Indian Journal of Agricultural Sciences **86** (7): 930–4, July 2016/Article
https://doi.org/10.56093/ijas.v86i7.59830

Role of microclimate in management of yellow rust (*Puccinia striformis* f sp *tritici*) of wheat (*Triticum aestivum*) under Ludhiana conditions

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Received: 21 August 2015; Accepted: 16 February 2016

ABSTRACT

The field experiment was conducted during *rabi* seasons of 2012-13 and 2013-14 at the Research Farm, School of Climate Change and Agricultural Meteorology, PAU, Ludhiana. Wheat (*Triticum aestivum* L.) varieties HD 2967, PBW 550 and PBW 343 were sown under two row direction, viz. North-South (N-S) and East-West (E-W). Yellow rust (*Puccinia striformis* f sp *tritci*) severity and incidence was recorded at weekly intervals. Disease severity index was higher (100%) during *rabi* 2012-13 as compared to 2013-14 (91%). Among different row direction the disease severity was higher under N-S row direction as compared to E-W row direction during both the years. Area under disease progress curve (AUDPC) was maximum in PBW 343 sown under N-S row direction as compared to other treatments. Among three varieties HD 2967 was highly resistant to yellow rust as it showed zero AUDPC. Highly significant value of R^2 (0.91 and 0.90) was found when maximum meteorological parameters were combined in PBW 343 and PBW 550, respectively. Relationships were developed between microclimatic parameters, viz. canopy temperature and relative humidity. Analysis of these relationships indicated that disease and microclimatic parameters were interrelated. Higher R^2 values of Humid Thermal Ratio (HTR), Special Humid Thermal Ratio (SHTR) and disease severity indicated that HTR and SHTR can be used as a disease predictor.

Key words: Canopy temperature, Humid thermal ratio, Relative humidity, Wheat, Yellow rust

Wheat (*Triticum aestivum* L.) crop is attacked by large number of diseases and insects which often appear in epidemic proportions causing yield losses and deterioration in quality. Out of various diseases of wheat, rust diseases i.e. yellow rust, brown rust and black rust are the most significant. Stripe rust (yellow rust) is caused by *Puccinia striformis* f.sp. *tritici*. Periodic leaf rust epidemics have occurred in most decades of the last century, thus worldwide leaf rust is considered as important disease of wheat. The stripe rust has been reported in more than 60 countries and all continents except Antarctica (Chen 2005). Plant diseases affect 55% of the global wheat growing area, causing an estimated loss of 20 million tonnes of wheat per annum (Kosina *et al.* 2007). Under the north-western plain zone, which is major wheat producing area in the country, yellow rust is the major disease problem. Stripe rust is traditionally important for wheat grown in cooler environments due to the lower temperatures required for optimum development (Singh *et al.* 2002). In North India, due to the favourable weather conditions for disease spread the area remain perpetually under the threat of this disease. Huerta-Espino *et al.* (2011) reported that *Puccinia tritici* has a wide virulence range and is broadly adapted to diverse climatic conditions, leading to regular and significant yield losses over large geographical areas. Singh *et al.* (2004) estimated that leaf rust could affect 80% of wheat production in India (21.6 mha) under favourable conditions. Besides genetic resistance, which affects the individual crop risk, weather variables influence the incidence and severity of leaf rust (Moschini and Perez 1999). Several environmental variables affect the production, dispersal and survival of uredinospores (Eversmeyer and Kramer 1995).

It is well known that the pathogens are capable of producing the new races which may overcome the resistance in particular variety or may adapt to warmer temperatures to cause severe disease in previously unfavourable environments (Milus *et al.* 2009). Microclimate influence disease incidence and severity so modification of microclimate can be helpful to manage diseases. The overall powdery mildew and yellow rust disease incidence percentage and severity index were higher under flat planted crop than bed planted crop under Punjab conditions. Under bed planted crop due to more circulation of air, the relative humidity remained lower than flat planted crop so less incidence of disease under bed planted crop

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was observed (Kaur 2012). Severity of yellow rust is effected by different meteorological parameters and microclimate of crop. Microclimate modification can be useful in management of yellow rust as disease is highly influenced by microclimate of the crop. So keeping this in view, the experiments were conducted to study the effect of microclimate modification on yellow rust severity.

