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*Full Length Research Paper*

# Wheat disease surveys in Zambia mainly targeted to wheat blast caused by *Magnaporthe oryzae* pathotype *Triticum* (MoT)

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## Abstract

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Wheat is an important cereal crop worldwide and in Zambia it is the second most cultivated cereal crop after maize. It is produced in both winter and summer seasons. However, the production of wheat in Zambia is threatened by wheat blast caused by *Magnaporthe oryzae* pathotype *Triticum.* The disease was first detected in Zambia during the 2017/18 cropping season. It is prevalent rainy season due to conducive weather conditions prevailing during this period. To assess the distribution of wheat blast, a survey was conducted in wheat fields grown in winter and summer season from 2021 to 2024. A zigzag or W sampling pattern was used during the survey. The survey revealed the presence of wheat blast in wheat grown during rainy season. The incidences and severity varied each season, depending on the prevailing weather conditions. High disease incidences were observed in seasons with good rainfall and humidity such as 2021-22 and 2022-23, while in the 2023-24 season, disease incidences were very low due to the severe drought experienced in the country. However, no blast was detected in wheat grown under the cool and dry irrigated season in all four years when surveillance was conducted.

**Keywords**: Climate change, incidences, monitoring, pathogen, rainy season, winter season, wheat.

### Introduction

Wheat is one of the most important cereal crops in the world. In Zambia, wheat is second to maize in in terms of production and consumption (FAOSTAT, accessed 2025). It is produced under two agro-climatic systems: during the winter season (May-September, cool and dry) and the summer season (November–April, warm and

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humid). Irrigated wheat production is mainly undertaken by large commercial farmers. During 2023, for example, 277, 491.9 tonnes of wheat were produced on about 36,551 hectares (Table 1; FAOSTAT accessed 2025). On the other hand, summer wheat production (rain-fed) is dominated by smallholder resources-limited farmers due to lower production cost when compared with irrigated wheat. Smallholder farmers mainly produced wheat for home consumption on small pieces of lands of around 0.25 to 1.0 ha. However, the summer wheat production is limited due to biotic constraints, mainly diseases, including wheat blast caused by *Magnaporthe oryzae* pathotype *Triticum* (MoT), spot blotch caused by *Bipolaris sorokiniana* (Sacc.) Shoem, Fusarium head blight caused by *Fusarium graminearum* and to some lesser extent, powdery mildew caused by *Blumeria graminis* f. sp. *tritici,* leaf rust caused by *Puccinia recondita* f. sp. *tritici,* tan spot caused by *Pyrenophora tritici-repentis,* smut caused by *Ustilago tritici* and basal glume rot caused by *Pseudomonas syringae pv. atrofaciens*. Among the diseases, wheat blast is an emergent new threat and most infectious constraint in summer wheat production in Zambia.

The disease was first reported on wheat in Brazil, Parana state in 1985 (Igarashi et al., 1986). It later spread to Bolivia in 1996 (Barea et al., 1996), Paraguay, 2002 (Viedma, 2005), Argentina, 2007 (Perello et al., 2015), and Bangladesh, 2016 (Malaker et al., 2016). The Bangladesh report was the first appearance of wheat blast beyond South America. In 2018, the disease was first detected in Zambia, Mpika district (Tembo et al. 2020), the first report in Africa. In 2023, wheat blast was reported in Uruguay (Silva et al., 2025). This review therefore, shows that wheat blast has the potential to spread to other wheat producing areas with favorable conditions for the blast pathogen. Warm temperatures combined with high humidity and frequent rainfall create conducive conditions for the pathogen. In Zambia, the disease is prevalent during rainy season due to the season being constantly wet and humid, hence, encouraging disease epidemics and posing a threat to food security.

The disease is very devastating and is characterized by rapid spread and high ability to devastate crops, leading to substantial yield losses and reduced grain quality. Because of its devasting nature, wheat blast is considered a high research urgency in areas where it has been discovered. In view of the above, wheat blast surveillance was conducted to assess the distribution of the disease, mapping of infected areas and halting it's spread.

