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Environmental Factors and Yellow Rust Epidemic on Wheat Varieties in Punjab, Pakistan

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Abstract

This study was conducted at Barani Agricultural Research Station, Fatehjang, Punjab, Pakistan for two years during 2018 and 2019. A set of one hundred genotypes of wheat including commercial varieties and advanced lines from different sources were screened against yellow rust under field conditions. Based on observations against yellow rust, it was found that out of these 100 wheat genotypes 48 showed 60-100% yellow rust severity and characterized as susceptible to moderately susceptible. Twenty-three genotypes showed 40 – 59% yellow rust infection, while 17 showed 20-39% disease severity and characterized as moderately susceptible & moderately resistant to moderately susceptible respectively. Four genotypes showed 10-19% disease severity and were characterized as moderately resistant while only eight genotypes remained resistant. Yield losses were more than 46 % in wheat genotypes having maximum yellow rust severity upto 80% and yield losses were minimum in moderately resistant to resistant genotypes. When the maximum temperature rises in the winter months (February and March) then an increase in the yellow rust epidemic was seen. It was concluded from the study of these two consecutive years that the stripe rust disease epidemic is highly dependent on favorable environmental conditions like more humidity due to rainfall and a rise in maximum temperature.

Keywords: Srtipe Rust, Climatic Change, Yield Gaps

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Introduction

Agriculture is still the largest sector of the economy of Pakistan in terms of labor participation as the livelihood of the majority of the population directly or indirectly depends on it. However, during the last few decades, its contribution to GDP has gradually decreased to 19.3 percent. There is a lot of potential in this sector to increase its share in GDP through increased productivity utilization of the latest agricultural technologies. "Rabi", the second sowing season, begins from October to December and ended April to May. It is the major contributor to food security as wheat is grown in this season which is the main source of food in many developing countries. Wheat accounts for 8.7 percent in value addition of agriculture and 1.7 percent in GDP. With the 2.5 percent increase, wheat crop production reached up to 24.95 million tonnes in Pakistan (Anonymous, 2019-20).

Usually, three different types of rust attacks have been reported on wheat in Pakistan. These are Yellow rust (strips of yellow pustules on leaves), Leaf rust (brown pustules on leaves and stem), and Black rust (black pustules on-ear and stem) (Gessese, 2019). The epidemic of these types of rusts varies according to the agro-ecological zones of Pakistan (Bahri et al., 2011; Khan et al., 2021). In recent years, the yellow rust epidemic was observed in almost all over Pakistan (Ibrahim et al., 2017). Whereas, leaf rust epidemic was severe in northern areas of Pakistan and black rust attack was noticed in Sind Province. In past years, it was noted that the severity of yellow rust was increased in many latest approved wheat varieties which caused heavy yield losses all over Pakistan (Raza et al., 2018). Environmental conditions (such as rainfall, relative humidity, and temperature) were found to play an important role in the spreading of yellow rust. Maximum disease severity was observed when minimum and maximum temperature were ranging from 13.7-16.7 and 23.5-27.65 °C respectively. Humidity ranging from 52-64 %, rainfall ranging from 5.7-21.99 mm, and wind speed 6.88-11.73 km h^{-1} proved conducive for yellow rust development (Ali et al., 2017). A similar study was reported by Singh et al. (2001) that under suitable environmental conditions, the chances of disease epidemic and severity have been increased.

The objective of the study was to screen out the available germplasm to estimate yield losses caused by stripe rust disease concerning other environmental factors. The severity of rust disease and its correlation with yield losses can be helpful to build up germplasm which may be used in future breeding programs to develop rust-free and high-yielding wheat varieties according to different agro-ecological zones of Pakistan.

