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ASSESSMENT OF YIELD LOSSES CAUSED BY *PUCCINIA STRIIFORMIS* TRIGGERING STRIPE RUST IN THE MOST COMMON WHEAT VARIETIES

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Abstract

Studies were carried out to assess wheat yield losses inflicted by *Puccinia striiformis* f.sp. *tritici*. Investigations revealed that there exists a direct linkage between the disease level and the yield loss in the most common commercially adopted wheat varieties in Pakistan. The yield was significantly negatively correlated with the proportion of leaf area affected by stripe rust. The correlation coefficient (-0.67805) depicted highly significant effect of stripe rust in lowering wheat yield. There was varying resistance level among different wheat varieties. The extensively cultivated wheat variety, Inquilab-91 was found to be most resistant with minimum yield loss of 5.77% followed by Wafaq-2001 and Bakhtawar with yield loss of 6.63% and 14.90%, respectively. Whereas Morocco, proved to be the most susceptible wheat variety with maximum yield deficit to the tune of 39.79%. Evaluation of disease resistance revealed that Inquilab-91, Bakhtawar and Wafaq-2001 exhibited 2.24, 1.57 and 1.36 fold resistance in respect of wheat yield as compared to the most susceptible variety Morocco. Sowing of Inquilab-91 and Bakhtawar is recommended to escape heavy yield losses wreaked by the stripe rust.

Introduction

By the year 2020, two-third of the world's wheat consumption will transpire in developing countries (Anon., 1997). The current statistics depict that average annual augment in population of Pakistan is around 2.5%, which has resulted in a tremendous amplification in population from 137 millions during 1999 to more than 164.74 millions in June 2007 (Anon., 2007). On the contrary, Pakistan is much below in respect of international average wheat yield and the same is stagnant for the last years while the population has increased drastically thereby widening the gap between demand and supply of basic staple food. Accordingly, there is a dire need to bridge this gap to ensure food security for the country's inhabitants. The trouble with our agriculture is lack of innovation in agricultural research. During the last decades, the researchers have not been able to come with any high-yielding and disease resistant variety. Hence, the wheat growers have no option except to cultivate the varieties introduced in the early nineties. A wheat research program is, therefore, vital whereby the scientists would make collaborative efforts for the genetic improvement and development of new varieties. At the same time, it is imperative to acquire maximum yield from the existing varieties through better agronomic and plant protection measures. Huge losses in wheat yield are attributed to the invasion of various diseases out of which, rusts especially "the stripe rust" has caused enormous yield losses in the recent years. Planting resistant varieties is a simple solution if such varieties have been introduced because breeding for disease resistance is a continuous phenomenon as new races of rusts evolve and overcome resistance. A wheat variety that has been resistant in the past may not remain resistant to new races of rusts (Brian, 2006).

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Stripe rust of wheat caused by *Puccinia striiformis* f.sp. *tritici* reduces the yield and quality of the grain and forage. Seed produced from crop damaged by stripe rust have low vigor and thus express poor emergence after germination. Stripe rust can cause 100% yield loss if infection occurs very early and the disease continues to develop during the growing season provided the cultivars are susceptible. In most wheat producing areas, yield losses caused by stripe rust have ranged from 10-70% depending upon the susceptibility of cultivar, earliness of the initial infection, rate of disease development and duration of the disease (Chen, 2005). Grant & John (2005) reported from Australia that stripe rust attacks all the above-ground parts of the wheat plant and is characterized by powdery masses (pustules) of yellow spores, which form stripes on the leaf surface. The pustules occur in blotches covering large areas of affected leaves on young plants while pustules are arranged in parallel lines, giving affected leaves a characteristic striped appearance on older plants. Infection of leaf sheaths and stems can also occur, but spore production on these parts is less than on leaves. Stripe rust can also attack the heads. The rust fungus infects the glumes and awns at flowering. This results in an accumulation of spores in the florets and on the surface of the developing grain. In Victoria, stripe rust can reduce yield by up to 50% and leaf rust by greater than 20% in susceptible varieties. Colson & Wilkinson (2006) also witnessed this disease throughout the wheat growing regions of Queensland in 2005.

