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Characterization of environmental conditions conducive for stripe rust epidemic on wheat

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Abstract

In the present study, different wheat varieties were evaluated for stripe rust resistance against local pathotypes under natural environmental conditions of district Layyah. The relationship of meteorological variables viz. maximum and minimum temperature, rainfall, relative humidity and wind speed with leaf rust severity on different genotypes were determined through Pearson correlation and simple linear regression analysis. Results demonstrated that only one genotype Punjab-11 was resistant with 85.75 AUDPC value. The three varieties Millat-11, V-2 and V-5 indicated moderately resistant whereas, Galaxy-13 showed moderately resistant to moderately susceptible response against disease development with high to moderate AUDPC values. All meteorological variables showed a significant relationship with stripe rust severity. Maximum disease severity was recorded at maximum and minimum temperatures ranging from 20-26 and 12.5-16.5 °C, respectively. The relative humidity, rainfall and wind speed proved most conductive for stripe rust development in the range of 55-70 %, 5-15 mm, 4.5-10.9 Km/h, respectively. It was concluded that all meteorological variables were significantly contributed to the stripe rust disease development in the district Layyah.

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Introduction

Wheat (*Triticum aestivum* L.) is the world's most cultivated cereal crop. For the people of Pakistan, it is the main source of a nutritional diet. It is cultivated under an area of 237 million hectares all over the world whereas 95 million hectares in Asia (FAO, 2015). In Pakistan, it is cultivated in areas of 9.20 million hectares with 25.48 million tons of production (GOP, 2017-2018). Its production is influenced by several fungal (bunts, smuts rusts), bacterial (black chaff, bacterial mosaic, bacterial leaf blight) and viral (wheat streak mosaic, wheat spot mosaic, wheat dwarf) diseases. Among all these diseases, stripe rust also known as yellow rust caused by *Puccinia striiformis* f.sp. *tritici* Westend is the main threat to grain production all over the world (Figueroa *et al.* 2018). The pathogen caused 40 % yield losses with some fields destroyed under favorable environmental conditions (Singh *et al.* 2019). The huge yield losses were recorded in fall-seeded wheat in the areas with the cool nights as compared to the spring wheat. Grain shrove and nutrients produced in the flag leaf area primarily used by the pathogen rather than move to the grain (Roelf *et al.* 1992). Therefore, early infections result in weak plants, less root and tiller development. Severe yield losses recorded when spikes were infected (He *et al.* 2019).

The small yellow color uredinospores appeared in linear or stripe form on leaves, spikes and awn and rarely penetrate through the plant surface. The stunting is common if the disease occurs with severe infection before the booting stage (Chen *et al.* 2017). The mild day and night temperatures ranging from 0-25°C, with adequate free water on the surface of leaf favored the disease development (Ali *et al.* 2020).

The wind and rain splash increased the uredinospores dispersal to the nearby fields (Lyon *et al.* 2017). Generally, the pathogen overwinters as resting mycelium in infected volunteer wheat in most of the regions during winter and in spring pathogen grow and produce several uredinospores under favorable environmental conditions. In the hilly tropical and subtropical regions, *P. striiformis* survive by moving up and down on the seeded wheat. The infected grassed do not play any role in pathogen survival in most of the world (Lyon *et al.* 2017).

The environmental conditions play a significant role in host-pathogen interaction (Ali *et al.* 2017a). The maximum disease severity was noted on different wheat genotypes at the minimum and maximum air temperatures ranging from 13.7-16.7 and 23.5-27.65 °C with more than 52-64 % relative humidity (Ali *et al.* 2017b). The climatic conditions of the country are changing constantly which is the main cause of the appearance of the novel strain of pathogen. Hence, keeping in view all the above mention facts the present study was designed to evaluate the resistance source of wheat genotypes against leaf rust and to characterize environmental conditions conducive to disease development.

Materials and methods

For evaluation and characterization of environmental conditions conducive for stripe rust, 12 varieties were obtained from Wheat Research Institute, Ayub Agriculture Research Institute Faisalabad and sown in the Research Area of Plant Pathology, College of Agriculture, Bahauddin Zakariya University Multan under augmented design during November 25, 2019. Each variety was sown in a single row of 7 m length with the row to row and plant to plant distance 30 and 15cm, respectively. Along with each variety, a line of rust spreader Morocco was sown. To keep crops in good condition recommended dose of fertilizers and irrigation schedules were applied.

