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Identification of Yellow Rust Virulence Pattern on Wheat Germplasm in Relation to Environmental Conditions in Faisalabad

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ABSTRACT
One hundred and fifty varieties/lines were screened against stripe. Most of the varieties/lines showed reaction to these diseases. For the development of stripe rust disease of wheat artificial and natural inoculums was relied upon for infection and the environmental conditions of Ayub Agricultural Research Institute, Faisalabad were favorable. Out of 150 lines/varieties which were screened against sixty four lines/varieties were immune, resistance shown by 42 lines/varieties and remaining all were susceptible against yellow rust. Area under disease progress curve (AUDPC) of all varieties was calculated. The virulence and avirulence formula studied showed that 42 varieties of yellow rust were avirulent and 29 varieties were virulent by yellow rust fungi. Environmental factors had great effect on the progress of stripe rust diseases of wheat. A positive linear relationship between temperature (maximum, minimum) and disease severity showed that maximum stripe rust develops was highly recognized to 28-32 °C maximum and 14-18 °C minimum temperatures. While, other environmental factors like relative humidity, rainfall and wind speed showed positive correlation. On the basis of data these environmental factors were tested for correlation with stripe rust severities. It was concluded that screening and identifying the virulence pattern of yellow rust on wheat germplasm and utilizing these virulence genes on advanced lines may be helpful to produced for rust resistance in wheat to get maximum production.
Keywords: Yellow rust, Virulence Pattern, Resistance source, Epidemiology, Correlation

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most essential cereal crop of the world. It is the most widely grown crop and is staple food of nearly 35 percent of the world's population. Because of its increasing demand due to increase in population of Pakistan, its requirements have become increasing day by day.

Of the total area (approximately 215 million hectares) sown to hexaploid and tetraploid wheat (*Triticum aestivum* and *T. turgidum var. durum*) worldwide, 44% (95 million hectares) is in Asia. Of this, 62 million hectares are located in just three countries: China, India and Pakistan (Singh *et al*., 2004). In Pakistan, wheat is grown under an area of 8.80 million hectare and gives 25.09 million tons of production (Anon., 2011). Despite of its economic importance, wheat is attacked by number of pathogens which cause diseases like fungi (rusts, smuts, bunts etc), bacteria (bacterial leaf blight, bacterial mosaic, black chaff etc) and virus (wheat dwarf, wheat spot mosaic, wheat streak mosaic etc).

Food protection of the world, rely on production of two important cereal crops i.e., rice and wheat. Wheat rusts problem has emerged due to attack of fungus not only in Asia but all over the wheat growing areas of the world. However, leaf rust caused *Puccinia recondite* f. sp. *tritici* and stripe rust caused *Puccinia striiformis* f. sp. *tritici* and stem rust caused by *Puccinia graminis* f. sp. *tritici* are potential risk that cause decrease in the yield of wheat (Singh *et al*., 2005).

Stripe rust could affect production on approximately 43 m ha, in Asia if susceptible cultivars were grown there (Aquino *et al*., 2002). In Pakistan all the wheat rusts occur with different intensities under different agro climatic zones. Among all wheat rusts, the stripe rust is the most important, favored mildly winter, cool summer and long cool wet springs. Symptoms of the disease are citron yellow uredia (spore mass) in long stripes over the leaf surface. When the crop matures, black telial spores are produced which are in stripe form and covered by leaf epidermis (Smiley and Cynthia, 2003).

During 1960s, the rusts were conservatively estimated to have reduced North American wheat yield by over 1 million tons (2%) annually (Wiese, 1977). In 1995, yellow rust epidemic caused 20% yield losses in Islamabad, Rawalpindi, KPK and other parts of the country where wheat varieties Pak-81 and Pirsabak-85 were grown (Chaudhary *et al*., 1996).

Stripe rust is the main cause of yield losses in most of the wheat producing areas. 10-70% yield losses on wheat are due to rusts which depend on the susceptibility of the cultivars, initial infection, disease development rate and duration of the disease (Chen, 2005). Yellow rust epidemics resulted in significant yield losses during the year 1988 to 1990. Annual losses, ranged 2 to 15% in Danish wheat trials (average of 236 trials), these losses of about 50 % recorded for mainly susceptible cultivar (Ullerup, 1991). Rust diseases are the major risk to future wheat production; grain yield losses in the susceptible varieties may exceed more than 50%

(Yaqoob, 1991). Losses due to rust have been estimated Rs. 30-40 million which were very high in the epidemic year i.e., in 1977-78. Reduction in total wheat production due to epidemics of stripe and leaf rusts 2.2 million tons worth US$ 330 million (Hafiz, 1986). During 1977-78 in Pakistan, 10 % yield losses of 0.83 million tons valuing US $86 million (Hassan *et al*., 1979).

Rust fungi are obligate parasites and must require living host for their survival. The survival of fungi during offseason is either on other grass species or on other voluntary wheat plants. Furthermore, in different locations of Asia, cool and irrigated agriculture encourage the inoculums. Similarly, during growing season of wheat, temperature and high humidity support development of disease that leads to dew development (Singh *et al.,* 2004b). There are five stages of spore of Wheat rusts where, in the spring and in summer huge quantity of uredospores produce significant epidemic. Wind is also responsible in the dispersal of spore from one plant to other plant where, they generate new infections and secondary uredospores with a low period of seven days (Wiese, 1987). The uredospores are free from nutrient and as soon as they germinate and build a contact with humidity and go through the germ tubes straight in stomata. Thus substomatal vesicles are produced and intercellular hyphae having globose or lobed haustoria which set up physiologic contact with host cell membranes thus starting infection process (Wiese, 1987).

Thirty seven different virulence patterns were detected from 926 yellow rust samples (Wan *et al*., 2002). All of sixty seven virulence patterns on the basis of their avirulence/virulence formula on the 17 differentials and the population structures of the pathogen have diverse with the related resistance change in wheat cultivar (Wu *et al*., 1993). Virulence patterns of rust and definite relations between pathogen (rusts) avirulence genes and host (wheat) resistance genes provide valuable marker for description of population of rust (Samborski and Dyck, 1976).

Environmental parameters play vital role in the scattering of rust and cause epidemics. At the right time, blowing wind in the opposite direction may bring spores and vectors far away from the infected plants. Stripe rust has positive association with relative humidity (R.H), temperature (maximum and minimum) and rainfall, while maximum temperature have significant effect to combat the disease (Singh *et al*., 2001; Salman *et al*., 2006; Khan, 1997; Khan *et al*., 1998). In Pakistan, yellow rust may emerge in January and prevail in March depending upon the occurrence of low temperature (Hussain *et al*., 1996).

The preferable and most economical method is the utilization of genetic resistance to manage the wheat rusts. Chemical control neither is advocated nor advisable due to health hazards of pesticides in staple food. To screen out each and every variety/advance line is the prime focus of wheat breeders and pathologists. Many new varieties were released after the green revolution, but new races of rust quickly breakup the resistance (Khan, 1987).

So, to enhance farmers' earnings and wheat productivity, appropriate measures and strategies are to be adopted to overcome these serious losses. Various management strategies are used for rust which is sowing of resistant varieties, fungicide application and discussion predictions on the basis of environmental factors conducive for disease development etc. Chemotherapy of leaf and stripe rust is not experienced in Pakistan on large scale due to low market price of wheat, health vulnerability concerns and lack of a systematic disease diagnostic pattern.