In Ethiopia, yellow rust epiphytotics were recorded in 1977, 1980-1983, 1986, 1988 and 1990 with severe losses during 1988 in bread wheat (Badebo & Bayu, 1992). Major epiphytotics were recorded in Egypt once in each decade since 1960s with the most recently reported in the Delta region during 1995. The average grain yield loss ranged from 14% to 26% in this region, while the national loss was about 10% (El-Daoudi *et al*., 1996). Similarly, the southern region of West Asia also witnessed severe epidemics of yellow rust in the past as the yield losses remained 10-50% in Yemen during 1991-96 (Bahamish *et al*., 1997). Stripe rust was a dominant disease in Central Asian Muslim states in the late 1990s and early 2000s, accounting for yield losses of 20 - 40% in 1999 and 2000 (Morgounov *et al.*, 2004). During the last decade, several yellow rust epidemics in most of the wheat-growing areas of Iran caused over 30% crop loss and estimated grain losses were 1.5 million tons and 1.0 million tons in 1993 and 1995, respectively (Torabi *et al*., 1995). In the Cukurova area of Turkey, a loss of over 0.5 million tons was recorded due to epidemics of yellow rust on the cultivar "Seri 82" (Dusunceli *et al*., 1996). Losses due to stripe rust during 1996 in South Africa were $22.5 millions (Pretorius, 2004). In China during 2002, an area of 6.6 million hectares of wheat was affected in about 11 provinces and yield losses were around 13 million tons (Wan *et al*., 2004). In USA, Small Grain Workgroup carried out thorough probe into epidemic and losses caused by the stripe rust observed that stripe rust was devastating to the California wheat crop in 2003, while many other states across the country also experienced severe stripe rust. The disease developed early and was more severe than normal throughout the U.S. The Workgroup demonstrated the impact of the disease in California as highly susceptible varieties suffered $\geq$75% loss due to the stripe rust in fields receiving no fungicide applications whereas susceptible varieties sustained 50-70% loss; moderately susceptible varieties 20-40% loss; and moderately resistant varieties 5-15% loss (Anon., 2004). Yield losses due to stripe rust in 2003 (2.42×10^6 t) were a record for the United States (Chen *et al.*, 2004). Losses due to stripe rust amounted to more than $30 million in the United States in 2003 (Chen, 2005).

Studies on rust in Pakistan have revealed 10.1% yield loss to the tune of 0.83 million tons valuing US$86 million during 1977-78 (Hassan *et al.*, 1979). Similarly, Ahmad *et al*., (1991) reported a revenue loss valuing US$8 million in just three districts of Baluchistan. Khan & Mumtaz (2004) also witnessed rust epidemic appearance during 1995 on wheat varieties Pak 81, Pirsabak 85 and also on Inquilab 91 during 2003. A loss of Rs. 2 billion in Pakistan was reported by Hussain *et al.*, (2004) during the year 1997 and 1998 due to progressive increase in virulence on pathotypes attached to cultivars possessing *Yr*A (Bahawalpur 79, Chenab 79, Nuri 70), *Yr*A and *Yr*6 (LU26, Lyallpur 73, Pari 73, Sandal 73, Yecora etc.) and *Yr*22 (Blue Silver, Sonalika, WL 711). Eventually, heavy losses inflicted by wheat rust in the past have upset the economy of the country thereby, giving a serious jolt to the planners. The salient objective of the study was aimed to assess the effect of stripe rust towards yield loss in the commercially grown wheat varieties in rainfed areas of Pakistan.

Materials and Methods

To ascertain wheat yield losses caused by stripe rust, the present investigations were executed at the experimental area of the University of Arid Agriculture (UAAR), Rawalpindi during the year 2005-06. Wheat seeds of 4 varieties viz. Bakhtawar, Inquilab-91, Wafaq 2001 and Morocco (universally susceptible cultivar) collected from CDRP, NARC, Islamabad were sown at the experimental area in a Randomized Complete Block Design (RCBD). The first three selected varieties are commercially grown on large scale especially Inquilab-91, which is the most popular variety adopted by the farming community of Pakistan. Each of the three commercial wheat varieties and a universally susceptible cultivar, Morocco, was grown in 6 rows where each row length was kept 5 meter by maintaining a row to row distance of 30 cm. Three replications were made for each of the variety. A seedling rate of 100 kg ha^{-1} was used in each planting. The trials were managed with optimum nutrient application (150 N: 20 P: 0 K) while the weeds were controlled manually.

