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IMPACT OF STRIPE RUST ON KERNEL WEIGHT OF WHEAT VARIETIES SOWN IN RAINFED AREAS OF PAKISTAN

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Abstract

The stripe rust is the most striking among various factors that contribute towards enormous wheat yield losses in the northern Punjab and NWFP. Investigations revealed that there exists a direct linkage between the disease level of *Puccinia striiformis* Westend f.sp. *Tritici* Eriksson and weight loss of kernel in the most common wheat varieties sown in Pakistan. The kernel weight was significantly negatively correlated with the proportion of leaf area affected by stripe rust. The correlation coefficient (-0.9185) depicted highly significant effect of stripe rust on lowering 1,000 grain weight, ultimately the wheat yield. Variation in resistance level was also observed among different wheat varieties. The extensively cultivated wheat variety, Inquilab-91 proved to exhibit minimum kernel weight loss followed by Bakhtawar and Wafaq-2001. The Morocco, however, expressed as the most susceptible of all the varieties with maximum grain weight loss. Evaluation of disease resistance revealed that wheat variety Bakhtawar proved to be the moderately susceptible whereas Wafaq-2000, Inquilab-91 and Morocco ranked as susceptible to *Puccinia striiformis.* Among the four wheat varieties grown to assess the yield loss, sowing of Inquilab-91 and Bakhtawar was recommended because of their potential to withstand heavy yield losses inflicted by the stripe rust.

Introduction

Plants contribute around 93% of the food to feed the people of the world, two-third of which is contributed by the cereals (wheat, maize, rice, barley, sorghum and millet). About 80% of the global cereal production is shared by wheat, maize and rice. Among the cereals, wheat is the largest one being cultivated in 27 countries of the developing world. Of the two principle types of wheat i.e., Bread and Durum, 90% of the world's wheat is attributed to bread wheat (Stubbs, 1985). Wheat is used mainly for human consumption and supports nearly 35% of the world population (Dreisigacker, 2004). It is estimated that more than 75% of the world's population consumes wheat as part of their diet daily. In parts of northern Africa and in the newly independent republics in the Caucuses region, annual consumption per person is the highest at around 200 kg (Maarten & Ogbonnaya, 2006). As far Pakistan is concerned, wheat *(Triticum aestivum* L.em.Thell) is a leading food grain and a staple diet of its inhabitants. It occupies a central position in the agricultural policies. Wheat cultivation encompasses a major production area of 8.303 million hectares thereby engaging 33% of the cultivated area of the country each year and exhibited production around 21.7 million tones in last wheat season (Anon., 2006). The same is not sufficient to meet the country's ever-increasing population growth rate of 2.5% per annum. To achieve self-sufficiency, sustainable productivity of wheat is of paramount importance in the context of food security.

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Limiting factors in wheat production are associated with several biotic and abiotic stresses. Of these in the former category, rust disease is the most significant wheat disease, which has continued to ravage this crop since ancient times. Stripe rust probably occurred long before wheat was grown for food, but Gadd from Europe first described it in 1777 (Eriksson & Henning, 1896). Hassebrauk (1965), Stubbs (1985), Line (2002), and Li & Zeng (2003) were among those who reported stripe rust and its distribution around the world. By now, stripe rust of wheat has been reported in more than 60 countries of the world. Out of the three wheat rusts viz. stripe/yellow rust (*Puccinia striiformis tritici*), leaf/brown rust (*Puccinia triticina tritici*) and stem/black rust (*Puccinia graminis tritici*), the former two occur in Pakistan with variable intensities under various agro-ecological zones. The stripe rust pathogen is the most important among all wheat rusts, favoured by mild winters and long, cool, wet springs. Its symptoms on the host include appearance of citron-yellow uredia (spore masses) in long stripes over the leaf surfaces but rarely present on stem and heads. As the crop matures, black spores (telia) are produced in stripes, which are covered by the leaf epidermis (Smiley & Cynthia, 2003). Literature has depicted that stripe rust of wheat reduces the weight and quality of the kernel and forage. Seed produced from crop damaged by stripe rust are shriveled, 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). Monetary losses due to the reduction of wheat yield caused by stripe rust in the central great plains of the US were estimated to be $27M, $119M, $24M and $267M US for 2000, 2001, 2002 and 2003, respectively (Chen *et al.*, 2004).