To avoid rust outbreak in the state is a multifaceted confront, given that less number of cultivars are on hand, that many of them lines/varieties are sheltered by the same immune source at genetic level. The need is to identify those cultivars with resistant sources so as to be suggested as most fit for the cultivation in the more diseased areas of the country keeping in view different ecological zones. The monitoring/screening is considered as the best and the cheapest way to identify these cultivars of wheat which show resistance against stripe rust. This would be helpful for the future studies on the identification of resistant sources in wheat against stripe rust.

To predict the favorable conditions of environment to the disease, yellow rust virulence pattern in relation to environmental factors was planned with the following objectives

- To identify the resistant lines/varieties against yellow rust.
- To monitor rusts virulences pattern through avirulence/virulence formula.
- To correlate environmental factors with yellow rust response values.

In order to accomplish above mentioned objectives following line of work was followed:

- Establishment of wheat germplasm screening nursery against stripe rust during the crop season 2010-2012.
- Artificial inoculation of stripe rust, especially through spray method.
- Recording of disease severity data and collection of metrological data from an observatory.
- Monitoring of rusts virulence pattern.
- Determination of correlation of environmental factors with stripe rust response values.

MATERIALS AND METHODS

For monitoring of wheat stripe/yellow rust virulence/avirulence pattern yellow rust differential set and commercial wheat germplasms/cultivars was obtained from Wheat Research Institute, Ayub Agricultural Research Institute (AARI), Faisalabad. During the year 2010-2012, these host differentials were sown at wheat research area in AARI (Ayub Agricultural Research Institute), Faisalabad. As a single row, each entry was planted while, in nursery every 10 entry Morocco was included and to make artificial epidemic condition Morocco was planted around the trial as a rust spreader. Row to row distance was 2m; line to line distance 30cm with 1m path. Plantation of these lines/cultivars was done during third week of November 2010 and 2011 in the experimental area. These lines were inoculated with the mixture of virulent races of the pathogen.

Inoculation of wheat germplasm

Inoculum was stored in vacuum and ultra-low refrigeration at -196 ºC. Organisms that survive cooling, freezing, and subsequent thawing can be stored indefinitely in liquid N_2. Different methods of artificial inoculation were followed, such as spraying with rust inoculums, rubbing, dusting with talcum powder and transplanting of rusted plants (Stubbs et al., 1986). At booting stage twice in a week, with an aqueous suspension of uredospores @ of 106/ml of water (Rao *et al*., 1989), nursery was inoculated to sustain the rust inoculum pressure (Roelf *et al*., 1992).

Recording of stripe rust disease severities data

On the appearance of symptoms, rust severity (percentage) and response of the plants to disease were assessed for three consecutive observations at 10 day intervals. The severity and the reaction of stripe rust were recorded by modified Cobb's scale (Peterson *et al*., 1948). Rust data was taken upto physiological maturity of wheat crop. When severities of disease became 80-100%, the final disease rating was determined. The final disease severity data for the stripe rust was converted into a coefficient of infection (CI) by multiplying severity with a constant value for field response (Yadav, 1985; Stubbs *et al.,* 1986; and Roelf *et al.,* 1992) given in table.1. Cobb's scale (Peterson *et al.,* 1948) was used only to record the rust severity data.

Table-1. Rust reaction, infection type for field response and response value

Reaction	Infection type	Field response	Response value
No disease	0	No visible infection	0
Resistant	R	Necrotic areas with or without minute uredia	0.2
Moderately resistant	MR	Small uredia present surrounded by necrotic area	0.4
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	0.6
Moderately susceptible	MS	Medium uredia with no necrosis but possible some distinct chlorosis	0.8
Moderately susceptible-susceptible	MSS	Medium uredia with no necrosis but possible some distinct chlorosis as well as large uredia with little or chlorosis present	0.9
Susceptible	S	Large uredia and little or no chlorosis present	1.0

Area under Disease Progress Curve (AUDPC)

Set of 150 germplasms/cultivars was sown to estimate the stripe rust virulence races. Inoculation of lines was done with the virulent races mixture. Data of rust recorded after every one week interval. Area Under Disease Progress Curve (AUDPC) was calculated by using formula developed at CIMMYT (1988)

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

Where
X_i = rust intensity on date *i*
t_i = time in days between *i* and date *i* + 1
n = number of dates on which disease was recorded

(Shaner and Finney, 1980).

The minimum and maximum limits of AUDPC were 1 to 199 which categorized under resistant (R). The minimum and maximum limits of AUDPC were 200 to 399 which categorized under moderately resistant (MR). But for the moderately susceptible (MS) to susceptible (S) the minimum and maximum limits were 400 to 599 and 600 to so on, respectively.

Monitoring of rust virulence pattern through avirulence/virulence formula

The trial was consisted of rust differential sets of which consist of near isogenic germplasm for stripe rust, wheat cultivars with identified genes planted at different locations in Ayub Agricultural Research Institute (AARI), Faisalabad. Wheat cultivars and reaction of genes was recorded. In an area, data of rust differential and wheat varieties was used to determine the rust virulence pattern.

Environmental data

Environmental data consist of wind velocity, temperature (minimum, maximum), relative humidity (R.H.) and rainfall was recorded by instruments installed in observatory in the field of Ayub Agricultural Research Institute, Faisalabad which are close to wheat experimental area.

Analysis of data

Simple correlation was determined between the different environmental factors (maximum & minimum temperature, relative humidity, rainfall and wind speed) and stripe rust response value through modified Cobb's scale described by Peterson *et al.,* (1948) for wheat varieties/lines (Steel, *et al*., 1997). The response value/relative resistance index (RRI) was calculated on the basis of following formula;

$$RRI = \frac{(100-CARPA) \times 9}{100}$$

Whereas the scale used for calculating RRI value ranged from 0 to 9 and CARPA stands for Country Average Relative Percentage Attack. All the rust severities and environmental data were subjected to correlation and regression analysis to determine the relation of epidemiological factors with wheat rusts.

RESULTS AND DISCUSSION

Wheat lines/varieties screening against yellow rust

Out of 150 advanced lines/varieties screened against stripe/yellow rust, 64 lines/varieties were immune, resistance was shown by 42 varieties and remaining all were susceptible which were given in Table-2. Symptoms of the yellow rust shown in Fig.1.

Fig-1. Symptoms of Stripe/Yellow rust.

Level of resistance/susceptibility on the basis of area under disease progress curve (AUDPC)

Five lines V-27, V-38, V-52, V-76 and V-107 were resistant to yellow rust and there lines showed the AUDPC values as 175, 105, 157.5, 210 and 175, respectively and their response values were 0.2. The response value for susceptible lines V-11, V-39, V-66, V-85 and V-108 were 1.0 and their AUDPC values were 735, 910, 455, 770 and 735, respectively as given in Table-2.

