Research Article

Identification of Resistance Sources in Wheat to Brown and Yellow Rust

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Abstract | Current research was depicted the level of resistance among the available wheat germplasm in Pakistan against the deadly rust disease. 152 lines of the wheat were screened against brown and yellow rust of wheat which are a serious pathosystem of wheat throughout the world. Some varieties were found resistant some were found moderately resistant while some were in susceptible response against the both rust disease. No variety was found to be resistant at all against the rust pathosystems. Correspondingly, in the results of yellow rust some varieties were found resistant and some were found to be the most susceptible on the record. The epidemiological studies showed the correlation of the relative humidity of morning, evening and temperature positively in both of the rust disease. Fungicidal application showed great reduction in the management of the disease.

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Keywords | *Triticum aestivum* L., Leaf rust, *Puccinia recondita* f. sp. *tritici*, Stripe rust, *Puccinia striiformis* f. sp. *tritici*

Introduction

Wheat (*Triticum aestivum* L.) is an important crop and staple food for the people of Pakistan. It contributes 34% to GDP (Anonymous, 2015). During recent studies, it has been reported that 100g of edible portion of wheat grains contain 11.50% proteins, 59.40% carbohydrates, 9.70% fats, 10.60% crude fibers and 1.80% ash (Agarwal et al., 2005). In Pakistan, wheat ranked first as staple food followed by rice and maize. The cultivated area of wheat has been recorded 8.49 million ha with production of 23.52 million tons (Anonymous, 2015). This alarming gap between ever increasing demand and current production is a big challenge for all plant scientists. This challenge can be met over by increasing: (a) area under production, (b) yield per unit area and (c) minimizing the production losses. Increasing area seems almost impossible because of constraints like drought, salinity, water logging and trends in urbanization. The wheat crop is attacked by many diseases, of which rusts are of great importance. There are three types of rusts which are found on wheat. Leaf rust or brown rust is caused by *Puccinia recondita* f.sp. *tritici* while stripe rust or yellow rust is caused by *Puccinia striiformis* f. sp. *tritici* and stem rust or black rust is caused by *Puccinia graminis* f. sp. *tritici*. Leaf and stripe rusts appear periodically on wheat crop and induce heavy losses in yield (Kolmer et al., 2009). Leaf rust or brown rust of wheat is a serious production hazard in wheat all over the world and is an air-borne foliar disease on which early maturing wheat cultivars largely escape serious rust damage. Round to oblong, brick-red pustules (uredia) appear on leaves, stems

and later on heads. As the crop ripens, black spores (telia) are produced. Similarly, stripe rust or yellow rust, is one of the most common fungal diseases of bread wheat in many countries because it is also an air borne disease. In the same way oblong, brick red pustules (uredia) appear on leaves, stems and later on heads and as crop ripens the black spores are produced (Hafiz, 1986). Hussain (1989) reported the occurrence of race one hundred and four *Puccinia recondita* f. sp. *Tritici* of which three pathotypes were distinguished. However, the new race was unable to overcome the resistance gene *Lr13* and *Lr26* most probably occurring in Pakistan cultivars. Environmental conditions play an important role in the development of the disease. Khan (1985) studied fifteen varieties of Wheat genotypes on slow rusting response in relation to environmental factors on these varieties. Different varieties showed slow rusting response at 77-78% R.H, 22-28 ˚C maximum temperature and 16-18 ˚C minimum temperature. Keeping in view the above facts regarding the rust diseases of the wheat the current research was planned to evaluate the collection of resistant sources against the rust disease of wheat and to determine the conducive environmental variable facilitating the disease in the field.

Materials and Methods

Establishment of rust screening nursery

Seeds of 152 genotypes were collected from the Ayub agriculture research institute (AARI) Faisalabad. Nursery was sown in area of wheat research institute (WRI) of ARRI. Nursery was sown in normal wheat season in experimental area. Line sowing 3m was done with R×R = 30cm. In order to maintain crop health and vigor agronomic practices were followed to keep the crop in good condition.

Artificial inoculation of wheat plants

Artificial inoculation was done by spraying urediospore suspension (30 gram of spore/16 liter of water). After every 5th line/variety a line of highly susceptible wheat cultivar i.e. Morocco, was sown to act as rust spreader row. (Morocco is highly susceptible to all the prevalent rust races and provides a substrate for rapid multiplication and distribution of rust inoculums). The nursery was also surrounded by sowing two rows of morocco to increase the inoculums pressure.

Data collection

Leaf and Stripe rust reaction, symbol field response and response value were recorded by the modified Cobb's scale described by Peterson et al. (1948). Disease severity was recorded after seven days' interval. Rust data were recorded up to physiological maturity of the wheat. The disease severity data was for leaf and stripe rusts was converted into coefficient of infection by multiplying severity with constant value for field response as described by Stubbs et al. (1981) and Raelf et al. (1992). Cobb's scale (Peterson et al., 1948) was used to record the rust severity data (Table 1).

Table 1: *Leaf and Yellow rust reaction, symbol field response and response value.*

Reaction	Visual symptoms	Infection %
No disease	No visible infection	0
Moderately resistant	Small uredia present surrounded by necrotic area	10-19
Moderately resistant to moderately susceptible	Small uredia present surrounded by necrotic areas as well as medium uredia with no necrosis but possible some distinct chlorosis	20-39
Moderately susceptible	Medium uredia with no necrosis but possible some distinct chlorosis.	40-59
Moderately susceptible susceptible	Medium uredia with no necrosis but possible some disinct chlorosis as well as large uredia with little or chlorosis present.	60-79
Susceptible	Large uredia and little or no chlorosis present.	80-100

Meteorological data collection

Environmental data consisting of maximum and minimum air temperature, relative humidity and sunshine were recorded by conventional instruments installed in meteorological section of Ayub agriculture research institute Faisalabad.

Fungicidal management

Different chemicals were applied to evaluate the efficiency of chemicals in controlling the rust diseases. Susceptible variety MORROCO was selected for this purpose. Trial was conducted at experimental area of Ayub Agricultural Research Institute (AARI), Faisalabad. Fungicides were applied between leaf emergence and booting stages. Three chemicals, Tilt, Myco-guard and Score were evaluated at 200mL/10L, 125 ml/10 L and 125mL/10 L the recommended dose concentration respectively. Trial was conducted in Randomize Complete Block Design (RCBD) with

three replications. Data was analyzed statistically to determine the effectiveness of fungicides at 5% least significant difference using appropriate statistical tools.

Statistical analysis

All the collected datasets were subjected to analysis of variance by using SAS Carry Inc. 8.1 USA to determine the level of variability among the various genotypes through new Duncan's multiple range tests.

