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Genetic diversity of wheat hybrid lines against leaf rust of wheat in relation to epidemiological factors

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Abstract

Wheat rusts are the significant diseases of wheat crop and significant threats all over the world. Among all major wheat diseases occurring worldwide leaf rust caused by *Puccinia recondita* f. sp. tritici is a big hazard when it occurs in severe condition. The susceptible germplasm and favorable environmental conditions contribute towards wide epidemic of rust diseases. In the present investigation, twenty hybrid wheat lines were screened out and correlated with epidemiological factors (i.e. minimum and maximum temperature, relative humidity, rainfall and wind speed). Results demonstrated that only one hybrid line (E9) showed resistance response against leaf rust with 70% AUDPC value. Maximum disease severity was observed at minimum and maximum temperature ranging from 8-17 and 24.5-32.5 °C, respectively. Similarly, maximum disease severity was recorded at maximum wind speed and rain fall ranging from 2.0-2.8 km/h and 1.9-5.4 mm, respectively. A negative relationship was found between relative humidity and disease severity which indicated that with increase in relative humidity disease severity decreased. A positive correlation was observed between disease severity and epidemiological factors. Thus, this disease predicting model will help the farmers in minimizing yield losses caused by leaf rust.

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Introduction

Wheat (*Triticum aestivum*) is third most important crop Worldwide, and 35% peoples of whole world depends upon wheat for their food (Ogbonnaya *et al.,* 2013). Wheat is among the most traded commodities in the World markets and fall in most commanding cereal crops (Curtis and Hal ford, 2014).

It's estimated that demand of wheat has been escalating with continuous increase in population from time of its domestication in 15,000-10,000 BC. Expectations are there that, by the year 2030 demand will increase 40% (Dixon *et al.,* 2009). Whereas it occupies acme position among cereals in Pakistan and it is main source of nutritional diet.

It contains carbohydrates, iron and vitamins like gluten, thiamine, niacin and riboflavin (Botella-Pavia and Rodriguez, 2006).Annually production of wheat is six hundred million tons around the globe and cultivated on 240 million hectares. But in Pakistan production level is 25.3 million tons and cultivated on an area of 9.03 million hectares that play important role by contributing 10.3% in agriculture sector following by GDP of the country which is 2.2% (Economic Survey of Pakistan, 2014) various significant losses are observed due to a variety of abiotic and biotic aspects. Among biotic problems smuts, rusts, bunts, and aphids are important.

The prominent abiotic aspects like salinity, drought, excessive heat, wind, extreme cloudy weather, hail storms and fog during growth and ripening season (Hussain *et al.*, 2006). Whereas fungal diseases like rusts i.e. leaf, stem and stripe rust are most destructive and fatal threat to wheat production worldwide because of its novel recognizable infectious races through genetic recombination and mutation (Roelfs *et al.,* 1992; Dadkhodaie *et al.,*2011) and their multicultural movements. *Puccinia triticina* Eriks., caused leaf rust of wheat and found to be more cruel disease in the majority of the wheat growing areas (Park *et al.,* 2007). Losses due to leaf rust were recorded 40-50% (Ahmad *et al.,* 2010). Probably stem and stripe rusts contribute less in greater total losses than leaf rust (Huerta-Espino *et al.,* 2011).Diverse climatic conditions are adopted by leaf rust pathogen and cause interruption in translocation of photosynthates and photosynthetic process which deteriorate quantity quality and market value. Pathogen infection results into lower kernel weight and lower number of kernels per head depending upon various stages of crop development (Kolmer, 2005). Major epidemics that happens in 1978 due to leaf rust cause 10% losses that cost US $86 million national loss (Hussain *et al.,* 1980). Environmental conditions play an important role in deriving pathogen host interaction. Leaf rust epidemic depends upon the climatic factors such as relative humidity, rain fall and temperature. Pathogen infection should be less at temperature of about 20^{o}C with dew period of three hours and infection increases with prolong dew period. Few if any infection occurs where dew period and temperature is above 32^{o}C (Stubbs *et al.,* 1986) or below 2^{o}C. During initial infection abundant teliospores were produce by pathogen which later on produce telia on each infection site. Wind helps in spreading spores and increases the lethalness of rust disease.