Table-2. Area under disease progress curve and lines\varieties reaction against yellow rust

Sr. No	Ranges of AUDPC	Varieties /Lines (2010-2011)	Varieties /Lines (2011-2012)	Level of Resistance or Susceptibility
1	1-200	V-2, V-8, V-14, V-15, V-18, V-21, V-22, V-25, V-26, V-27, V-38, V-45, V-47, V-52, V-54, V-65, V-73, V-79, V-81, V-82, V-86, V-87, V-88, V-92, V-97, V-107, V-122	V-27, V-38, V-47, V-52, V-61, V-63, V-88, V-89, 93, V-107, V-136	R (Resistant)
2	201-400	V-9, V-42, V-44, V-48, V-61, V-62, V-63, V-69, V-75, V-76, V-89, V-93, V-104, V-109, V-136	V-2, V-8, V-9, V-14, V-15, V-18, V-21, V-22, V-25, V-26, V-42, V-44, V-45, V-48, V-54, V-62, V-65, V-69, V-73, V-75, V-76, V-79, V-81, V-82, V-86, V-87, V-92, V-97, V-104, V-109, V-122	MR (Moderately Resistant)
3	401-600	V-1, V-12, V-13, V-23, V-35, V-43, V-46, V-53, V-57, V-58, V-66, V-83, V-91, V-101	V-1, V-4, V-12, V-24, V-41, V-55, V-66, V-72, V-78, V-83, V-84, V-91, V-96, V-101,	MS (Moderately Susceptible)
4	601-More	V-4, V-11, V-24, V-37, V-39, V-41, V-55, V-72, V-78, V-84, V-85, V-96, V-99, V-103, V-108	V-11, V-13, V-23, V-35, V-37, V-39, V-43, V-46, V-53, V-57, V-58, V-85, V-99, V-103, V-108	S (Susceptible)

R=Resistant, MR=Moderately Resistant, MS=Moderately Susceptible, S=Susceptible.

Monitoring of yellow rust virulence pattern through avirulence/virulence formula

To observe the virulence pattern of *Puccinia striiformis* f. sp. *tritici* under field condition a set of trap nursery consisting of 56 near isogenic lines and 94 commercial wheat varieties and few unknown sources of resistances along with rust differentials were planted during the cropping season. Monitoring of yellow rust virulence pattern through avirulence/virulence formula was done on the basis of reaction types in a host pathogen system. In Table-3 only the stripe rust virulence pattern showed. The lines/varieties had genes *Yr-18, 2, 8, 1, 4, 31* and *Lr-11* were moderately resistant (MR). While, lines/varieties had genes *Yr-5, 30, 6* and *Lr-22b* were resistant (R). The lines/varieties had genes *Yr-17, 27, 29, 30, A, AOC-YRA* and *AOC+YRA* were moderately susceptible (MS) while, lines/varieties had genes *Yr-7* and *26* were susceptible. Also 13 lines had unknown genes were moderately susceptible to susceptible while, 18 lines had unknown genes were moderately resistant, resistant and 0 reaction type against yellow rust pathogen showed in Table-3.

Table-3. Nearisogenic lines and wheat differentials used for the observation of virulence pattern of stripe rust under field conditions

Sr. No	Symbols of Varieties/ Differentials	Gene	Reaction Type
1	Morocco	-	S
2	V-1	-	MS
3	V-2	Yr18	MR
4	V-3	Yr9	0
5	V-4	Yr30	MS
6	V-5	Yr18	0
7	V-6	Yr18	0
8	V-7	-	0
9	V-8	Yr2	MR
10	V-9	Yr4,9,18	MR
11	V-11	-	S
12	V-12	-	MS
13	V-13	-	S
14	V-14	-	MR
15	V-15	-	MR
16	V-16	YrA,2	0
17	V-17	-	0
18	V-18	-	MR

19	V-19	Yr18	0
20	V-21	Yr9	MR
21	V-22	-	MR
22	V-23	-	S
23	V-24	Yr29	MS
24	V-25	-	MR
25	V-26	-	MR
26	V-27	Yr5	R
27	V-28	Yr5	R
28	V-29	-	0
29	V-31	-	0
30	V-32	-	0
31	V-33	Yr9	0
32	V-34	-	0
33	V-35	-	S
34	V-36	Yr18	0
35	V-37	Yr27	S
36	V-38	Yr9	R
37	V-39	Yr30	S
38	V-41	Yr30	MS
39	V-42	Yr18	MR
40	V-43	-	S
41	V-44	Yr18	MR
42	V-45	Yr18	MR
43	V-46	Yr7	S
44	V-47	Yr18	R
45	V-48	-	MR
46	V-49	Yr9	0
47	V-51	Yr18	R
48	V-52	Yr18	R
49	V-53	-	S
50	V-54	-	MR
51	V-55	YrA	MS
52	V-56	Yr18	0
53	V-57	-	MS
54	V-58	Yr29,30	S
55	V-59	Yr9	0
56	V-61	Yr18	R
57	V-62	Yr18	MR
58	V-63	Yr18	R
59	V-64	Yr18	0
60	V-65	Yr9	MR
61	V-66	Yr7	MS
62	V-67	Yr18	0
63	V-68	Yr18	0
64	V-69	Yr2	MR
65	V-71	Yr9	0
66	V-72	-	MS
67	V-73	-	MR
68	V-74	-	0
69	V-75	-	MR
70	V-76	Yr18	R

71	V-77	Yr9	0
72	V-78	Yr29	MS
73	V-79	Yr9	MR
74	V-81	-	MR
75	V-82	Yr18	MR
76	V-83	-	MS
77	V-84	AOC-YRA	MS
78	V-85	AOC+YRA	S
79	V-86	Yr-I	MR
80	V-87	Yr-2	MR
81	V-88	Yr-5	R
82	V-89	Yr-6	R
83	V-91	Yr-7	MS
84	V-92	Yr-8	MR
85	V-93	Yr-9	R
86	V-94	Yr-10	0
87	V-95	Yr-15	0
88	V-96	Yr-17	MS
89	V-97	Yr-18	MR
90	V-98	Yr-24	0
91	V-99	Yr-26	S
92	V-101	Yr-27	MS
93	V-102	Yr-28	0
94	V-103	Yr-29	S
95	V-104	Yr-31	MR
96	V-105	Yr18	0
97	V-106	Yr18	0
98	V-107	Yr9	R
99	V-108	Yr29	S
100	V-109	Yr9,18	MR
101	V-111	YRCV	0
102	V-112	Lr-I	0
103	V-113	Lr-2a	0
104	V-114	Lr-2b	0
105	V-115	Lr-2c	0
106	V-116	Lr-3	0
107	V-117	Lr-3KA	0
108	V-118	Lr-3BG	0
109	V-119	Lr-9	0
110	V-121	Lr-10	0
111	V-122	Lr-11	MR
112	V-123	Lr-12	0
113	V-124	Lr-13	0
114	V-125	Lr-14a	0
115	V-126	Lr-14b	0
116	V-127	Lr-15	0
117	V-128	Lr-16	0
118	V-129	Lr-17	0
119	V-131	Lr-18	0
120	V-132	Lr-19	0
121	V-133	Lr-20	0
122	V-134	Lr-21	0

123	V-135	Lr-22a	0
124	V-136	Lr-22b	R
125	V-137	Lr-23	0
126	V-138	Lr-24	0
127	V-139	Lr-25	0
128	V-141	Lr-26	0
129	V-142	Lr-27+31	0
130	V-143	Lr-28	0
131	V-144	Lr-29	0
132	V-145	Lr-30	0
133	V-146	Lr-32	0
134	V-147	Lr-33	0
135	V-148	Lr-34	0
136	V-149	Lr-35	0

Reaction Types-0, R=Resistant, MR=Moderately Resistant, MS=Moderately Susceptible, S=Susceptible.