Material and methods

The wheat crop yield losses caused by yellow rust were estimated on a severity basis by using (Munday, 1973) equation based on the regression model. The yield losses with severity were explained graphically by the relationship of calculated and predicted losses. The equation used to calculate yield losses by stripe rust is given below:

Loss = (0.44 × disease severity) + 3.15 OR

Loss = (5.06 × the square root of the disease severity) – 17.15

For this purpose, an experiment was planned for two consecutive years i.e. 2018-19 and 2019-20. The germplasm consisting of one hundred wheat genotypes was sown in augmented design having two rows of each entry under field conditions at Barani Agricultural Research Station, Fatehjang, Punjab, Pakistan. Morocco and WL-711 were used as local yellow rust spreaders to induce rust inoculum under natural environmental conditions. Climatic data of air temperature (maximum and minimum), relative humidity (%), and rainfall (mm) were recorded by conventional instruments installed at the observatory of Soil and Water Conservation Research Station, Fatehjang (SAWCRS) which was close to the experimental area. Rust data was recorded after 7 days interval from mid-February to the end of March (Muhammad et al., 2020) The disease ratings were taken weekly by following the modified Cobb's scale described by (Peterson et al., 1948). The average coefficient of infection (ACI) was calculated according to (Stubbs et al., 1981) by multiplying disease severity (DS) and constant values of infection type (IT). The relationship of each environmental condition with stripe rust on different genotypes was determined by correlation and regression (Khan et al., 1998; Steel & Torrie, 1986).

Table 1. Yellow Rust Reaction in field

Reaction	**Reaction Symbol**	**Visual Symptoms**	**Infection%**
Resistant	R	No visible infection	0
Moderately resistant	MR	Small uredia present surrounded by necrotic area	10-19
Moderately resistant to moderately susceptible	MRMS	Small uredia present surrounded by necrotic areas as well as medium uredia with no necrosis but possible some distinct chlorosis	20-39
Moderately susceptible	MS	Medium uredia with no necrosis but possible some distinct chlorosis.	40-59
Moderately susceptible to susceptible	MSS	Medium uredia with no necrosis but possible some distinct chlorosis as well as large uredia with little or chlorosis present.	60-79
Susceptible	S	Large uredia and little or no chlorosis present.	80-100

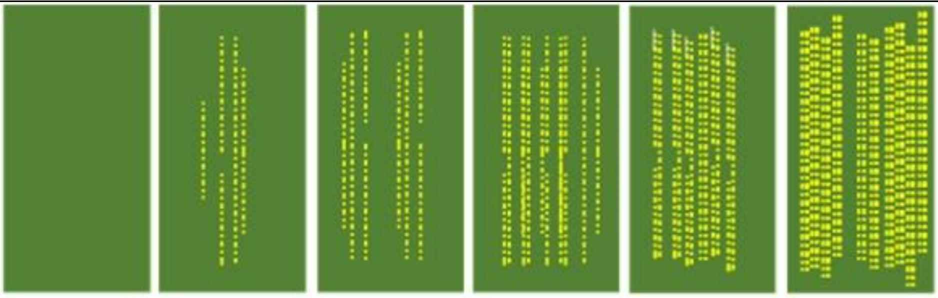

Figure 1. Scale of yellow rust severity (percentage of leaf area infected

The climatic data including rainfall pattern and its intensity, temperature, and humidity for the period of reported two years is given in the table 2 and table 3 for 2018-19 and 2019-20 respectively.

Table 2. Environmental data for 2018-19

Sr. No.	Month	Rainfall (mm)	Temperature (°C)	Humidity (%)
01	October 2018	40	18-30	60
02	November 2018	00	14-25	65
03	December 2018	32	10-20	75
04	January 2019	128	08-16	72
05	February 2019	72	09-17	76
06	March 2019	92	12-22	60
07	April 2019	00	20-32	60

Table 3. Environmental data for 2019-20

Sr. No.	Month	Rainfall (mm)	Temperature (°C)	Humidity (%)
01	October 2019	25	20-30	65
02	November 2019	10	14-22	73
03	December 2019	05	09-18	75
04	January 2020	90	06-13	68
05	February 2020	19	10-20	63
06	March 2020	296	13-21	75
07	April 2020	101	18-29	78