Therefore to raise the earning of farmers, wheat production and to conquer yield losses various preventive measures should be kept under consideration. Different types of manage mental strategies are available to conquer rust disease, but most reliable and safe way is the use the resistant germplasm, to overcome disease infection (Khan *et al.,* 2002; Stuthman *et al.,* 2007; Afzal *et al.,* 2009).

Yield losses can be minimized by using genetic resistance which is most effective system (Kolmer, 1996). To escape pathogen occurrence there is a need of those varieties which are genetically resistant against leaf rust disease and fittest for growing in disease area of any country. Considered screening method effective for recognition of genetic source following experiment was design. Objective of this experiment was the characterization of epidemiological factors that are conducive for leaf rust development.

Materials and methods

Sowing of disease screening nursery

Wheat seed of twenty hybrid lines viz., E-2, E-4, E-9, E-3, E-5, E-1, E-7, E-8, E-6, E-10, E-11, E-20, E-13, E-17, E-19, E-16, E-14, E-18, E-15 and E-12 were obtained from [WRI] Wheat Research Institute, AARI Faisalabad. During 2016-2017 wheat growing season hybrid lines were sown in field area of Department of Plant Pathology, University of Agriculture Faisalabad. For rapid development of rust infection and distribution susceptible variety "Morocco" was sown to act as spreader (Jacob, 1990).

Each entry sown in three plots following three replications and 2 m-200 cm long row, distance between two rows were kept 30cm and seed was sown by putting two seed per hole by keeping 6 cm plant to plant distance as; plot size = 304.8 cm.

Along with three lines, line of Morroco highly susceptible wheat rust spreader was sown for creating leaf rust epidemic. Experiment was conducted by following RCBD design.

The recommended agronomic practice was followed to raise the crop in Faisalabad. For attaining maximum disease severity on crop no fungicides were spray. Agronomic practices was done with specific interval of time for maintaining crop vigor.

For artificial inoculation uredospore suspension (30 gm of spore/16 L of water)was prepared and before taking data of rust 4 times inoculation was done at 7 days regular intervals.

Recording of Rust Severity

Field response and leaf rust reaction were recorded by using modified Cobb's scale designated by Peterson *et al.,* (1948) given in *Table 1*. With seven days intervals data were recorded from mid-February to end of March. At the initiation of disease on different hybrid lines of wheat, rating was taken.

Disease severity on diverse genotype was kept recording according to crop maturity. When spreader become highly susceptible than final disease rating near maturity was taken.

Relationship of environmental conditions conducive for leaf rust development

Agro-metrology observatory, University of Agriculture Faisalabad was used for collection of environmental data i.e. rain fall, wind speed, maximum and minimum temperature and relative humidity. By using statistical software correlation of environmental conditions was determined.

Disease severity was kept dependent variable and environmental factors kept as in-dependent variable. By plotting data graphically environmental parameters was studied which have significant influence on development of leaf rust. Throughout present investigation Minitab 15 by Minitab Inc. U.S.A was kept under consideration.

Statistical analysis

Correlation and regression analysis were made to determine relationship between disease severity and environmental data.

Disease severity data of 20 hybrid lines were processed for AUDPC (area under disease progress curve) using CIMMYT software (Singh *et al.,* 2000).

Results

Hybrid lines evaluation against leaf rust disease

20 hybrid lines were assessed against leaf rust of wheat only 1 hybrid line (E9) showed resistance response against leaf rust with 70 AUDPC value, 4 lines (E2, E11, E12and E14) were found moderately resistance with AUDPC value ranging from 119-217.91, seven lines (E5, E6, E7, E8, E16, E18and E20) showed moderately susceptible response with AUDPC value ranging from 496-816.51.Six lines (E1, E3, E4, E10, E13and E15) exhibited moderately resistance to moderately susceptible response with AUDPC value ranging from 234.5-456.12 whereas, remaining 2 lines viz. E17and E19exhibited susceptible response with AUDPC value 1000.4 and 1020.11, respectively (Table 2).

Table 1. Leaf rust field response, code and symptoms.

Response	Code	Symptoms
Immune	0	No visible infection
Resistant	R	Visible necrotic or chlorosis with or without uredia
Moderately Resistant	MR	Small uredia surrounded by necrotic areas
Mixed (Intermediate)	MRMS	Small uredia present surrounded by necrotic areas as well as medium uredia with no necrosis but possibly some distinct chlorosis
Moderately susceptible	MS	Medium uredia with no necrosis but possibly 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 are present with little or no chlorosis

Cobb's scale (Peterson *et al.,* 1948).