The formula of avirulence/virulence showed in Table-4. There were 63 varieties immune which were zero reaction type, 43 varieties were avirulent having reaction type moderately resistant (MR) to resistant (R) having combination and single genes of *Yr-18, 9, 2, 8, A, 5, 1, 6, 15, 10, 24, 4, 31, 28, Lr-1, 2a, 2b, 2c, 3, 3KA, 3BG, 9, 10, 11, 12, 13, 14 (a, b), 15, 16, 17, 18, 19, 20, 21, 22a, 22b, 23, 24, 25, 26, 27+31, 28, 29, 30, 32, 33, 34, 35* and remaining 29 were virulent having reaction type moderately susceptible (MS) to susceptible (S) having genes of *Yr-29, 27, 30, 7, 17, 26, AOC-YRA, AOC+YRA* were showed in Table-4.

Table-4. Avirulence/Virulence formula for stripe rust

Avirulence	Virulence
Yr-18, 9, 2, 8, A, 5, 1, 6, 15, 10, 24, 4, 31, 28, Lr-1, 2a, 2b, 2c, 3, 3KA, 3BG, 9, 10, 11, 12, 13, 14 (a, b), 15, 16, 17, 18, 19, 20, 21, 22a, 22b, 23, 24, 25, 26, 27+31, 28, 29, 30, 32, 33, 34, 35	*Yr-29, 27, 30, 7, 17, 26, AOC-YRA, AOC+YRA*

Formula: Avirulence=R and MR type of reaction, Virulence=S and MS type of reaction.

Determination of correlation of environmental factors and yellow rust severity

In table 5 given the data shows the correlation of environmental conditions with yellow rust. Ten varieties/lines V-12, V-24, V-25, V-37, V-38, V-46, V-73, V-83, V-104 and V-108 show statistically significant relation with maximum temperature. Ten varieties/lines V-12, V-24, V-25, V-37, V-38, V-46, V-73, V-83, V-104 and V-108 show statistically significant relation with minimum temperature. These varieties/lines V-12, V-24, V-25, V-37, V-38, V-46, V-73, V-83, V-104 and V-108 having statistically significant relation with relative humidity and wind speed.

Table-5. Correlation of environmental factors with yellow rust disease severity

Sr. No.	Varieties/ Lines	Maximum Temperature	Minimum Temperature	Relative Humidity	Rainfall	Wind Speed
1	V-1	0.9968*	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
2	V-2	0.9936**	0.9967**	0.9477	0.9406	0.9550*
		0.0064	0.0033	0.0523	0.0594	0.0450
3	V-4	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
4	Morocco	0.9963**	0.9919**	0.9390	0.9595*	0.9707**
		0.0037	0.0081	0.0610	0.0405	0.0293
5	V-11	0.9968**	0.9950**	0.9780*	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
6	V-12	0.9920**	0.9693*	0.9248	0.9853**	0.9959**
		0.0080	0.0307	0.0752	0.0147	0.0041
7	V-13	0.9585*	0.9330	0.8369	0.9891**	0.9766**
		0.0415	0.0670	0.1631	0.0109	0.0234
8	V-14	0.9936**	0.9967**	0.9477	0.9406	0.9550*
		0.0064	0.0033	0.0523	0.0594	0.0450

9	V-15	0.9936**	0.9967**	0.9477	0.9406	0.9550*
		0.0064	0.0033	0.0523	0.0594	0.0450
10	V-18	0.9936**	0.9967**	0.9477	0.9406	0.9550*
		0.0064	0.0033	0.0523	0.0594	0.0450
11	Morocco	0.9754**	0.9687*	0.8824	0.9638*	0.9599*
		0.0246	0.0313	0.1176	0.0362	0.0401
12	V-21	0.9943**	0.9804**	0.9225	0.9786**	0.9857**
		0.0057	0.0196	0.0775	0.0214	0.0143
13	V-22	0.9936**	0.9967**	0.9477	0.9406	0.9550*
		0.0064	0.0033	0.0523	0.0594	0.0450
14	V-23	0.9936**	0.9967**	0.9477	0.9406	0.9550*
		0.0064	0.0033	0.0523	0.0594	0.0450
15	V-24	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
16	V-25	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
17	V-26	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
18	V-27	0.9943**	0.9804**	0.9225	0.9786**	0.9857**
		0.0057	0.0196	0.0775	0.0214	0.0143
19	Morocco	0.9547*	0.9350	0.8317	0.9788**	0.9644*
		0.0453	0.0650	0.1683	0.0212	0.0356
20	V-35	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
21	V-37	0.9938**	0.9768**	0.9604*	0.9599*	0.9835**
		0.0062	0.0232	0.0396	0.0401	0.0165
22	V-38	0.9576*	0.9172	0.9021	0.9699*	0.9878**
		0.0424	0.0828	0.0979	0.0301	0.0122
23	V-39	0.9705**	0.9624*	0.9874**	0.8978	0.9397
		0.0295	0.0376	0.0126	0.1022	0.0603
24	Morocco	0.9303	0.8996	0.7865	0.9826**	0.9609*
		0.0697	0.1004	0.2135	0.0174	0.0391
25	V-41	0.9943**	0.9804**	0.9225	0.9786**	0.9857**
		0.0057	0.0196	0.0775	0.0214	0.0143
26	V-42	0.9936**	0.9967**	0.9477	0.9406	0.9550*
		0.0064	0.0033	0.0523	0.0594	0.0450
27	V-43	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
28	V-44	0.9936**	0.9967**	0.9477	0.9406	0.9550*
		0.0064	0.0033	0.0523	0.0594	0.0450
29	V-45	0.9936**	0.9967**	0.9477	0.9406	0.9550*
		0.0064	0.0033	0.0523	0.0594	0.0450
30	V-46	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
31	V-48	0.9943**	0.9804**	0.9225	0.9786**	0.9857**
		0.0057	0.0196	0.0775	0.0214	0.0143
32	Morocco	0.9963**	0.9919**	0.9390	0.9595*	0.9707**
		0.0037	0.0081	0.0610	0.0405	0.0293
33	V-52	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
34	V-53	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
35	V-54	0.9765**	0.9555*	0.8741	0.9889**	0.9841**
		0.0235	0.0445	0.1259	0.0111	0.0159
36	V-55	0.9936**	0.9967**	0.9477	0.9406	0.9550*
		0.0064	0.0033	0.0523	0.0594	0.0450
37	V-58	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389