Inoculation of wheat genotypes

To develop disease pressure, the nursery was artificially inoculated by spraying, rubbing and dusting methods described by Stubbs *et al.* 1986. The nursery was frequently inoculated every seven days after the emergence of leaves and tillers. The aqueous suspension of uredinospores @ of 10^6/ml of water consisting of different virulent races mixtures of *P. striiformis* was sprayed at the booting stage twice a week to sustain the disease pressure (Roelf *et al.* 1992).

Data recording and calculation of AUDPC

At the initiation of disease symptoms, rust severity percentage and plant response to disease were recorded for 3 consecutive observations after ten days intervals. The disease severity and field response were recorded by using Modified Cobb's scale described by Peterson *et al.* 1948 (Table 1). Data were recorded up to physical maturity of crop and the final rating was determined when disease severity became 80-90%.

The area under the disease progress curve was determined by using the following formula developed by CIMMYT.

The area under disease progress curve (AUDPC) was calculated by using the formula developed by CIMMYT (reference)

$$AUDPC = \sum_{i=1}^{n-1} \left[\frac{X_i + X_i + 1}{2}\right] (t_{i+1} - t_i)$$

Where the X_i showed disease severity on the date *i;* t_i indicated time in days between *i* and date *i* + 1and n exhibited the total number of dates on which disease was recorded.

Relationship of meteorological variables with disease severity

Meteorological variables data consisting maximum and minimum temperature, relative humidity, rainfall and wind speed were collected from the meteorological department of Agronomic Research Station, Karor-Layyah.

The Agro-metrology observatory station was at a 20 km distance to the wheat experimental area.

Statistical analysis

The relationship between meteorological variables and rust severity data were recorded through correlation and simple linear regression analysis. Meteorological variables indicating a strong relationship with leaf rust severity were graphically plotted and critical ranges conducive for disease severity were determined. During the current investigation Minitab Ver.17 by Minitab Inc. U.S.A. and SPSS Ver. 17 were used.

Results

The final response of wheat varieties indicated that only single line viz. Punjab-11 was resistant with a lower AUDPC value of 85.75.

The three varieties Millat-11, V-2 and V-5 (coded varieties) indicated moderately resistant response with 395.5, 217 and 262.5 AUDPC values. The genotype Galaxy-13 showed moderately resistant to moderately susceptible response with 1330 AUDPC value whereas, four varieties Inq.91, WL-711, PB-96, and SA-75 exhibited moderately resistant response with 752.5, 647.5, 490 and 612.5 AUDPC values.

Table 1. Modified cobbs scale used for data recording during present study.

Reaction	Infection type	Field response
No disease	0	No visible infection
Resistant	R	Necrotic areas with or without minute uredia
Moderately resistant	MR	Small uredia present surrounded by necrotic area
Moderately resistant, moderately susceptible	MRMS	Small uredia present surrounded by necrotic areas as well as medium uredia with no necrosis but possible some distinct chlorosis
Moderately susceptible	MS	Medium uredia with no necrosis but possible some distinct chlorosis
Moderately susceptible-susceptible	MSS	Medium uredia with no necrosis but possible some distinct chlorosis as well as large uredia with little or chlorosis present
Susceptible	S	Large uredia and little or no chlorosis present

The remaining two varieties Maxi-Pak-65 and PB-81 showed susceptible responses and one genotype MH-97 demonstrated highly susceptible response with a higher value of AUDPC values (Table 2).

Relationship of meteorological variables with disease severity

The all epidemiological variables viz. maximum and minimum temperature, relative humidity, rainfall and wind speed showed significant (P< 0.05) and highly significant (P< 0.01) correlation on most of the genotypes except V-2 which demonstrated non-significant (P>0.05) relationship with leaf rust severity (Table 3).

Table 2. Response of different wheat varieties against disease severity based on AUDPC.