MATERIALS AND METHODS

Wheat varieties HD 2967, PBW 550 and PBW 343 were sown under two row direction, viz. North-South (N-S) and East-West (E-W) during *rabi* seasons of 2012-13 and 2013-14. Microclimate of crop was modified by sowing crop in two different row directions. The crop was raised as per recommendations of Punjab Agricultural University, Ludhiana. Daily meteorological observations on maximum and minimum temperatures (^{o}C), relative humidity (%), sunshine hours (hours/day) and rainfall (mm) were recorded at the Agrometeorological Observatory (30^{o} 54' N, latitude and 75^{o} 48' E longitude and altitude of 247 m above the mean sea level) which is situated 150 m away from the experimental area. Microclimatic parameters, viz. canopy temperature and relative humidity within crop canopy were recorded under different treatments. Canopy temperature was measured at 1400 hr at weekly interval with the help of Infrared Thermometer. The relative humidity was measured at 1400 hr at weekly interval with the help of Belfort psychron.

The average data of each score at weekly interval was converted to percent leaf area for computation of Area under disease progress curve (AUDPC) according to the formula suggested by Forbes *et al*. (1993) as following:

$$\text{AUDPC (\% days)} = \sum_{i=1}^{i=n} \left(\frac{xi + xi + 1}{2}\right) * (ti + 1 - ti)$$

where, t = time in days of each reading, x = percentage of affected foliage at each reading and n = number of readings.

$$\text{rAUDPC (\%)} = \frac{\text{Total AUDPC}}{\text{Total Time (day)}} \times 100$$

where, rAUDPC = relative AUDPC, Total AUDPC= sum of weekly AUDPC values, Total time= Total days after disease appearance

Yellow rust severity was recorded visually as the percentage of leaf area infected according to the modified Cobb's or Peterson's scale (Peterson *et al* 1948). The disease was recorded on 10 randomly selected plants and per cent plants affected by the disease were recorded at weekly intervals. Severity index was calculated by using the following formulae:

$$\text{Severity index} = \frac{\text{Area of plant tissue infected}}{\text{Total area}} \times 100$$

For estimating the per cent severity on leaves different scales as Modified Mannar's scale for yellow rust of wheat (Peterson *et al.* 1948) were used.

Six categories of the scale were determined on the basis of the per cent area of the leaf covered by infection as follows:

5 - Up to 5% leaf area infected,
10 - Up to 10% leaf area infected,
20 - Up to 20% leaf area infected,
50 - Up to 50% leaf area infected,
75 - Up to 75% leaf area infected,
100 - Up to 100% leaf area infected.

Humid Thermal Ratio (HTR): HTR was calculated by using the following formulae:

$$\text{HTR} = \frac{\text{Mean Relative humidity}}{\text{Mean temperature}}$$

Special Humid Thermal Ratio (SHTR): SHTR was calculated by using following formulae:

$$\text{SHTR} = \frac{\text{Relative humidity within crop}}{\text{Canopy temperature}}$$