Table 2. Response of Different Lines/Varieties against leaf rust of wheat on the basis of AUDPC.

Sr. No.	Varieties/Lines	22-02-2016 Assessment # 1	29-02-2016 Assessment # 2	7-03-2016 Assessment # 3	14-03-2016 Assessment # 4	AUDPC Value	Disease Reaction
1	E1	5	15	23.33	25.66	375.62	MRMS
2	E2	1.6	5	15.33	20	217.91	MR
3	E3	1.66	14	22.33	25.66	349.93	MRMS
4	E4	10	20	26.66	27	456.12	MRMS
5	E5	10	20.66	40.33	44.5	617.68	MS
6	E6	10	25.66	50.33	53.66	754.74	MS
7	E7	5	20	44	45.66	625.31	MS
8	E8	5	15	40	43.66	555.31	MS
9	E9	0	0	5	10	70	R
10	E10	3	7	15	20	234.5	MRMS
11	E11	0	5	7	10	119	MR
12	E12	5	7	11	15	196	MR
13	E13	4	11	15	17.66	257.81	MRMS
14	E14	5	5	10	15	175	MR
15	E15	5	10	23	25.33	337.155	MRMS
16	E16	5	10	67.5	68.33	799.155	MS
17	E17	11.5	38.33	66.65	70	1020.11	S
18	E18	6.33	31.65	51	61.66	816.515	MS
19	E19	8.5	40	65	67.33	1000.40	S
20	E20	2	21.33	31.33	34.66	496.93	MS

Correlation of Environmental factors with leaf rust of wheat

Environmental factors correlated with leaf rust of wheat have been given in *Table 3*. Five hybrid lines (E3, E5, E10, E11 and E13) indicated significant correlation with all environmental factors i.e. rain fall and wind speed, minimum temperature and maximum temperature. A negative linear relationship was observed between leaf rust severity and relative humidity on all hybrid lines (Table 3).

Leaf rust severity vs. minimum temperature

The relationship of leaf rust with minimum temperature was found positive. Significant response showed by 5 hybrid lines (E3, E5, E10, E11 and E13) as temperature decreased rang 8-17^{o} C leaf rust value increased. Shows strong response of leaf rust values of hybrid lines to minimum temperature (Fig. 1).

Table 3. Correlation of leaf rust severity with environmental factors during year 2016-17 in Faisalabad.

Sr. No.	Lines	Mini. Temp. (oC).	Maxi. Temp (oC)	Relative Humidity (%)	Rainfall (mm)	Wind speed (km/h)
1	E1	0.998* 0.012	0.989* 0.011	-0.595 0.405	0.961* 0.039	0.920 0.080
2	E2	.981* .019	.932 .068	-.405 .595	.985* .015	.992** .008
3	E3	.986* .014	.995** .005	-.584 .416	.960* .040	.912 .088
4	E4	.962* .038	.980* .020	-.675 .325	.922 .078	.867 .133
5	E5	.987* .013	.957* .043	-.539 .461	.972* .028	.962* .038
6	E6	.984* .016	.962* .038	-.582 .418	.963* .037	.945 .055
7	E7	.979* .021	.958* .042	-.606 .394	.954* .046	.936 .064
8	E8	.977* .023	.939 .061	-.538 .462	.963* .037	.962* .038
9	E9	.920 .080	.848 .152	-.150 .850	.957* .043	.989* .011
10	E10	.990* .010	.950* .050	-.389 .611	.995** .005	.993** .007
11	E11	.986* .014	.997** .003	-.451 .549	.974* .026	.922 .078
12	E12	.977* .023	.934 .066	-.288 .712	.995** .005	.996** .004
13	E13	.989* .011	.999** .001	-.542 .458	.967* .033	.917 .083
14	E14	.920 .080	.848 .152	-.150 .850	.957* .043	.989* .011
15	E15	.918 .082	.938 .062	-.522 .478	.967* .033	.967* .033
16	E16	.916 .084	.865 .135	-.520 .480	.919 .081	.945 .055
17	E17	.977* .023	.977* .023	-.623 .377	.952* .048	.918 .082
18	E18	-.035 .965	.995** .005	-.531 .469	.977* .023	.938 .062
19	E19	.876 .124	.982* .018	-.653 .347	.937 .063	.890 .110
20	E20	.291 .709	.992** .008	-.624 .376	.935 .065	.876 .124

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

Leaf rust severity vs. maximum temperature

The relationship of leaf rust with maximum temperature was positive. The lines (E3, E5, E10, E11 and E13) showed significant response with increase in temperature 24.5-32.5°Cshows clear response of increased rust value of hybrid lines to maximum temperature (Fig. 2).