Results and discussion:

Characterization of wheat genotypes regarding yellow rust

The results mentioned in table 4 are based on two consecutive years of study at Barani Agricultural Research Station, Fatehjang during rabi seasons 2018-19 and 2019-20. These results showed that different wheat genotypes behaved differently against yellow rust severity during the reported years. It was seen that out of 100 wheat genotypes five showed 80-100% yellow rust severity and characterized as susceptible, while 43 showed 60-79% yellow rust infestation and characterized as moderately susceptible to susceptible, 23 showed 40 – 59% yellow rust infection and characterized as moderately susceptible, while 17 showed 20-39% disease severity characterized as moderately resistant to moderately susceptible, four genotypes showed 10-19% disease and characterized as moderately resistant. Only eight genotypes (Fatehjang-2016, PIRSABAK-13, SHAHKAR-13, ZINCOL-16, 94-R-30, Fakhr-e-Bhakar, 17FJ16, and 17FJ10) were characterized as resistant as they showed no visible infection. Genotypes Kiran-95 showed maximum (90%,) yellow rust severity followed by SA-75, Pak-81, Pasban-90, and TD-1 (80%) (Table-1).

Table 4. Average Yield losses and yellow rust infection in wheat varieties during 2018-19 and 2019-20.

Variety	YR (%)	PY (%)	Sr. no.	Variety	YR (%)	PY (%)
AARI-11	60MSS	37.11	51	SHALIMAR-88	70MSS	39.14
AAS-11	70MSS	38.41	52	SHAMISS-3	60MSS	37.41
ANMOL-91	60MSS	36.21	53	UFAQ-2000	60MSS	36.23
AS-2002	65MSS	34.12	54	UJALA-16	30MRMS	19.22
AUQAB-2000	40MS	22.14	55	WAFAQ-01	60MSS	36.33
BARS-09	40MS	20.19	56	WAFIR-02	50MSS	30.25
BHAKAR-02	70MSS	38.27	57	ZINCOL-16	R	5.41
BWL-97	60MSS	36.10	58	PR-111	40MS	18.21
BWL-2000	50MS	30.20	59	PR-112	50MS	30.12
Borlogue-16	40MS	20.19	60	PR-118	70MSS	38.11
BARANI-17	10MR	8.17	61	NR-449	20MRMS	7.18
CHAKWAL-50	70MSS	38.11	62	NR-517	15MR	6.22
CHENAB-2000	50MS	30.50	63	SA-42	60MSS	34.10
DHARABI-11	60MSS	34.16	64	SA-75	80S	42.25
EHSAN-16	40MS	19.18	65	92-R-10	20MRMS	6.58
FAREED-06	60MSS	35.11	66	94-R-30	R	5.10
Faisalabad-08	50MS	30.41	67	HAMMAL-13	60MSS	35.51
Fatehjang-2016	R	4.25	68	IMDAD-05	70MSS	38.56
GA-2002	30MRMS	17.18	69	KIRAN-95	90S	51.12
GALAXY-13	60MSS	36.14	70	KHIRMAN	70MSS	38.24
GOLD-16	40MS	18.22	71	LAYELPUR-13	60MSS	36.28