Table 2: *Response of different genotypes against leaf or brown rust of wheat.*

Sr. No.	Genotypes	Reaction Type	Sr. No.	Genotypes	Reaction Type
1	AS-2002	0	77	MOROCCO	100S
2	BHK-2002	0	78	V-03079	5MS
3	BLUE SILVER	20MR	79	HD-29	0
4	BOB WHITE	0	80	WH-542	0
5	BWP-2000	0	81	MOROCCO	100S
6	BWP-97	0	82	W-462	0
7	C-271	80S	83	BORLOG 95	5MR
8	MOROCCO	100S	84	DAMAN-98	30S
9	C-273	40S	85	LR-1	50S
10	C-518	30S	86	LR-29	10MRMS
11	C-591	40S	87	LR-2b	40S
12	CHK-86	0	88	LR-2c	30S
13	CHK-97	5S	89	LR-3	20S
14	CHAN-NAB-2000	0	90	MOROCCO	100S
15	CROW	0	91	LR-3KA	20MS
16	GA-2002	0	92	LR-3b6	10MSS
17	V-07096	30MRMS	93	LR-9	0
18	MOROCCO	100S	94	LR-10	40S
19	HD-2169	0	95	LR-11	5MRMS
20	HD-2179	0	96	LR-12	5MRMS
21	INQ-91	0	97	LR-13	5MS
22	IQBAL 2000	0	98	LR-149	30S
23	ERA	0	99	MOROCCO	100S
24	FSD-83	0	100	LR-14b	0
25	FSD-85	0	101	LR-15	10MS
26	FRONTANA	0	102	LR-16	10S
27	KOH-I-NOOR 83	10S	103	LR-17	10MRMS
28	MOROCCO	100S	104	LR-18	10MRMS
29	KOHSAR 95	10S	105	LR-19	0
30	KOH-97	0	106	LR-20	30S
31	LOCAL WHITE	0	107	LR-21	20MRMS
32	LU-26	0	108	MOROCCO	100S
33	LYP-73	0	109	LR-22a	0
34	MANTHAR	10MRMS	110	LR-22b	10S
35	MAXPAL 65	40S	111	LR-23	20S
36	MH-97	0	112	LR-24	0
37	NACOZAR 76	0	113	LR-25	5MS
38	MOROCCO	100S	114	LR-26	20MRMS
39	NASIR 24	0	115	LR-27+31	5MRMS
40	PAK-81	30S	116	LR-28	0
41	PARULLA	0	117	MOROCCO	100S
42	PARWAZ-94	0	118	LR-29	10MS
43	PASBAN 90	0	119	LR-30	30S
44	PAVON-76	0	120	LR-32	10MS
45	PBW-343	0	121	LR-33	5MRMS
46	PND-1	0	122	LR-34	10MRMS
47	POTOHAR 73	0	123	LR-35	10MRMS
48	MOROCCO	100S	124	LR-36	0
49	PB-76	60S	125	LR-37	MRMS
50	PB-81	30S	126	MOROCCO	100S
51	PB-85	10S	127	LR-b	60S
52	PB-96	0	128	LR-b(WL-711)	5S
53	RAWAL-87	0	129	LR-23 GAZA	0
54	ROHTAS 90	20S	130	AOCYRA	0
55	SEHAR 06	20S	131	AOC+YRA	0
56	SHAFAQ 06	0	132	YR-1	0
57	SA-42	60S	133	YR-2	20S
58	MOROCCO	100S	134	TATARA	30S
59	SA-75	5MS	135	MOROCCO	100S
60	SARSABZ	0	136	YR-5	0
61	SHALIMAR 88	20S	137	YR-6	5MRMS
62	SPICA	40S	138	YR-7	0
63	UFFAQ 2000	0	139	YR-8	0
64	UQAB 2000	0	140	YR-9	20S
65	FAREED 06	0	141	YR-10	0
66	V-085205	0	142	YR-15	10S
67	V-87094	0	143	YR-17	20S
68	MOROCCO	100S	144	MOROCCO	100S
69	V-02192	10S	145	YR-18	0
70	WL-711	0	146	YR-24	0
71	YACORA	0	147	YR-26	0
72	DR-07028	0	148	YR-27	5MRMS
73	DR-07029	0	149	YRSP	0
74	V-04179	0	150	MOROCCO	100S
75	LASSANI 08	10MR	151	SERI	0
76	FSD 08	0	152	PBW-343	0

Results and Discussion

Screening of wheat genotypes against leaf rust

Sixty eight resistant genotypes (AS-2002,BHK-2002,Bob-WHITE,BWP-2000,BWP-97, CHK-86, CHENAB-2000, CROW, GA-2002, HD-2169, HD-2179, INQ91, IQBAL2000, ERA, FSD-83, FSD-85,FRONTANA,KOH-97,LOCALWHITE, LU-26, LYP-73, MH97, NACOZAR-76, NASIR-2K, PARULLA, PARWAZ-94, PASBAN-90, PAVAN-76, PVW-343, PND-1, POTOHAR-73, PB-96, RAWAL-87, SHAFAQ-06, SARSABZ, UFFAQ-2000, UQAB-2000, FAREED-06, V-085205, V-87094, WL-711, YACORA, DR-O7028, DR-7029, V-04179, FSD-08, HD-29, WH-542, W462, LR-9, LR-14B, LR-19, LR-22A, LR-24,

LR-28, LR-23GAZA, AOC-YRA, AOC+YRA, YR-1, YR-5, YR-7, YR-8, YR-10, YR-18, YR-24, YR-26, YRSP, SERI, PBW343, showed AUDPC as 170, 85, 70, 110, 80, 80, 85 and 95 respectively. Thirty-seven susceptible varieties such as (C271, C273, C518, C591, CHAKWAL-97, KOH-INOOR-83, KOHSAR-95, MAX-PAK65, PAK-81, PB-76, PB-81, PB-85, ROHTAS-90, SAHAR-06, SA-42, SHALIMAR-88, SPICA, V-02192, DAMAN-98, LR-1, LR-2B, LR-2C, LR-3, LR-10, LR-149, LR-16, LR-20, LR-22B, LR-23, LR-30, LR-B, LR-BWL-711, YR-2, TATARA, YR-9, YR-15 and YR-17) with response value 1.0 for each variety (Table 2).

Table 3: *Response of different genotypes against stripe or yellow rust of wheat.*