RESULTS AND DISCUSSION

Disease severity index under different row direction

The increase of foliage disease in a cereal crop is usually the result of two simultaneous processes an increase in the proportion of leaves infected and in percentage of leaf area affected by disease hereafter referred as disease incidence and severity, respectively. Disease severity index was calculated on the basis of per cent disease severity observations. During 2012-13 and 2013-14, disease severity was maximum in N-S row direction as compared to E-W row direction in variety PBW 343 (Fig 1a and 1b). The main reason for low disease severity in E-W row direction was change in microclimate as canopy temperature was relatively high during early period of disease development and some pathogens require relatively low canopy temperature to thrive. The relative humidity was low during early period of disease development in E-W row direction. HD 2967 did not show any symptom of disease severity in any row direction. Milus and Seyran (2004) revealed that stripe rust caused by the new isolates tends to develop faster than the old isolates at relatively high temperatures. Infection efficiency of rust pathogen is affected by meteorological parameters. Temperature and humidity plays an important role in disease infection. Infection requires high humidity for 4 to 6 hr at 10 to 15°C. Infection seldom occurs below about 2°C and ceases above 23°C (Murray *et al.* 2005).

Area under disease progress curve

The area under the disease progress curve (AUDPC) is commonly used to quantify disease intensity over time. It is useful in part because it integrates the amount of disease overtime, rather than at a particular time point. Both the varieties PBW 343 and PBW 550 showed higher AUDPC when sown under N-S direction as compared to crop sown under E-W direction during both the year as presented in Fig 2a and 2b. Variety HD 2967 showed 0% AUDPC. Variety

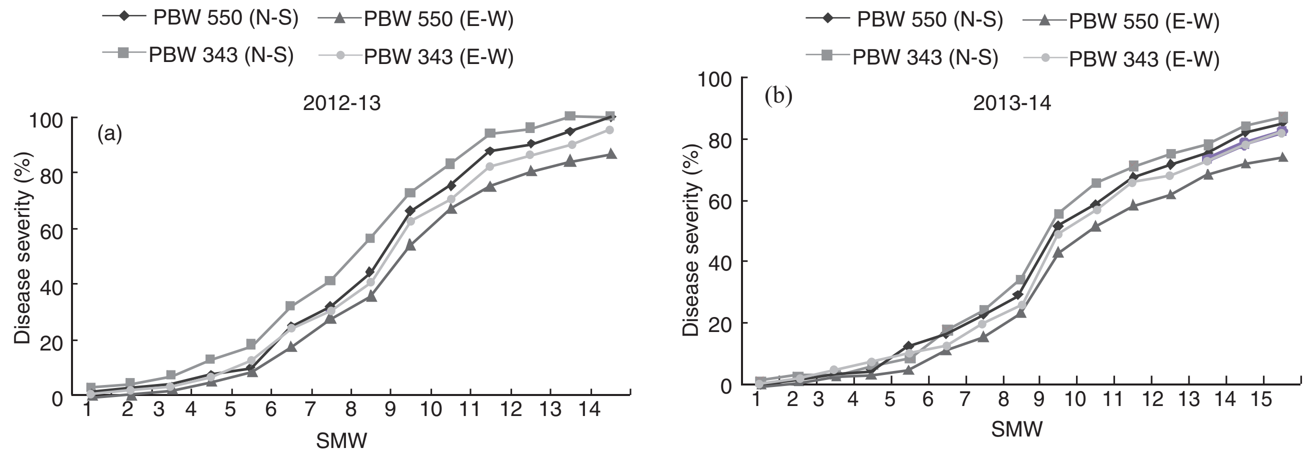

Fig 1 (a-b) Disease severity in different row direction during 2012-13 and 2013-14 crop seasons

