungicides, Propiconazole 25% EC, Thiophanate methyl 70% WP and no application. Even though there was no statistical significant difference among treatments (Folicur 250 EW and Nativo 75 WG), relatively better grain yield and thousand kernel weight was obtained from Folicur 250 EW and Nativo 75 WG sprayed plots while the lowest from Thiophanate methyl 70% WP and no application. Test fungicides revealed better grain yield advantage than the Thiophanate methyl 70% WP. Test fungicides also revealed significant yield advantage over unsprayed plot. Likely, Folicur 250 EW, Nativo 75 WG and Propiconazole 25% EC revealed 2050.0 kg/ha, 1923.33 kg/ha and 1700.0 kg/ha yield advantage respectively. There was no significant difference between no application and Thiophanate methyl 70%. WP.

Table 1: Evaluation of fungicides efficacy against yellow rust disease severity, yield and yield components of bread wheat in Shisham Bagh research station, during 2017/2018 main cropping season.

Treatment		Rate (l/ha)	Yellow rust severity (%)	TKWG/Plot	Grain yield (kg/ha)
Common name	**Trade name**				
Tebuconazole	Folicur 250 EW	1	1.67	33.39	2050.00
Tebuconazole 50%+ Trifloxystrobin 25%	Nativo 75 WG	1	2.33	31.80	1923.33
Thiophanate methyl 70% WP	Thiophanate Methyl	0.5	16.67	25.82	1490.00
Propiconazole 25% EC	Propiconazole	0.5	8.33	27.54	1700.00
Check		Nil	40.00	23.73	1340.00
Mean			13.80	28.46	1700.67
CV (%)			17.86	7.06	5.47
LSD (0.05)			4.32	3.52	162.95

TKW = Thousand Kernel Weight, LSD = Least significant difference among treatment means ($p \leq 5\%$), CV= Coefficient of variation, Means with the same letter within a column are significantly different.

Fungicide efficacy is based on proper and timely application to achieve optimum effectiveness as determined by labeled instructions and overall control over level of disease in the field at the time of application. Differences in efficacy among fungicide products were determined by direct comparisons among products in field tests and are based on a single application at the labeled rate (Kiersten Wise, 2016) [15]. Fungicide tests in Kenya showed 50% higher yield in the treated versus the untreated plots (Wanyera *et al*., 2009) [27]. Large scale wheat growers in Ethiopia are reported to spend around US$0.5 million annually on fungicides (Tadesse *et al*., 2010) [23]. The current study clearly shows that in Afghanistan it is not possible to grow susceptible wheat varieties without fungicide application in areas with wheat rust diseases as a major problem.

Ordish and Dufour (1969) [18] noted the popularity of spraying fungicides to control crop diseases; returns of up to three times the cost involved often were realized from a fungicide application. In the United Kingdom, experiments conducted from 1978 to 1982 showed that applying fungicides to winter wheat resulted in a yield response of up to 89%, and the value of increased yield from fungicide application to cereals in 1982 was nearly double the fungicide costs (Cook and King, 1984) [7]. In Denmark, fungicide application to control wheat powdery mildew and *Septoria* diseases resulted in yield increases of 400-2700 kg ha with a margin over cost varying from -500 kg ha^{-} to 2000 kg ha (Jørgensen *et al*., 2000) [13]. An economic evaluation of fungicide use in winter wheat in Sweden also showed a mean net return of US$28 ha during the period 1995-2007 and $16 ha^{-1}during the period 1983-2007 (Wiik and Rosenqvist, 2010) [29].

Different studies from different areas have demonstrated yield increases in wheat due to fungicide application. Wegulo *et al*. (2009) [28] showed that up to 42% yield loss was prevented by applying foliar fungicides to winter wheat. Kelley (2001) [14] also found that over a period of six years, the fungicide propiconazole significantly increased winter wheat yield by 77%. Also Vamshidhar *et al*. (1998) [25] demonstrated significant yield increases from fungicide application to control the disease complex of leaf rust, tan spot, and *Septoria tritici* blotch in wheat. They found that cultivar specific economic benefits were associated with improved wheat quality from fungicide treatment. Ransom and McMullen (2008) [21] showed that within an environment and across wheat cultivars, fungicides improved yields by 5.5 to 44.0%. Tebuconazole applied at Zadoks growth stage (GS) 37 (Zadoks, 1974) and propiconazole applied at GS 37 followed by triadimefon + mancozeb at GS 55 to control leaf rust and Septoria tritici blotch consistently resulted in the lowest disease severities and highest wheat yields (Milus, 1994) [17].

4. Conclusions

Folicur 250 EW and Nativo 75 WG statistically differed from the Propiconazole 25% EC, Thiophanate methyl 70% WP in controlling wheat yellow rust disease and provided better grain yield and thousand kernel weight than Propiconazole 25% EC and Thiophanate methyl 70% WP sprayed treatments. Moreover, these fungicides reduced yellow rust disease severity to the lowest level possible and revealed grain yield advantage better than the Thiophanate methyl 70% WP and nil fungicide application. After all assessment and evaluation results, the test fungicides are found to be very effective in controlling yellow rust disease of wheat. Thus, Folicur 250 EW, Nativo 75 WG and Propiconazole 25% EC are recommended for registration for the control of wheat rust disease (yellow rust) as sole or integrated disease management options on wheat.

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