Journal of King Saud University – Science 34 (2022) 101991

Contents lists available at ScienceDirect

Journal of King Saud University – Science

journal homepage: www.sciencedirect.com

Original article

Screening of different wheat genotypes against leaf rust and role of environmental factors affecting disease development

Ali Hassan [a], Muhammad Umair Akram [b], Muhammad Arshad Hussain [c], Muhammad Amjad Bashir [d,*], Yasser S. Mostafa [*,e], Saad A.M. Alamri [e], Mohamed Hashem [e,f]

[a] Department of Botany The Islamia University Bahawalpur, Punjab, Pakistan
[b] RHC Kacha Kho, Khanewal Punjab, Pakistan
[c] Central Cotton Research Institute Bahwalpur Punjab, Pakistan
[d] Department of Plant Protection Faculty of Agricultural Sciences, Ghazi University Dera Ghazi Khan Punjab, Pakistan
[e] King Khalid University, College of Science, Department of Biology, Abha 61413, Kingdom of Saudi Arabia
[f] Assiut University, Faculty of Science, Botany & Microbiology Department, Assuit 71516, Egypt

ARTICLE INFO

Article history:
Received 14 December 2021
Revised 16 March 2022
Accepted 20 March 2022
Available online 24 March 2022

Keywords:
Leaf resistance
Screening of varieties
Puccinia trichina
Yield loss
Wheat genotype
Resistant varieties

ABSTRACT

Leaf rust caused by pathogen Puccinia has more potential to threaten the yield of wheat up to 10% as compared to the other two types of rust stem and yellow rust. The severity of the disease depends upon the developmental stage of the plant and susceptibility of the plant. The variability of wheat growing conditions favorable climatic patterns, and genomic polyploidy nature it becomes the most financial and nutritional crop. The Food and Agriculture organization (FAO) report on annual global supply and demand for wheat is ample for wheat production. The population development rate is increasing, which is estimated at 9 billion by 2025. To meet the demand for staple food the production of wheat is an important interest for its significance turn out *Puccinia triticina* causing brown rust disease in our country causes a huge amount of yield losses up to 50% (in severe cases) every year in all wheat-growing areas. Breeding of resistant varieties is the best and economic way to control this problem. Moreover, developing varieties is a continuous process because it can break the resistance of any variety by mutation. After screening 45 commercial varieties in 2019,2020 and 2021, only one variety was symptomless. After comparing varieties, showing resistance against urediniospores in the last three years only three varieties were similar showing resistant response against leaf rust. Moreover, after comparing environmental conditions favoring disease development in last three years it was observed that low temperature from 18 to 25 degree centigrade, humidity above 80% and high rainfall increases the incidence of disease development.

1. Introduction

Mostly population of the earth is a farming community. The importance of agriculture on the earth is undeniable as it is the backbone of the any agriculture country . It contributes 25 percent of the total GDP of our country . It consumes 48% of the labor force and 70% population is related to agriculture directly or indirectly. It plays an important role in foreign exchange and stimulates growth in other sectors. (Importance of Agriculture in country 's economy and development). Wheat is the staple food of the mostly population of our country and 40% of world food is related to wheat directly or indirectly (Anonymous, 2007). Production of wheat in this country is not so high as compared to other developed countries (Brian, 2006). The reason is that they use good quality seed and technology to get handsome per hectare yield. According to FAO cereal supply and demand, production of wheat was 1,37,443 Million tons in EU-27 listed at No.1. Then, in China having production of wheat 1,21,000 Million tones after that in India 92,000 Million tones, 56,613 million tonnes in the USA, 54,000 million tonnes in Russia, Canada 29,000 million tones and in Australia 24,500 million tones. In this country , its production was 24,330

* Corresponding authors.
E-mail addresses: abashir@gudgk.edu.pk (M.A. Bashir), ysmosutafa@kku.edu.sa (Y.S. Mostafa).
Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.jksus.2022.101991
1018-3647/

million tonnes. So, it is a need of an hour to use modern techniques and tools to get a high yield. Now, the government has shown its interest to develop varieties and research on different crops. Fig. 1.Table 1.Table 2.Table 3..

Leaf rust caused by pathogen Puccinia has more potential to threaten the yield of wheat up to 10% as compared to the other two types of rust stem and yellow rust. The severity of the disease depends upon the developmental stage of the plant and susceptibility of the plant (Duplessis, et al., 2021). The variability of wheat growing conditions favorable climatic patterns, and genomic polyploidy nature it becomes the most financial and nutritional crop (Dubcovsky and Dvorak, 2007). The FAO report on annual global supply and demand for wheat is ample for wheat production (FAO). The population development rate is increasing, which is estimated at 9 billion by 2025 (Chartres and Noble, 2015). To meet the demand for staple food the production of wheat is an important interest for its significance turn out (Schnurbusch, 2019).