38	Morocco	0.9543*	0.9836**	0.9504*	0.8459	0.8711
		0.0457	0.0164	0.0496	0.1541	0.1289
39	V-61	0.9968*	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
40	V-62	0.9943**	0.9804**	0.9225	0.9786**	0.9857**
		0.0057	0.0196	0.0775	0.0214	0.0143
41	V-63	0.9705**	0.9624*	0.9874**	0.8978	0.9397
		0.0295	0.0376	0.0126	0.1022	0.0603
42	V-65	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
43	V-66	0.9882**	0.9826**	0.9125	0.9641*	0.9677*
		0.0118	0.0174	0.0875	0.0359	0.0323
44	V-69	0.7981	0.7303	0.6070	0.9364	0.8980
		0.2019	0.2697	0.3930	0.0636	0.1020
45	Morocco	0.9547*	0.9350	0.8317	0.9788**	0.9644*
		0.0453	0.0650	0.1683	0.0212	0.0356
46	V-72	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
47	V-73	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
48	V-75	0.9936	0.9967**	0.9477	0.9406	0.9550*
		0.0064	0.0033	0.0523	0.0594	0.0450
49	V-78	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
50	V-79	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
51	Morocco	0.9821**	0.9555*	0.8916	0.9947	0.9961**
		0.0179	0.0445	0.1084	0.0053	0.0039
52	V-81	0.9936**	0.9967**	0.9477	0.9406	0.9550*
		0.0064	0.0033	0.0523	0.0594	0.0450
53	V-82	0.9943**	0.9804**	0.9225	0.9786**	0.9857**
		0.0057	0.0196	0.0775	0.0214	0.0143
54	V-83	0.9938**	0.9768**	0.9604*	0.9599*	0.9835**
		0.0062	0.0232	0.0396	0.0401	0.0165
55	V-84	0.9920**	0.9693**	0.9248	0.9853**	0.9959**
		0.0080	0.0307	0.0752	0.0147	0.0041
56	V-85	0.9943**	0.9804**	0.9225	0.9786**	0.9857**
		0.0057	0.0196	0.0775	0.0214	0.0143
57	V-86	0.9938**	0.9768**	0.9604*	0.9599*	0.9835**
		0.0062	0.0232	0.0396	0.0401	0.0165
58	V-87	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
59	V-88	0.9943**	0.9804**	0.9225	0.9786**	0.9857**
		0.0057	0.0196	0.0775	0.0214	0.0143
60	V-89	0.9943**	0.9804**	0.9225	0.9786**	0.9857**
		0.0057	0.0196	0.0775	0.0214	0.0143
61	Morocco	0.9812**	0.9873**	0.9189	0.9347	0.9412
		0.0188	0.0127	0.0811	0.0653	0.0588
62	V-91	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
63	V-92	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389
64	V-93	0.9943**	0.9804**	0.9225	0.9786**	0.9857**
		0.0057	0.0196	0.0775	0.0214	0.0143
65	V-96	0.9145	0.9346	0.9920**	0.7742	0.8337
		0.0855	0.0654	0.0080	0.2258	0.1663
66	V-97	0.9968**	0.9950**	0.9780**	0.9344	0.9611*
		0.0032	0.0050	0.0220	0.0656	0.0389

67	V-99	0.9943** 0.0057	0.9804** 0.0196	0.9225 0.0775	0.9786** 0.0214	0.9857** 0.0143
68	Morocco	0.9774** 0.0226	0.9657* 0.0343	0.8810 0.1190	0.9742** 0.0258	0.9700* 0.0300
69	V-103	0.9943** 0.0057	0.9804** 0.0196	0.9225 0.0775	0.9786** 0.0214	0.9857** 0.0143
70	V-104	0.9774** 0.0226	0.9657* 0.0343	0.8810 0.1190	0.9742** 0.0258	0.9700* 0.0300
71	V-107	0.9943** 0.0057	0.9804** 0.0196	0.9225 0.0775	0.9786** 0.0214	0.9857** 0.0143
72	V-108	0.9968** 0.0032	0.9950** 0.0050	0.9780** 0.0220	0.9344 0.0656	0.9611* 0.0389
73	V-109	0.9936** 0.0064	0.9967** 0.0033	0.9477 0.0523	0.9406 0.0594	0.9550* 0.0450
74	V-110	0.9197 0.0803	0.8875 0.1125	0.7691 0.2309	0.9789** 0.0211	0.9543* 0.0457
75	Morocco	0.9774** 0.0226	0.9657* 0.0343	0.8810 0.1190	0.9742** 0.0258	0.9700* 0.0300
76	V-122	0.9936** 0.0064	0.9967** 0.0033	0.9477 0.0523	0.9406 0.0594	0.9550* 0.0450
77	Morocco	0.9968** 0.0032	0.9856** 0.0144	0.9689* 0.0311	0.9519* 0.0481	0.9767** 0.0233
78	Morocco	0.9725** 0.0275	0.9931** 0.0069	0.9545* 0.0455	0.8821 0.1179	0.9038 0.0962
79	Morocco	0.9943** 0.0057	0.9804** 0.0196	0.9225 0.0775	0.9786** 0.0214	0.9857** 0.0143

*** Significant** **** Highly Significant**
Upper values in a column indicate Pearson's Correlation Coefficients
Lower values indicate significance level at P = 0.05

Among 150 lines, 15 lines (Morocco) were used as disease spreaders. Morocco was highly susceptible to yellow rust, so it's typical performance to demonstrate linearity in correlation with all the environmental factors which were studied. However, all environmental factors, minimum and maximum temperature relative humidity, rainfall and wind speed showed significant correlation with yellow rust disease severity. 15 lines which are Morocco not included in each case of environmental factors.

Minimum temperature Vs Stripe rust severity

There was positive relationship between minimum temperature and stripe rust severities. The varieties V-24, V-37, V-46, V-83 and V-108 showed considerable reaction with an increase in temperature 14-18°C, values of stripe rust also increased. This demonstrates clearly about the response values of stripe rust varieties/lines to minimum temperature.

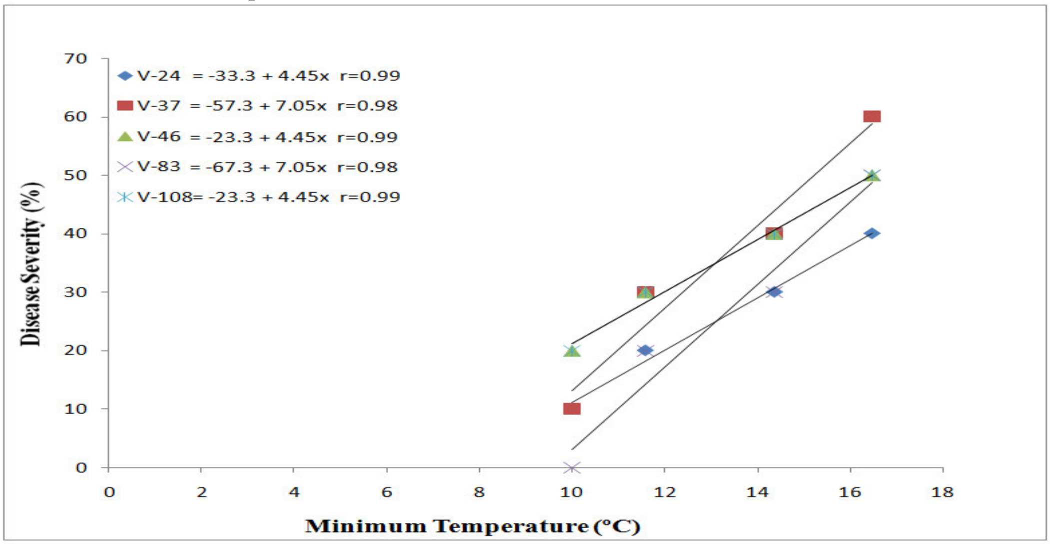

Fig-2. Relationship of minimum temperature with stripe rust disease severity on V-24, V-37, V-46, V-83 and V-108

Maximum temperature Vs Stripe rust severity

There was positive relationship between maximum temperature and stripe rust severities. The varieties V-24, V-37, V-46, V-83 and V-108 showed considerable reaction with an increase in temperature 28-32°C, values of stripe rust also increased. This demonstrates clearly about the response values of stripe rust varieties/lines to maximum temperature.