Severe epidemics in Australia in 1983 and 2003 cost wheat growers AU$8 million and AU$40 million, respectively for fungicide application to control stripe rust (Wellings & Kandel, 2004). In Egypt, major epiphytotics were recorded once in each decade since the 1960s with the most recently reported epiphytotics in the Delta region in 1995 where average grain yield loss ranged from 14 to 26%, while the national loss was about 10% (El-Daoudi *et al.,* 1996). In the southern region of West Asia, severe epidemics of yellow rust have also been recorded in past and 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). Similarly, several yellow rust epidemics in most of the wheat-growing areas of Iran caused over 30% crop loss in the last decade and estimated grain losses were 1.5 million tones and 1.0 million tones in 1993 and 1995, respectively (Torabi *et al*., 1995). In the Cukurova area of Turkey, a loss of over 0.5 million tones 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).

Rust scenario in Pakistan revealed that the pathogen exhibits its severity mainly in the country’s foothills, northern areas and upland of Baluchistan, which can jeopardize wheat production when it develops in an epidemic form, as occurred in 1992-93. Out of the total 8.303 million hectares of wheat production area in Pakistan, 70% is prone to stripe rust, which encompasses an area of about 5.8 million hectares. In Pakistan, the rust epidemics have occurred in 1947-48, 1953-54, 1958-59 and 1977-78. Mild epidemic of stripe and leaf rusts also occurred in 1972-73 and 1975-76. Hussain *et al*., (1979) accounted 10.1% yield loss to the tune of 0.83 million tons valuing US$86 million during 1977-78 due to rust. 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 intimated 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. The study was imperative to evaluate the economic impact of this disease thereby predicting the losses, if the disease occurs in epidemics.

Materials and Methods

The present investigations were executed at the experimental area of the University of Arid Agriculture (UAAR), Rawalpindi during the year 2006-07 to ascertain loss in weight of wheat kernel inflicted by stripe rust. Wheat seeds of four 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. Eight replications were used for each of the variety by using seed rate of 100 kg ha^{-1} in each planting. The trials were managed with optimum nutrient application 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* f. sp. *tritici.* 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 1st February 2007.

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 loss assessment was made by comparing 1,000 grain weight for each variety in diseased and disease free plots. The data was statistically computed by MSTAT-C program (Anon., 1991) and comparison of means was accomplished by Duncan's Multiple Range Test (Gomez & Gomez, 1984).

Results and Discussion

Analysis of the data indicated a strong negative correlation (-0.9185) between the disease level as well as 1,000 kernel weight (Fig. 1). Analysis of variance depicted highly significant differences among 1,000 grain weight of different wheat varieties to the stripe rust (Table 1).

Comparison of mean values Table 2 revealed that disease significantly affected grain weight of all the varieties used in the experiment. Appraisal of means indicated that maximum reduction in 1,000 grain weight was observed in case of Morocco with 28.025 gms. The mean value of 1,000 grain weight loss pertaining to Bakhtawar and Wafaq 2000 showed 18.98 and 20.32 gms, respectively whereas, minimum 1,000 grain weight loss was observed in Inquilab-91 despite of 36.25% disease severity.

The statistical analysis further showed highly significant differences in susceptibility levels of different wheat varieties used in the experiment (Table 3). Comparison of mean values through Duncan's Multiple Range Test at 0.01 level of probability enunciated that wheat variety Morocco proved to be the most susceptible with 57.50 % disease severity followed by Inquilab-91 and Wafaq-2000 with 36.25 and 31.875 % disease severity, respectively. The variety Bakhtawar, however, proved comparatively resistant showing 21.875 % disease severity (Table 2).