Leaf rust severity vs. relative humidity

There was no relationship between leaf rust and relative humidity on any wheat line. Linear regression between leaf rust and relative humidity also shows negative relationship during 2016-2017. With increase in relative humidity 78-85 % leaf rust value decreased (Fig. 3).

Leaf rust severity vs. wind speed

The relationship of leaf rust with wind speed was positive. 5 hybrid lines (E3, E5, E10, E11 and E13) showed significant response with wind speed ranging 2.0-2.8 km/h. Shows clear response of rust value of hybrid lines to wind speed (Fig. 4).

Leaf rust severityvs. rainfall

Positive relationship was observed between rainfall and rust.

The lines (E3, E5, E10, E11 and E13) showed significant response with increase in rainfall 1.9-5.4 mm rust value increased. Shows clear response of rust values of hybrid lines to rainfall (Fig. 5).

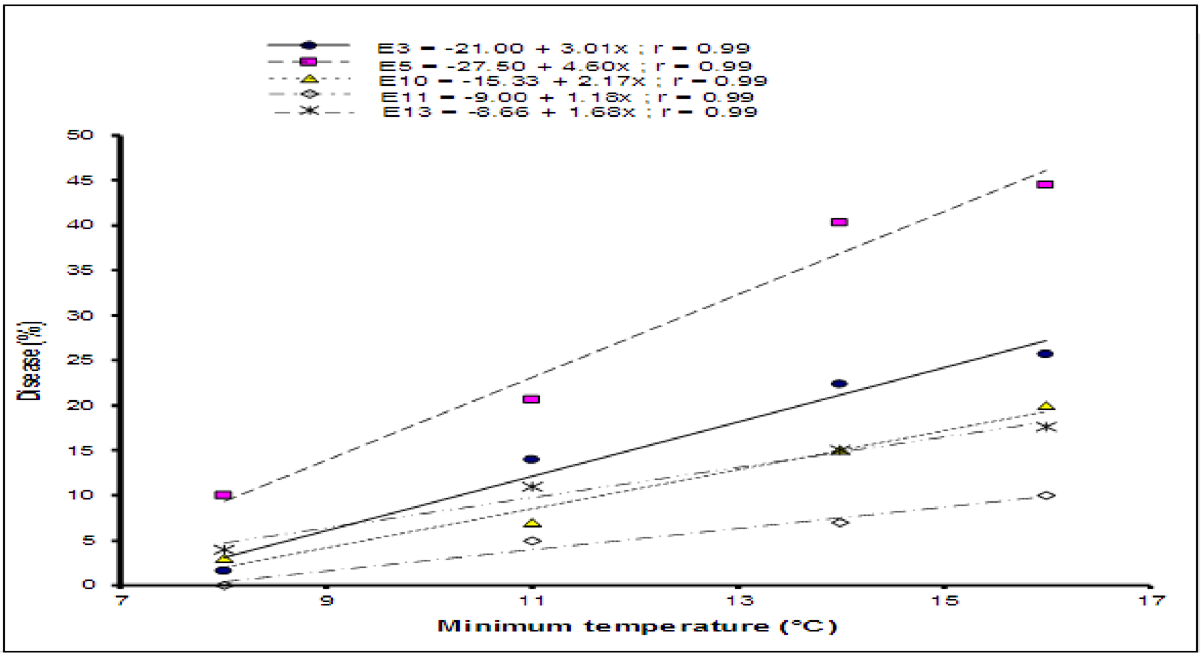

Fig. 1. Relationship of leaf rust severity with minimum temperature on E3, E5, E10, E11 and E13.

