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MONITORING AND DETECTION OF WHEAT BLAST DISEASE CAUSED BY *MAGNAPORTHE ORYZAE TRITICUM* PATHOTYPE IN PUNJAB, PAKISTAN

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SUMMARY

The wheat blast caused by the *Magnaporthe oryzae Triticum* pathotype has become a serious threat to wheat production in Pakistan and India after its severe outbreak in Bangladesh in 2016 and intermittent occurrence since then. Thus, planned systemic surveillance of wheat crops in two phases in 2018–2019 and 2019–2020 began to determine the status of wheat blasts in Punjab, Pakistan. In the first phase, a survey of 160 wheat fields in districts in Punjab ensued for typical blast symptoms. The surveillance's second phase occurred after the threshing of the wheat crop, with composite grain samples collected from all over Punjab, then analyzed in the lab. The surveillance results indicated that all the wheat fields were free from the typical blast symptoms. Similarly, none of the analyzed samples showed the presence of wheat blast pathogens. Therefore, the study validates that this dreadful disease (blast) does not exist in Punjab, Pakistan. Hence, the reason to remain calm needs dissemination among the farming community and the training of technical agriculture extension staff for vigilance in the future for monitoring this disease in different agro-ecological zones of Punjab.

Keywords: Wheat blast, monitoring, *Magnaporthe oryzae Triticum* pathotype, environmental conditions, Punjab-Pakistan

Key Findings: Thorough surveillance of fields during the years 2018–2019 and 2019–2020 wheat crop seasons, as well as seed analysis from all over Punjab, depicted no infestation of wheat blast in Punjab, Pakistan.

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INTRODUCTION

Among cereals, wheat (*Triticum aestivum* L.) is recognized as one of the major crops in the whole world (Javed *et al.,* 2022), being the staple food of about 35% of the world's population (Ahmad *et al.,* 2022) and a good source of carbohydrates, protein, and vitamin E (Iqbal *et al.,* 2022). The consumption demand for wheat rises daily due to the boosting population worldwide. The biotic and abiotic stresses also significantly lower the yield of wheat (Javed *et al.,* 2022).

The disease 'wheat blast' is caused by the fungal pathogen *Magnaporthe oryzae Triticum* pathotype (MoT). It causes complete failure and drastically affects the quality of crops during epidemic years (He *et al*., 2021). In wheat fields, wheat blast detection is easy as it causes the bleaching of spikes. The infection in the regions of the peduncle and rachis blocks the mobility of photosynthates, causing the upper parts of the spike to die. Furthermore, partial or complete sterility of spike can happen depending upon the available conditions like timing, susceptibility of variety, and point of infection.

Maximum yield losses are resulted when disease occurs at early grain formation or during flowering. Grains obtained from the infected crop are deformed, shrunken in size, and with reduced test weight. Most of the time, such grains are thrown away during the post-harvest process of threshing or winnowing (Goulart *et al.,* 2007). A report of this devastating fungal disease came out in Brazil in 1985. Afterward, it spread extensively in wheat fields in South America. It lowered the cropping potential of wheat in the regions of vast savannas by affecting three million hectares during the early 1990s (Ceresini *et al.,* 2018).

Many researchers concluded and predicted the spread of fungal blasts from Latin America to different regions of Asia (Bangladesh, India, Pakistan, China) and Africa due to the resemblances of climatic conditions (Mottaleb *et al*., 2018). A strong attack of wheat blast throughout Southwestern Bangladesh in 2016 confirmed the prediction of previous researchers (Callaway, 2016; Malaker *et al*., 2016; Tembo *et al*., 2020). The first devastating wave of wheat blast hitting Bangladesh damaged almost 15% of the wheat cropping area. Pathogenomics studies confirmed the movement of blast fungi from South America to Bangladesh (Islam *et al.,* 2016). This event of wheat crop damage due to a blast outside of South America alarmed the world about its possible spread to other wheat-growing areas in South Asia and beyond.

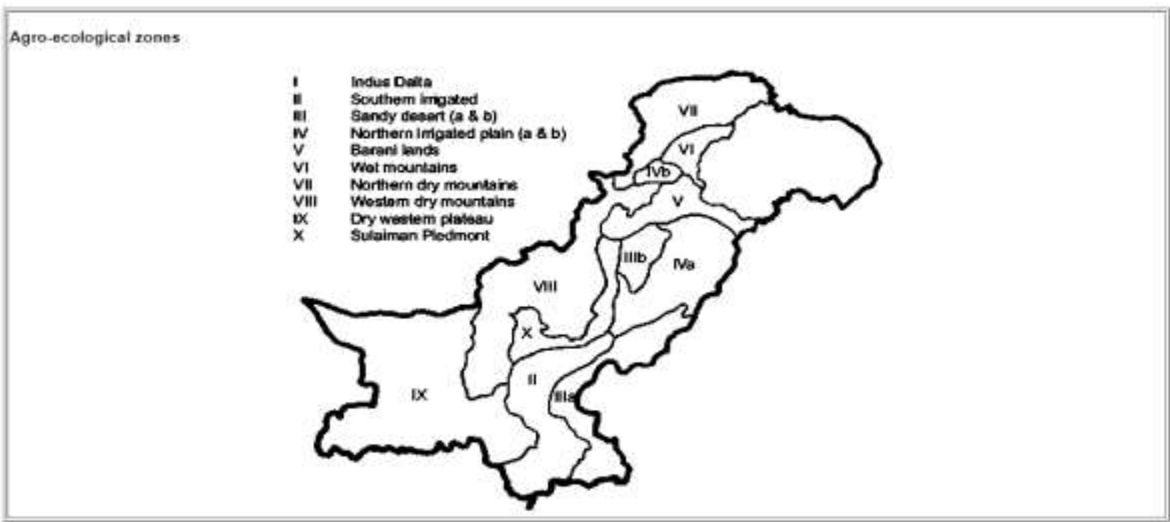
The spread of wheat blasts to South Asia may cause severe damage, with South Asia as homeland for more than 300 million humans and wheat consumption at more than 100 million tons annually (Khan, 2017). The blast pathogen can also survive on the residues of the crop and can spread via seed. Most wheat cultivars are vulnerable to blast, and chemical control of the disease remains ineffective. Wheat blast pathogen can cause 100% yield loss under favorable environmental conditions (Cruz and Valent, 2017). Wheat is the staple food of Pakistan and the country's dependence on this crop for food security makes it essential for more vigilance among all the stakeholders. There requires a dire need to develop a disease management strategy, as reports on the wheat blast disease in Bangladesh linger hence, considered a potential threat to South Asia, including Pakistan. Therefore, a disease surveillance, seed sample analysis, and screening for resistance at the hot spot (Bolivia) need action as the foundation management strategy in the country. Such surveillance will reveal the current status of the disease and lead to infected sample analysis.