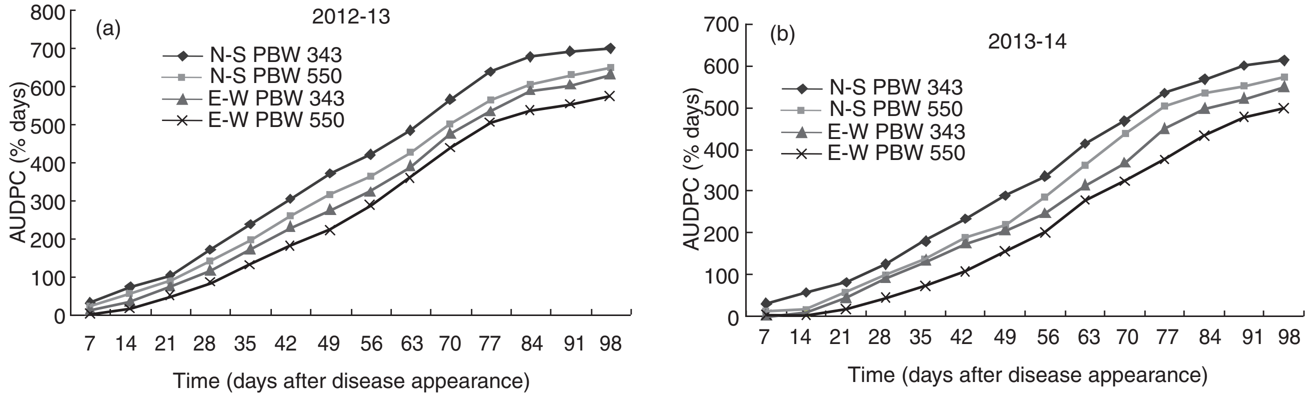

Fig 2 (a-b) AUDPC in different row direction during 2012-13 and 2013-14 crop seasons

PBW 343 showed more AUDPC as compared to PBW 550. Mean values of AUDPC under different treatments showed that variety PBW 343 is highly susceptible, PBW 550 is susceptible and HD 2967 is highly resistance to yellow rust under Ludhiana conditions. Similarly, Taye *et al*. (2014) observed yellow rust severity in different wheat varieties and found that variety PBW 343 showed highest AUDPC (1740 % days). Total AUDPC, Mean AUDPC and relative AUDPC was more in wheat varieties when sown under N-S row direction as compared to E-W row direction as presented in Table 1.

Microclimate and disease severity

Microclimate of the crop influences disease development, multiplication and spread. As some pathogens require specific leaf temperature to develop and multiply. Canopy temperature was low in N-S row direction during the early period of disease development but with the advancement in disease canopy temperature increased in N-S row direction as compared to E-W row direction. The maintenance of healthy tissues by plants enables them to maintain a lower canopy temperature which, in turn, helps against the pathogen which requires relatively high

Table 1 AUDPC, relative AUDPC and mean AUDPC under different treatments during 2012-13 and 2013-14

	North-South PBW 343	North-South PBW 550	East-West PBW 343	East-West PBW 550	North-South HD 2967	East-West HD 2967
			2012-13			
Total AUDPC	5462	4814	4482	3925	0	0
r-AUDPC	56	49	46	40	0	0
Mean AUDPC	390	344	320	280	0	0
			2013-14			
Total AUDPC	4506	3976	3592	2969	0	0
r-AUDPC	46	41	37	30	0	0
Mean AUDPC	322	284	257	212	0	0

Table 2 Relationship between yellow rust disease severity (Y) and canopy temperature (X) (pooled data PBW 550 and PBW 343)

	Regression equation	R^2
	2012-13	
N-S	$Y = -0.028X^3 + 1.567X^2 - 32.19X + 159.3$	0.87
E-W	$Y=-0.018X^3+1.454X^2-26.15X+147.2$	0.90
	2013-14	
N-S	$Y=-0.024X^3+1.419X^2-24.17X+119.2$	0.84
E-W	$Y=-0.011X^3+0.779X^2-10.19X+16.48$	0.86

temperatures for faster growth and development. Relative humidity was 2 to 3% higher in N-S row direction as compared to E-W row direction during 1st to 7th SMW but with advancement in disease relative humidity was decreased in N-S row direction as compared to E-W row direction due to necrosis of leaves caused by yellow rust. Higher relative humidity was more favourable for disease development. Relationships were developed between disease severity and microclimatic parameters viz. canopy temperature and relative humidity within crop canopy (Table 2 and 3). Higher R^2 values in different treatments indicated that canopy temperature and relative humidity within crop influenced disease severity during both the crop seasons. Paveley *et al.* (2000) and Schubert (2005) also reported that microclimate of a crop influence yellow rust incidence. From this analysis it is clear that E-W sowing can be helpful to decrease the rate of disease severity and to get higher yield.