The entire trial was subdivided into two experiments. In experiment-1, the stripe rust epidemic was initiated by inoculating plants of all varieties with equal doses of urediniospores of *Puccinia striiformis.* In experiment-2, wheat plots were sprayed with fungicide – Bayleton 125 EC (Triadimefon), Bayer Crop Science Pvt. Ltd @ 500 ml ha^{-1} to maintain disease free wheat plants enabling us to compare wheat yield in diseased and disease free experimental units. The fungicide spray was applied four times with an interval of 15 days starting from 15th February 2006.

Rust severity and response on flag leaves of the cultivars were recorded thrice in non-protected plots at approximately 10 days intervals, beginning with the appearance of the first symptoms. Severity estimation of plots was based on the modified Cobb's scale (Peterson *et al.*, 1948), whereas response to infection was recorded according to Leogering (1959).

Yield was worked out initially by randomly throwing standard ($1m^2$) quadrat in each varietal plot and harvesting all the plants within the quadrat. Later on, the data was transformed into kg ha^{-1} by multiplying 10,000 as a constant factor. Yield loss assessment was made by comparing the yield difference of each variety in diseased and disease free plots. The data was statistically computed by MSTAT-C program as well as by using MS-Excel programme for regression and correlation analysis.

Results and Discussion

Analysis of the data indicated a strong negative correlation (-0.67805) between the disease level as well as wheat yield (Fig. 1). Analysis of variance depicted highly significant differences among susceptibility of different wheat varieties to the stripe rust (Table 1).

Comparison of mean values revealed that the cultivar Morocco proved to be the most susceptible receiving 53.33% infection level followed by Wafaq-2001 and Bakhtawar with 25 and 13.33% disease level, respectively. Inquilab-91, however, proved to be the most resistant of all with only 8.33% disease level. Regression analysis also revealed a strong dependence of wheat yield on severity percentage of the stripe rust (Table 2).

Data pertaining to yield was subjected to statistical analysis. Analysis of variance pertaining to wheat yield recorded in diseased and disease free wheat plots also indicated highly significant differences among different varieties under the present investigations (Tables 3, 4)

Table 5 indicated the comparison of wheat yield, total and percent yield loss due to stripe rust. It has been found that maximum yield loss of 688.6 kg ha^{-1} (39.79%) was observed in Morocco followed by Bakhtawar showing 287.3 kg ha^{-1} loss (14.90%). The other two varieties *vis*-à-*vis* Wafaq-2001 and Inquilab-91 showed wheat loss to the tune of 6.63 and 5.77 %, respectively (Fig. 2).

Though all the wheat varieties belong to the same *Triticum aestivum* L., species, yet highly significant differences were found among wheat yield as well as disease level. The present investigations are in line with the work done by Smith *et al*., (1986) who found that stripe rust cause a 51 % loss in grain yield on the well watered plots from (4.9-2.1 t ha^{-1}) and a 46 % reduction on rainfed plots (2.8-1.5 t ha^{-1}). Other researchers have also conducted trials on stripe rust and have established association between the disease epidemic and yield loss of wheat crop. It has been established that out of 5 disease components infection efficiency (IE), sporulation capacity (SC), lesion expansion rate (LE), latent period (LP) and infectious period (IP), the LE, IE and SC were found to be the most important components. Final disease was, however, more strongly influenced by weather and initial disease (Luo & Zeng, 1995). Salman *et al*., (2006) reported that yield losses increase proportionately with the increase in severity of the disease. According to their investigations, varieties like Morocco, WL-711, SA75, SA42 and Chakwal exhibited maximum losses of 52-57% against the leaf rust. Some other workers also reached the same conclusion that slow ruster varieties / lines usually suffer less yield losses as compared to the fast rusters like Morocco etc., in which losses were as high as 52-57%. Keeping in view the above results, it is evident that there is a need to avoid fast ruster susceptible varieties. Besides, plant breeding departments should be encouraged, appreciated as well as accounted for to continuously monitor rust situation and evolve resistant varieties to ensure food security of the country.

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Table 1. Analysis of variance showing level of resistance to different wheat varieties among different wheat varieties.

S.O.V.	Df	SS	MS	F-value	P
Wheat varieties	3	3650.0	1216.7	64.89	0.000
Error	8	150.0	18.7		
Total	**11**	**3800.0**			

Table 2. Regression analysis showing dependence of wheat yield on disease level.