The negative results of surveillance verify the absence of a pest in a particular area and also give adequate knowledge regarding the magnitude of the threat posed by it. The results would enable researchers to have some clue to work on in the future for screening of Pakistani wheat germplasm at hot spots and to utilize resistant germplasm in the breeding program, as well as, intra- and inter-specific hybridization to overcome the upcoming issue of wheat blast in the country. Therefore, an effort needs implementation to prevent the spread of *Magnaporthe oryzae Triticum* to other parts of the world because inaction may lead to a catastrophe. By keeping this in view, the contemporary study determined the status of wheat blasts in Pakistan, especially in different agro-ecological zones of Punjab, Pakistan, through surveillance and collection of blast-suspected samples and their analysis in a plant pathology lab for the confirmation of blast pathogen.

Geographical Zone Wise-Division of Districts of Punjab Pakistan

Central Zone	North Zone	South Zone
Faisalabad, Sahiwal, Lahore, Okara, Kasur, Chiniot, Hafizabad, Gujranwala, Sheikhopura, T.T. Singh, Jhang, Nankana Sahib.	Mianwali, Khushab, Sialkot, Narowal, Sargodha, Chakwal, Attock, Rawalpindi, Jhelum, Mandi Bahauddin, Gujrat.	Khanewal, Bhakhar, Layyah, Bahawalnagar, Bahawalpur, Vehari, Multan, Dera Ghazi Khan, Rajanpur, Rahim Yar Khan.

Figure 1. The geographical position-wise division of the Districts of Punjab, Pakistan.



Source PARC 1980

Figure 2. The agro-ecological zones of Pakistan.

MATERIALS AND METHODS

Surveillance for the blast at the wheat field before harvesting

During the wheat cropping season of 2018–2019 and 2019–2020, comprehensive surveillance proceeded to monitor the emergence of wheat blasts in different agro-ecological zones of Punjab, particularly the rice belt of the province. At each location, the surveillance team scouted for typical blast symptoms in the wheat fields, i.e., whitish discoloration of heads (a key for wheat blast identification in the fields). The geographical position-wise separation of districts of Punjab, Pakistan, appears in Figure 1. The Pakistan Agriculture Research Council (PARC) and Food and Agriculture Organization (FAO) divided the whole of Pakistan into 10 agro-ecological zones (Figure 2). This division relied on physiography, climate, land use, and water availability (Baig *et al.,* 2021). The area of Punjab province falls under Zone-I to Zone-V.

In this study phase, 160 different wheat fields in 20 districts in the Punjab Province, Pakistan, gained scrutiny for wheat blast prevalence during 2018–2019 and 2019–2020. About 12 districts of central Punjab zone, viz., Lahore, Faisalabad, Toba Tek Singh, Jhang, Kasur, Nankana Sahib, Chiniot, Hafizabad, Sheikhupura, Gujranwala, Okara, and Sahiwal; five districts of North Punjab zone, viz, Mianwali, Khushab, Sialkot, Narowal, and Sargodha, and three districts of south Punjab zone, viz., Khanewal, Bhakkar, and Layyah underwent wheat blast surveillance. The GPS data recording also occurred for each of the wheat fields, which included waypoint number, latitude (N or S), longitude (E or W), and elevation (m) (Tables 1a, 1b, 2, and 3).

Table1a. Surveillance for wheat blast in Central Punjab, Pakistan, during 2018–2019 and 2019–2020.

District	Year	Locations	Location of Farmer's Field	Cultivar at the field	Crop stage	Disease
						Blast
Faisalabad	2018-19	1	Elev.173, N-31.35, E-072.85	Galaxy-13	Flowering	0
		2	Elev.167, N-31.31, E-072.30	Punjab-11, Faisalabad-08	Flowering	0
		3	Elev.170, N-31.09, E-072.82	Faisalabad-08, Galaxy-13	Flowering	0
		4	Elev.164, N-31.07, E-072.83	Inqlab-91	Flowering	0
	2019-20	1	Elev.164 , N-31.09, E-072.82	Seher-06, Faisalabad-08	Milking	0
		2	Elev.170. N-31.39, E-073.05	Galaxy-13, Faisalabad-08	Dough	0
		3	Elev. Nil, N-31.39, E-073.05	Galaxy-13, Faisalabad-08	Flowering	0
		4	Elev. Nil, N-31.39, E-073.05	Faisalabad-08, Punjab-11	Flowering	0
Sahiwal	2018-19	1	Elev.167, N-31.41, E-073.08	Galaxy-13, Faisalabad-08	Dough	0
		2	Elev.167, N-31.41, E-073.08	Faisalabad-08	Milking	0
		3	Elev. Nil, N-31.41, E-073.08	Galaxy-13, Faisalabad-08	Dough	0
		4	Elev. Nil, N-31.41, E-073.08	Millat-11, Faisalabad-08	Dough	0
	2019-20	1	Elev. Nil, N-31.41, E-073.08	Galaxy-13, Punjab-11, Aas-11	Dough	0
		2	Elev. Nil, N-31.41, E-073.08	Galaxy-13, Faisalabad-08	Dough	0
		3	Elev. Nil, N-31.69, E-74.47	Galaxy-13,Seher-06	Milking	0
		4	Elev.167, N-31.41, E-073.08	Galaxy-13, Faisalabad-08	Milking	0
Lahore	2018-19	1	Elev. 220, N-31.72, E-74.74	Galaxy-13	Booting	0
		2	Elev. 221, N-31.58, E-74.49	Millat-11,Seher-06	Booting	0
		3	Elev. 218, N-31.62, E-74.49	Galaxy-13, AARI-11	Flowering	0
		4	Elev. 217, N-31.62, E-74.49	Ujjala-16, Lasani-08	Booting	0
	2019-20	1	Elev. 218, N-31.62, E-74.49	AARI-11, Galaxy-13	Booting	0
		2	Elev. 215,N-31.66, E-074.48	Faisalabad-08	Booting	0
		3	Elev. 217, N-31.62, E-74.49	Ujjala-16, Faisalabad-08	Flowering	0
		4	Elev. 221, N-31.58, E-74.49	Millat-11,Seher-06	Flowering	0
Okara	2018-19	1	Elev.164.5, N- 30.68, E-73.33	Faisalabad-08	Milking	0
		2	Elev.171.9, N- 30.73, E-73.38	Seher-06	Milking	0
		3	Elev.157.8, N- 30.69, E-73.40	Faisalabad-08, Millat-11	Dough	0
		4	Elev.164.5, N- 30.68, E-73.33	Galaxy-13	Milking	0
	2019-20	1	Elev.159.4, N- 30.66, E-73.59	Galaxy-13, Punjab-11	Milking	0
		2	Elev.167, N- 30.68, E-73.68	Galaxy-13, Faisalabad-08	Flowering	0
		3	Elev.170.3, N- 30.72, E-73.75	Galaxy-13, Punjab-11	Flowering	0
		4	Elev. 176.1, N-30.84, E-73.96	Galaxy-13, Faisalabad-08	Flowering	0
Kasur	2018-19	1	Elev. 183.4, N-31.08, E-74.43	Faisalabad-08	Milking	0
		2	Elev. 182.2, N-31.92, E-74.16	Seher-06	Milking	0
		3	Elev. 180.7, N-31.94, E-74.00	Punjab-11	Flowering	0
		4	Elev. 177.3, N-31.10, E-74.95	Galaxay-13	Dough	0
	2019-20	1	Elev. 188.9, N-31.07, E-74.38	Lasani-08, Ujala-16	Flowering	0
		2	Elev.186.8, N-31.04, E-73.84	Faisalabad-08	Flowering	0
		3	Elev.185.9, N-30.94, E-73.72	Faisalabad-08	Milking	0
		4	Elev.195.9, N-31.20, E-73.92	Faisalabad-08	Milking	0
Chiniot	2018-19	1	Elev.184, N-31.57, E-73.04	Faisalabad-08	Dough	0
		2	Elev.167, N-31.31, E-72.30	Punjab-11, Faisalabad-08	Dough	0
		3	Elev.192, N-31.62, E-73.02	Galaxy-13	Flowering	0
		4	Elev.191, N-31.70, E-73.03	Faisalabad-08	Flowering	0
	2019-20	1	Elev.189, N-31.77, E-73.09	Galaxy-13	Flowering	0
		2	Elev.167, N-31.31, E-72.30	Faisalabad-08	Milking	0
		3	Elev.191, N-31.70, E-73.03	Galaxy-13	Milking	0
		4	Elev.192, N-31.62, E-73.02	Faisalabad-08	Dough	0