Sr. No	Genotypes	Reaction Type	Sr. No	Genotypes	Reaction Type
1	AS-2002	0	77	MOROCCO	100S
2	BHK-2002	40S	78	V-03079	5S
3	BLUE SILVER	10MRMS	79	HD-29	10S
4	BOB WHITE	10S	80	WH-542	10MRMS
5	BWP-2000	5S	81	MOROCCO	100S
6	BWP-97	5S	82	W-462	5S
7	C-271	0	83	BORLOG 95	0
8	MOROCCO	100S	84	DAMAN-98	20S
9	C-273	0	85	LR-1	0
10	C-518	0	86	LR-29	20S
11	C-591	0	87	LR-2b	0
12	CHK-86	5MR	88	LR-2c	5S
13	CHK-97	10MRMS	89	LR-3	10MS
14	CHANNAB-2000	20S	90	MOROCCO	100S
15	CROW	10S	91	LR-3KA	10S
16	GA-2002	10MRMS	92	LR-3b6	10S
17	V-07096	0	93	LR-9	20S
18	MOROCCO	100S	94	LR-10	5S
19	HD-2169	10MRMS	95	LR-11	40S
20	HD-2179	20S	96	LR-12	5S
21	INQ-91	40S	97	LR-13	5S
22	IQBAL 2000	10S	98	LR-149	10MS
23	ERA	5S	99	MOROCCO	100S
24	FSD-83	30S	100	LR-14b	10S
25	FSD-85	10S	101	LR-15	5S
26	FRONTANA	5S	102	LR-16	5S
27	KOH-I-NOOR 83	10S	103	LR-17	5S
28	MOROCCO	100S	104	LR-18	5MS
29	KOHSAR 95	5S	105	LR-19	10S
30	KOH-97	20S	106	LR-20	5MRMS
31	LOCAL WHITE	80S	107	LR-21	10MS
32	LU-26	20MRMS	108	MOROCCO	100S
33	LYP-73	5MS	109	LR-22a	5S
34	MANTHAR	5MS	110	LR-22b	0
35	MAXPAL 65	20S	111	LR-23	10S
36	MH-97	10S	112	LR-24	5S
37	NACOZAR 76	20S	113	LR-25	20S
38	MOROCCO	100S	114	LR-26	10MR
39	NASIR 24	20S	115	LR-27+31	5MRMS
40	PAK-81	5MRMS	116	LR-28	0
41	PARULLA	0	117	MOROCCO	100S
42	PARWAZ-94	0	118	LR-29	5MS
43	PASBAN 90	10S	119	LR-30	0
44	PAVON-76	10S	120	LR-32	0
45	PBW-343	0	121	LR-33	0
46	PND-1	20S	122	LR-34	0
47	POTOHAR 73	60S	123	LR-35	5S
48	MOROCCO	100S	124	LR-36	5S
49	PB-76	10S	125	LR-37	10S
50	PB-81	20S	126	MOROCCO	100S
51	PB-85	10S	127	LR-b	0
52	PB-96	30S	128	LR-b(WL-711)	20S
53	RAWAL-87	10S	129	LR-23 GAZA	30MRMS
54	ROHTAS 90	5S	130	AOCYRA	80S
55	SEHAR 06	10S	131	AOC+YRA	50S
56	SHAFAQ 06	10S	132	YR-1	5S
57	SA-42	0	133	YR-2	10S
58	MOROCCO	100S	134	TATARA	5S
59	SA-75	0	135	MOROCCO	100S
60	SARSABZ	5S	136	YR-5	0
61	SHALIMAR 88	30S	137	YR-6	10S
62	SPICA	10S	138	YR-7	20S
63	UFFAQ 2000	5S	139	YR-8	40S
64	UQAB 2000	10MS	140	YR-9	0
65	FAREED 06	10MR	141	YR-10	0
66	V-085205	5MRMS	142	YR-15	0
67	V-87094	10S	143	YR-17	0
68	MOROCCO	100S	144	MOROCCO	100S
69	V-02192	5S	145	YR-18	0
70	WL-711	30S	146	YR-24	5MR
71	YACORA	5S	147	YR-26	5MRMS
72	DR-07028	0	148	YR-27	5S
73	DR-07029	0	149	YRSP	5MRMS
74	V-04179	0	150	MOROCCO	100S
75	LASSANI 08	0	151	SERI	5MS
76	FSD 08	10MS	152	PBW-343	20S

Screening of wheat genotypes against yellow rust

Thirty one resistant varieties (AS-2002, C-271, C-273, C-518, C-591, V07096, PARULLA, PARWAZ-94, PBW-343, SA-42, SA-75, DR-07028, DR-07029, V-04179, LASANI-08, BORLOUG-95, LR-1, LR-2B, LR-22B, LR-28, LR-30, LR-32, LR-33, LR-34, LR-B, LR-5, YR-9, YR-10, YR-15, YR-17, YR-18), with response value 0.2 for each variety. Sixty three susceptible varieties such as (MAX-PAK-65, MH-97, NACOZAR-76, NASIR-2K, PASBAN-90,

PAVAN-76, PND-1, POTOHAR-73, PB-76, PB-81, PB-85, PB-96, RAWAL-87, ROHOTAS-90, SEHAR-06, SHAFAQ-06, SARSABZ, SHALIMAR-88, SPICA, UFAQ-2000, V-87094, V-02192, WL-711, YACURA, V-03079, W-462, DAMAN-98, LR-29, LR-2C, LR-3KA, LR-3B6, LR-9, LR-10, LR-11, LR-12, LR-13, LR-14B, LR-15, LR-16, LR-17, LR-19, LR-22A, LR-23, LR-24, LR-25, LR-35, LR-36, LR-37, LR-BWL711, AOC-YRA, AOC+YRA, YR1, YR-2, TATARA, YR-6, YR-7, YR-8, YR-27, PBW-343), with response value 1.0 for each variety. Three moderately resistant varieties (CHK-86, FAREED-06, LR-26) with response value 0.4 for each variety. Ten moderately susceptible varieties (LYP-73, MANTHAR, UQAB-2000, FSD-08, HD-29, LR-3, LR-149, LR-18, LR-21and LR-29) with response value 0.8 for each variety. Ten moderately resistant to moderately susceptible varieties (BLUE SILVER, CHK-97, GA-2002, HD-2169, LU-26, PAK-81, V-085205, WH-542, LR-20 and LR-27+31) with response value 0.6 for each variety (Table 3).

Relationship of environmental variables with disease severity of leaf rust and stripe rust

Effect of maximum temperature on leaf rust: The correlation of maximum temperature with leaf rust infection was found to be positive in all five genotypes/varieties. There was increasing trend in leaf rust disease development with maximum air temperature. The data shows that the disease severity increase with the increase in Temperature in varieties MANTHAR, MAXPAL 65, SHALIMAR 88, MOROCCO and LR-30 (Figure 1).

Effect of minimum temperature on leaf rust: The correlation of minimum temperature with leaf rust infection was found to be positive in all five genotypes/varieties. There was increasing trend in leaf rust disease development with minimum air temperature. The data shows that the disease severity increase with the increase in Temperature in varieties MANTHAR, MAXPAL 65, SHALIMAR 88, MOROCCO and LR-30. (Figure 2).

Effect of relative humidity on leaf rust: The correlation of relative humidity with leaf rust infection was found to be positive in all five genotypes/varieties. There was increasing trend in leaf rust disease development with relative humidity. The data shows that the disease severity increase with the increase in Temperature in varieties MANTHAR, MAXPAL 65, SHALIMAR 88, MOROCCO and LR-30 (Figure 3).

Effect of rain fall on leaf rust: The correlation of rain fall with leaf rust infection was found to be negative in all five genotypes/varieties. There was decreasing trend in leaf rust disease development with rain fall. The data shows that the disease severity decrease with the increase in rain fall in varieties MANTHAR, MAXP AL 65, SHALIMAR 88, MOROCCO and LR-30 (Figure 4).

Effect of maximum temperature on stripe rust: The correlation of maximum temperature with leaf rust infection was found to be positive in all five genotypes/varieties. There was increasing trend in leaf rust disease development with maximum air temperature. The data shows that the disease severity increase with the increase in Temperature in varieties CHANNAB-2000, GA-2002, MANTHAR, ROHTAS 90 and SARSABZ (Figure 5).

Effect of minimum temperature on stripe rust: The correlation of minimum temperature with leaf rust infection was found to be positive in all five genotypes/varieties. There was increasing trend in leaf rust disease development with minimum air temperature. The data shows that the disease severity increase with the increase in Temperature in varieties CHANNAB-2000, GA-2002, MANTHAR, ROHTAS 90 and SARSABZ (Figure 6).

Effect of relative humidity on stripe rust: The correlation of relative humidity with leaf rust infection was found to be positive in all five genotypes/varieties. There was increasing trend in leaf rust disease development with relative humidity. The data shows that the disease severity increase with the increase in Temperature in varieties CHANNAB-2000, GA-2002, MANTHAR, ROHTAS 90 and SARSABZ (Figure 7).

Effect of rain fall on stripe rust: The correlation of rain fall with leaf rust infection was found to be negative in all five genotypes/varieties. There was decreasing trend in leaf rust disease development with rain fall. The data shows that the disease severity decrease with the increase in rain fall in varieties CHANNAB-2000,GA-2002, MANTHAR, ROHTAS 90 and SARSABZ (Figure 8).