INQALAB-91	70MSS	38.22	72	Fakhre Bhakar	R	4.79
JAWAHIR-20	30MRMS	16.17	73	NIA AMBER	40MS	19.25
JAUHAR-16	20MRMS	11.25	74	NIA SUNDER	50MS	30.22
KAGHAN-95	50MS	29.15	75	BENAZEER-13	30MRMS	17.11
KOHISTAN-97	40MS	20.18	76	ANAJ-17	20MRMS	8.18
LASANI-08	60MSS	33.47	77	ABADGAR	60MSS	36.11
Margalla-99	60MSS	34.56	78	BHITTAI	40MS	20.18
MARVI-2000	60MSS	32.18	79	POTHWAR	70MSS	38.14
MAXIPAK-65	70MSS	37.11	80	PASBAN-90	80S	48.12
MERAJ-08	60MSS	35.66	81	SINDHU-16	40MS	22.18
MH-97	70MSS	38.21	82	SH-2002	70MSS	39.14
MILLAT-11	70MSS	39.14	83	SARSABZ	60MSS	37.12
NARC-09	60MSS	34.51	84	TD-1	80S	46.02
NARC-11	50MS	30.21	85	WL-711	70MSS	39.11
PAK-81	80S	49.29	86	07FJ17	20MRMS	7.23
PAK-13	20MRMS	10.29	87	13FJ35	30MRMS	17.24
PAVAN-76	60MSS	36.27	88	15FJ05	15MR	6.11
PIRSABAK-04	20MRMS	11.34	89	17FJ16	R	4.01
PIRSABAK-05	20MRMS	9.28	90	17FJ10	R	3.22
PIRSABAK-08	15MR	8.11	91	16FJ39	20MRMS	8.14
PIRSABAK-13	R	6.39	92	16FJ17	30MRMS	17.14
PUNJAB-11	60MSS	38.17	93	06FJS3013	40MS	19.18
RAWAL-87	70MSS	39.28	94	05FJS3074	30MRMS	18.11
SALEEM-2000	70MSS	38.66	95	11FJ08	40MS	21.08
SATLUJ-86	60MSS	35.14	96	11FJ39	20MRMS	7.25
SEHER-06	70MSS	38.47	97	12FJ26	40MS	21.14
SHAFAQ-06	60MSS	35.45	98	10FJ09	60MSS	38.12
SHAHEEN-94	40MS	18.33	99	10FJ17	40MS	23.19
SHAHKAR-13	R	5.85	100	10FJ23	50MS	30.10

Impact of yellow rust on yield of different varieties

It was noticed that the genotypes suffering from more yellow rust exhibited major yield losses as compared to tolerant genotypes. Yield losses in susceptible wheat genotypes were ranged from 42 to 51% while 32 to 40 % yield losses were noted in moderately susceptible to susceptible genotypes. Similarly, 18 to 30% yield losses were seen in moderately susceptible wheat varieties and 6.5 to 19% in moderately resistant to moderately susceptible genotypes (table 1). The resistant wheat genotypes Fatehjang-

2016, Fakhre Bhakar, Shahkar-13, Pirsabak-13, Zincol-16, 94-R-30, 17FJ16 and 17FJ10 showed yield losses up to 4.25%, 4.79%, 5.85%, 6.39%, 5.41%, 5.10%, 4.01% and 3.22% respectively. Kiran-95 followed by Pak-81, Pasban-90 and TD-1 estimated yield losses for these genotypes were 51.12%, 49.29%, 48.12%, and 46.02% respectively. These results were also verified by (Qamar et al., 2008) that the severity of yellow rust causes heavy losses in the wheat yield of varieties. Coram et al. (2008) also reported that an increased epidemic of stripe rust on the wheat due to changing climatic conditions in the world may cause yield losses up to 60%. Similar results were also found in the study of (Salman et al., 2006) that slow spreading of rust disease in wheat varieties caused fewer yield losses.

Relationship among yellow rust severity and environmental variables

Stripe rust disease epidemic was found as highly dependent on favorable environmental conditions like more humidity due to rainfall and low temperature (Chen 2005). These results showed that stripe rust was strongly correlated with maximum temperature, minimum temperature, rainfall, and humidity in the atmosphere. Dereje & Chemeda (2007) also reported that environmental factors have an important role in the spreading of stripe rust in different wheat varieties.

Table 5. Correlation of Stripe rust and yield losses with environmental factors.