## Materials and Methods

The surveys were conducted in summer under rainfed conditions (warm and humid), as well as in winter under irrigated conditions (cool and dry). The survey was undertaken in 2020-21, 2021-22, 2022-23 and 2023-24 in all rainfed wheat growing areas (Chilanga, Chibombo, Chitambo, Mpongwe, Masaiti, Mpika, Solwezi, Mpulungu, and Mbala districts; Figure 1). Rain season surveillance was undertaken each year in February for the wheat planted in November or December, and in March for wheat planted in January as this is the time when wheat is at anthesis to milk stage. The best time to check for wheat blast in the field is during the reproductive stage, especially at two to three weeks after flowering or anthesis (Singh et al., 2021). This is when the most recognizable symptoms, such as bleached spikes, are most likely to appear. The survey was also extended to irrigated wheat in 2021 to 2024 to check the presence of wheat blast. During the irrigated season, wheat disease survey was undertaken between July and September in major irrigated wheat growing areas (districts) in Zambia such as Mazabuka, Chiawa, Chinkankata, Chilanga, Kafue, Lusaka, Chongwe, Chisamba, Chibombo, Kabwe, Mkushi, Mpongwe and Kapiri-Mposhi (Figure 2). Coucal, a variety susceptible to wheat blast during rainy season was planted at Mt. Makulu, Chongwe, Chiawa and Mpongwe to monitor the occurrence of this disease during irrigated cool and dry season

For sampling, a zigzag or W sampling pattern was followed (Kishowar et al., 2021; Savary et al. 1996) taking samples at intervals along the way.

A total of 263 infected wheat (*Triticum aestivum*) samples were collected during rainy season from the wheat fields in Mt. Makulu (longitude -15.5491, latitude 28.2513), Mpongwe (longitude -12.110367, latitude 31.244333), Mbala Lucheche trial assessment site (longitude -8.83442, latitude 31.36716) and Mpika Malashi trial assessment site (longitude -11.802415, latitude 31.4495). Infected head/spike appear bleached with blackened (dark gray fungal growth) rachis at the point of infection. The infected spikes can either be completely or partially bleached. Wheat heads/spikes with clear wheat blast symptoms were collected from the field and were air-dried for 2-3 days on a paper towel/tissue. The air-dried infected wheat heads were then put in a paper bag which was sealed with a staple or a paper clip and transported to the laboratory. Laboratory confirmation of the pathogen was done at Zambia Agriculture Research Institute (ZARI), Mt. Makulu Research Station. Other diseases were also collected during the survey. During the irrigated season, a total of 80 fields, including both commercial and small-scale farmers' fields, were surveyed in 2021, 2022 and 2023, while 77 fields were surveyed in 2024.

Pure culture preparation of the collected samples

The spikelets were detached from the infected spike from which the glumes and seeds were separated. The infected rachis was cut into 3-5 cm sections and washed with 5.25% sodium hypochlorite and followed by distilled

**Table 1:** Area harvested, productivity and production of wheat in Zambia.

| Year | Area harvested (ha) | Yield (t/ha) | Production (t) |
|---|---|---|---|
| 2010 | 27291 | 6311.8 | 172256.0 |
| 2011 | 37631 | 6306.8 | 237332.0 |
| 2012 | 37209 | 6813.5 | 253522.0 |
| 2013 | 41810 | 6543.5 | 273584.0 |
| 2014 | 28159 | 7155.9 | 201504.0 |
| 2015 | 31137 | 6880.2 | 214230.0 |
| 2016 | 24170 | 6600.5 | 159533.0 |
| 2017 | 26741 | 7243.9 | 193713.2 |
| 2018 | 21675 | 5280.8 | 114462.7 |
| 2019 | 22706 | 6687.8 | 151850.5 |
| 2020 | 26007 | 7368.0 | 191619.8 |
| 2021 | 30319 | 6790.5 | 205882.0 |
| 2022 | 33568 | 6998.6 | 234924.6 |
| 2023 | 36551 | 7592.0 | 277491.9 |

Source: FAOSTAT accessed, 26 June 2025.