Chemical control of brown rust and yellow rust: At the start of the experiment when no treatment was applied the value of mean disease severity was 40.

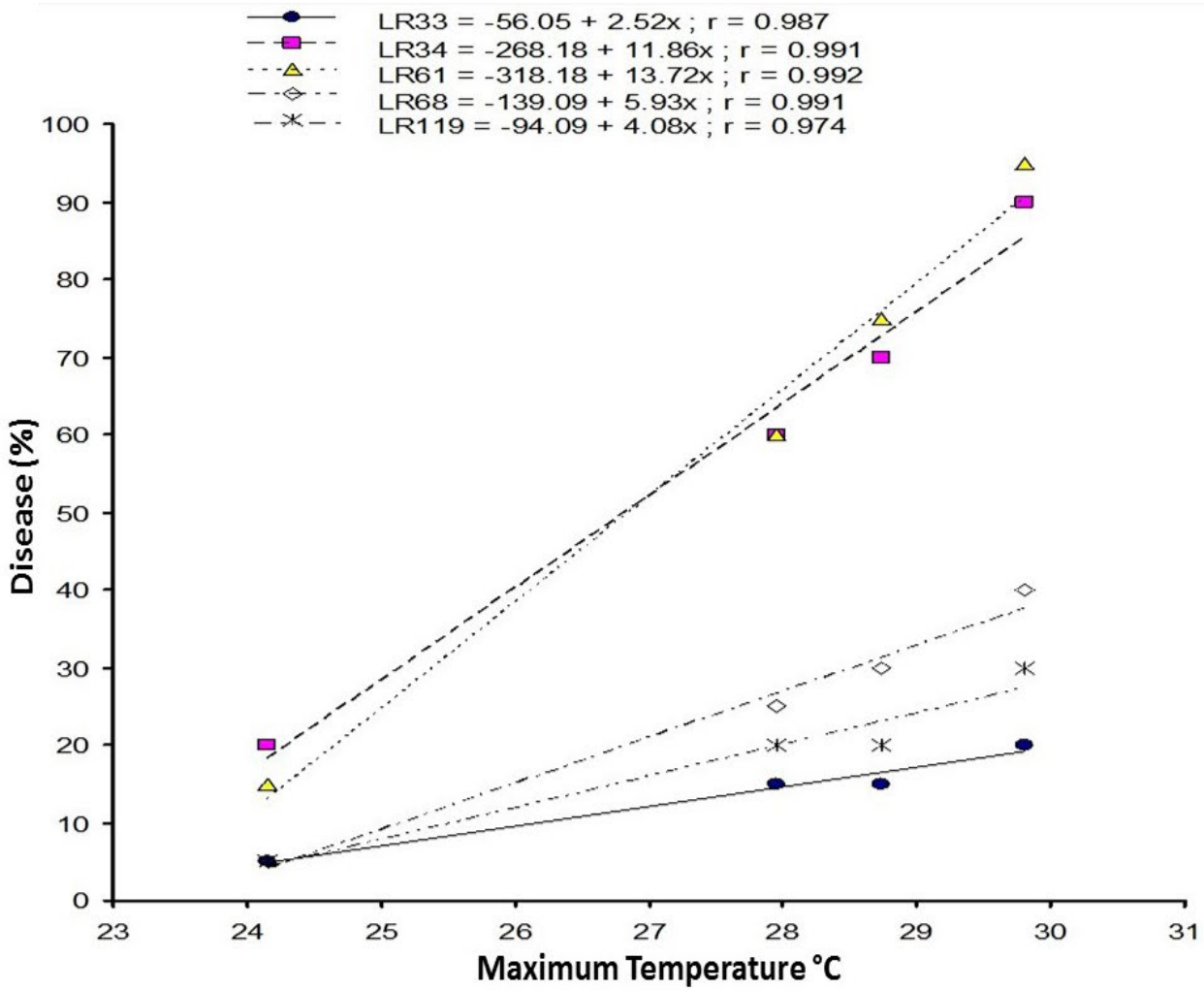

Figure 1: *Relationship between maximum temperature and Leaf rust for varieties.*

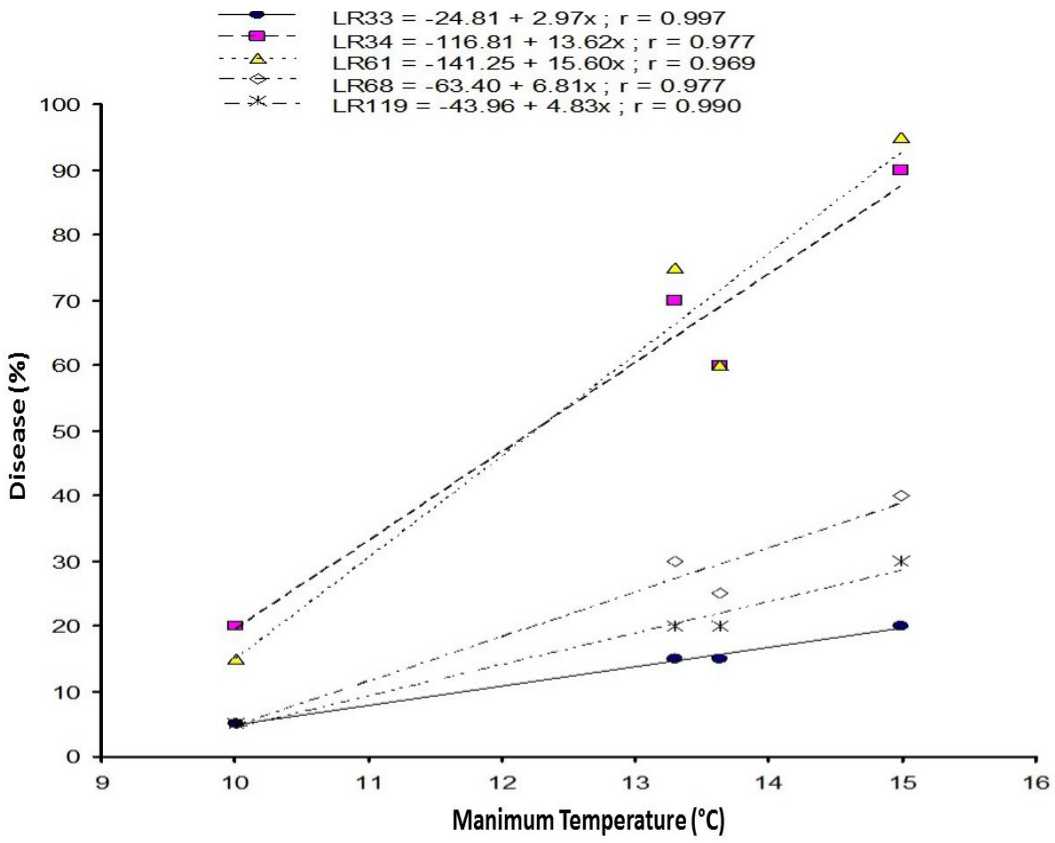

Figure 2: *Relationship between minimum temperature and Leaf rust for varieties.*