Table 1b. Surveillance for wheat blast in Central Punjab, Pakistan, during 2018–2019 and 2019–2020.

District	Year	Locations	Location of Farmer's Field	Cultivar at the field	Crop stage	Disease Blast
Hafizabad	2018-19	1	Elev.184, N-31.85, E-73.22	Galaxy-13	Flowering	0
		2	Elev.187, N-31.88, E-73.35	Ujjala-16	Flowering	0
		3	Elev.208, N-31.90, E-72.49	Faisalabad-08	Milking	0
		4	Elev.202, N-32.024, E-73.62	Ujjala-16, Millat-11	Milking	0
	2019-20	1	Elev.201, N-32.08, E-73.75	Faisalabad-08	Dough	0
		2	Elev.202, N-32.024, E-73.62	Galaxy-13	Milking	0
		3	Elev.208, N-31.90, E-72.49	Ujjala-16	Dough	0
		4	Elev.187, N-31.88, E-73.35	Faisalabad-08	Flowering	0
Gujranwala	2018-19	1	Elev.212, N-32.11, E-73.95	Aas-11, Millat-11	Dough	0
		2	Elev.225, N-32.28, E-74.15	Galaxy-13	Dough	0
		3	Elev.220 , N-32.34, E-074.13	NR-399, Ujjal-16	Milking	0
		4	Elev.222, N-32.44, E-74.16	Pakistan-13, Galaxy-13	Milking	0
	2019-20	1	Elev.212, N-32.11, E-73.95	Millat-11	Dough	0
		2	Elev.225, N-32.28, E-74.15	Ujjal-16	Milking	0
		3	Elev.222, N-32.44, E-74.16	Galaxy-13	Dough	0
		4	Elev.220 , N-32.34, E-074.13	Galaxy-13	Flowering	0
Sheikhupura	2018-19	1	Elev.217, N-31.97, E-74.63	Faisalabad-08	Flowering	0
		2	Elev.212, N-31.93, E-74.54	Galaxy-13	Milking	0
		3	Elev.207, N-31.76, E-74.47	Faisalabad-08	Milking	0
		4	Elev.229, N-31.72, E-74.27	Ujalla-16, Galaxy13, Seher-06	Milking	0
	2019-20	1	Elev.184, N-32.22, E-74.44	Seher-06	Milking	0
		2	Elev.243, N-31.89, E-74.51	Punjab-11	Milking	0
		3	Elev.232, N-31.65, E-74.46	Faisalabad-08	Booting	0
		4	Elev. 213, N-31.69, E-74.47	Faisalabad-08	Booting	0
Toba Tek Singh	2018-19	1	Elev. 144, N-30.52, E-72.21	Faisalabad-08	Booting	0
		2	Elev. 155, N-30.72, E-72.40	Millat-11	Milking	0
		3	Elev. 154, N-31.31, E-72.49	AARI-11	Booting	0
		4	Elev. 160, N-31.02, E-72.55	Seher-06	Booting	0
	2019-20	1	Elev. 641, N-31.24, E-72.76	Seher-06	Milking	0
		2	Elev.162, N-31.24, E-72.76	Seher-06	Milking	0
		3	Elev.168, N-31.33, E-72.71	Seher-06	Milking	0
		4	Elev. 155, N-30.72, E-72.40	Faisalabad-08	Booting	0
Jhang	2018-19	1	Elev.159, N-31.30, E-72.57	Galaxy-13	Milking	0
		2	Elev.151, N-31.37, E-72.31	Galaxy-13	Milking	0
		3	Elev.148, N-31.36, E-72.32	Galaxy-13, Faisalabad-08, Pakistan-13	Milking	0
		4	Elev153, N-31.32, E-72.31	Galaxy-13	Milking	0
	2019-20	1	Elev.152, N-31.39, E-72.28	Punjab-11	Milking	0
		2	Elev.151, N-31.43, E-72.26	AARI-11	Milking	0
		3	Elev.150, N-31.56, E-72.25	Punjab-11	Booting	0
		4	Elev.184, N-32.29, E-72.47	Faisalabad-08	Milking	0
Nankana-Shahiab	2018-19	1	Elev.196, N-31.58, E-73.71	Millat-11, Punjab-11	Milking	0
		2	Elev.182.2, N-31.32, E-73.65	Watan, Millat-11	Milking	0
		3	Elev.181.6, N-31.35, E-73.67	Seher-06, Faisalabad-08	Milking	0
		4	Elev.211.2, N-31.32, E-73.66	Seher-06	Booting	0
	2019-20	1	Elev.182.8, N-31.34, E-73.66	Faisalabad-08	Milking	0
		2	Elev.194.1, N-31.25, E-73.84	Faisalabad-08	Milking	0
		3	Elev.197, N-31.52, E-73.70	Seher-06	Booting	0
		4	Elev.182, N-31.32, E-73.65	Punjab-11	Milking	0

Table 2. Surveillance for wheat blast in Northern Punjab, Pakistan, during 2018–2019 and 2019–2020.

