Pak. J. Bot., 42(1): 401-407, 2010.

PREDICTION OF YIELD LOSSES IN WHEAT (*TRITICUM AESTIVUM* L.) CAUSED BY YELLOW RUST IN RELATION TO EPIDEMIOLOGICAL FACTORS IN FAISALABAD

S. AHMAD*, M. AFZAL, I.R. NOORKA, Z. IQBAL, N. AKHTAR, Y. IFTKHAR AND M. KAMRAN

[1]*University College of Agriculture,*
University of Sargodha, Sargodha, Pakistan.

Abstract

Thirty six genotypes were screened against yellow rust to check their level of susceptibility or resistance. Among 36 genotypes screened against yellow rust, 18 were susceptible, 6 were moderately susceptible to susceptible, 7 were moderately resistant to moderately susceptible and 5 genotypes remained resistant. Yield losses were predicted in wheat on the basis of varying level of yellow rust severities. It was observed that susceptible genotypes showed higher yield losses as compared to resistant genotypes. Maximum severity of 90% of yellow rust resulted in 54% to 55% calculated and predicted losses, respectively. While 40, 50, 60 and 70% disease severity of yellow rust caused 35-34%, 38-37%, 42-40% and 46-47% calculated and predicted losses, respectively. However, the decline in losses was observed as the genotypes changed their reaction from susceptible to moderate susceptible. Similarly, losses were diminished as the varieties/lines showed moderate resistant reaction from moderate susceptible. Minimum temperature and relative humidity remained positively correlated while the maximum temperature showed negative correlation with stripe rust severity. With the increase of minimum temperature and relative humidity a rise up in stripe rust infection was seen while as the maximum temperature increased stripe rust infection decreased on different genotypes. It may be concluded from the study that environmental factors played major role in the spread of the disease which result in yield losses.

Introduction

Wheat (*Triticum aestivum.* L.) is main crop and staple food of Pakistani nation. It contributes 34% to GDP (Anon., 2007). The wheat crop is attacked by many diseases, of which rusts are of great importance. Three types of rusts are found on wheat, viz. leaf rust (brown rust) caused by *Puccinia recondita* Rob. ex. Desm. f. sp. *tritici*, Stripe rust (yellow rust) caused by *P. striiformis* f. sp. *tritici* and Stem rust (black rust) caused by *P. graminis* Pers. f. sp. *tritici.*

Stripe rust appears periodically on wheat crop and induce heavy losses in yield. Several epidemics of stripe rust on wheat crop have been reported in the past and this disease will be a persistent menace to future wheat production. Losses in grain yield in susceptible varieties might exceed 50% in case of an early onset of rust (Yaqoob, 1991). The annual losses from rusts have been estimated at Rs. 30-40 million while in epidemic year they are very high; e.g., in 1977-78 epidemics of stripe and leaf rusts reduced the total wheat production by 2.2 million tones worth US$ 330 million (Hafiz, 1986).

The main cause of the epidemic may be the favourable environmental conditions. Under suitable environment the chances of disease incidence are increased. (Singh *et al*., 2001). Stripe rust have been found in showing highly positive correlation with minimum temperature, relative humidity and rainfall, while maximum temperature reduces the chances of disease (Salman *et al.*, 2006; Khan, 1997; Khan *et al*., 1998).

*Corresponding author, E.mail adress: sal_uaf@yahoo.com

Yellow rust caused by *P. striiformis* f.sp. *tritici* appears on leaves as small yellowish pustules arranged in lines parallel to veins. The damage caused depends upon the severity and time of infection resulting into yield reduction. It may appear in January and continue to develop in March depending upon the prevalence of low temperature (Hussain, 1989; Hussain *et al*., 1996).

The objective of the study was to screen out the available germplasm to estimate yield losses caused by this rust disease in relation to epidemiological factors. The amount of rust disease and its correlation with yield can be helpful to build up a model which may be used in future to predict not only the stripe rust but also the yield losses on wheat genotypes affected by this disease.

Materials and Methods

Experimental nursery was planted on 12th December, 2006, consisting of 36 wheat genotypes. Morocco, WL-711, Pak-81 and Local white were sown as rust spreader. The rust inoculum was sprayed two times in a week. No fungicides were sprayed to keep the crop under maximum disease severity conditions. In order to maintain crop vigour normal agronomic practices including recommended fertilization dose and irrigation schedule were applied. At the time of maturity the crop was harvested and yield of each entry of 4.5 m was weighed by conventional balance. The influence of stripe rust severities on yield was determined by comparing the yield of diseased and healthy genotypes.