The favourable condition for rust to infect the plant at high relative humidity with a temperature range in 15-22°C with optimum temperature for spore's development is 20C in only 6–8 h for the development of disease. Leaf rust infections can cause yield losses beyond 50 per cent at even earlier stages. The damage to rust in leaves sometimes is less spectacular than that produced by strip (yellow), but as leaf rust frequently occurs the total yearly losses worldwide are likely more than the others. (Huerta-Espino et al., 2011).

Rust challenges the yield of the wheat crop so chemicals are used in terms to prevent and treat the disease incidence, but the chemical nature of the synthetic fungicide has a worse effect on the health metabolic life of humans and animals. It also makes wheat single-quality varieties resistant to the pathogen (Collard and Mackill, 2008). Some measures are proving very helpful to overcome the losses caused by Leaf rust fallowed by researchers as well as field workers including cultivars susceptibility, varieties genetic resistance, climatic interaction, microorganism disease transmission capacity, and field management process (Temesgen, 2015). Some plants have pathogens-toxic substances that are isolated from plants and administered to diseased plants.

During 2017–18, wheat was cultivated at 8734 thousand hectares than that of 8982 thousand hectares in the previous year which is decreased by 2.6 percent. Its production was 25.492 million tonnes than previous year production 26.674 million tones and production is reduced to 4.4 percent. The share of wheat cultivation in Pakistan out of total crops is 10.1% and it contributes to 2.2% of the total GDP of the country.

Due to the increase in the population of Pakistan, the requirement for food is increasing day by day. Overall edible consumption in Pakistan, the wheat share is 9%. In farming areas, it is the only single item used than that of urban places. The country's population is growing at the rate of 2.4 percent annum. Therefore, the demand of wheat also increased in the future. According to projected data, in 2025, the requirement of wheat will be 31.415 million tonnes and the area of cultivation will be 9.050 million/hectare. In 2030, its demand would increase up to 34.25 million tones having the same area under cultivation (wheat in Pakistan, A status paper by PARC, 2013).

Wheat is grown as a rabi crop in the spring season in Punjab, Sindh, NWFP, and in northern areas of Balochistan. It is grown in the winter season in limited areas as well. In Punjab, wheat is grown in irrigated areas while its cultivation in rainfed areas is 10%, depending only on rainwater for its growth. The wheat cultivated area in Punjab is 6.026,500. In Sindh, most of the land is irrigated and the area of cultivation is 1,103,600. (M.S.Cheema and M. Hussain vol. 45 Annual wheat newsletter).

Diseases include rust (leaf, stripe, stem) smut, karnal bunt and powdery mildew caused economic losses to wheat crops (Soliman, N et al.,2012). *Puccinia triticina* has been an issue for the wheat crop that causes yield losses over large areas (Kolmer JA 2005). It is an airborne disease caused by *Puccinia triticina*. Spores of this fungus travels thousands of miles and effected different continents. Pakistan is facing a lack of appropriate varieties for yield and to tackle disease (Hussain et al., 2006).

In western Australia loss of 20 million dollars caused by leaf rust was reported. In Pakistan, it causes 10 % yield losses in 1978 (Hassan 1979). In 1978, an epidemic of leaf rust resulted in losses of 86 US dollars (Hussain et al., 1980). At a severe level, it can cause fifty percent yield losses. (Ahmad et al. 2010).So, it is a need of an hour to develop resistant varieties every year because it is a potential threat to any variety that its resistance could be broken. So, varieties are screened against leaf rust to evaluate its potential.

2. Materials and method:

2.1. List of verities under trial

Following commercial wheat varieties were screened at seedling and adult stage at Regional Agricultural Research Institute