Variety Code	Response	AUDPC Value
Punjab-11	R	85.75
Inqlab-91	MS	752.5
Galaxy-13	MRMS	1330
Millat-11	MR	395.5
WL-711	MS	647.5
MH-97	HS	1365
V-2	MR	217
PB-96	MS	490
Maxi-Pak-65	S	997.5
PB-81	S	945
SA-75	MS	612.5
V-5	MR	262.5

Characterization of meteorological variables conducive for disease development

Maximum temperature vs. disease severity

The relationship of maximum temperature with stripe rust severity was found significant. With an increase in maximum temperature disease severity also increased. This relationship was best explained by the correlation coefficient (r) values of 0.99, 0.95, 0.88 and 0.98 indicated in Fig.1.

The maximum disease severity was noted temperature increased from 22-26 °C.

Table 3. Correlation of meteorological variables with leaf rust disease severity.

Varieties	Maxi. Temp. (°C)	Mini. Temp. (°C)	R.H. (%)	R.F. (mm)	W.S. (Km/h)
Punjab-11	0.71 ns	.946*	0.894 ns	.950*	0.742 ns
	0.145	0.027	0.053	0.025	0.129
Inqlab-91	.992**	.902*	.956*	0.828 ns	.997**
	0.004	0.049	0.022	0.086	0.002
Galaxy-13	.980*	.960*	.990**	.920*	.983**
	0.01	0.02	0.005	0.04	0.008
Millat-11	-.999**	-0.894 ns	-.952*	-0.826 ns	-1.000**
	0.001	0.053	0.024	0.087	0.001
WL-711	.916*	.989**	.992**	.954*	.934*
	0.042	0.005	0.004	0.023	0.033
MH-97	.995**	.910*	.960*	0.859 ns	.993**
	0.002	0.045	0.02	0.071	0.004
V-2	0.837ns	0.753 ns	0.791 ns	0.76 ns	0.812 ns
	0.082	0.124	0.104	0.12	0.094
PB-96	0.791 ns	.980*	.943*	.976*	0.817 ns
	0.105	0.01	0.028	0.012	0.092
Maxi-Pak-65	.990**	.922*	.969*	0.855 ns	.997**
	0.005	0.039	0.015	0.073	0.002
PB-81	.945*	.987**	.997**	.964*	.952*
	0.028	0.007	0.002	0.018	0.024
SA-75	.905*	0.774 ns	0.83 ns	0.754 ns	0.883 ns
	0.047	0.113	0.085	0.123	0.058
V-5	-.948*	-.988**	-1.000**	-.956*	-.959*
	0.026	0.006	0	0.022	0.02

Upper values indicating Pearson's correlation coefficient; Lower values indicating level of significance at 5 % probability; * = Significant (P<0.05); ** = highly significant (P<0.01); ns = non-significant (P>0.05).

Minimum temperature vs. disease severity

A positive relationship was recorded between minimum temperature and stripe rust severity percentage within four genotypes V1, V3, V6 and V10. With one unit increase in minimum temperature from 12.5 -16.5°C disease severity also increased gradually. This relationship was best explained by 0.82, 0.96, 0.91 & 0.89 correlation coefficient (r) values of the simple linear regression model as exhibited in Fig.2.