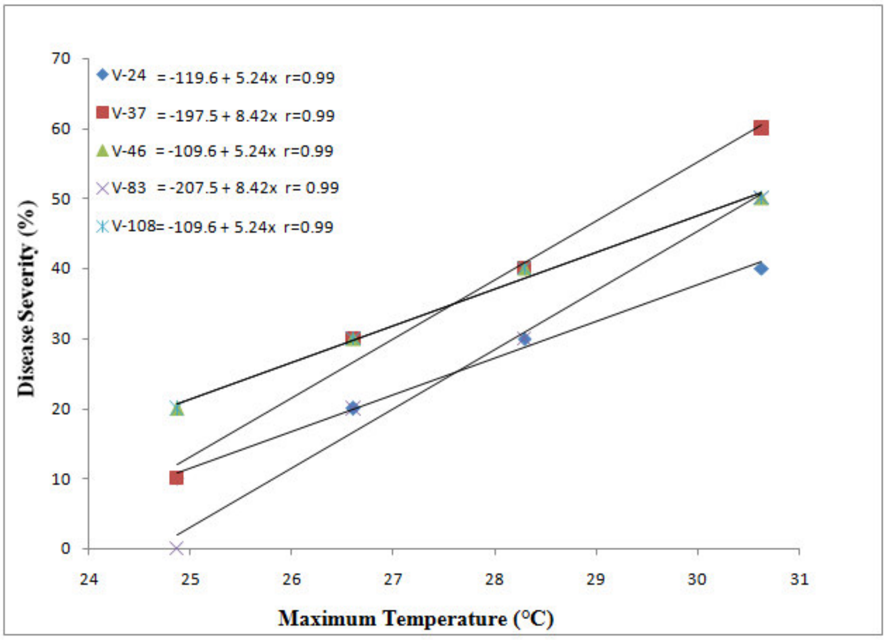

Fig-3. Relationship of maximum temperature with stripe rust disease severity on V-24, V-37, V-46, V-83 and V-108

Relative humidity Vs Stripe rust severity

There was positive relationship between relative humidity and stripe rust severities. The varieties V-24, V-37, V-46, V-83 and V-108 showed considerable reaction with an increase in relative humidity 75-80 %, values of stripe rust also increased. This demonstrates clearly about the response values of stripe rust varieties/lines to relative humidity.

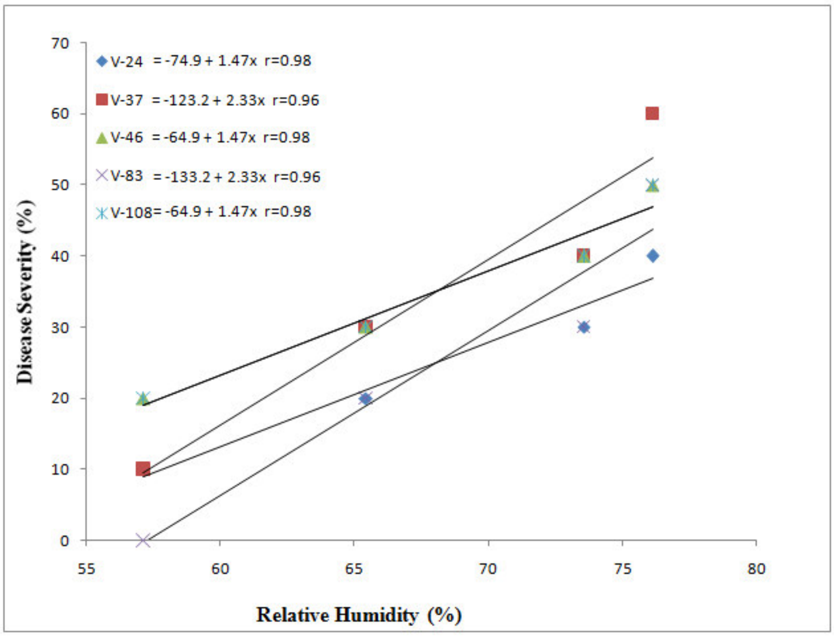

Fig-4. Relationship of relative humidity with stripe rust disease severity on V-24, V-37, V-46, V-83 and V-108

Wind speed Vs Stripe rust severity

There was positive relationship between wind speed and stripe rust severities. The varieties V-24, V-37, V-46, V-83 and V-108 showed considerable reaction with an increase in wind speed 2.8-3.3, values of stripe rust also increased. This demonstrates clearly about the response values of stripe rust varieties/lines to wind speed.

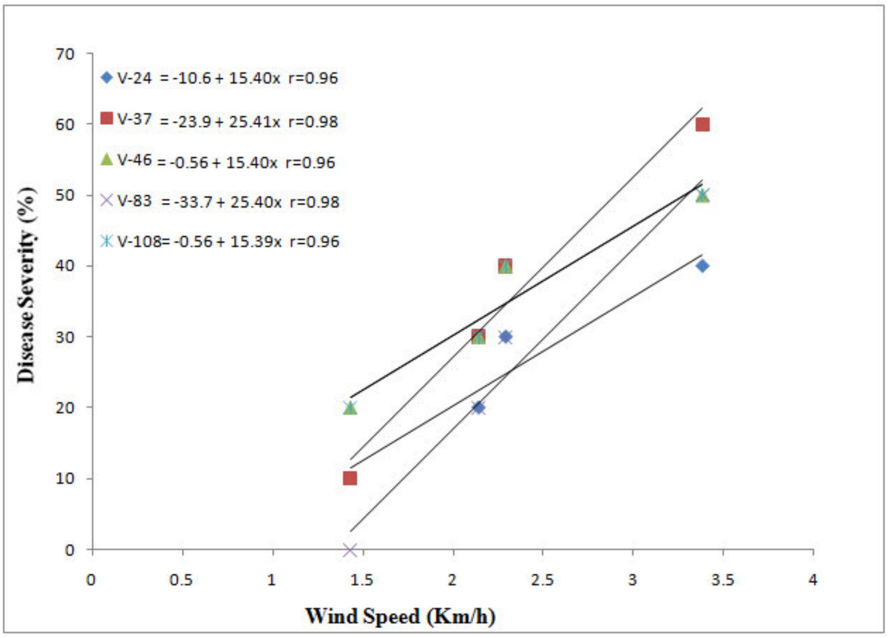

Fig-5. Relationship of wind speed with stripe rust disease severity on V-24, V-37, V-46, V-83 and V-108

Rainfall Vs Stripe rust severity

There was positive relationship between rainfall and stripe rust severities. The varieties V-24, V-37, V-46, V-83 and V-108 showed considerable reaction with an increase in wind rainfall 1.43-2.38, values of stripe rust also increased. This demonstrates clearly about the response values of stripe rust varieties/lines to rainfall.