District	Year	Locations	Location of Farmer's Field	Cultivar at the field	Crop stage	Disease
						Blast
Mianwali	2018-19	1	Elev.190, N-32.21, E-71.31	Galaxy-13	Milking	0
		2	Elev.193, N-32.33, E-71.40	Galaxy-13	Milking	0
		3	Elev.198, N-32.33, E-71.43	Bhakkar-02	Milking	0
		4	Elev.196 , N-32.35, E-71.45	Aas-11, Galaxy-13	Dough	0
	2019-20	1	Elev.193, N-32.33, E-71.49	Bhakkar-02	Dough	0
		2	Elev.190, N-32.26, E-71.51	Galaxy-13	Milking	0
		3	Elev.193, N-32.33, E-71.40	Galaxy-13	Milking	0
		4	Elev.196 , N-32.35, E-71.45	Bhakkar-02	Dough	0
Khushab	2018-19	1	Elev.183, N-32.25, E-72.14	Galaxy-13	Dough	0
		2	Elev.182, N-32.24, E-72.09	Faisalabad-08	Milking	0
		3	Elev.182, N-32.24, E-72.95	Faisalabad-08	Dough	0
		4	Elev.183, N-32.09, E-72.80	Aas-11, Faisalabad-08	Milking	0
	2019-20	1	Elev.183, N-32.33, E-71.79	Faisalabad-08, Seher-06	Dough	0
		2	Elev.182, N-32.24, E-72.95	Galaxy-13	Milking	0
		3	Elev.183, N-32.09, E-72.80	Faisalabad-08	Milking	0
		4	Elev.183, N-32.25, E-72.14	Faisalabad-08	Dough	0
Sialkot	2018-19	1	Elev.250, N-32.53, E-74.65	Faisalabad-08	Milking	0
		2	Elev.232, N-32.48, E-74.37	Galaxy-13	Dough	0
		3	Elev.240, N-32.30, E-74.46	Faisalabad-08, Ujalla-16	Milking	0
		4	Elev.232, N-32.48, E-74.37	Faisalabad-08	Dough	0
	2019-20	1	Elev.250, N-32.53, E-74.65	Faisalabad-08	Milking	0
		2	Elev.240, N-32.30, E-74.46	Galaxy-13	Milking	0
		3	Elev.232, N-32.48, E-74.37	Faisalabad-08, Ujalla-16	Dough	0
		4	Elev.250, N-32.53, E-74.65	Galaxy-13	Milking	0
Narowal	2018-19	1	Elev.244, N-32.19, E-75.24	Ujjala-16, Millat-11	Milking	0
		2	Elev.247, N-32.22, E-75.12	Faisalabad-08, AARI-11	Dough	0
		3	Elev.228, N-32.07, E-74.84	Galaxy-13	Dough	0
		4	Elev.273, N-32.31, E-74.91	Punjab-11	Milking	0
	2019-20	1	Elev.272, N-32.31, E-74.89	Punjab-11	Milking	0
		2	Elev.269, N-32.19, E-74.75	Faisalabad-08	Milking	0
		3	Elev.239, N-32.19, E-74.10	Faisalabad-08	Dough	0
		4	Elev.272, N-32.31, E-74.89	Galaxy-13	Milking	0
Sargodha	2018-19	1	Elev.159, N-31.64, E-72.27	Millat-11	Dough	0
		2	Elev.158, N-31.64, E-72.27	Millat-11	Dough	0
		3	Elev.165, N-31.79, E-72.26	Galaxy-13	Flowering	0
		4	Elev.164, N-31.34, E-72.23	Millat-11, Seher-06, Shafaq-06	Milking	0
	2019-20	1	Elev.172, N-31.98, E-72.33	Punjab-11, Shafaq-06	Milking	0
		2	Elev.172, N-31.98, E-72.33	Galaxy-13	Milking	0
		3	Elev.170, N-32.07, E-72.36	Millat-11, Seher-06	Booting	0
		4	Elev.170, N-32.07, E-72.40	Ujala-16	Flowering	0

Table 3. Surveillance for wheat blast in Southern Punjab, Pakistan, during 2018–2019 and 2019–2020.

District	Year	Locations	Location of Farmer's Field	Cultivar at the field	Crop stage	Disease Blast
Khanewal	2018-19	1	Elev.126, N-29.59, E-71.66	Faisalabad-08, Seher-06	Milking	0
		2	Elev.109, N-29.78, E-71.74	Aas-11	Milking	0
		3	Elev.112, N-29.86, E-71.76	Galaxy-13, Seher-06	Dough	0
		4	Elev.111, N-29.96, E-71.30	Gold-16,Aas-11	Milking	0
	2019-20	1	Elev.121, N-30.08, E-71.83	AARI-11, Aas-11	Milking	0
		2	Elev.124, N-30.21, E-71.37	Faisalabad-08	Dough	0
		3	Elev.120, N-30.32, E-71.96	Galaxy-13	Dough	0
		4	Elev.138 ,N-30.03, E-72.07	Faisalabad-08	Milking	0
Bhakkar	2018-19	1	Elev.192, N-32.05, E-71.63	Faisalabad-08	Milking	0
		2	Elev.191, N-32.09,E-71.54	Galaxy-13, Faisalabad-08	Dough	0
		3	Elev.189, N-32.15, E-71.36	Faisalabad-08	Milking	0
		4	Elev.191, N-32.09,E-71.27	Galaxy-13, Aas-11	Dough	0
	2019-20	1	Elev.179, N-32.05, E-71.48	Galaxy-13	Milking	0
		2	Elev.175, N-31.32, E-71.41	Galaxy-13	Milking	0
		3	Elev.163, N-31.63, E-71.30	Bakkar-02	Dough	0
		4	Elev.162, N-31.43, E-71.23	Bakkar-02	Milking	0
Layyah	2018-19	1	Elev.154, N-31.30, E-71.22	Faisalabad-08, Aas-11	Dough	0
		2	Elev.144, N-31.15, E-71.20	Aas-11, Faisalabad-08	Milking	0
		3	Elev.144, N-31.15, E-71.20	Faisalabad-08	Milking	0
		4	Elev.128, N-30.68, E-71.23	Punjab-11, Faisalabad-08, Seher-06	Dough	0
	2019-20	1	Elev.128 , N-30.68, E-71.23	Faisalabad-08, Seher-06	Milking	0
		2	Elev.117, N-30.52, E-71.23	Faisalabad-08	Milking	0
		3	Elev.119, N-30.39, E-71.24	Faisalabad-08, Seher-06	Dough	0
		4	Elev.144, N-31.15, E-71.20	Faisalabad-08, Aas-11	Milking	0