Climatic factors	Yellow rust severity (%)	Yield
Temperature	0.354**	0.421**
Humidity	0.418*	0.712**
Rainfall intensity	0.324*	0.387*

* = Significant (p<0.05), ** = Highly significant (p<0.01), NS= Non-significant (p>0.05)

Effect of temperature on yellow rust severity and yield losses

The correlation of maximum temperature with stripe rust infection and yield losses was found to be positive in all varieties (Table 5). There was an increasing trend in leaf rust disease development with maximum air temperature in both years (Fig. 2). An increase in stripe rust and stem rust with the increase in maximum temperature has also been reported by (Rehman et al., 2019).

Effect of humidity on yellow rust severity and yield losses.

The correlation studies between humidity percentage and disease spreading revealed the significant correlation of humidity with the yellow rust epidemic and yield losses in wheat genotypes (Table 5). There was an increasing trend in leaf rust disease development within both years (Fig 3). Ali et al. (2017) optimized the effect of environmental factors in the development of yellow rust of wheat and found that increase in humidity percentage ranging from 52-64% favors the yellow rust disease epidemic. However (Singh and Tewari, 2001) found humidity percentage ranging from 49.6 to 88.1% favorable for yellow rust development.

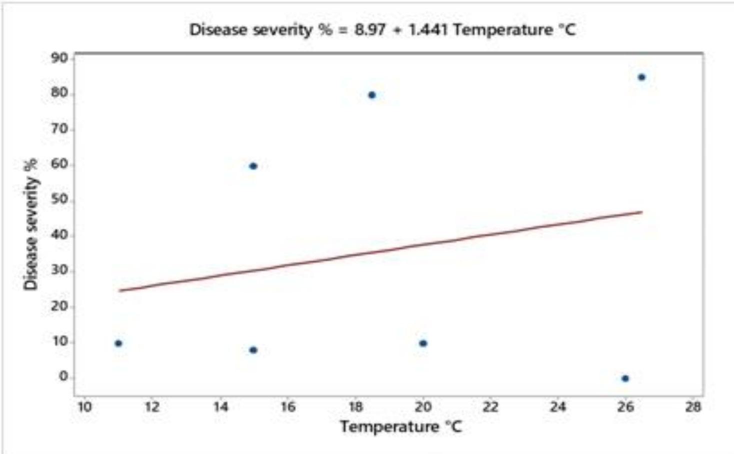

Figure 2. Relationship between Maximum Temperature and Stripe Rust

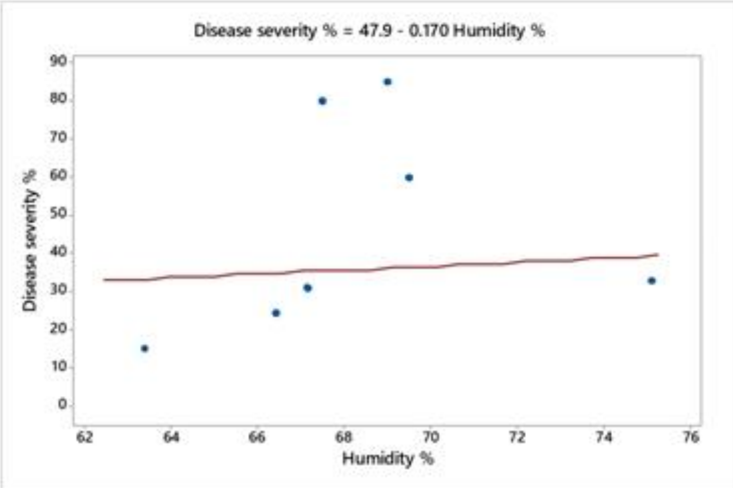

Figure 3. Relationship between Humidity % and Stripe Rust Severity

Effect of rainfall on yellow rust severity and yield losses.