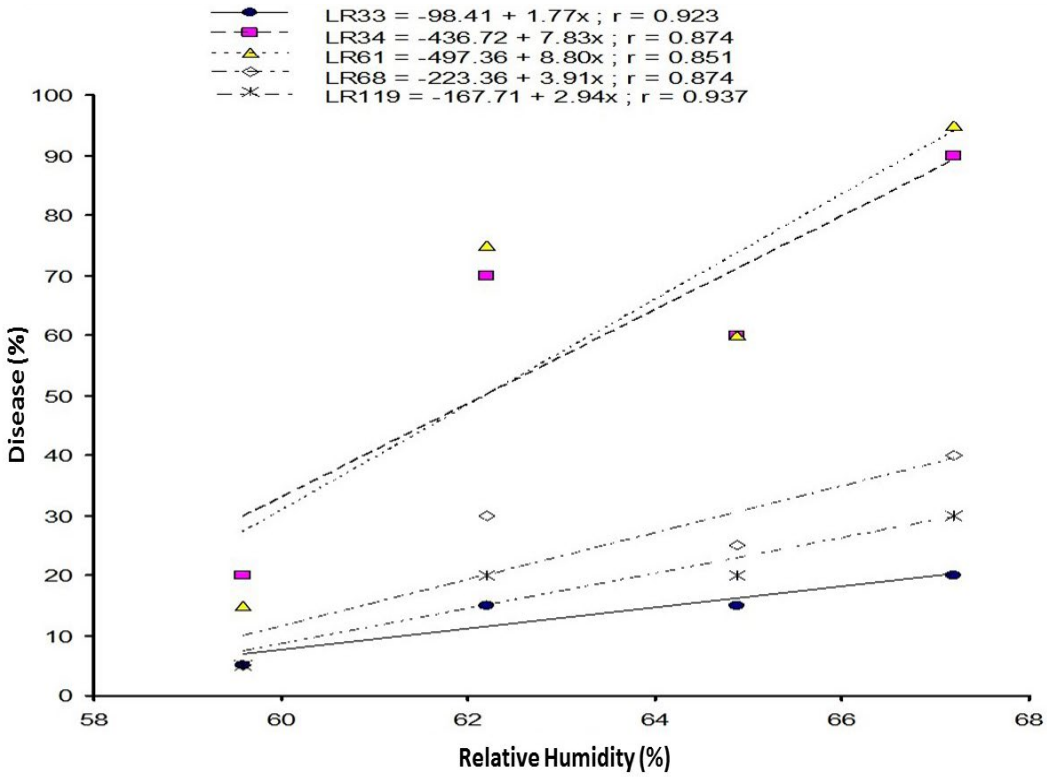

Figure 3: *Relationship between relative humidity and Leaf rust for varieties.*

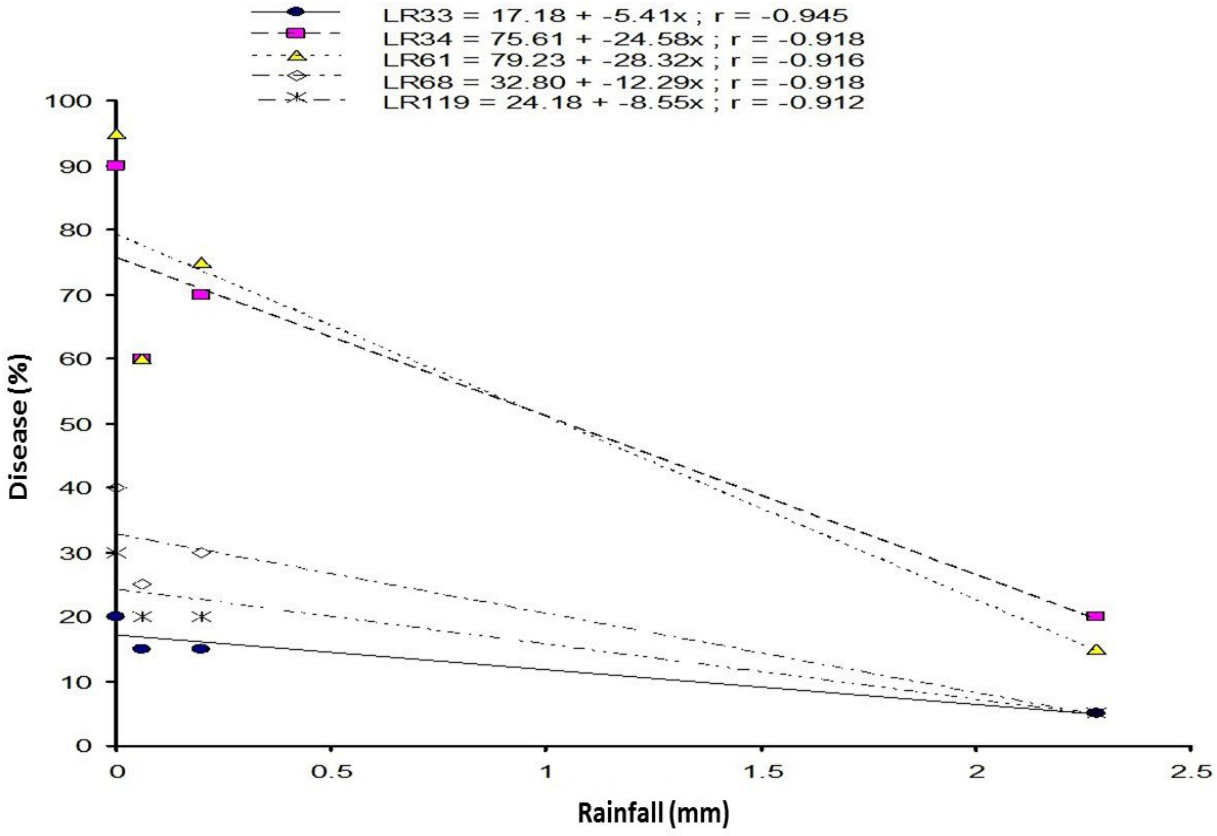

Figure 4: *Relationship between rain fall and Leaf rust for varieties.*

After three days' mean disease severity was reduced in those blocks where fungicides were applied and in the block of control. Values remain constant which was 40. After 7 days and 10 days' mean disease severity was also calculated (Table 4, Figure 9, Table 5, Figure 10).

Plant diseases are a great threat to plants, in such that fungal diseases facade a potential threat to successful cereal production in general and particularly wheat in Pakistan. Wheat is a staple food for the people of Pakistan so the rust diseases are of too economic