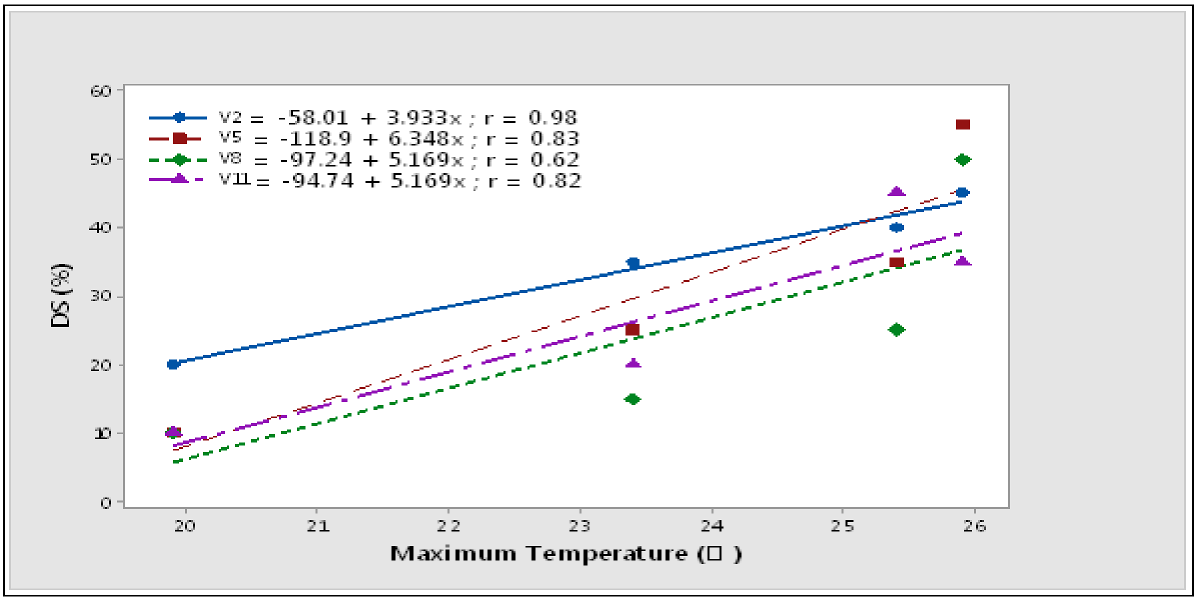

Fig. 1. Relationship of maximum temperature (°C) with disease severity recorded on Inqlab-91 (V1), Galaxy-13 (V2), WL-711 (V3) and Maxi-Pak-65 (V4).

Relative humidity vs. disease severity

The relative humidity was significantly correlated with disease development. The maximum disease severity was recorded in the range of 55-70 % relative humidity. A significant contribution of relative humidity in disease development was recorded as exhibited by the high correlation coefficients (r) values such as 0.90, 0.99, 0.99 and 0.94 (Fig.3).

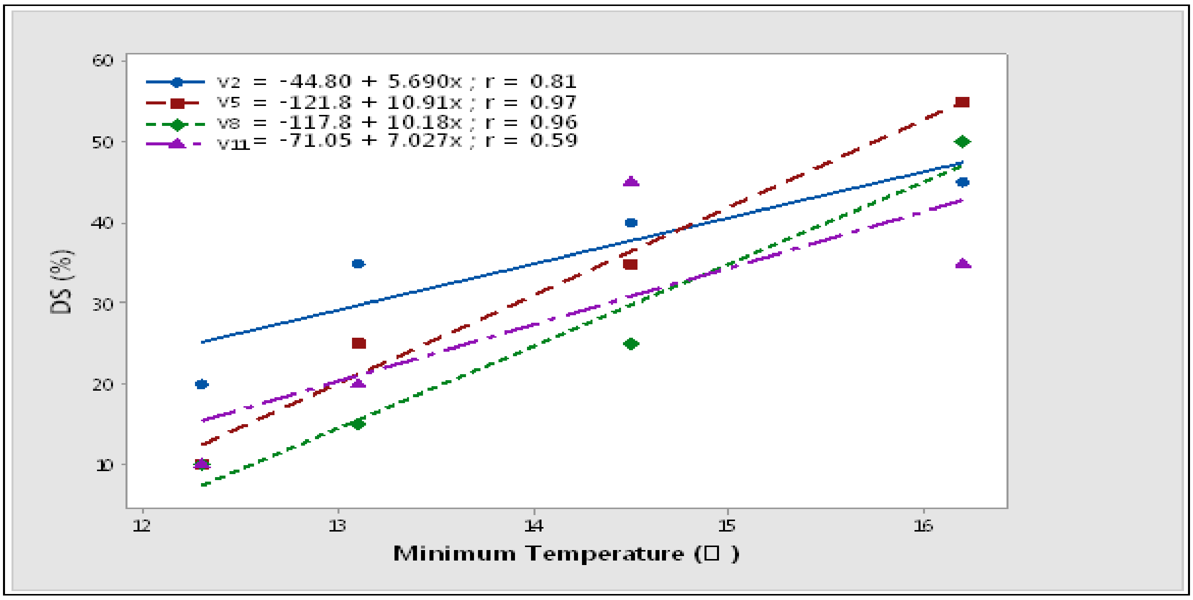

Fig. 2. Relationship of minimum temperature (°C) with disease severity (%) recorded on Inqlab-91 (V1), Galaxy-13 (V2), WL-711 (V3) and Maxi-Pak-65 (V4).