Rainfall patterns exhibited a significant correlation for stripe rust and also showed a positive correlation with the yield losses (Table 5). There was an increasing trend in leaf rust disease development with rainfall in both years (Fig. 4). Ali et al. (2017); Rehman et al. (2019) ; Singh & sTewari, (2001) also reported in their findings that rainfall plays a vital role in yellow rust spreading in wheat susceptible varieties. Rainfall of 44.6 mm was found as a favorable factor for increasing yellow rust (Singh & Tewari, 2001). Similarly, the results of this study are also congruent with these previous findings.

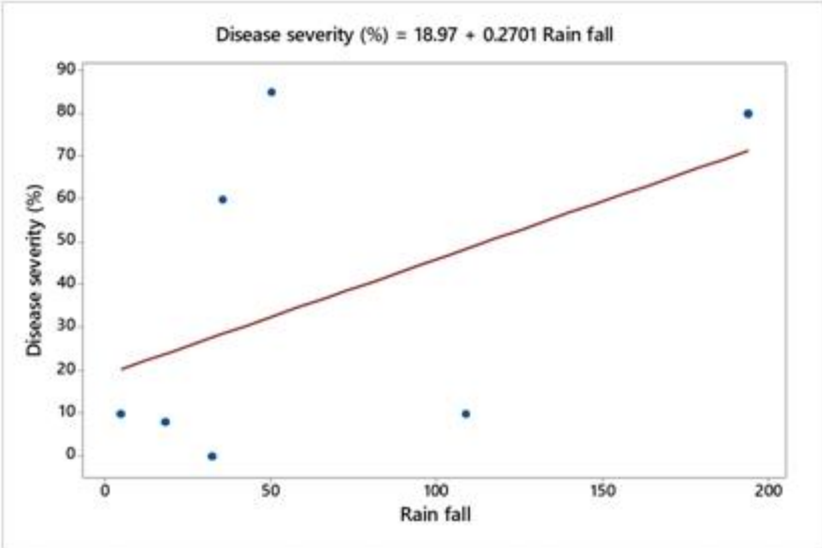

Figure 4. Relationship between Rainfall and Stripe Rust

Conclusion

In this study based on the findings of two years, it was seen that environmental conditions contributed a major role in stripe rust spreading and ultimate heavy yield losses in susceptible wheat genotypes. It was estimated that yield losses were up to 51 % where rust severity was 10 % to 100%. The present study revealed that low temperature due to heavy rainfall and increased relative humidity caused the rise in disease epidemic and it was checked in the areas of high-temperature ecological zones. Based on these verdicts, only rust-resistant wheat genotypes should be promoted for general cultivation in the farming community and wheat susceptible varieties should be discouraged for sowing. It is also recommended that wheat varieties resistant/tolerant for various agro-ecological zones of Pakistan should be identified and certified seeds of these varieties should be enhanced for distribution to the maximum farming community to reduce the yellow rust epidemic and wheat yield losses.

References

Ali, Y., Khan, M. A., Atiq, M., Sabir, W., Hafeez, A., & Tahir, F. A. (2017). Optimization of environmental factors conducive for stripe rust of wheat. *Pakistan Journal of Phytopathology*, *29*(2), 239-245.

Anonymous. 2019-20. Pakistan Economic Survey, Government of Pakistan, Finance Division, Economic Advisor’s Wing, Islamabad.

Bahri, B., Shah, S. J. A., Hussain, S., Leconte, M., Enjalbert, J., & de Vallavieille-Pope, C. (2011). Genetic diversity of the wheat yellow rust population in Pakistan and its relationship with host resistance. *Plant Pathology*, *60*(4), 649-660.

Coram, T. E., Wang, M., & Chen, X. (2008). Transcriptome analysis of the wheat–Puccinia striiformis f. sp. tritici interaction. *Molecular Plant Pathology*, *9*(2), 157-169.