The yield losses due to stripe rust were calculated on severity basis by using Mundy's equations (1973). Then yield losses were predicted on severity basis by using regression model. The relationship of calculated and predicted yield losses with severity was explained graphically. The equation used to calculate yield losses by stripe rust is given below:

Loss = (0.44 x disease severity) + 3.15 OR

Loss = (5.06 x the square root of the disease severity) – 17.15

Environmental data consisting of maximum and minimum air temperature, relative humidity, rainfall, wind speed and solar radiation were recorded by conventional instruments installed at observatory of Crop Physiology Department, University of Agriculture, Faisalabad which was close to experimental area. The disease ratings were taken on weekly basis by following the modified Cobb's scale described by Peterson *et al*., (1949). The relationship of each environmental condition with stripe rust on different genotypes were determined by correlation and regression (Steel & Torrie, 1986; Khan *et al.*, 1998).

Environmental data served as independent variable while disease severity was used as dependent variable. Environmental parameters having significant influence on stripe rust development were studied in detail by plotting the data graphically.

Results and Discussion

The present study clearly showed that genotypes on which disease severity was maximum exhibited maximum yield losses and the genotypes on which disease severity was less displayed minimum yield losses. It was also evident that susceptible genotypes suffered more yield losses than those having moderately resistant to resistant reactions to stripe rust. It was seen that the genotypes like Moroco which showed 90% severity showed 55% calculated and 54.35% predicted losses against stripe rust. Similarly, the genotypes e.g., Lr3Ka, HD-2169, Lr-1 and Lr13 having the severity level of 60% displayed losses of 42% and 41.66% calculated and predicted losses respectively (Table 1). While the susceptible genotypes like Lr3G, Lr12 and Lr15 exhibiting severity level of 70% expressed 46% calculated and 47% predicted losses. Same type of pattern was seen in those susceptible genotypes (Lr10, Lr16, 93111) with 50% severity level suffered 38% calculated and 38.66% predicted losses. Moreover, those Genotypes which having 55% and 40% severity level with susceptible reaction revealed 39.15% and 38.12% losses and 35% and 36.12% calculated and predicted losses, respectively. However, it was seen that as the reaction was changed from susceptible to moderately susceptible the difference in yield loss was also observed. For example, the genotypes Shalimar-88 and Lr27+31 with 40% and Faisalabad-83, Punjab-85 and Lr30 having 30% with moderately susceptible to susceptible reaction level showed 25% to 21% and 17.55% to 18% calculated and predicted losses, respectively. Furthermore, the genotypes which exhibited moderately resistant to resistant reactions suffered less yield losses as compared to moderately susceptible to susceptible genotypes (Table 1). Resistant genotypes like Laylpure-73, Lr-9, Lr-23, Lr-24 and Lr-26 displayed very less severity level and thus in these genotypes minute losses up to 5.35% calculated and 5.21% predicted were observed (Table 1). The results were explained with graph (Fig. 1). The relationship was best explained by linear regression model as indicated by 0.93 and 0.94 r values of calculated and predicted losses, respectively. The graph also explained that as the severity of stripe rust increased on the genotypes both the calculated and predicted losses were also increased.

Theses results are in consistency with the findings of (Afzal *et al*., (2007); Qamar *et al*., (2008) who reported that stripe rust may cause heavy losses in the wheat crop. The disease may cause yield loss by reducing the kernel weight and quality deterioration (Afzal *et al.*, 2008). Yellow rust has produced heavy losses in the different parts of the world and is also a future threat for global wheat production (Coram *et al*., 2008). The disease may cause loss up to 40-78% under normal conditions (Duwadi *et al.*, 1993; Chen, 2005) but if the conditions are favourable for disease spread the loss may rise up to 84% (Murray *et al.*, 1994). The predicted losses may be less if the wheat varieties are resistant or slow rusting against rust diseases (Salman *et al*., 2006). Similarly, the varieties which show less area under disease progress curve (AUDPC) normally bear less yield losses (Hussain *et al.*, 1996).