Humid thermal ratio and disease severity

Temperature and relative humidity are most important predictor variables in a number of leaf rust prediction models. The analysis of multiple correlation coefficient showed that temperature and humidity gave significant value of multiple correlation coefficient. So humid thermal ratio (HTR) was calculated for different treatments and relationships were developed between HTR and disease severity (Table 4).

As microclimatic parameters, viz. canopy temperature and relative humidity within crop canopy showed interactions with disease severity so special humid thermal ratio (SHTR) was calculated by using canopy temperature and relative humidity within crop canopy. Relationships were developed between SHTR and disease severity as shown in Table 5. Polynomial equations were found to be best fit and gave higher R^2-value. Similarly, Jhorar *et al.* (1992) used HTR to forecast karnal bunt disease in Punjab. The HTR indices were used by Dutta (2006) to predict yellow rust incidence under Punjab conditions. She reported that 46 to 52% variation in yellow rust incidence in a region was due to HTR. The main concept was to account for the combined effect of humidity and temperature on disease. Similarly, Kumar (2014) also developed relationship between leaf rust and meteorological parameters and found that the correlation coefficients were highest for the Humid Thermal Ratio (HTR), Maximum Temperature (MXT) and Special Humid Thermal Ratio (SHTR), and these three weather variables were selected as predictor variables.

Table 3 Relationship between yellow rust disease severity (Y) and relative humidity (X) within crop canopy (pooled data PBW 550 and PBW 343)

	Regression equation	R^2
	2012-13	
N-S	$Y = 0.023X^3 - 1.645X^2 + 112.7X – 24.12$	0.73
E-W	$Y=0.021X^3-6.454X^2+342.3X-10.128$	0.76
	2013-14	
N-S	$Y = 0.023X^3 - 1.645X^2 + 112.7X – 24.12$	0.73
E-W	$Y=0.021X^3-6.454X^2+342.3X-10.128$	0.76

Table 4 Relationship between yellow rust disease severity (Y) and humid thermal ratio (X) (pooled data 2012-13 and 2013-14)

	Regression equation	R^2
	PBW 550	
N-S	$Y = 2.591X^2 - 49.10X + 224.8$	0.74
E-W	$Y = 2.696X^2 - 48.65X + 208.1$	0.81
	PBW 343	
N-S	$Y = 2.375X^2 - 46.03X + 218.0$	0.69
E-W	$Y=2.615X^2- 48.15X+212.9$	0.74

Table 5 Relationship between yellow rust disease severity (Y) and special humid thermal ratio (X) (pooled data 2012-13 and 2013-14)

	Regression equation	R^2
	PBW 550	
N-S	$Y = 3.252X^2 - 58.15X + 119.6$	0.74
E-W	$Y = 3.300X^2 - 61.38X + 228.4$	0.81
	PBW 343	
N-S	$Y=-0.285X^2-14.59X+112.4$	0.69
E-W	$Y = -0.538X^2 -15.06X+115.3$	0.74

Yellow rust severity and incidence is influenced by microclimate of the crop. Analysis of microclimatic parameters and disease indicated that disease and these microclimatic parameters were interrelated. Among the three varieties, HD 2967 was found to be highly resistant to yellow rust, whereas, PBW 550 was susceptible and PBW 343 was highly susceptible to yellow rust. On the basis of this experiment it can be concluded that E-W row direction can be used to lower down the rate of disease development. Higher R^2 values of Humid Thermal Ratio (HTR), Special Humid Thermal Ratio (SHTR) and disease severity indicated that HTR and SHTR can be used as a disease predictor. Such a forecasting technique can be useful to guide within season fungicide application to reduce the risk of yield losses due to yellow rust.

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