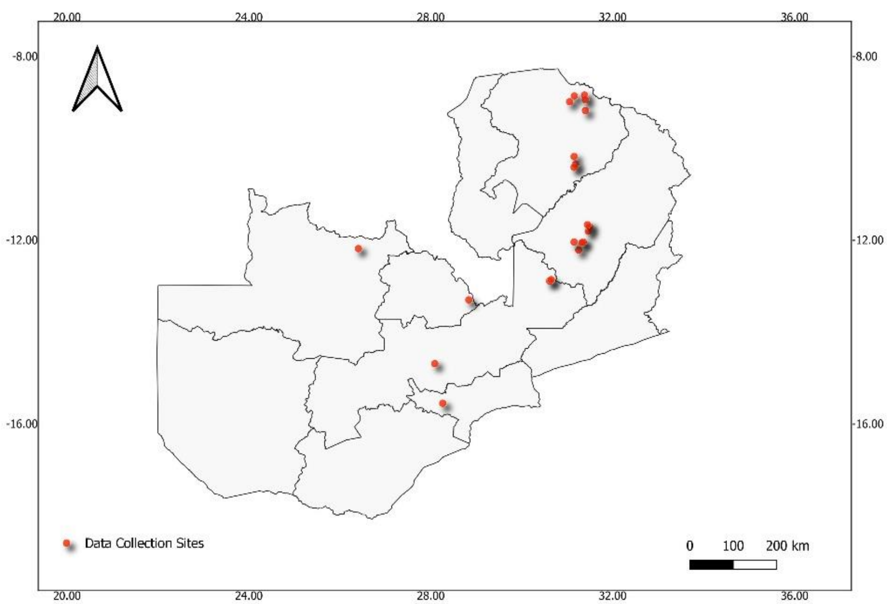


**Figure 1:** Location visited during rainy season disease surveillance, February-March.

water. The glumes, the seed and the rachis were placed on water agar and then incubated at 25˚C for 5–7 days. Pear-shaped double septate hyaline single spores were selected and plated on potato dextrose agar (PDA)

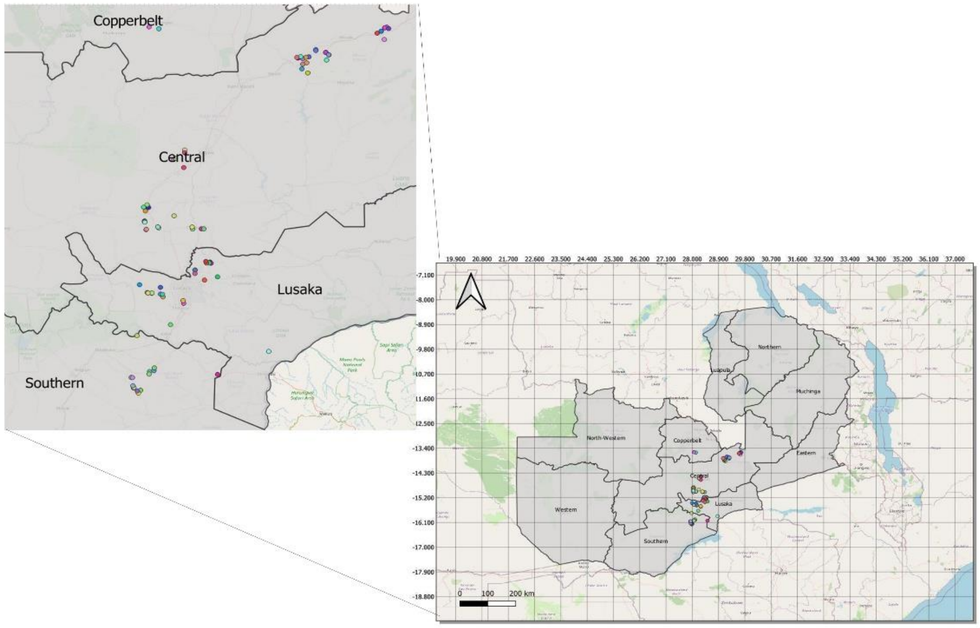


**Figure 2:** Locations visited during the irrigated season disease surveillance, July-September.

amended with Karamycin (1g/L) and incubated for about 10-12 days preceding morphological examination with stereomicroscope.