Environmental factors play important role in the spread of epidemic of stripe rust (Chen, 2005; Dereje & Chemeda, 2007; Zeng & Luo, 2008; Milus *et al*., 2009). In the present study, correlation of stripe rust and yield with environmental conditions was also determined (Table 2). The results showed that stripe rust was strongly correlated with maximum temperature, minimum temperature, and sunshine radiations while other environmental conditions remained insignificant against stripe rust. It was seen that with the increase of minimum temperature the severity of stripe rust over different genotypes increased (Fig. 2). Similarly, disease severity also showed exponential curve against relative humidity which means that as the relative humidity enhanced stripe rust infection over different genotypes also increased (Fig. 3). However, response of maximum temperature to stripe rust infection was different as with the increase of maximum temperature the stripe rust severity over the genotypes decreased (Fig. 4). The relationship of these epidemiological factors with disease severity was explained by the linear regression model (Figs. 2-4). The regression equations clearly exhibited that these environmental conditions have played important role in the spread of the disease. These results coincide with the findings of many research workers (Mcintosh, 1992; Meenakumari *et al*., 1992; Knott *et al.* 1993; Hussain *et al*., 1996; Khan, 1997; Khan *et al.*, 1998; Singh & Tewari, 2001 and Padmakar *et al.*, 2001).

Table 1. Response and prediction of yield losses due to stripe rust in wheat genotypes.

Genotypes	Reaction of wheat genotypes	YR Severity (%)	Calculated loss (%)	Predicted loss (%)
HD-2169	S	60	42.00	41.66
Lalypur-73	R	5	5.35	5.21
Punjab-81	MS,S	20	12.00	13.00
Faisalabad-83	MS,S	30	17.55	16.00
Shalimar-88	MS,S	40	22.25	21.00
Punjab-85	MS,S	30	17.55	16.00
Moroco	S	90	55.00	54.35
Lr3KA	S	60	42.00	41.66
Lr3G	S	70	46.00	47.00
Lr9	R	5	5.35	5.21
Lr10	S	50	38.00	37.20
Lr11	S	60	42.00	41.66
Lr12	S	70	46.00	47.00
Lr13	S	60	42.00	40.66
Lr15	S	70	46.00	47.00
Lr16	S	50	38.00	38.66
Lr17	S	40	35.00	36.12
Lr18	S	30	32.55	31.00
Lr20	S	40	35.00	36.12
Lr21	MR,R	10	7.50	7.00
Lr22A	S	40	35.00	36.12
Lr22B	S	20	7.55	7.44
Lr23	R	5	7.55	7.44
Lr24	R	5	5.35	5.21
Lr26	R	5	5.35	7.44
Lr27+31	MS,S	40	22.25	21.00
Lr30	MS,S	30	17.55	16.00
Lr32	MR,R	10	7.50	7.00
Lr34	MR,R	10	7.50	7.00
Lr36	MR,R	15	8.05	8.00
LrB	MR,R	10	7.50	7.00
Yr8+E26	MR,R	10	7.50	7.00
Yr9-E32	S	15	11.50	11.90
Yr10-E30	S	55	39.75	38.12
Yr95ERI-E45CHECH	MR,R	10	7.50	7.00
93111	S	50	38.00	38.66

* = Rust intensity as percentage leaf area rusted, ** = Reaction types, S = Susceptible,
R = Resistant, MS = Moderately susceptible, MR = Moderately resistant

Table 2. Correlation of environmental conditions with Yellow rust and yield.

Environmental conditions	% Disease severity YRST	Yield
Maximum temperature	0.0453 0.0001**	0.4610 0.0001**
Minimum temperature	0.0299 0.0001**	0.8686 0.0001**
Relative humidity	0.0487 0.0001**	-0.8173 0.0001**
Rain fall	-0.0452 0.3689 NS	-0.4550 0.0001**
Sun radiations	0.0408 0.2536N.S	0.2987 0.0001**
Wind speed	0.0465 0.3551 NS	0.8716 0.0001**

* = Significant (p<0.05), ** = Highly significant (p<0.01), NS= Non-significant (p>0.05)

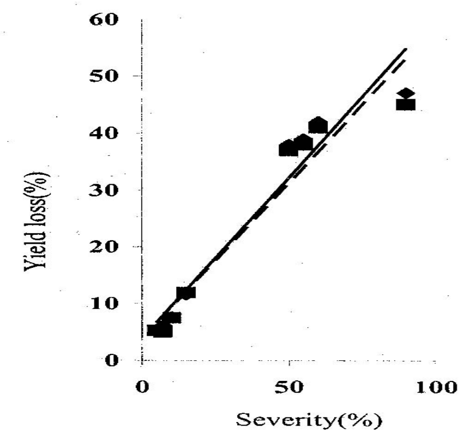

Fig. 1. Calculated (Y1) and Predicted (Y2) yield losses due to stripe rust in Wheat genotypes.