Rainfall vs. disease severity

Different varieties gave a different response to rainfall. A positive relationship was observed between rainfall and stripe rust severity. With the increase in rainfall from 5-15 mm disease severity also increased gradually. This relationship was best explained by the r values 0.53, 0.91, 0.95 and 0.56 of the regression model as indicated in the Fig.4.

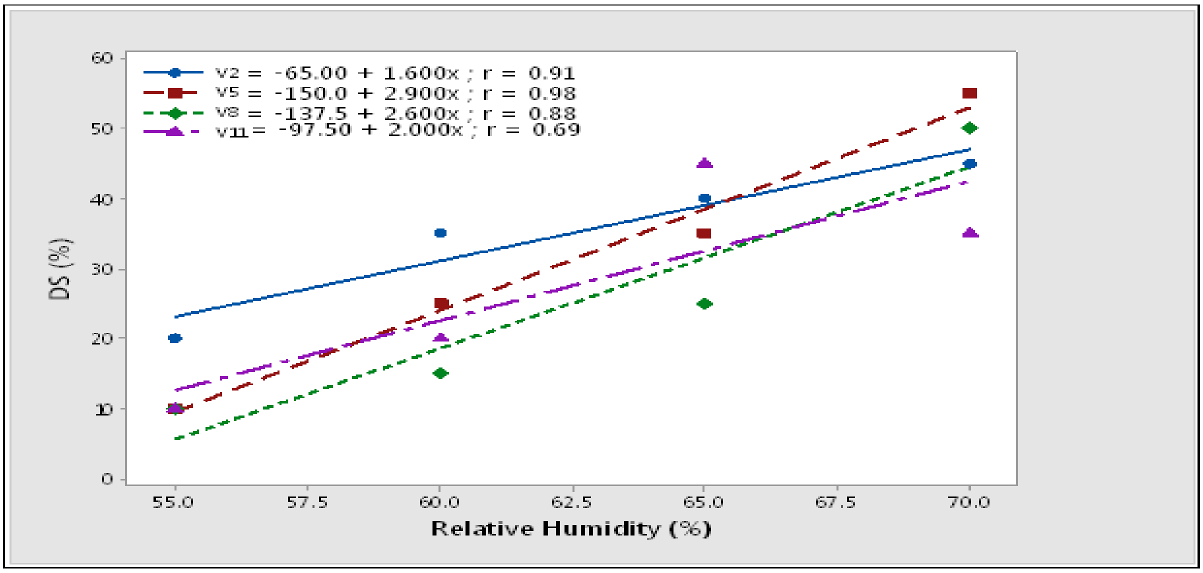

Fig. 3. Relationship of relative humidity (%) with disease severity (%) recorded on Inqlab-91 (V1), Galaxy-13 (V2), WL-711 (V3) and Maxi-Pak-65 (V4).

Wind speed vs. disease severity

The wind speed exhibited a linear and positive relationship with disease severity. The simple linear regression model developed on four wheat genotypes based on wind speed demonstrated r values of 0.95, 0.92, 0.83 and 0.97, respectively indicating with an increase in wind speed disease severity also increased. The impact of wind speed on four varieties was positive (Fig. 5).

The disease severity was maximum recorded maximum in the range of wind speed 4.5-10.9 Km/h.