Table 3. Surveillance for wheat blast in Southern Punjab, Pakistan, during 2018–2019 and 2019–2020.

Detection of wheat blast after the crop harvesting

This surveillance phase immediately followed during the wheat cropping season of 2018–2019 and 2019–2020 after harvesting and threshing of wheat crop. A modification of the methodology for this activity slightly differed from that used in activity 1. During this phase of investigation, the collection of district-wise composite grain samples progressed from the Punjab Seed Corporation, private seed companies, adaptive research farms, and farmer fields across different geographical zones (Central, North, and South) of Punjab, Pakistan (Tables 4, 5, and 6). The collected grains brought to the laboratory underwent further testing.

Testing of grains samples in the seed pathology laboratory

The processing of the collected samples continued in the laboratory to identify the wheat blast pathogen, *Magnaporthe oryzae Triticum* pathotype, through incubation test, SB (Standard Blotter) technique, as well as, agar plate method, as described by Camargo *et al.* (2017). In blotter tests, the seeds, placed on moistened layers of blotter paper, received incubation under conditions that induced fungal growth. After seven days of incubation, the seeds got observed at the preliminary phase of development of the fungus under a stereoscope for the presence of blast fungal growth. The testing of seeds also followed through the agar plate method to confirm the results. In this test, inducing seeds for the growth of seed-born fungi used sterile agar media (potato dextrose) to examine the pathogens associated with the tested samples (Tsedaley, 2015).

RESULTS

Central Punjab, Pakistan

The districts of the Central Punjab zone covered in this surveillance included Lahore, Faisalabad, Toba Tek Singh, Jhang, Kasur, Nankana Sahib, Chiniot, Hafizabad, Sheikhupura, Gujranwala, Okara, and Sahiwal. The farmer's fields, examined for the wheat blast, happened before harvesting, either at flowering, milk, and dough stages. The cultivars, Faisalabad-08, Galaxy-13, Punjab-11, Inqlab-91, Seher-06, Millat-11, Punjab-11,

Table 4. Wheat grain sampling from Central Punjab, Pakistan, for the detection of wheat blast pathogen, during 2018–2019 and 2019–2020.

District	Sample Collection Site	Composite Sampled Varieties	Blast Pathogen (*Magneporthe* spp.)
Faisalabad	Wheat Research Institute, AARI, Faisalabad	Ujalla-16, Gold-16, Jhohar-16, Galaxy-13, Punjab-11, Millat-11, AARI-11, Aas-11, Faisalabad-08, Lasani-08, Seher-06, Shafaq-06, AS-02, MH-97, Inqilab-91	Not Found
	Farmer field	Faisalabad-08, Galaxy-13, Faisalabad-08, Ujalla-16, Seher-06	Not Found
Sahiwal	Farmer field	Galaxy-13	Not Found
	MMRI, Yousafwala	Galaxy-13, Faisalabad-08, All set of PUWYT & NUWYT	Not Found
Lahore	Rice Research Institute, Kala Shah Kaku	Ujala-16, Galaxy-13, Punjab-11, Millat-11, AARI-11, Aas-11, Faisalabad-08, Lasani-08, Seher-06, Shafaq-06, AS-02, MH-97, MH-97, PUWYT & NUWYT	Not Found
Okara	Rinala Khurd	PUWYT & NUWYT	Not Found
Kasur	Farmer field	Faisalabad-08, Millat-11, Ujalla-16	Not Found
Chiniot	Farmer field	Galaxy-13, Faisalabad-08, Bhakar-02, Ujala-16,Punjab-11, V-11160, Millat-11	Not Found
Gujranwala	Farmer field	Seher-06, Faisalabad-08, Galaxy-13	Not Found
	Adoptive Research Farm	PUWYT & NUWYT	Not Found
Toba Tek Singh	Farmer field	Seher-06, Galaxy-13, Faisalabad-08, V-12304	Not Found

Table 5. Wheat grain sampling from Northern Punjab, Pakistan for the detection of wheat blast pathogen, during 2018–2019 and 2019–2020.

District	Sample Collection Site	Composite Sampled Varieties	Blast Pathogen (*Magneporthe* spp.)
Narowal	Adoptive Research Farm, Kot Naina	PUWYT & NUWYT	Not Found
Khushab	Farmer field	Faisalabad-08, Galaxy-13	Not Found
Sargodha	Farmer field	Galaxy-13, Faisalabad-08, AARI-11, Seher-06	Not Found
Chakwal	BARI Govt. Farm	Durabi	Not Found
	Farmer field	Galaxy-13,Chakwal-50, Aas-11, Seher-06	Not Found
	BARI, Chakwal	Ihsan-16, Chakwal-50, Fateh-jhang-16, Galaxy-13, Ujalla-16,Borlaug-16, NARC-11	Not Found
Attock	Farmer field	Chakwal-50	Not Found
	BARS, Fateh Jhang	BARS-09, F. Jhang-16	Not Found
Rawalpindi	Farmer field	Chakwal-50, Un known	Not Found
Jhelum	Farmer field	Pak-13, Ujala-16, Dharabi-11, Chakwal-50, Aas-11, Ujala-16, Faisalabad-08	Not Found
Mandi Bahaw Din	Farmer field	Faisalabad-08, Pak-81	Not Found
Gujrat	Farmer field	Faisalabad-08,Galaxy-13,Seher-06	Not Found

Aas-11, AARI-11, Ujjala-16, and Lasani-08, were planted at sampling sites during the surveillance in central Punjab. No symptoms of the wheat blast showed in the wheat field of the central zone of Punjab, Pakistan, for both the cropping seasons of 2018–2019 and 2019–2020 (Table 1a, b). During the second phase of the investigation, district-wise composite grain samples collected from Punjab Seed Corporation, private seed companies, adaptive research farms, and farmer fields across the central zone of Punjab underwent testing in the laboratory. The lab testing for each composite sample from districts of the Central Punjab zone revealed the absence of the blast pathogen, *Magnaporthe oryzae Triticum* pathotype (Table 4).