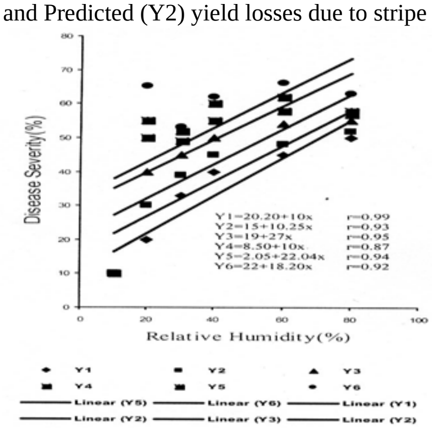

Fig. 2. Relationship of weekly minimum temperature with stripe rust on genotypes Y1 (Moroco), Y2 (HD-2169), Y3 (Lr11), Y4 (Lr13), Y5 (Lr22B) and Y6 (Yr10-E30) during 2007.

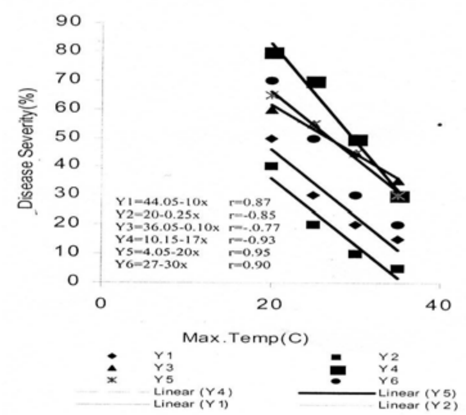

Fig. 3. Relationship of weekly Relative humidity with stripe rust on genotypes Y1 (Moroco), Y2 (HD-2169), Y3 (Lr11), Y4 (Lr13), Y5 (Lr22B) and Y6 (Yr10-E30) during 2007.

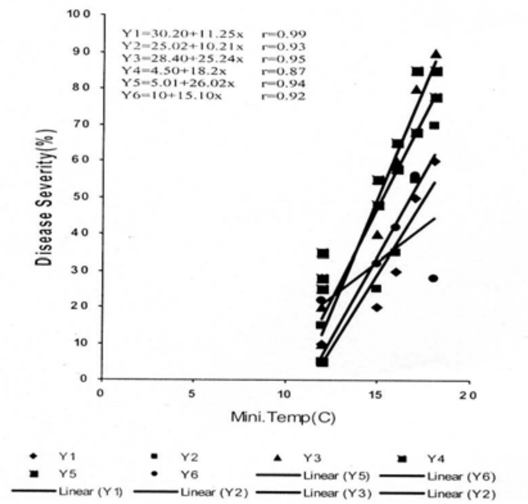

Fig. 4. Relationship of weekly maximum temperature with stripe rust on genotypes Y1(93111), Y2(Lr 17), Y3(Lr18), Y4(Lr 20), Y5(Lr22A) and Y6(Lr22B) during 2007.

Conclusion

In the light of the present study, it is evident that yield losses may be high in susceptible genotypes than the resistant. Similarly, yield losses may decrease as the varieties/lines changed their reaction from the susceptible to resistant. Stripe rust may cause 55% loss in the yield of wheat at severity level of 90% while a level of 50% disease incidence may create 35% yield loss. Minimum temperature and relative humidity may play vital role in the spread of the disease epidemic while maximum temperature may halt the disease spread. Similar type of prediction model may be helpful to manage the disease by forecasting the stripe rust virulences. The present model in this context may be helpful for future studies.

References

Afzal, S.N., M.I. Haque, M.S. Ahmedani, A. Rauf, M. Munir, S.S, Firdous, A.R. Rattu and I. Ahmad. 2008. Impact of stripe rust on the kernel weight of the wheat varieties sown in rainfed area of Pakistan. *Pak. J. Bot*., 40(2): 923-929.

Afzal, S.N., M.I. Haque, M.S. Ahmedani, S. Bashir and A. Rehman. 2007. Assessment of yield losses caused by *Puccinia striiformis* triggering stripe rust in the most common wheat varieties. *Pak. J. Bot*., 39(6): 200-207.

Anonymous. 2007. *Pakistan Economic Survey*. Government of Pakistan, Finance Division, Economic Advisor's Wing, Islamabad.

Chen, X.M. 2005. Epidemiology and control of stripe rust (*Puccinia striiformis f. sp. tritici*) on wheat. *Can. J. Plant Pathol*., 27: 314-337.

Coram, T.E., M. Wang and C. Xianming. 2008. Transcriptome analysis of the wheat-*Puccinia striiformis* f. sp. *tritici* interaction. *Mol. Plant Pathol*., 9(2): 157-169.

Dereje, H. and F. Chemeda. 2007. Epidemics of stripe rust (*Puccinia striiformis*) on common wheat (*Triticum aestivum*) in the highlands of Bale, southeastern Ethiopia. *Crop .Prot*., 26(8): 1209-1218.