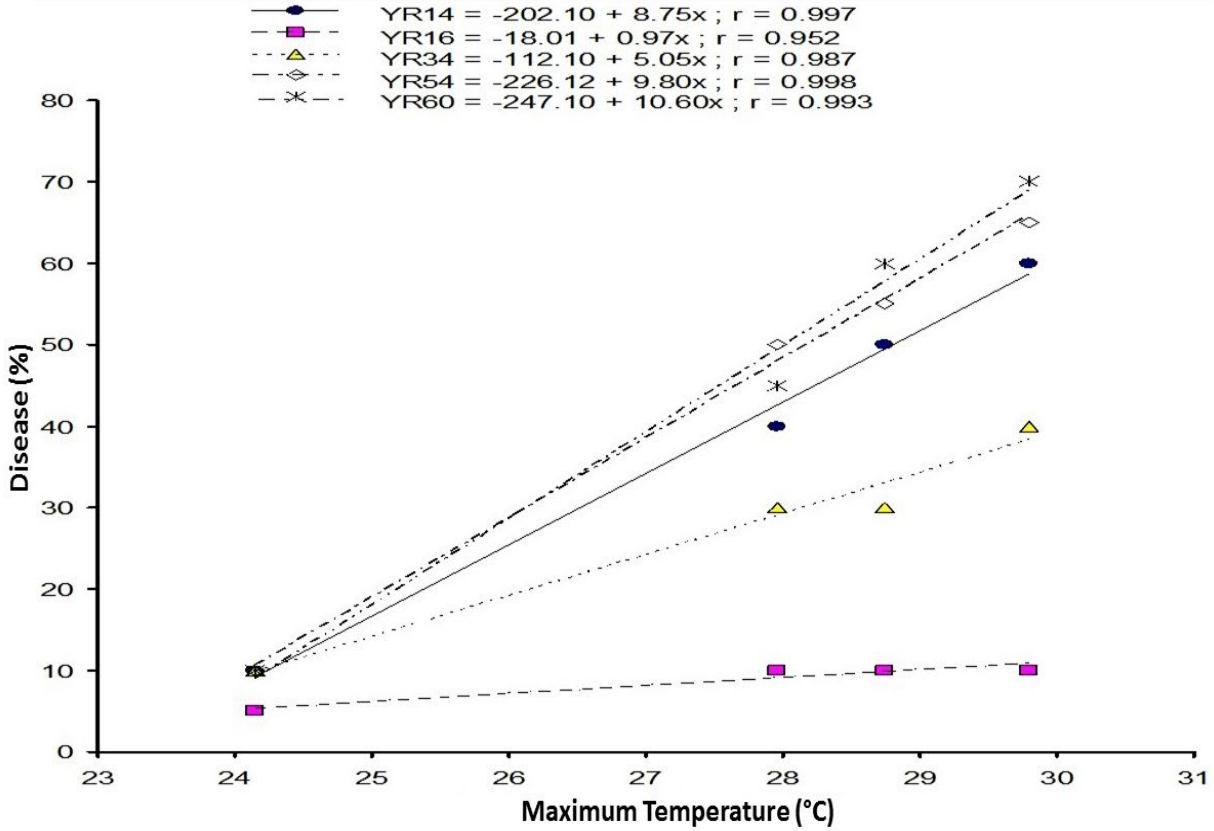

Figure 5: *Relationship between maximum temperature and Yellow rust for varieties.*

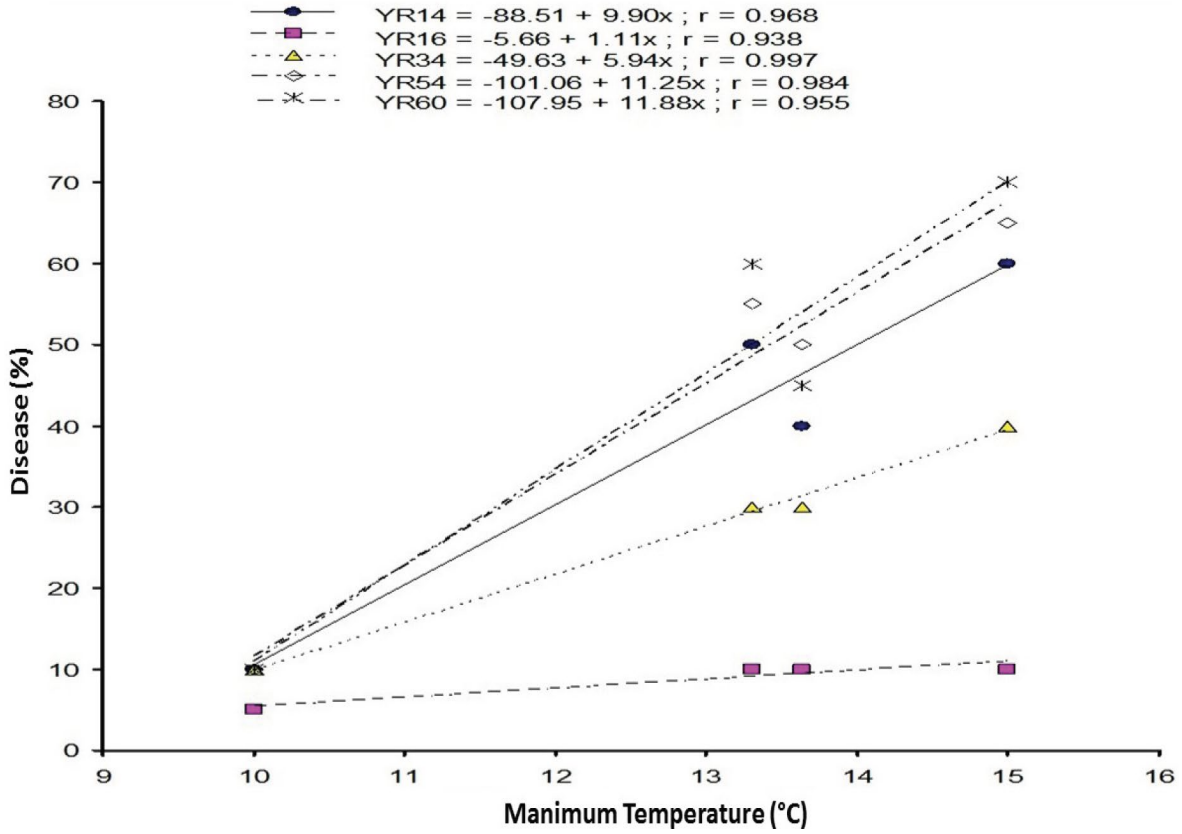

Figure 6: *Relationship between minimum temperature and Yellow rust for varieties.*

importance for Pakistan because they pose a serious threat to the wheat production. During the current research all the varieties showed a varying response regarding the development of disease with moderately resistant to highly susceptible. Yet it is too alarming that no variety is resistant against the rust pathogen in Pakistan. Afzal et al. (2009) during 2005-2007, carried out variability for field based partial resistance