North Punjab, Pakistan

The districts of North Punjab zone, Pakistan, covered in this surveillance consisted of Mianwali, Khushab, Sialkot, Narowal, Sargodha, Chakwal, Attock, Rawalpindi, Jhelum, Mandi-Bahawuddin, and Gujrat. The crop was either at the flowering, milk, or dough stage. The cultivars, Faislabad-08, Galaxy-13, Bhakkar-02, Aas-11, Ujalla-16, Millat-11, AARI-11, Punjab-11, Seher-06, and Shafaq-06, were planted at sampling sites. No

Table 6. Wheat grain sampling from Southern Punjab, Pakistan for the detection of wheat blast pathogen during 2018–2019 and 2019–2020.

District	Sample Collection Site	Composite Sampled Varieties	Blast Pathogen (*Magneporthe* spp.)
Bahwalnagar	Station RRI,	Galaxy-13, Faisalabad-08, PUWYT & NUWYT	Not Found
	Farmer field	Galaxy-13, Faisalabad-08, Aas-11	Not Found
Bahawalpur	Farm Manager and Govt. Bahawalpur	Faisalabad-08	Not Found
	Farmer field	Faisalabad-08, Ujala-16, T.D-1, As-02, Galaxy,Seher-06, Watan, Aas-11	Not Found
	RARI, Bahawalpur	Jhor-16, Galaxy-13, Gold-16, Millat-11 Faisalabad-08,Seher-06, NARC-11, Borlaug-16	Not Found
Vehari	Farmer field	Gandum-1, Galaxy-13	Not Found
	Adoptive Research Farm	PUWYT & NUWYT	Not Found
	Govt. Farm, Farmers Field,	Johar-16, Galaxy-13, Lasani-08	Not Found
Multan	Cotton Research Institute, Multan	Faisalabad-08, Galaxy-13, Aas-11	Not Found
	Farmer field	Seher-06, Faisalabad-08, Aas-11	Not Found
Dera Ghazi Khan	Talib Hussain, Moza Basti, Mlana, Kot Chutta	Faisalabad-08, Aas-11	Not Found
	Seed company Jam Pur	Galaxy-13, Faisalabad-08, As-2002	Not Found
Rajanpur	Farmer field	Galaxy-13	Not Found
Rahim Yar Khan	Farmer field	Galaxy-13, Gandum-1, Punjab-11	Not Found
	Jalandher Seed Corporation, Rasham Seed Corporation	Galaxy-13, Aas-11, Faisalabad-08	Not Found
Khanewal	PSL, Khanewal	Borlag-16, Faisalabad-08, Aas-11, Johar-11, Punjab-11, Gold-1, NARC-1, Galaxy-13, Zincol-16, PUWYT & NUWYT	Not Found
	Farmer field	Faisalabad-08, Aas-11, Ujala-16, Galaxy-13, AARI-11	Not Found

recording of symptoms of the wheat blast existed during both years (Table 2). The composite grain samples collected in the said districts from Punjab Seed Corporation, private seed companies, adaptive research farms, and farmer fields across North Punjab followed testing in the laboratory. All samples were found free of blast pathogens (Table 5).

South Punjab, Pakistan

The districts of South Punjab zone, Pakistan, i.e., Khanewal, Bhakkar, Layyah, Bahawalnagar, Bahawalpur, Vehari, Multan, Dera Ghazi Khan, Rajanpur, and Rahim Yar Khan, proceeded for wheat blast surveillance during 2018–2019 and 2019–2020. The crop was either at the flowering, milk, or dough stage. The cultivar, Faisalabad-08, Galaxy-13, Seher-06, Gold-16, Aas-11, AARI-11, Bakkar-02, and Pb-11 existed at sampling sites. No symptoms of the wheat blast came out during both years (Table 3). District-wise composite grain sampling continued from Punjab Seed Corporation, private seed companies, adaptive research farms, and farmer fields across Southern Punjab. All samples were found free of the wheat blast during lab testing (Table 6).

Wheat cultivars scouted for the wheat blast at farmer's field

During the wheat blast surveillance, scouting wheat cultivars for wheat blast pathogens at farmer's field included Faisalabad-08, Galaxy-13, Seher-06, Millat-11, Ujala-16, Aas-11, Punjab-11, AARI-11, Bhakkhar-02, Lasani-08, Shafaq-06, Pakistan-13, Inqalab-91, NR-399, Watan, and Gold-16 (Tables 1a, 1b, 2, and 3). No symptoms of the wheat blast materialized in all of these noted wheat cultivars at the farmer's field. Faisalabad-08, Galaxy-13 and Seher-06 were found the most planted cultivars at farmer fields during the blast surveillance in both years. Faisalabad-08 shared 43.75%, Galaxy-13 33.75% and Seher-06 13.75% of the total visited farmer's fields (Figure 3).