S.O.V.	df	SS	MS	F-value	Significance F
Regression	1	2240994	2240994	18.72167	0.000272
Residual	22	2633412	119700.6		
Total	**23**	**4874407**			

Table 3. Analysis of variance showing grain yield/hectare in response to varying level of stripe rust among different wheat varieties.

S.O.V.	df	SS	MS	F-value	P
Wheat varieties	3	2666548	888849	127.66	0.000
Error	8	55702	6963		
Total	**11**	2722250			

Table 4. Analysis of variance showing grain yield/hectare among different wheat varieties having zero percent stripe rust.

S.O.V.	df	SS	MS	F-value	P
Strains	3	1531721	510574	65.58	0.000
Error	8	62285	7786		
Total	**11**	1594006			

Table 5. Yield reduction in different wheat varieties due to stripe rust.

Variety	Yield in control Kg ha^{-1}	Yield in diseased field Kg ha^{-1}	Yield loss Kg ha^{-1}	Yield loss %
Bakhtawar	1,928.0	1,640.7	287.3	14.90145
Morocco	1,730.3	1,041.7	688.6	39.79657
Wafaq-2001	1,518.7	1,418.0	100.7	6.630671
Inquilab-91	2,480.0	2,336.7	143.3	5.778226

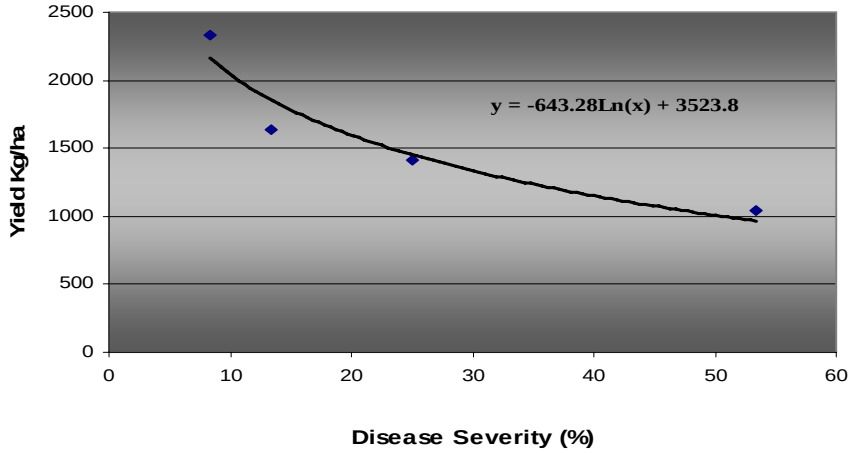

Fig. 1. Graph showing relationship between disease severity and wheat yield.

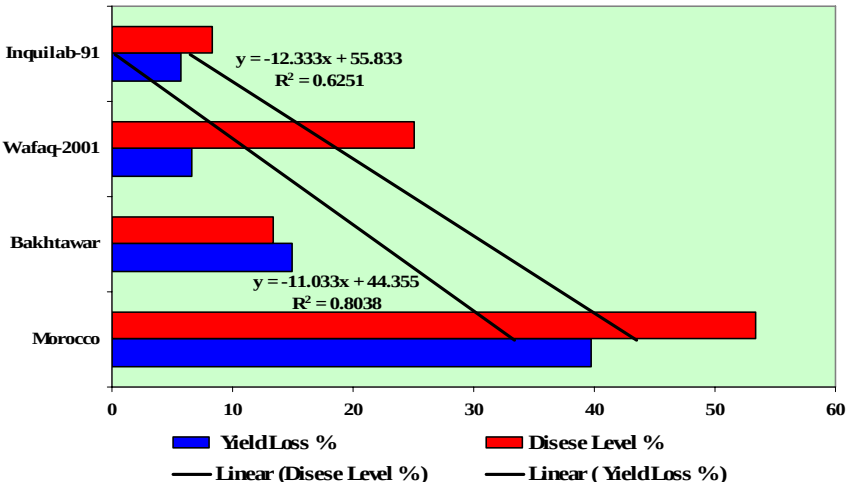

Fig. 2. Estimated yield losses in response to different levels of stripe rust.

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