Gessese, M. K. (2019). Description of wheat rusts and their virulence variations determined through annual pathotype surveys and controlled multi-pathotype tests. *Advances in Agriculture*, ID 2673706 https://doi.org/10.1155/2019/2673706

Ibrahim, M., Shah, S. J. A., Hussain, S., & Ahmad, M. (2017). Yellow Rust Surveillance and Deployment of Wheat Cultivars in the Region of Pathogen Diversity in Pakistan. *Sarhad Journal of Agriculture*, *33*(3), 466–473. http://dx.doi.org/10.17582/ journal.sja/ 2017/33.3.466.473

Khan, M. A., Yaqub, M. & Nasir, M. A. (1998). Slow rusting response of wheat genotypes against *Puccinia recondita* f. sp. *tritici* in relation to environmental conditions. *Pakistan Journal of Phytopathology*, 10(2), 78–85.

Khan, M. R., Imtiaz M., Munir, I., Hussain, I. & Ali, S. (2021). Differential distribution of leaf rust across major wheat growing regions of Pakistan revealed through a three years surveillance effort. *Pakistan Journal of Botany*, 53(5), 261-266.

Munday, E. (1973). The effect of yellow rust and its control on the yield of joss Cambier Winter Wheat. *Plant Pathology*, 22(4), 171-176. http://dx.doi:10.1111/j.1365-3059.1973.tb01801.x

Peterson, R., Campbell, A. & Hannah, A. (1948). A diagrammatic scale for estimating rust intensity on leaves and stems of cereals. *Canadian Journal of Research*, 26c, 496-500. https://doi.org/10.1139/cjr48c-033

Qamar, M., Ahmad, S. D., Shah, A. H., Wellings, C. R. & Batool, F. (2008). Postulation of stripe rust resistant genes in some Australian bread wheat cultivars and their response to temperature. *Pakistan Journal of Botany*, 40(6), 2573-2585.

Raza, W., Ghazanfar, M. U., Rehman, A. U. & Fayyaz, M. (2018). Screening of wheat germplasm against stripe rust disease under field conditions in Pakistan. *Plant Protection*, 2(3), 87-92.

Rehman, A. U., Naqvi, S. A. H., Zafar, M. I., Hussain, F., Zulfiqar, M. A. & Khan, A. A. (2019). Identification of resistance sources in wheat to brown and yellow rust. *Pakistan Journal of Agricultural Research*, 32(1), 185-196. http://dx.doi.org/10.17582/journal.pjar/2019/ 32.1.185.196

Salman, A., Khan, M. A. & Hussain, M. (2006). Prediction of yield losses in wheat varieties/lines due to leaf rust in Faisalabad. *Pakistan Journal of Phytopathology*, 18(2), 178-182.

Sher, M., Sajjad, M., Khan, S.H., Shahid, M., Zubair, M., Awan, F.S., Khan,A.I., Mubarak, M.S., Tahir,A., Umer, M., Keyani, R., Afzal,M.I., Manzoor, I., Wattoo, J.I. & Aziz-ur-Rehman. (2020). Genome-wide association analyses for stripe rust resistance in spring wheat (*Triticum aestivum L.*) germplasm. *Journal of integrative Agriculture*, 19 (8), 2035 – 2043

Singh, T. & Tewari, A. (2001). Role of weather conditions in the development of foliar diseases of wheat under Tarai conditions of north-western India. *Plant Disease Research-Ludhiana*, 16, 173 – 178.

Steel, R., & Torrie, J. (1986). Principles and Procedures of Statistics. McGraw-Hill Book Company, New York, Toronto, London.

Stubbs, C., Kouyama, T., Kinosita, K., & Ikegami, A. (1981). Effect of double bonds on the dynamic properties of the hydrocarbon region of lecithin bilayers. *Biochemistry*, 20, 4257 – 4262. http://dx.doi.org/10.1021/bi00518a004.

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