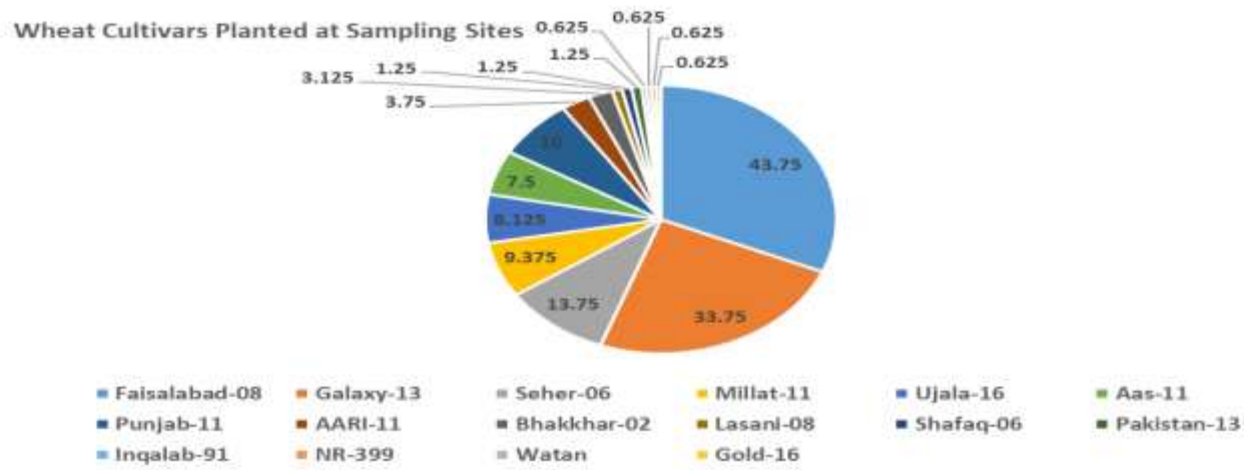


Figure 3. Wheat cultivars examined for the wheat blast at farmer's fields during 2018–2019 and 2019–2020.

DISCUSSION

The fungal disease, i.e., wheat blast, proved as an emerging threat to the food security and sustainable production of wheat crop in Asia. As the wheat blast is seed-borne, the grain trade has become a primary source of the spread from South America to Bangladesh and Zambia, thus concerns arise about future wheat production in South Asian countries (Gomes *et al*., 2017). Therefore, an action plan encompassing multiple strategies designed by experts mitigated the spread of wheat blasts in wheat-producing countries around the globe (Sadat and Choi, 2017; Sharma, 2017).

Primarily, through the restriction on the movement of infected seeds from one region to another, the development of blast-resistant wheat cultivars (Cruz *et al*., 2016) integrated wheat blast management, surveillance and forecasting of wheat blast epidemiology (Valent *et al.,* 2021). Correspondingly, in Pakistan, immediate action unfolded for effective surveillance/detection of wheat blast pathogens in the province of Punjab.

The surveillance reports indicated that all the surveyed wheat fields were free from the wheat blast symptoms; the lab analysis reports indicated that the wheat-blast pathogen (*Magnaporthe oryzae Triticum* pathotype) does not exist in all the analyzed samples (Tables 1a, 2a, 2-6). However, continued monitoring should progress for the future forecast of the disease prevalence, particularly in the rice-growing districts of Punjab, Pakistan. Quarantine law implementation in South Asian countries is not as stringent as in Australia and America. The unrestricted drive of infected seeds from Brazil, Bangladesh and other blast-infected countries would cause a serious threat to non-infected countries.

Therefore, the highest priority should resolve to strengthen the quarantine protocols and establishment of biosafety regulations to avert further spread in other Asian countries and introduction into blast-free wheat-producing regions of the globe, i.e., Australia, Europe, and North America (Singh, 2017; Ceresini *et al*., 2018; Fitriah *et al*., 2019; Hairmansis *et al*., 2019). Furthermore, under changing climatic scenarios, such as, irregular rains, global warming, cultivation of susceptible genotypes, the increasing virulence and fungicide resistance of the pathogen, prospective sexual recombination, and apparent cross-host infections could outcome in frequent occurrences of the disease in other wheat-growing republics (Government of India, 2016; Saharan *et al*., 2016).

In this regard, international collaboration is the key to successful disease management. A recent example is "BARI Gom 33," a wheat blast-resistant variety jointly developed and released in 2017 by the Bangladesh Agricultural Research Institute (BARI) and CIMMYT, Mexico. BARI Gom 33 was a cross of 'Kachu' and 'Solala,' the Kachu bears 2NS segment for blast resistance (Hossain *et al.,* 2019; Mottaleb *et al*., 2019). The said variety delivered 5–8% more production than the other commercial varieties in Bangladesh (Biswas *et al*., 2020). The existence of 2NS translocation verifies the reason for resistance against wheat blasts in wheat lines (Cardozo *et al*., 2018). These efforts need sustainability to counter future threats. He *et al.* (2021) performed a genome-wide association study (GWAS) on 184 Asian and CIMMYT genotypes. They concluded that genotypes with 2NS carriers showed resistance to wheat blast. During the study, significant marker association resulted on chromosomes 1BS, 2AS, 6BS, and 7BL, but the 2AS at the 2NS/2AS translocation region constantly occurred significantly.

CONCLUSIONS

The surveillance results were encouraging and indicated that all the wheat fields were free from the typical blast symptoms. However, the notable prevalence of rust almost existed on all old wheat varieties grown in the field under current changing climatic conditions. Similarly, the grain health test indicated that all the collected samples were free from the blast pathogen, *Magnaporthe oryzae Triticum* pathotype. However, continued monitoring requires sustainability for the future forecast of disease prevalence. Along with this, a countrywide campaign needs action to ensure blast-pathogen-free import of wheat seeds into the country, particularly from Bangladesh or another infected country.

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REFERENCES

Ahmad N, Javed A, Gohar S, Ahmed J, Sher A, Abdullah M, Asghar S, Javed K, Iqbal J, Kumar S, Qayyum A (2022). Estimation of drought effects on different bread wheat genotypes using morpho-physiological traits. *Biochem. Syst. Ecol.* 104: 104483.

Baig MB, Burgess PJ, Fike JH (2021). Agroforestry for healthy ecosystems: Constraints, improvement strategies and extension in Pakistan. *Agrofor. Systems* 95(5): 995-1013.

Biswas CS, Hannan A, Monsur A, Sagor GHM (2020). Screening and biochemical characterization of wheat cultivars resistance to *Magnaporthe oryzae pv Triticum* (MoT). *J. Plant Stress Physiol.* 1-6.

Callaway E (2016). Devastating wheat fungus appears in Asia for the first time. *Nature*. 532**:** 421-422.

Camargo MPD, Moraes MHDD, Menten JOM (2017). Efficiency of blotter test and agar culture medium to detect *Fusarium graminearum* and *Pyricularia grisea* in wheat seeds. *J. Seed Sci*. 39: 297-302.

Cardozo TL, Chavez A, Bobadilla N, Pérez-Estigarribia P, Kohli M (2018). Variable resistance of bread wheat (*Triticum aestivum*) lines carrying 2NS/2AS translocation to wheat blast. Plant Breed. 00:1–7. https://doi.org/10.1111/pbr.12661

Ceresini PC, Castroagudín VL, Rodrigues FÁ, Rios JA, Aucique-Pérez CE, Moreira SI, Alves E, Croll D, Maciel JLN (2018). Wheat blast: Past, present and future. *Annu. Rev. Phytopathol.* 56: 427-56.