The overall performance of wheat varieties presented in fig.1 indicated that Inquilab-91 exhibited minimum reduction of 7.838 grams in 1,000 kernel weight inspite of the fact that maximum severity was observed in this variety after Morocco. Results have proved high yielding potential of Inquilab-91 even under disease stress. It was further evident that disease severity in all the varieties increased during 2006-07 as compared to 2005-06 wherein, 53.33% disease severity was observed in case of Morocco followed by Wafaq-2001, Bakhtawar and Inquilab-91 with 25, 13.33 and 8.33%, respectively (Afzal *et al.,* 2007) against 57.50, 31.875, 12.50 and 36.25% recorded during 2006-07. The abrupt increase in disease severity of Inquilab-91 could be due to the genetic potential of the variety that coupled with the increased rainfall during the year. The phenomenon may be attributed to more rainfall during 2006-07 in comparison with 2005-06. The results are in line with the previous work which indicates that disease severity is strongly affected by meteorological factors such as temperature, rainfall and humidity. The present investigations are supported 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 five 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, however, disease was 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 (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 dire need to avoid fast ruster and susceptible varieties. Besides, plant breeding departments should be encouraged and accounted for to continuously monitor rust situation through Plant Pathologists and evolve resistant varieties thereby ensuring sustainable food security of the country.

Table 1. ANOVA exhibiting effect of wheat varieties and disease levels on 1,000 grain wt.

Source of variance	df	SS	MS	F-value	P
Wheat varieties	3	582.2	194.1	37.86	0.000
Disease level	1	5651.3	5651.3	1102.42	
Variety * Disease level	3	830.6	276.9	54.01	
Error	5 6	287.1	5.1		
Total	**63**	**7351.1**			

Table 2. Comparison of mean values of disease severity and 1,000 grain weight in disease plots through DMR Test at $\alpha = 0.01$.

Wheat Varieties	Disease severity * (%)	Host response to infection	1,000 Grain wt (gms)		
			Control plot	Disease plot	Kernel weight loss
Bakhtawar	21.88 **c**	MS-S $^{+}$	42.530 **ab**	23.550 **b**	18.980
Inquilab-91	36.25 **b**	S $^{++}$	41.450 **b**	33.612 **a**	7.838
Wafaq-2000	31.88 **b**	S $^{++}$	44.937 **a**	24.613 **b**	20.324
Morocco	57.50 **a**	S $^{++}$	43.225 **ab**	15.200 **c**	28.025

* Severity was recorded as percent of rust infection according to modified Cobb's scale
$^{+}$ MS-S: Moderately Susceptible-Susceptible, $^{++}$ S: Susceptible

Table 3. Response of wheat varieties to incidence of stripe rust.

Source of variance	df	SS	MS	F-value	Significance F
Variety	3	10706.3	3568.8	123.62	0.000
Replicate	7	225.0	32.1	1.11	0.391
Error	21	606.3	28.9		
Total	**31**	**11537.5**			

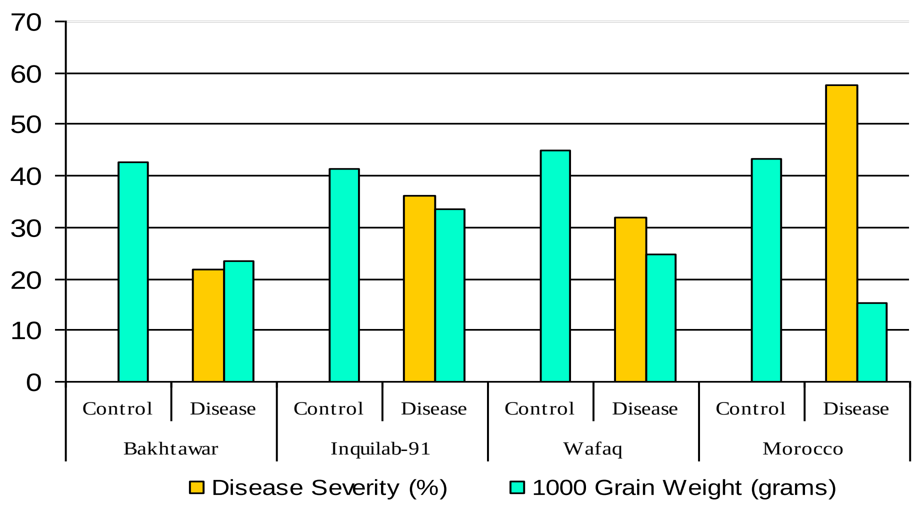

Fig. 1. Comparison of 1,000 grain weight of wheat varieties in control and diseased plots.

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