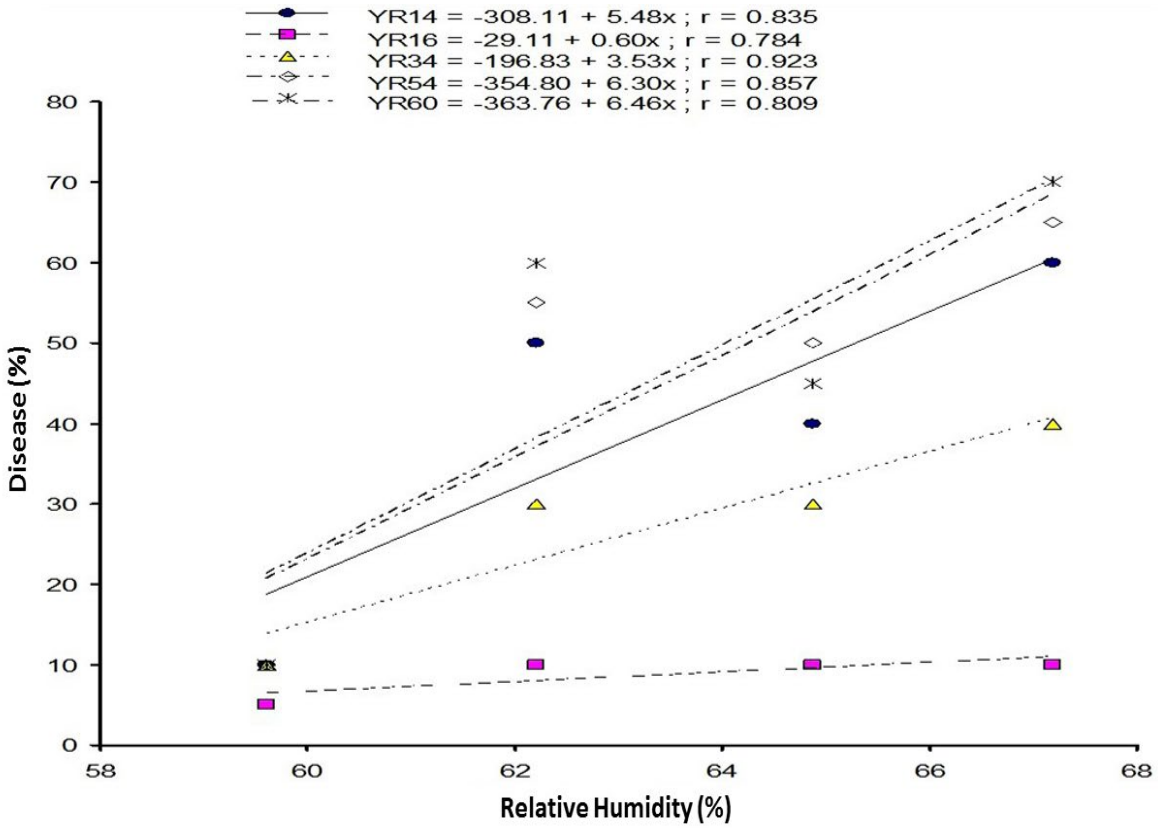

Figure 7: *Relationship between relative humidity and Yellow rust for varieties.*

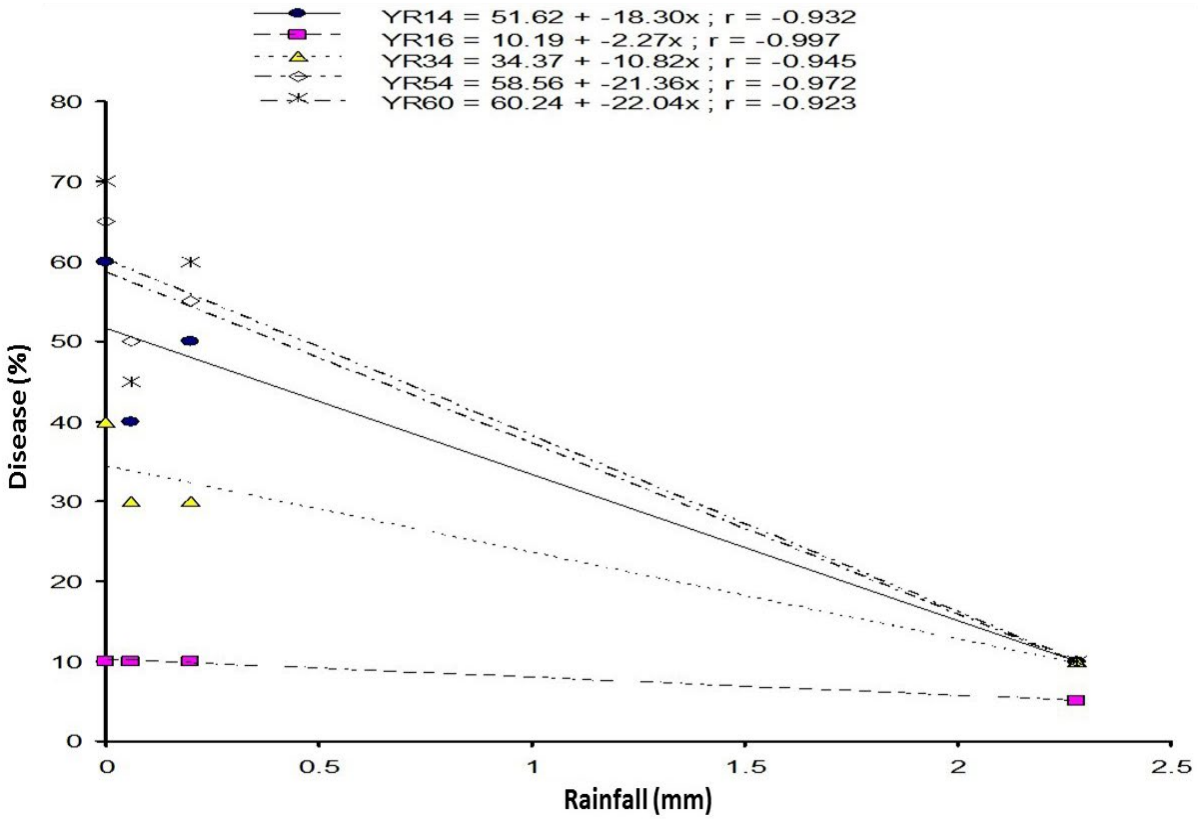

Figure 8: *Relationship between rain fall and Yellow rust for varieties.*

against stripe rust among 188 wheat breeding lines grown at the experimental area of the PMAS Arid Agriculture University, Rawalpindi, along with Morocco as susceptible check. The wheat lines and commercial varieties were screened out under natural climatic conditions of arid zone of Pakistan. Average Coefficient of Infection (ACI) and Relative Resistance Index (RRI) values of two year trial showed