**DNA extraction**

DNA was extracted according to Pieck et al., (2017). The liquid-grown mycelial mats were harvested, blotted dry on paper towels, and lyophilized for 24 h. The lyophilized mycelium was ground to a fine power in liquid nitrogen. Lyophilized powder (200 mg) was suspended in 4 ml of lysis buffer (50 mM Tris-HCl [pH 8.0], 50 mM EDTA, [pH 8.0], 0.5 M NaCL, and 1% sodium dodecyl sulfate) at 65°C and ground with a mortar and pestle. Phenol/chloroform/isoamyl alcohol (4 ml, 25:24:1) was added and mixed thoroughly. The mixture was transferred to a 30-ml Corex tube and centrifuged at 8,500 rpm at 4°C for 30 min. The aqueous phase was transferred to a clean tube and the DNA was precipitated by adding 0.54 volumes of isopropanol, mixed by inverting, and centrifuged at 8,500 rpm at 4°C for 10 min. The pellet was washed with 2 ml of 70% (vol/vol) ethanol, dried, and resuspended in 0.5 ml of Tris-EDTA (TE) with RNAse A at 100 mg/ml. The DNA concentration was quantified using a NanoDrop NO-1000 spectrophotometer (NanoDrop technologies, Wilmington, DE).

**Detection of MoT by polymerase chain reaction and *Magnaporthe Oryzae* Triticum Isothermal Amplification Kit**

**Polymerase chain reaction (PCR)** was performed in a 25 µl reaction containing 200–400 ng of DNA template, 1x Dream Taq buffer, 0.2 mM dNTPs, 0.2 µM of each MoT3F (5-GTCGTCATCAACGTGACCAG-3) and MoT3R (5-ACTTGACCCAAGCCTCGAAT-3) specific primers of MoT [6] and 1 U of Dream Taq DNA polymerase. Thermal cycling conditions included an initial denaturation at 94˚C for 2 min, followed by 35 cycles of 94˚C for 30 s, 55˚C for 30 s, and 72˚C for 1 min with a final extension step of 72˚C for 7 min.

**Isothermal Amplification technique** using a rapid detection diagnostic kit a colloidal gold test strip type (supplied by Dr. Kang of Chinese Academy of Agricultural Sciences from Amp-Future Bio, Manufacturer: AMP-Future (Changzhou) Biotechnology Co., Ltd. China) was also used to check the presence of MoT on the infected samples.

50 µl of diluted DNA template was added into microspheres and mixed upside down for 8 – 10 times, after mixing the reaction liquid was shaken (or rapidly centrifuge) and immediately transferred to the amplification area for amplification. The mixture was incubated at 39-42ºC for at most 20 minutes. Then a small amount of DNA of about 5 µl-10 µl was diluted 10

times for brighter bands. Later 50 µl of the diluted amplicon was placed into the sample well on the strip and results were read within 5 minutes.

## Results

### Rainy seasons 2020-21, 2021-22, 2022-23 and 2023-24

During the 2021-22 and 2022-23 cropping seasons, no blast was observed in farmers' fields. However, high wheat blast incidence (>50%) and severity were found in experimental fields in Mpongwe and Mpika (Figure 3) during both years. On the other hand, low infection levels were observed at Mt. Makulu Research Station during 2020-21, 2021-22 and 2022-23 season. Additonlaly, very low disease incidences were observed in Mbala during 2022-23 season.