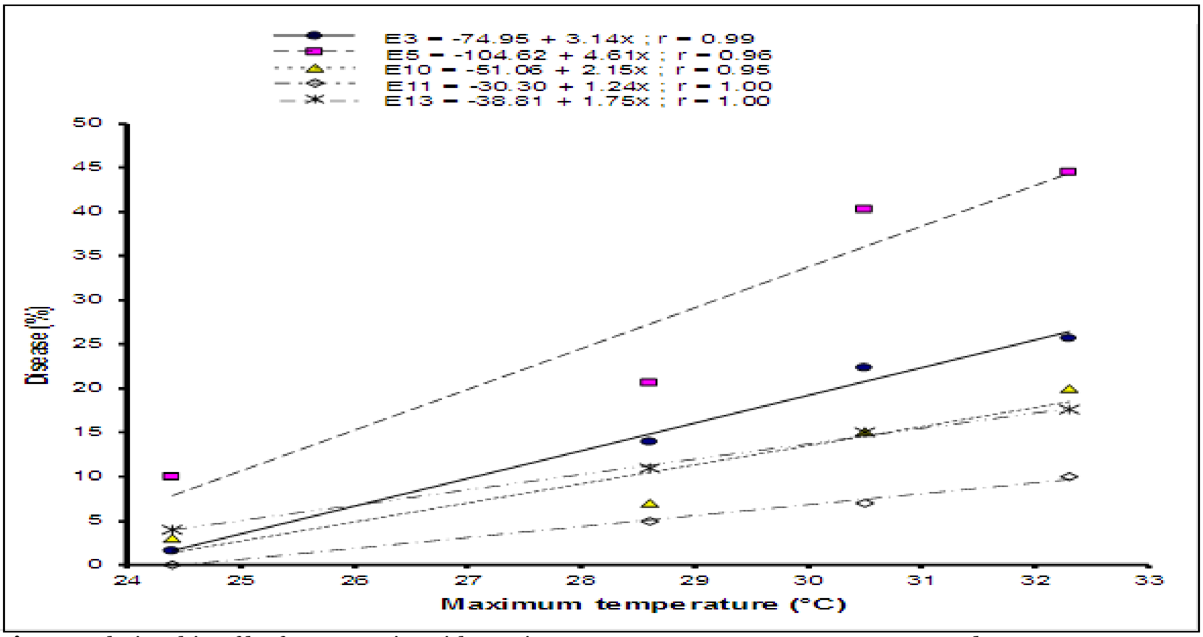

Fig. 2. Relationship of leaf rust severity with maximum temperature on E3, E5, E10, E11 and E13.

Discussion

In the above performed experiment results indicate that leaf rust prevails when suitable environmental conditions available and every factors play a key role in disease development and it support the idea that disease can be minimize by estimating environmental conditions during sowing. Hybrid varieties benefits more than other varieties due to higher abiotic and biotic stress resistance, have ability to enhanced yield stability and minimize heterosis (Hallauer *et al.,* 1988) Yield response and slow rusting response of 37 cultivars was studied by Pretirious (1987) against infection of brown rust.28 lines including 1 control cross among highly vulnerable Morroco & Dick were evaluated for finding effective resistance source to under natural conditions and pot culture in 1985-86; at booting stage artificial inoculation was done. Same outcomes was observed under field and pot conditions (Goswani and Ahmad, 1991). Singh *et al.,* (2001) carried out a CIMMYT of different varieties against fresh race of leaf rust and found that new race BN/BBG not much lethal against resistant varieties but in susceptible varieties cause 27% loses. 3 fast and 3 slow rusting varieties were screened against leaf rust and evaluated after artificial and natural inoculation pathogen during winter period from 1986-1987 to 1989-90. Varieties S69, 5577 and HB 208 showed deliberate rusting dignified by AUDPC (Prabhu *et al.*, 1993).