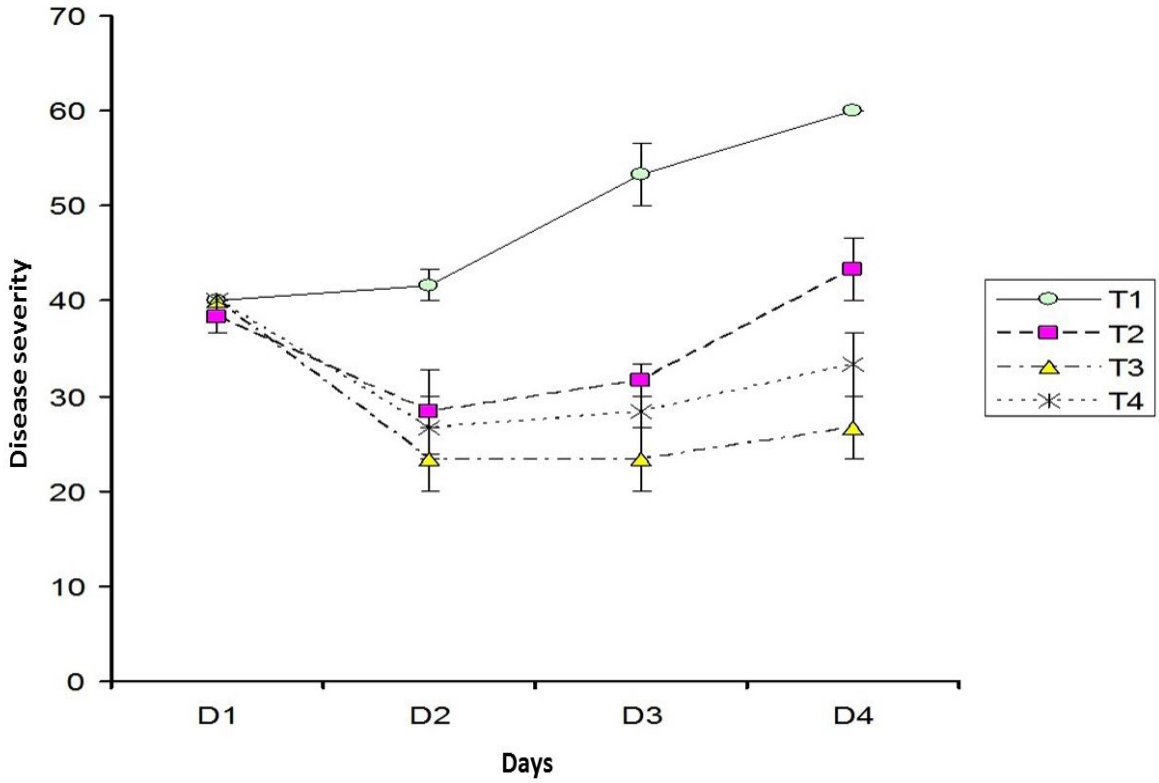

Figure 9: *Relationship of disease severity reduction of brown rust with days.*

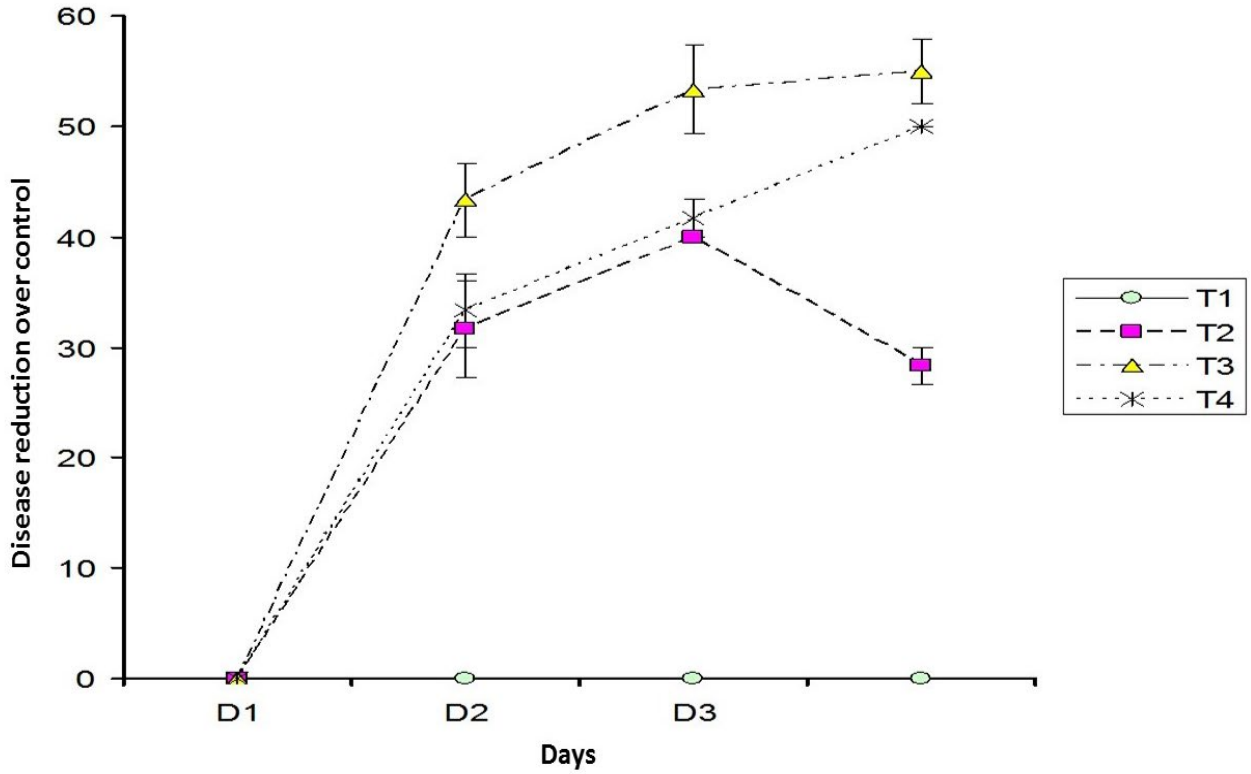

Figure 10: *Relationship of disease severity reduction of yellow rust with days.*

that out of 188 cultivars, 150 responded with RRI value ≥7 ≤9 and were found in the desirable range; 28 cultivars were included among the acceptable range having RRI value ≥5 ≤ 7. However, only 10 cultivars showed RRI value <5 and were placed under undesirable range. Ahmad et al. (2010) screened thirty six genotypes against yellow rust to check their level of susceptibility or resistance. Among these, 18 were susceptible, 6 were moderately susceptible to susceptible, 7 were moderately resistant to moderately susceptible and 5 genotypes remained resistant. Wheat yield lost due to varying level of yellow rust

Table 4: *Effect of different treatments on the disease severity of brown rust.*

Treatments	Application				Mean
	Before Application	After 3 days	After 7 days	After 10 days	
T1	40.00 ± 0.00 b-e	41.67 ± 1.67 b-d	53.33 ± 3.33 ab	60.00 ± 0.00 a	48.75 ± 2.62 A
T2	38.33 ± 1.67c-e	28.33 ± 4.41 d-f	31.67 ± 1.67 c-f	43.33 ± 3.33 bc	35.42 ± 2.17 B
T3	40.00 ± 0.00 b-e	23.33 ± 3.33 f	23.33 ± 3.33 f	26.67 ± 3.33 ef	28.33 ± 2.41 C
T4	40.00 ± 0.00 b-e	26.67 ± 3.33 ef	28.33 ± 1.67 d-f	33.33 ± 3.33 c-f	32.08 ± 1.89 BC
Mean	39.58 ± 0.42 A	30.00 ± 2.54 B	30.00 ± 2.54 B	34.17 ± 3.63 B	----

Table 5: *Effect of different treatments on the disease severity of yellow rust.*

Treatments	Application				Mean
	Before Application	After 3 days	After 7 days	After 10 days	
T1	39.00 ± 0.00 b-e	0.00±0.00e	0.00±0.00e	0.00±0.00e	0.00±0.00D
T2	36.33 ± 1.37c-e	31.67±4.41cd	40.00±0.00bcd	28.33±1.67d	33.33±2.20C
T3	38.00 ± 0.00 b-e	43.33±3.33abc	53.33±6.67ab	55.00±2.89a	50.56±2.94A
T4	37.00 ± 0.00 b-e	33.33±3.33cd	41.67±1.67a-d	50.00±0.00ab	41.67±2.64B
Mean	36.51 ± 0.41 A	27.08±5.09B	33.75±6.25A	33.33±6.58A	----

severities. Maximum severity of 90% of yellow rust resulted in 54% to 55% calculated and predicted losses, respectively. While 40, 50, 60 and 70% disease severity of yellow rust caused 35-34%, 38-37%, 42-40% and 46-47% calculated and predicted losses, respectively. Minimum temperature and relative humidity remained positively correlated while the maximum temperature showed negative correlation with stripe rust severity. With the rise of minimum temperature and relative humidity a rise up in stripe rust infection was seen while as the maximum temperature rise stripe rust infection decreased on different genotypes. From this study it may be concluded that epidemiological factors played important role in the dispersion of the disease which resulted in yield losses.

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Author's Contribution

Faqeer Hussain and Ateeq ur Rehman conceived the idea. The experiments were conducted by Muhammad Irfan, Syed Atif Hasan Naqvi, Muhammad Irfan wrote the article while statistical analysis was made by Ummad ud Din Umar and Muhammad Asif Zulfiqar.

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