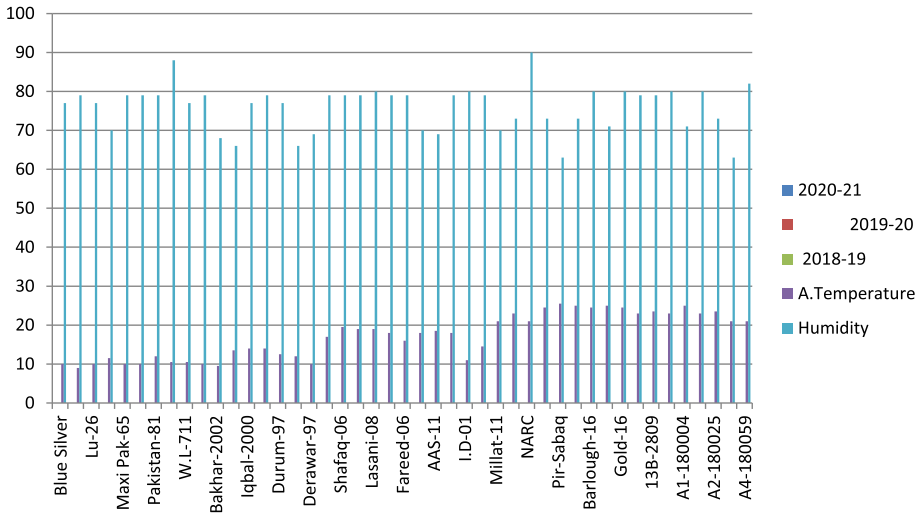

Fig. 1. The above graph showing the relationship of leaf rust severity with average Temperature and Humidity of 2020–21, 2019–20, 2018–19.

Table 1
List of 45 under trial Commercial verities.

No.	Varieties	No.	Varieties	No.	Varieties
1	Blue Silver	16	B.W.P-2000	31	Shafaq-06
2	Inqlab	17	Bakhar-2002	32	Chakwal-50
3	Lu-26	18	A.S-2002	33	Lasani-08
4	Kohi Noor	19	Iqbal-2000	24	Mairaj-08
5	Maxi Pak-65	20	Uqab-2000	35	Fareed-06
6	Benazir-13	21	Durum-97	36	Faisalabad-08
7	Pakistan-81	22	Punjnad-01	37	AAS-11
8	Bahawalpur-97	23	Derawar-97	38	AARI-2011
9	W.L-711	24	Sehar-06	39	I.D-01
10	Punjab-11	25	Millat-11	40	Ufaq-02
11	Pir-Sabaq	26	NARC-11	41	Galaxy-13
12	A2-180025	27	A4-180059	42	A2-180026
13	A1-180015	28	A1-180004	43	A1-180003
14	Gold-16	29	Johar-16	44	13B-2809
15	Zincol	30	Barlough-16	45	Ujala-15

Table 2
Leaf rust reaction, symbol and field response:

Infection types of wheat leaf rust used in disease assessment at adult stage		
Infection type	Host response	Symptoms
1	No disease	No Visible Infection
2	Moderately Resistant-Moderately Susceptible	Small Uredia present surrounded by necrotic area as well as medium uredia with no necrosis but possible some distinct chlorosis.
3	Moderately Susceptible-Susceptible	Medium uredia with some necrosis to chlorosis
4	Moderate Resistant	Small uredia present surrounded by necrotic area
5	Resistant	Necrotic with or without minute uredia
6	Resistant-Moderate	Symptoms between resistant and
7	Resistant	moderate resistant
8	Tolerant Resistant Moderately	Uredia is present but no economic effect on plant
9	Susceptible	Medium uredia with no necrosis but possible some distinct chlorosis
10	Tolerant Susceptible	Large uredia is present but not enough
11		to cause economic loss to plant
	Susceptible	Large uredia with little or no chlorosis present
	Susceptible-Tolerant	
	Resistant	Symptoms showing mix response in between susceptible and tolerant resistant.

Bahawalpur to find out the potential varieties showing resistance against leaf rust.

2.2. Experiment plan

In 2018–19, 2019–20 and 2020–21, 45 commercial varieties were cultivated for screening against leaf rust by drill method. Entry to entry distance maintained at 30 cm. The length of each line was 2 m. The experimental area was covered by two lines of Morocco variety from each side as a natural source of inoculum and multiplication.

2.3. Data collection

Each variety was observed daily to know the impact of temperature and other environmental factors involved in disease development. Lines were sown early in October to find out the disease severity. All the varieties were cultivated in a set of three blocks so that each block contains 15 varieties. All the agronomic practices were given to plants during the cultivation. The quantity of fertilizer and number of water applications was the same during all these years.

Inoculum of leaf rust stored every year and inoculated artificially in the next season. This process was repeated in all these years and every time plants were artificially inoculated with urediniospores taken in the previous year. At the booting stage suspension of urediniospores was sprayed after three days of interval. This whole process was carried out from Mid-February to Mid-March. A careful observation was given to leaf rust symptoms on daily basis.

3. Results and discussion

Genotypic resistance is the most appropriate and environment friendly way which is economical to control losses, caused by leaf rust. That's why these experiments were conducted to find out where the resistance of different varieties was tested against leaf rust to find out the best varieties in Pakistan that can perform better against leaf rust. The response showed by the entire crop is divided into 8 categories to critically observe the effect of the disease.