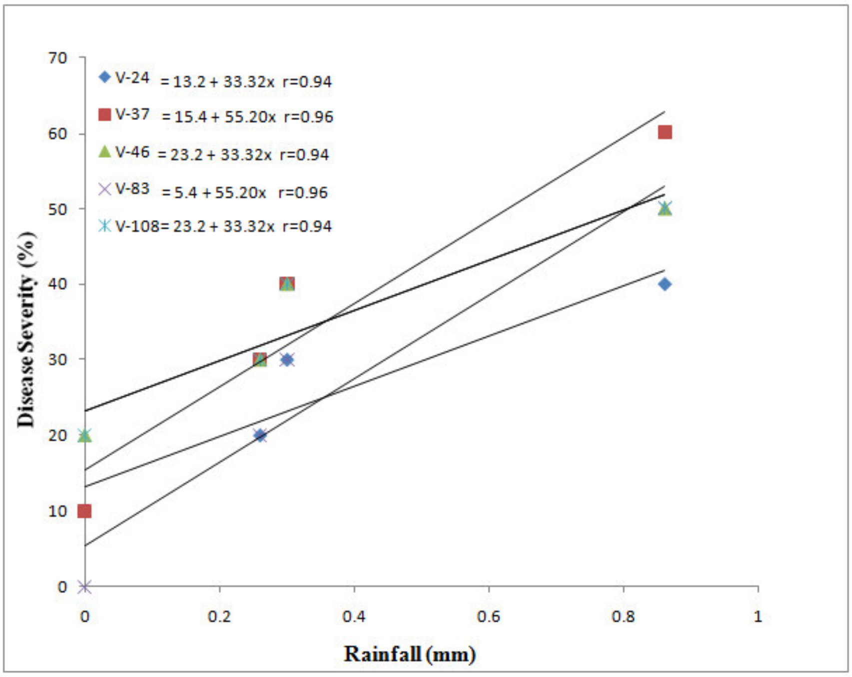

Fig-6. Relationship of rainfall with stripe rust disease severity on V-24, V-37, V-46, V-83 and V-108

During the cropping season 2010-2012, studies regarding identification of the virulence pattern of yellow rust on wheat germplasms in relation to environmental conditions were carried out. Along with natural inoculums, artificial inoculation of yellow rust spores were done on wheat varieties/lines by using various methods like transplanting of rusted plants, rubbing, dusting with talcum powder and spraying. **In 2000, Reis *et al*.,** used one of the same technique i.e., spraying of uredospores suspension on wheat germplasm to evaluate the resistant source from the available lot. Similar studies were also carried out in 1992 by Roelfs *et al*., by using one of the same method i.e., fresh spores (uredospores) mixed with talcum powder and then applied at tillering, heading and flag leaf stages of the wheat crop to evaluate the resistance source of wheat germplasm, including a checked (Morocco) after each 9th line/variety, one hundred and fifty varieties/lines were screened against yellow rust disease severities in the present studies and resultantly during 2010-2012, it was found that the yellow rust disease severity on spreader Morocco attained 100S (Susceptible: High values above 600 of AUDPC showed greater incidence of yellow rust on wheat plants, with lower AUDPC values indicating resistance to yellow rust in wheat genotypes) out of all the varieties/lines sown 64 were immune, 42 varieties showed resistance response and 29 were susceptible against yellow rust. In 1987, Arora *et al*., screened 158 durum and aestivum wheat lines and showed that there was only 1 line immune. Ali *et al*., in 2009, perform the task to identify the resistance source against stripe rust and found that zero immune, 27 resistant, 9 were moderately resistant and only one was susceptible variety out of the lines/varieties studied. To monitor the yellow rust virulence pattern, the present studies were carried out on the basis of reaction types in a host pathogen system. There were 63 varieties which were immune having zero reaction, 43 varieties were avirulent having infection type reaction moderately resistant (MR) to resistant (R) and remaining 29 were virulent having infection type reaction moderately susceptible (MS) to susceptible (S) to yellow rust excluding Morocco. In the present study the lines having genes *Lr-9, 15, 17, 18, 13, 34, 26, 3, 21, 16, 46, 14A, 19. 24, 32, 33, 34, 35, Yr-1, 2, 15, 17, 28, 29, 31, 3KA* were moderately resistant (MR). While, lines having genes *Lr-11, 20, 22a, 25, 27+31, Yr-8, 9, 10, 18, 26, AOC-YRA, AOC+YRA* were resistant (R). From the present study lines having these genes *Lr-1, 10, 14, 23, 27, 31, 2a, 2b, 2c, 3, 3BG, 12, 14a 14b, 16, 22b, 29, 30, 23, Yr-5, 6, 7, 24, 27, YRCV* and *Lr-1, 10, 14, 23, 27, 31, 2a, 2b, 2c, 3, 3BG, 12, 14a 14b, 16, 22b, 29, 30, 23, Yr-5, 6, 7, 24, 27, YRCV* were moderately susceptible (MS) to susceptible. In this study found that *Yr-18, 2, 8, 1, 4, 31* and *Lr-11* were effective against stripe rust pathogen. Genes such as *Yr-5, 30, 6 and Lr-22b* showed high level of resistance against stripe rust pathogen. In 2005 Chen and 2008 Afshari found that *Yr-5* gene previously known to show resistance against yellow rust in Iran and China. Moreover, *Yr-15* and *Yr-5* genes rarely found in wheat producing areas of the world. In 1992 McIntosh, examined that *Yr-18* showed durable resistance for yellow rust. While, in 2004 Singh *el al*., found that *Yr-18* with other minor genes is known to be resistance source such as Parula, Trap, Yaco and others. In 2001 Hovmùller, studied that Ritmo (*Yr-1*) was effective to in controlling yellow rust due to the pathotypes with the same combinations of virulence declined in the pathogen population. In 2000 Bayles *et al*., examined that *Yr-17* became infected against yellow rust in Britain in 1994. From the present study these genes *Yr-17, 27, 29, 30, A, AOC-YRA, AOC+YRA, Yr-7* and *26* were moderately susceptible to susceptible. In 2002 Manninger, reported that *Yr-17, 7* and *A* genes were not effective against yellow rust. In 1976, Samborski and Dyck, studied to identify the virulence patterns of rusts which moreover alter nearby or introduced through movement. The definite relations between pathogen (rusts) avirulence genes and host (wheat) resistance genes provided valuable marker for description of population of rust. In 1993, Wu *et al*., all of sixty seven virulence patterns on the basis of their avirulence/virulence formula on the 17 differentials and the population structures of the pathogen have diverse with the related resistance change in wheat cultivar. Chaudhary *et al*., in 1996 monitored rust virulence and found that varieties Inq-91, Parwaz-94 and Chkwal-86 were resistant to yellow rust. Fsd-85 and Rawal-87 were also resistant to yellow rust. In 2000, Wan *et al*., detected 37 different virulence patterns from 926 yellow rust samples. In 2008, Fayyaz *et al*., carried out the virulence studies and found the *Lr* genes having virulence at Nawabshah and Karachi, partial virulence was seen on different *Lr* genes at 3 localities. Bux *et al*., in 2011 examined the virulence pattern of wheat stripe rust and found that *Yr5*, *Yr26, Yr3, Yr15, Yr10, YrCV* and *YrSP* were resistant and Yr18 moderately susceptible and fifty one commercial varieties Marvi2000, Barani70, GA2000 and Seher2006 were resistant. To predict disease severity, relationship of environmental conditions to disease severity has its importance as well. The study of environmental factors conducive for stripe rust which help out to predict stripe rust epidemics, so that precautionary measures should be taken well in time to minimize the yield losses and to ensure the quality of the wheat. Present study was also focused on the correlation of environmental factors with yellow rust responses. Hussain, in 1999, examined that Inq-91 was not infected from rust pathogen also had various temperature susceptible genes confer resistance to stripe rust. When temperature increased from 22 ºC stripe rust in progress to decline. While, at temperature 40 ºC the spores of yellow rust were healthy and fresh. With the increasing amount of precipitation and in relative humidity stripe rust of wheat were also in increasing trend. Wind speed also an environmental factor which cannot be neglected here. TeBest *et al*., in 2008, reported that intensity of stripe rust was favored by a model with temperature, humidity and rainfall. In the same line stripe rust had showed same association with environmental factors. There was positive relationship between stripe rust severities and maximum temperature as observed on all 150 varieties/lines. Out of the varieties/lines 74 showed considerable reaction with an increase in temperature. There was positive relationship between stripe rust severities and relative humidity. 35 varieties showed considerable reaction with an increase in relative humidity. There was positive correlation between wind speed and stripe rust disease severities. While, results are conflicting to that of Khan 1994, there was negative linear relationship between relative humidity, rainfall and yellow rust severities. Singh and Tewari in 2001 showed that the main cause of epidemic may be the favorable environmental conditions. Under suitable environment, the chance of disease incidence increases. Padmaker *et al*., in 2001 showed that there was negative correlation of stripe rust severities with relative humidity, maximum temperature and wind speed. Sajjid *et al*., in 2010, creating infection, artificial inoculation on to the crop with stripe and leaf rust urediospores and determined the correlation between yellow rust. There was positive correlation between minimum and maximum temperature at 15-25 ºC and 30-35 ºC, respectively, while negative correlation in rising relative humidity and rainfall for the development of stripe rust.