Cruz CD, Peterson GL, Bockus WW, Kankanala P, Dubcovsky J, Jordan KW, Akhunov E, Chumley F, Baldelomar FD, Valent B (2016). The 2NS translocation from *Aegilops ventricosa* confers resistance to the *Triticum* pathotype of *Magnaporthe oryzae*. *Crop Sci.* 56(3): 990-1000.

Cruz CD, Valent B (2017). Wheat blast disease: Danger on the move. *Trop. Plant Pathol.* 42: 210-222.

Fitriah N, Suharsono, Nugroho S, Suwarno, Miftahudin (2019). Introgression of resistance to blast disease from monogenic line IRBLta2-Re to Ciherang rice variety. *SABRAO J. Breed. Genet.* 51(4): 419-429.

Gomes DP, Rocha VS, Pereira OL Souza MAD (2017). Damage of wheat blast on the productivity and quality of seeds as a function of the initial inoculum in the field. *J. Seed Sci.* 39: 66-74.

Goulart ACP, Sousa PG, Urashima AS (2007). Damages in wheat caused by infection of *Pyricularia grisea*. *Summa Phytopathol.* 33: 358-363.

Government of India (2016). Minutes of the meeting on "Occurrence of blast disease on wheat" held under the Chairmanship of Agriculture Commissioner on 28 September 2016 at Kolkata. File no. 4–2/20 13-NFSM (Ministry of Agriculture and Farmers Welfare, Department of Agriculture Cooperation and Farmers Welfare Crops Division NFSM Cell, ed.). Krishi Bhawan, New Delhi, pp. 14.

Hairmansis A, Supartopo, Aswidinnoor H, Suwarno WB, Suwarto, Riyanto A, Hanarida I, Utami DW, Nasution A, Yullianida, Santoso, Nafisah, Vera-Cruz CM, Suwarno (2019). High yielding and blast resistant rice cultivars developed for tropical upland area. *SABRAO J. Breed. Genet*. 51(2): 117-127.

He X, Juliana P, Kabir MR, Roy KK, Islam R, Marza F, Peterson G, Singh GP, Chawade A, Joshi AK, Singh RP (2021). Screening and mapping for head blast resistance in a panel of

CIMMYT and South Asian bread wheat germplasm. *Front. in Genet*. 13.12: 679162.

Hossain A, Mottaleb KA, Farhad M, Barma NC (2019). Mitigating the twin problems of malnutrition and wheat blast by one wheat variety, "BARI Gom 33," in Bangladesh. *Acta Agrobot.* 72: 1775. doi:10.5586/aa.1775.

Iqbal J, Ahmad N, Tabassum MI, Rabbani G, Hassan F, Rafique M, Iqbal M, Mustafa R, Ashraf S, Javed A, Abdullah S (2022). MA-21: A disease-tolerant and long-rooted wheat variety depicting long-stay in the rainfed regime. *J. Agric. Res.* 60(2): 107-113.

Islam MT, Croll D, Gladieux P, Soanes DM, Persoons A, Bhattacharjee P, Hossain MS, Gupta DR, Rahman MM, Mahboob MG, Cook N (2016). Emergence of wheat blasts in Bangladesh was caused by a South American lineage of *Magnaporthe oryzae*. *BMC Biol.* 14: 84.

Javed A, Ahmad N, Ahmed J, Hameed A, Ashraf MA, Zafar SA, Maqbool A, Al-Amrah H, Alatawi HA, Al-Harbi MS, Ali EF (2022). Grain yield, chlorophyll, and protein contents of elite wheat genotypes under drought stress. *J. King Saud Univ. Sci.* 34(7): 102279.

Khan MSH (2017). Scientists trained to fight wheat blast in South Asia. https://csisa.org/ scientists-trained-to-fight-wheat-blast-in-south-asia/.

Malaker PK, Barma NCD, Tiwari TP, Collis WJ, Duveiller E, Singh PK, Joshi AK, Singh RP, Braun HJ, Peterson GL, Pedley KF, Farman ML, Valent B (2016). First report of the wheat blast caused by *Magnaporthe oryzae* pathotype *Triticum* in Bangladesh. *Plant Dis.* 100: 2330.

Mottaleb KA, Govindan V, Singh PK, Sonder K, He X, Singh RP, Erenstein O (2019). Economic benefits of blast-resistant biofortified wheat in Bangladesh: The case of BARI Gom 33. *Crop Prot.* 123:45-58.

Mottaleb KA, Singh PK, Sonder K, Kruseman G, Tiwari TP, Barma NC, Malaker PK, Braun HJ, Erenstein O (2018). Threat of wheat blast to South Asia's food security: An ex-ante analysis. *PloS One 5* e0197555.

Sadat MD, Choi J (2017). Wheat blast: A new fungal inhabitant to Bangladesh threatening world wheat production. *Plant Pathol. J.* 33: 103-108.

Saharan MS, Bhardwaj SC, Chatrath R, Sharma P, Choudhary AK, Gupta RK (2016). Wheat blast disease-an overview. *J. Wheat Res.* 8:1-5.

Sharma R (2017). Wheat blast research: Status and imperatives. *Afr. J. Agric. Res.* 12: 377-381.

Singh DP (2017). Wheat blast caused by *Magnaporthe oryzae* pathotype *Triticum*: Present status, variability, and strategies for management In: *Management of Wheat and Barley Diseases*. D.P. Singh (ed.), Waretown, NJ: Apple Academic Press. pp. 635-643.

Tembo B, Mulenga RM, Sichilima S, M'siska KK, Mwale M, Chikoti PC, Singh PK, He X, Pedley KF, Peterson GL, Singh RP, Braun HJ (2020). Detection and characterization of fungus (*Magnaporthe oryzae* pathotype *Triticum*) causing wheat blast disease on rain-fed grown wheat (*Triticum aestivum* L.) in Zambia. *PLoS One* 15:e0238724. doi:10.1371/journal.pone.0238724.

Tsedaley B (2015).Review on seed health tests and detection method of seed-borne diseases. *J. Biol. Agric. Healthcare* 5(5): 176-185.

Valent B, Cruppe G, Stack JP, Cruz CD, Farman ML, Paul PA, Peterson GL, Pedley KF (2021). Recovery plan for wheat blast caused by *Magnaporthe oryzae* pathotype *Triticum*. *Plant Health Prog.* 22:182-212. https://doi.org/10.1094/PHP-11-20-0101-RP.