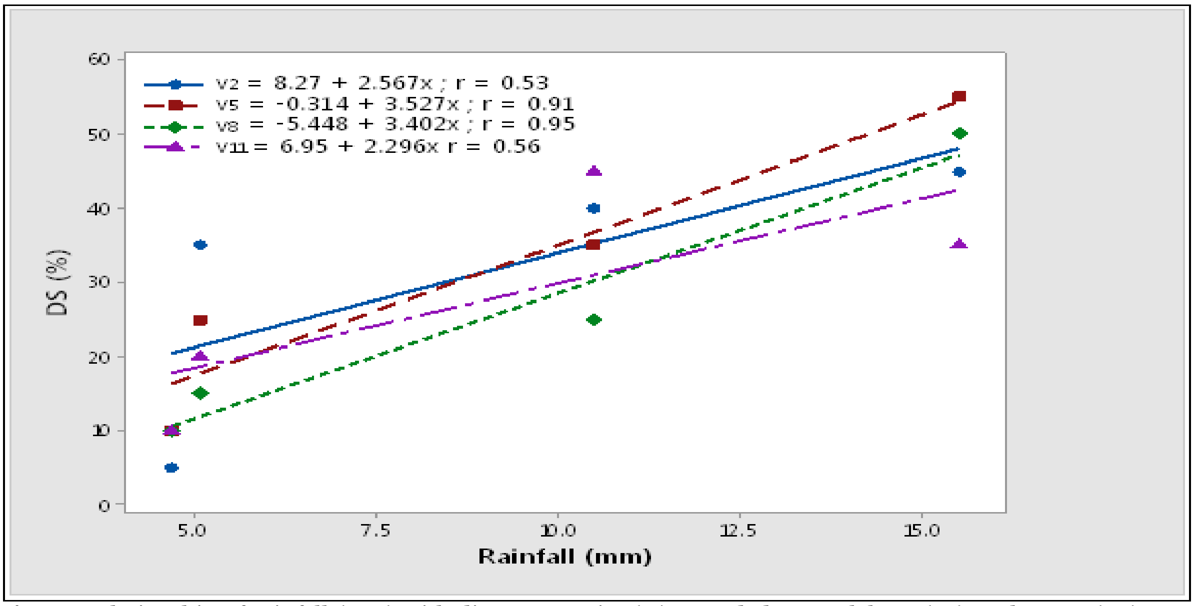

Fig. 4. Relationship of rainfall (mm) with disease severity (%) recorded on Inqlab-91 (V1), Galaxy-13 (V2), WL-711 (V3) and Maxi-Pak-65 (V4).

Discussion

The rust diseases have a constant threat to wheat production all over the world. In the wheat-growing regions, stripe rust is the main wheat disease and caused huge yield losses in its production.

The conducive environmental conditions and susceptible varieties also favor the disease epidemic. To avoid wheat crops from the ruts epidemic, the cultivation of resistant varieties is the most effective and sustainable strategy (Ali *et al.* 2019). Therefore in the current investigation, different wheat varieties were evaluated against stripe rust and it was observed that only one variety of Punjab-11 indicated resistant response to disease development. Afzal *et al.* 2009 used the same strategy to evaluate resistance source in 188 wheat germplasm against stripe rust under filed condition. It was observed that among them only twenty-eight indicated adult plant resistance to disease development.