Duwadi, V.R., R.B. Paneru and M.R. Btittarai. 1993. Yield loss assessment in wheat caused by yellow rust (*Puccinia striiformis* West) disease. *PAC Working Paper Pakhribas Agricultural Center*., 82(7): 51-54.

Ezzahiri, B. and A.P. Roelfs. 1989. Inheritance and expression of adult plant resistance to leaf rust in Era wheat. *Plant Dis*., 73: 549-551.

Hafiz, A. 1986. *Plant Diseases*. PARC Islamabad, pp. 552.

Hussain, M ., H. Mumtaz and J.A. Shah, 1996.Wheat rust scenario in 1994-1995. *Pak. J. Phytopathol*., 96-100.

Hussain, S.F. 1989. Wheat disease situation in Pakistan. *Proc. Nat. Sem. on Wheat Res. and Prod.* . 6-9.

Khan, M.A. 1997. Evaluation of multiple regression models based on epidemiological factors to predict leaf rust on wheat. *Pak. J. Agric. Sci*., 5(34): 1-7.

Khan, M.A., M. Yaqub and M.A. Nasir. 1998. Slow rusting response of wheat Genotypes against *Puccinia recondita* f. sp. *tritici* in relation to environmental conditions. *Pak. J. Phytopathol*., 10(2): 78-85.

Knott, D.R. and B. Yadan. 1993. The mechanism and inheritance of adult plant leaf rust resistance in the 12 wheat lines. *Genome*, 36: 877-883.

Mcintosh, R.A. 1992. Close genetic linkage of genes conferring adult plant resistance to leaf rust and stripe rust in wheat. *Plant Pathol*., 41: 523-527**.**

Meenakumari, K.V.S., D.V. Singh and K.D. Srivastava. 1992. Estimation of yield losses in wheat cultivation to leaf rust and at different growth stages under artificial inoculation. *Indian Phytopathol*., 45(2): 266-268.

Milus, E.A**,** K, Kristensen**,** and S.H. Mogens. 2009. Evidence for Increased Aggressiveness in a Recent Widespread Strain of *Puccinia striiformis* f. sp. *tritici* Causing Stripe Rust of Wheat. *Phytopathol*., 99(1): 89-94.

Munday, E.J. 1973. The effect of yellow rust and its control on the yield of joss Cambier Winter Wheat. *Plant Pathol*., 22: 171-176 .

Murray, G., M. Ellison, P. J. Watson and B.R. Cullis. 1994. The relationship between wheat yield and stripe rust as effected by length of epidemic and temperature at grain development stage of crop growth. *Plant Pathol*., 43(2): 397-405.

Padmakar, T., R.S. Mishra, S.K. Tomar and P. Tripathi. 2001. Effect of climatic factors on stripe rust on wheat. *Ann. Plant Prot. Sci*., 9(1): 154-155.

Peterson, R. F., A.B. Campbell and Hanna. 1949. A diagrammatic scale for estimating rust severity on leaves and stems of cereals. *Can. J. Res. Sci*., 26: 249-500.

Qamar, M., S.A. Dilnawaz., A.H. Shah, C. Wellings and F. Batool. 2008. Postulation of stripe rust resistant genes in some australian bread wheat cultivars and their response to temperature. *Pak. J. Bot*., 40(6): 2573-2585.

Salman, A., M.A. Khan and Mumtaz Hussain. 2006. Prediction of yield losses in wheat varieties/lines due to leaf rust in Faisalabad. *Pak. J. Phytopathol*., 18(2): 178-182.

Singh, R.P., T.S. Pyne, P. Figueroa and S. Valeza. 1991. Comparison of the effect of leaf rust on grain yield of resistant, partially resistant and susceptible spring wheat cultivars. *Amer. J. Alter. Agric*., 6: 115-121.

Singh, T.B. and A.N. Tewari. 2001. The role of weather conditions in the development of foliar diseases of wheat under tarai conditions of north western India. *Plant Dis. Res*., 16(2): 173-178.

Steel, R.G.D. and J.H. Torrie. 1986. *Principles and Procedures of Statistics*. 2end. Ed. McGraw Hill Book Inter. Co. New York.

Yaqoob, M. 1991. *Study on rusts and tolerance in wheat cultivars in greed lines in Pakistan*. M.Sc. Thesis, Department of Plant Pathology, University of Agriculture, Faisalabad, pp. 98.

Zeng, S. M and Y. Luo. 2008. Systems analysis of wheat stripe rust epidemics in China. *Eur. J. Plant Pathol*., 101: 425-438.

(Received for publication 12 October 2008)