Screening of wheat varieties in 2018–19, 2019–20 and 2020–21 showed different results against leaf rust. Out of 45 varieties, three varieties were resistant showing the same response in three years. Only one variety (Pakistan-81) was susceptible throughout this period. While other varieties showed a mixed response.

Temperature plays an important role in the development of disease and sporulation. The development of leaf rust depends upon temperature, humidity, wind speed and rainfall of the field area as the landing of urediniospores disease incidence and disease severity is much concerned by these environmental factors. The temperature has a negative correlation with the disease while humidity, rainfall, and wind speed have a positive correlation with disease development. Before March, despite low temperature, humidity and wind speed was not favorable for disease development. During the first week of March, environmental conditions were favorable for disease development as the temperature was low and humidity and wind speed were high causing urediniospores to infect, multiply and spread at a higher rate. Therefore, brown rust spores were observed in Morocco on March 4 followed by Sahar-06.

Therefore, we compare three years of data having Average Temperature and Humidity from Mid- January to Mid-April to find out the environmental conditions that favor the infection of urediniospores.

Table 3
Three years response of tested verities Against Wheat Leaf Rust.

No.	Varieties	2020–21	2019–20	2018–19
1	Blue Silver	0	10R-MR	TR
2	Inqlab	5MRMS	20MS	5MR
3	Lu-26	20MSS	60S	10MRMS
4	Kohi Noor	30MSS	60S	5MSS
5	Maxi Pak-65	10MRMS	60S	TR
6	Benazir-13	5MRMS	5R-MR	20MRMS
7	Pakistan-81	40S	70S	10S
8	Bahawalpur-97	60MSS	80S	10MRMS
9	W.L-711	40S	60S	TR
10	B.W.P-2000	5S	20MSS	5MSS
11	Bakhar-2002	20MRMS	10MR	10MSS
12	A.S-2002	20MSS	60S	15MSS
13	Iqbal-2000	5MR	20MSS	15MSS
14	Uqab-2000	10MRMS	30S	TR
15	Durum-97	0	5R	10MSS
16	Punjnad-01	10MRMS	80S	0
17	Derawar-97	10MSS	40S	10MSS
18	Sehar-06	20MRMS	80S	5MSS
19	Shafaq-06	20MSS	30S	MR
20	Chakwal-50	5MRMS	30S	TR
21	Lasani-08	5R	20MS	TR
22	Mairaj-08	10MRMS	80S	5MR
23	Fareed-06	20TR	5MR	5MSS
24	Faisalabad-08	10MSS	60S	5MR
25	AAS-11	5S-TR	10RMR	TR
26	AARI-2011	20S	10RMR	5MSS
27	I.D-01	0	70S	5MSS
28	Punjab-11	5MRMS	5R	5MR
29	Millat-11	40S	20MSS	0
30	Ufaq-02	10MRMS	60S	5MSS
31	NARC-11	0	TR	0
32	Galaxy-13	30MSS	40MS	TR
33	Pir-Sabaq	0	60MSS	15MSS
34	Zincol	TR	10MSS	20S
35	Barlough-16	0	40S-TR	10MSS
36	Ujala-15	0	TR	TR
37	Gold-16	5MRMS	60S-5R	5MR
38	Johar-16	10R	5R	5R
39	13B-2809	0	50S	5MR
40	A1-180003	0	TR	TR
41	A1-180004	0	TS	TR
42	A1-180015	5R	5R	10R
43	A2-180025	0	5R-MR	TR
44	A2-180026	5R	10R	5R
45	A4-180059	0	0	0

4. Conclusion

Only three varieties were common that showed resistance after comparing the data of 2018–19, 2019–20 and 2020–21. Varieties named Johar-16, A1-180015, A2-180026 were resistant against leaf rust after infection of urediniospores that were artificially inoculated. While Pakistan-81 was only one variety that was susceptible throughout this period.

Varieties were cultivated in early October for screening against leaf rust in Pakistan. Due to this, plants reached their dough and maturity stage early when urediniospores infect different varieties. That's why losses caused by urediniospores infection were reduced. The flowering stage is most vulnerable causing a high yield loss when urediniospores cause infection. But, environmental factors also play an important role in disease development. It is concluded that temperature, humidity and rainfall increase chances of leaf rust infection after comparing three years of data. The temperature has a negative correlation with leaf rust while humidity and rainfall have a positive correlation with leaf rust. Spores need a low temperature between 18 and 25^{o}C humidity

above 80% and rainfall in the range of 10 mm favors disease a lot. Urediniospores require six to eight hours of moisture for infection (Dawn, 2008). Wind speed is also needed for spreading urediniospores to long distances as they can travel and infect on the continental level.