Morphological characterisation of the 263 samples collected during rainy season confirmed the presence of wheat blast isolates on 44 samples (Figure 4). A 361-bp PCR product characteristic of MoT were amplified from all 44 isolates, using molecular marker MoT3 specific to MoT pathogen. Futhermore, the presence of MoT on the infected samples was also confirmed with the rapid diagnostic kit (Figure 5). Of the remaining 219 samples collected, 116 isolates were found to be *Fusarium* spp., 74 isolates to be *B. sorokiniana*, while the other 29 isolates to be *Alternaria* and *Cavularia*. On the other hand, during the 2023-24 season, wheat blast incidence and severity were very low due to drought experienced in the country, where some fields completely dried up. However, a few genotypes in the hotspot areas were infected with the disease as they received some rainfall that led to relatively high humidity at the heading stage. During both years, disease symptoms were observed in late February on the crop planted in November and in mid- to - late March on the crop planted in January.

### Irrigated season- May to September -2021, 2022, 2023 and 2024

No blast was detected during the cool, dry irrigated winter season on irrigated commercial wheat crop, small scale farmers' wheat crop and wheat breeding trials. The local rainfed variety (Coucal) susceptible to wheat blast showed no blast symptoms in all sites, but exhibited severe powdery mildew infection (Figure 6). Other diseases observed at low incidence and severity during all four years include Fusarium head blight (FHB), bacterial leaf strike, loose smut, tan spot, and take all (Figure 7). However, FHB was the most common disease being detected in 60% of the irrigated wheat fields surveyed, with low to medium severities. Fusarium head blight infection often causes partial (Figure 8a) or complete bleaching of the spike, which is frequently confused with wheat blast infection. Infected samples that were collected from the fields during the irrigated season confirmed the presence of FHB (Figure 8b and c). Apart from the aforementioned diseases, yellow rust was observed in 2024 at a trial site in Chisamba (Figure 9). Results from the analysis from Global Rust Reference Center (GRRC) in Denmark indicated that the yellow rust sample belong to PST genetic group PstS1_2.

## Discussion

During the 2021-22 and 2022-23 seasons, smallholder rainfed wheat farmers were encouraged to temporally suspend wheat cultivation to contain wheat blast disease detected in Zambia during the 2017-18 season (Tembo et al., 2020). This was because the famous rainfed wheat variety Coucal was found to be highly susceptible to wheat blast. To further mitigate the effect of wheat blast, two rainfed wheat varieties (Tyetye and Mpheta) with 2NS segment that confer resistant to the disease were released to the farming community in 2023. The importance of 2NS segment in wheat lies in its transfer of broad-spectrum resistance to many diseases such as wheat blast, stripe rust, leaf rust, stem rust and root knot nematodes (Gao et al., 2021). 2NS segment has been reported to be crucial in developing wheat varieties resistant to blast (Roy et al., 2021). It has been described by several scientist to be highly effective at providing resistance against wheat blast (Wu et al., 2022; He et al., 2020). Studies by Cruz et al. (2016) revealed that 2NS translocation was associated with substantial resistant levels to head blast in both spring and winter wheat.

Low infection levels of wheat blast observed at Mt. Makulu during the 2021-22 season could be due to weather conditions that were less favorable for disease development, as the site experienced a partial drought, leading to low rainfall and high temperature (>29ºC) at the heading and flowering stage. The 2023-24 season was rather less favourable for wheat blast to develop due to severe drought experienced in the country. Severe drought resulted in dry (no rainfall) and hot weather conditions, giving no chance for blast to develop and spread. Wheat blast infection on wheat plants occurs between 25ºC and 30ºC and the lowest at 15ºC. However, above 35ºC the temperatures become too high for blast to develop (Cardoso et al., 2008). Wheat blast spread very quickly when the conditions are warm, wet and humid during heading or flowering time and also when the heavy dew hours are extended.