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Appendix: List of varieties/Lines included in the trial conducted at AARI during 2010-2012.

Sr.No	Symbols of Varieties	Varieties/Lines
1	V-1	Chenab-2000
2	V-2	Frontana
3	V-3	Iqbal-2000
4	V-4	Lu-26
5	V-5	ERA
6	V-6	Nacozari-76
7	V-7	Crow
8	V-8	Fsd-83
9	V-9	Fsd-85
10	Morocco	Morocco
11	V-11	GA-2002
12	V-12	CHK-86
13	V-13	CHK-97
14	V-14	CHRIS
15	V-15	AS-2002
16	V-16	Blue Silver
17	V-17	BWP-97
18	V-18	BHK-02
19	V-19	GPWP 118
20	Morocco	Morocco
21	V-21	Kohisar-95
22	V-22	Local White
23	V-23	LYP-73
24	V-24	MH-97
25	V-25	C-271
26	V-26	C-273
27	V-27	HD-2169
28	V-28	HD-2179
29	V-29	Bou White
30	Morocco	Morocco
31	V-31	C-518
32	V-32	C-591
33	V-33	Koh-i-Noor-83
34	V-34	Maxipak-65
35	V-35	Manthar
36	V-36	Bwp-2000
37	V-37	Inq-91
38	V-38	Koh
39	V-39	SA-42
40	Morocco	Morocco
41	V-41	SA-75
42	V-42	V-85205
43	V-43	V-87094
44	V-44	V-02192
45	V-45	Pb-96

46	V-46	Pak-81
47	V-47	Parwaz-94
48	V-48	PND-I
49	V-49	Lasani-08
50	Morocco	Morocco
51	V-51	HD-29
52	V-52	Fsd-08
53	V-53	V-04179
54	V-54	Spica
55	V-55	Pb-76
56	V-56	Pb-81
57	V-57	Pb-85
58	V-58	Pavon-76
59	V-59	Shalimar-88
60	Morocco	Morocco
61	V-61	Borlog-95
62	V-62	WH-542
63	V-63	V-03079
64	V-64	Yecora
65	V-65	Uqab-2000
66	V-66	Sarsabaz
67	V-67	DR. 07028
68	V-68	DR. 07029
69	V-69	WL-711
70	Morocco	Morocco
71	V-71	Rawal-87
72	V-72	Rohtas-90
73	V-73	Shafaq-06
74	V-74	Pothohar-73
75	V-75	Nasir-2k
76	V-76	Parulla
77	V-77	Pasban-90
78	V-78	PBW-343
79	V-79	Seher-06
80	Morocco	Morocco
81	V-81	Ufaq-2000
82	V-82	Fareed-06
83	V-83	W-462
84	V-84	AOC-YRA
85	V-85	AOC+YRA
86	V-86	Yr-I
87	V-87	Yr-2
88	V-88	Yr-5
89	V-89	Yr-6
90	Morocco	Morocco
91	V-91	Yr-7

92	V-92	Yr-8
93	V-93	Yr-9
94	V-94	Yr-10
95	V-95	Yr-15
96	V-96	Yr-17
97	V-97	Yr-18
98	V-98	Yr-24
99	V-99	Yr-26
100	Morocco	Morocco
101	V-101	Yr-27
102	V-102	Yr-28
103	V-103	Yr-29
104	V-104	Yr-31
105	V-105	Punjab-11
106	V-106	Millat-11
107	V-107	AARI-11
108	V-108	PBW-343
109	V-109	Super Kauz
110	Morocco	Morocco
111	V-111	YRCV
112	V-112	Lr-I
113	V-113	Lr-2a
114	V-114	Lr-2b
115	V-115	Lr-2c
116	V-116	Lr-3
117	V-117	Lr-3KA
118	V-118	Lr-3BG
119	V-119	Lr-9
120	Morocco	Morocco
121	V-121	Lr-10
122	V-122	Lr-11
123	V-123	Lr-12
124	V-124	Lr-13
125	V-125	Lr-14a
126	V-126	Lr-14b
127	V-127	Lr-15
128	V-128	Lr-16
129	V-129	Lr-17
130	Morocco	Morocco
131	V-131	Lr-18
132	V-132	Lr-19
133	V-133	Lr-20
134	V-134	Lr-21
135	V-135	Lr-22a
136	V-136	Lr-22b
137	V-137	Lr-23

138	V-138	Lr-24
139	V-139	Lr-25
140	Morocco	Morocco
141	V-141	Lr-26
142	V-142	Lr-27+31
143	V-143	Lr-28
144	V-144	Lr-29
145	V-145	Lr-30
146	V-146	Lr-32
147	V-147	Lr-33
148	V-148	Lr-34
149	V-149	Lr-35
150	Morocco	Morocco