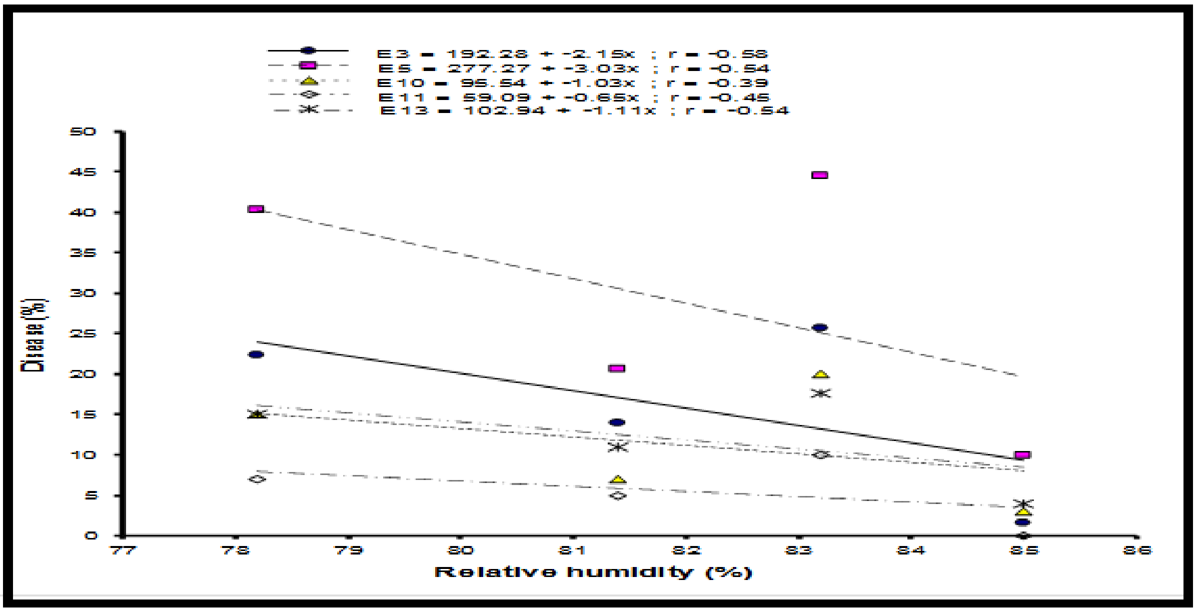

Fig. 3. Relationship of leaf rust severity with relative humidity on E3, E5, E10, E11 and E13.

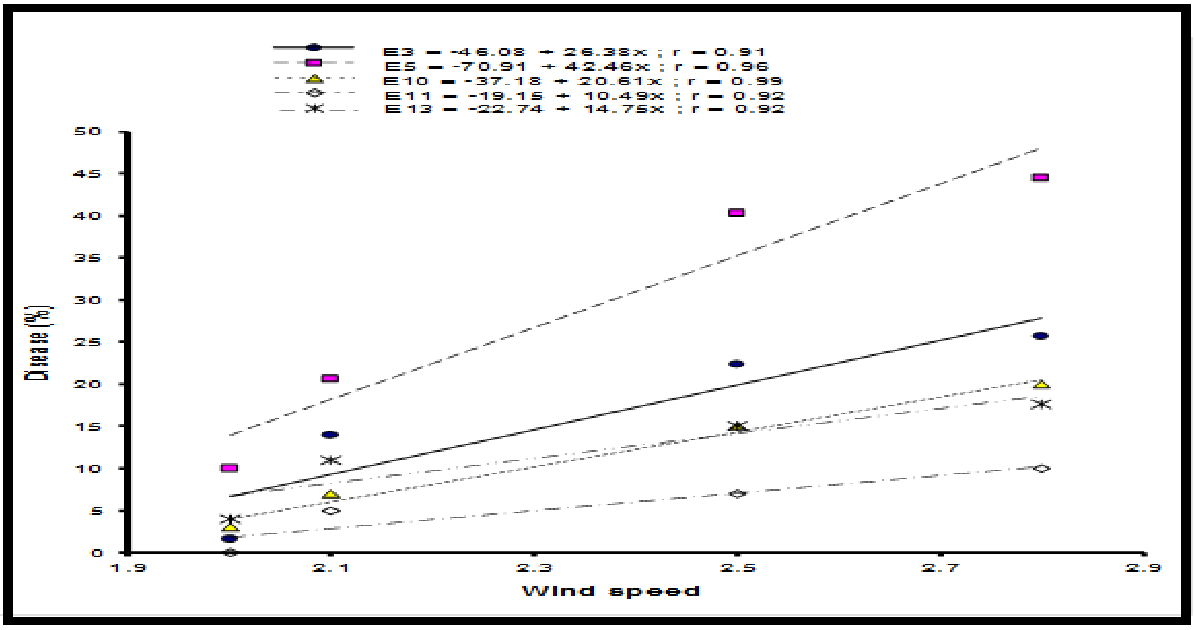

Fig. 4. Relationship of leaf rust severity with wind speed on E3, E5, E10, E11 and E13.