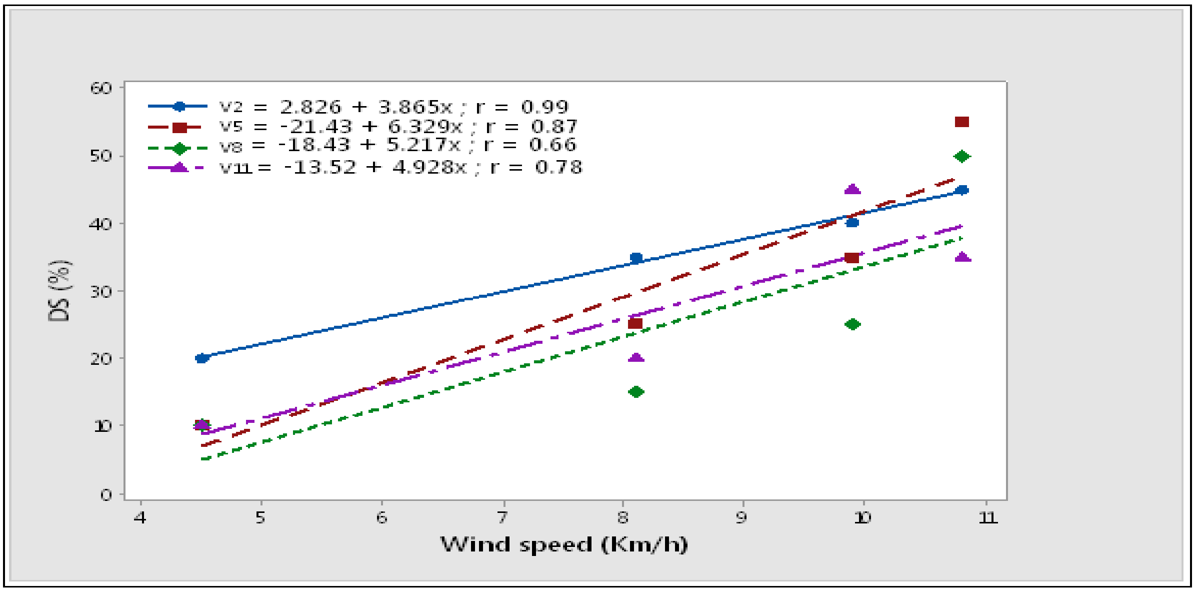

Fig. 5. Relationship of wind speed (Km/h) with disease severity (%) recorded on Inqlab-91 (V1), Galaxy-13 (V2), WL-711 (V3) and Maxi-Pak-65 (V4).

Ehsan-ul-Haq *et al.* 2003 evaluated 29 wheat genotypes against leaf rust severity under natural environmental conditions by spraying the urediospores suspension of water on a plant nursery. It was observed that 15 were and the rest of 14 lines indicated susceptible response to disease development. Similarly, the present investigation overcomes the finding of; Raza *et al.* 2018 and Lodhi *et al.* 2018 who evaluated the different wheat genotypes against stripe rust and reported the same results.

The epidemiological factors are considered significant for the development of pathogens on any crop. Therefore, understanding the relationship of meteorological variables with stripe rust development is the key issue for the early onset of disease (Javaid *et al.* 2018). Leaf rust severity is significantly influenced by natural environmental conditions (Ali *et al.* 2017a.). The significant correlation of all meteorological variables viz. minimum and maximum temperature, relative humidity, rainfall and wind speed with stripe rust severity was found significant.

The results of the present investigation concur with the findings of Razzaq *et al.* 2018 who found a positive correlation between leaf rust severity and epidemiological variables. Similar results were reported by Khan (1998). The significant relationship of minimum and maximum temperature with disease severity could be justified by the fact that is has a vital role in disease development. The pathogen both at high and low temperatures ranging from 0-25 ℃ established for the spore production, latent period and lesions area, width and length on the surface of plants (Ali *et al.*2018). At minimum temperature fungus more sporulate whereas at the maximum temperature it grew faster and produced a large number of spores per day (Milus *et al.* 2009).

The positive relationship of relative humidity with leaf rust severity was due in part to its important role in disease development starts with the formation of condensation droplets around which the fungus germ tube grows. The condensation must remain three to hours before sporulation begins. The rate of sporulation will stop if the period of dryness occurred (Zadoks, 1972). A significant relationship was found between rainfall the leaf rust development.

The rainfall keeps the air temperature low which is essential for the development of fungus uredinospores and rain splash also contributes to disease spread during the entire growing season (El Jarroudi *et al.* 2015).

The frequent rainfall during the growing season of the crop is an important factor in the leaf rust disease epidemic (Rapilly *et al.* 1970). The relationship of wind speed with leaf rust severity is that it transfer uredinospores from infected to healthy fields. However, results obtained from the model indicated that based on canopy roughness uredinospores dispersal is nil under 0.25 m/sec wind speed, moreover, uredinospores are considered as gas for over 2.5 m/s wind speed (Rapilly *et al.* 1970).

Conclusion

It was concluded that among all genotypes Punjab-11 showed a resistant response to stripe rust severity with lower AUDPC value. The maximum and minimum temperature proved most conducive for the stripe rust epidemic in the range of 20-26 and 12.5-16.5℃, respectively. The disease epidemic increased with an increase in relative humidity (55-70 %), rainfall (5-15 mm), and wind speed (4.5-10.9 Km/h) on different wheat germplasm. A significant relationship was recorded between weather conditions and stripe rust severity in district Layyah.

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