So, by cultivating and crossing above mentioned varieties we can minimize our annual yield loss. To protect wheat from leaf rust it should be cultivated from 15Oct-30 Oct as infection of urediniospores in Pakistan usually occurs in Mid-February to March and at this stage, the plant would have a dough or maturity stage. At this stage, the effect of leaf rust on grain yield is minimized. After the flowering stage, the plant concentrate on its grains and our main purpose is a grain, not fodder. So, chemical application after infection of leaf rust is a foolish activity because grains are consumed by humans which are hazardous for their life. Therefore, after infection of leaf rust after flowering stage, no chemical nor water and fertilizer should be applied as the main purpose of urediniospores is to turn leaves yellow which ultimately die the entire leaves which is a good sign ultimately for plant grain.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgement

The authors extend their appreciation to the Deputyship for Research & innovation, Ministry of Education in Saudi Arabia for funding this research work through the project number IFP-KKU2020/2.

References

Ahmad, S., Afzal, M., Noorka, I.R., Iqbal, Z., Akhtar, N., Iftkhar, Y., Kamran, M., 2010. Prediction of yield losses in wheat (*Triticumaestivum* L.) caused by yellow rust in relation to epidemiological factors in Faisalabad. Pakistan Journal of Botany 42, 401–407.

Anonymous, 2007. Economic Survey of Pakistan. Ministry of Food, Agriculture and Livestock (Federal Bureau of Statistics). Islamabad.

Brian, L.S.O., 2006. Identifying and managing wheat rusts. Kansas State University Agricultural Experiment Station and Cooperative Extension Service.

Collard, B.C., Mackill, D.J., 2008. Marker-assisted selection: an approach for precision plant breeding in the twenty-first century. Philosophical Transactions of the Royal Society B: Biological Sciences 363 (1491), 557–572.

Combating rust in wheat, Dawn Newspaper March24, 2008 https://www.dawn.com/news/294875/combating-rust-in-wheat#comments.

Dubcovsky, J., Dvorak, J., 2007. Genome plasticity is a key factor in the success of polyploid wheat under domestication. Science 316 (5833), 1862–1866.

Duplessis, S., Lorrain, C., Petre, B., Figueroa, M., Dodds, P.N., Aime, M.C., 2021. Host Adaptation and Virulence in Heteroecious Rust Fungi. Annual Review of Phytopathology 59 (1), 403–422.

FAO. 2009. Agribusiness handbook: Wheat flour. Rome. (Available at http://www.fao.org/docrep/012/al376e/al376e.pdf).

Hassan,, S∼, F., 1979. Wheat diseases situation in Pakistan. Sem. on Wheat Res. and Prod., Islamabad, Paper presented at Nat.

Huerta-Espino, J., Singh, R.P., Germán, S., McCallum, B.D., Park, R.F., Chen, W.Q., Bhardwaj, S.C., Goyeau, H., 2011. Global status of wheat leaf rust caused by *Puccinia triticina*. Euphytica 179 (1), 143–160.

Hussain, M., Ayub, N., Khan, S.M., Khan, M.A., Muhammad, F., 2006. Pyramiding rust resistance and high yield in bread wheat. Pak. J. Phytopathol. 18, 11–21.

James A Kolmer,Tracking wheat rust on a continental scale,Current Opinion in Plant Biology,Volume 8, Issue 4,2005,Pages 441-449,ISSN 1369-5266,https://doi.org/10.1016/j.pbi.2005.05.001.(https://www.sciencedirect.com/science/article/pii/S1369526605000622).

M.S.Cheema and M.HussainAnnual wheat newsletter vol. 45, Regional Agriculture Research Institute, Bahawalpur. https://wheat.pw.usda.gov/ggpages/awn/45/Textfiles/PAKISTAN.html#:∼:text=In%20Pakistan%2C%20spring%20wheat%20is,million%20tons%20in%201997-80.

Schnurbusch, T., 2019. *Wheat and barley biology*: Towards new frontiers. J. Integr. Plant Biol. 61 (3), 198–203.

Soliman, N., Abdelbacki, A., Najeeb, M., Omara, R., 2012. Geographical distribution of physiologic races of Pucciniatriticina and postulation of resistance genes in new wheat cultivars in Egypt. ESci J. Plant Pathol. 1 (1), 73–78.

Wheat in Pakistan A Status Paper by National Coordinator wheat Plant Science Division Pakistan Agricultural Research Council Islamabad, Pakistan 2013.