The study of the environmental factors play an important role in establishing disease predictive model to predict leaf rust epidemics, it results in the management of epidemics of rust disease and ultimate results in minimizing yield losses. So present study was conducted to check response of different wheat hybrid lines against leaf rust pathogen, aims to determine the environmental conditions encouraging development of leaf rust. Disease severity of 20 hybrid lines were correlated with environmental factors. 5 hybrid lines (E3, E5, E10, E11 and E13) showed significant correlation with environmental factors (wind speed, Rainfall and Max % Min Tem) and 5 lines showed no relationship with relative humidity. Show negative linear relationship. P. *recondita* f. sp. *Tritici* infection efficiency was 12 time greater under non limiting wetness and favorable conditions (Vallaviile *et al.,* 1995). Multiple regression models was developed by (Khan, 1997) by using several steps regression by engaging maximum temperature, minimum temperature, rainfall, relative humidity and 24 hours wind speed as independent variable, while brown rust severity act as dependent variables. For brown rust development epidemiological factors remains highly significant. Severity of brown rust on varieties FSD-85 and PAK-81, was recorded between 90-93%. 15 varieties were studied on slow rusting response in relation to epidemiological factors. At 22-28 °C Maximum temperature, 16-18 °C minimum temperature and 77-78% r.h slow rusting response showed by different varieties. Linear regression is best way to describe this relation. From these findings means it's evaluated that best way to identify the resistant souse against leaf rust is only possible through screening and better way to find resistant sources among any type of genotype.

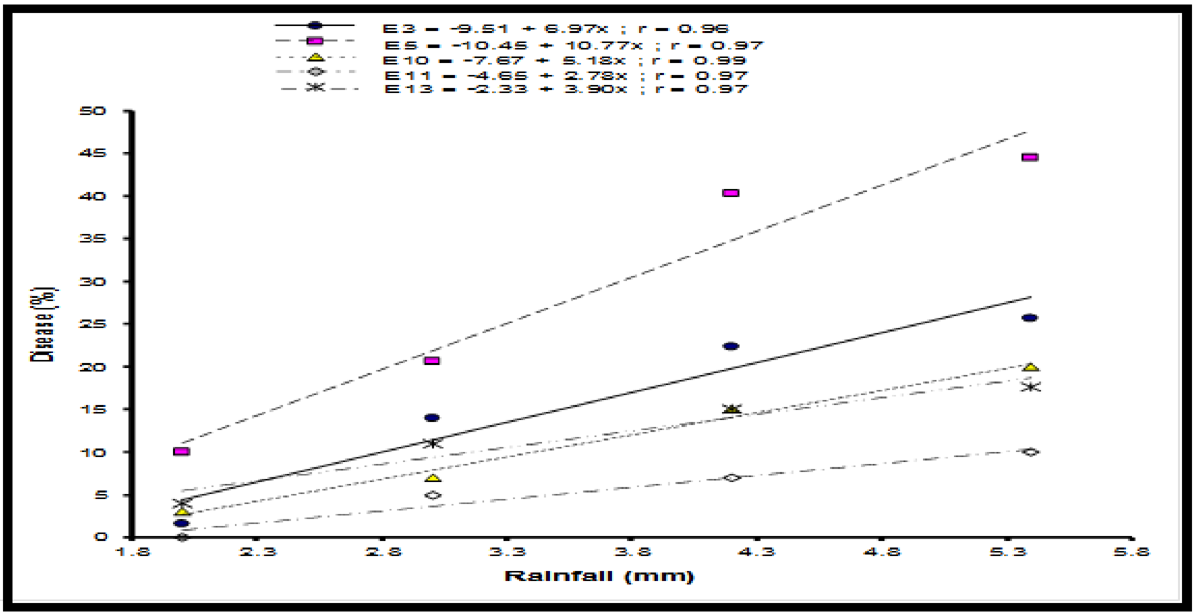

Fig. 5. Relationship between leaf rust severity and rainfall on E3, E5, E10, E11 and E13.

Conclusions

Present investigation shows that only one wheat hybrid line (E-9) were found resistant against leaf rust of wheat, breeder's may use these germplasm for future breeding trials, study also indicate that environmental factors play vital role in disease establishment if suitable environment factors has given that are essential pathogen survival.

This will help farmer's communities to adopt management practices in advance to insure crop security in future and help farmers in minimizing yield losses due to rust pathogen.

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