Morphological characterisation of the 263 samples collected during rainy season confirmed the presence of

**Figure 1:** Experimental field plots grown in the 2021-22 cropping season. a) Mpongwe site, where heavy wheat blast infection was observed for the susceptible genotypes Coucal (left row) and Sonalika (right row). b) Mpika site, where the arrow head indicate the highly susceptible genotype c) Sonalika infected in 2022-23 cropping season at Mpongwe site and d) one of the lines in the screening nursery.

a b

**Figure 2**: a) Colony of MoT isolates on PDA; b) Pear shaped two-septate hyaline MoT spores under compound microscope (magnification 400×).

wheat blast isolates on 44 samples. The PCR analysis using molecular marker MoT3 specific to MoT pathogen amplified a 361-bp from wheat blast isolates further confirming the pesence of the pathogen in the infected samples. Further analysis conducted using rapid diagnostic kit showed that the infected samples were positive for MoT. The isothermal amplification kit was easy to use and displayed results quickly. Using this technique, researchers can rapidly detect and identify the causal pathogen and implement disease control measures (Kang et al., 2020) without the need for a thermocycler. The technique can be a good source for rapid detection of the pathogen for Zambia and other countries. It has been reported to be a field-friendly alternative to PCR that requires minimal equipment to conduct the analysis (Kang et al., 2020).

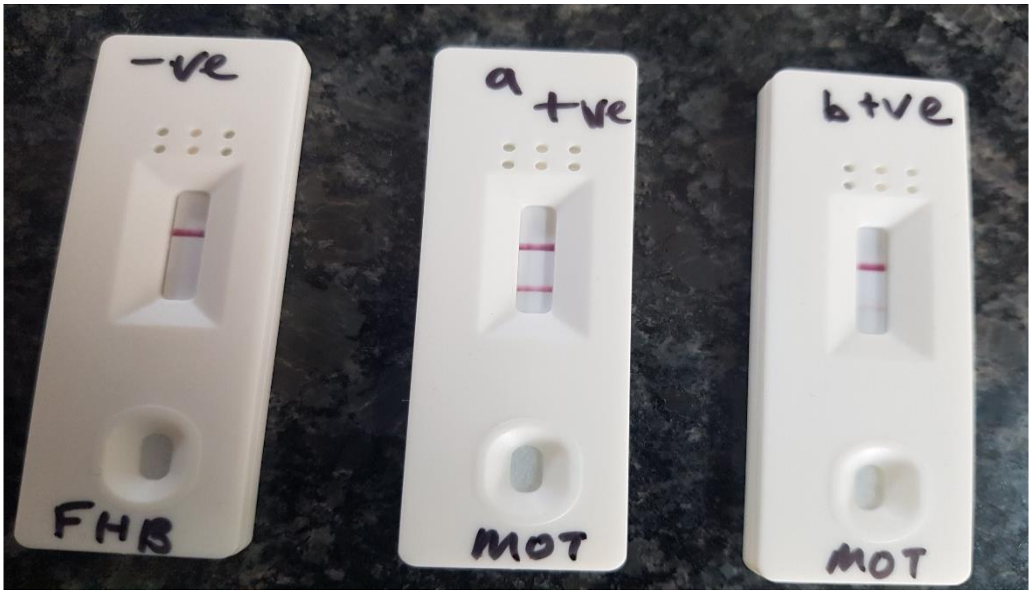


**Figure 5:** Detection of MoT using the Magnaporthe Oryzae Triticum rapid diagnostic Kit - June 2024.

**Figure 6:** The wheat variety Coucal with powdery mildew infection in the irrigated season.

The surveillance which was conducted in 2021, 2022, 2023 and 2024 under cool and dry season revealed the absence of wheat blast in all the surveyed irrigated wheat fields. The infected samples collected from the fields that had blast-like symptoms (partially bleached wheat head) showed the absence of MoT, the wheat blast pathogen. Instead, the infection was confirmed to be FHB on all the samples. Fusarium head blight infection causes bleaching of the spike which is very often confused with wheat blast infection (Mottaleb et al., 2018). In general, FHB was the dominant disease that was observed from the irrigated survey. This was due to conducive weather conditions particularly during anthesis that supports spore germination and infection. Studies have shown that FHB

**Figure 7**: Wheat diseases observed at low incidence during the irrigated season. a) Bacterial leaf strike: b) loose smut c) take all and d) tan spot.

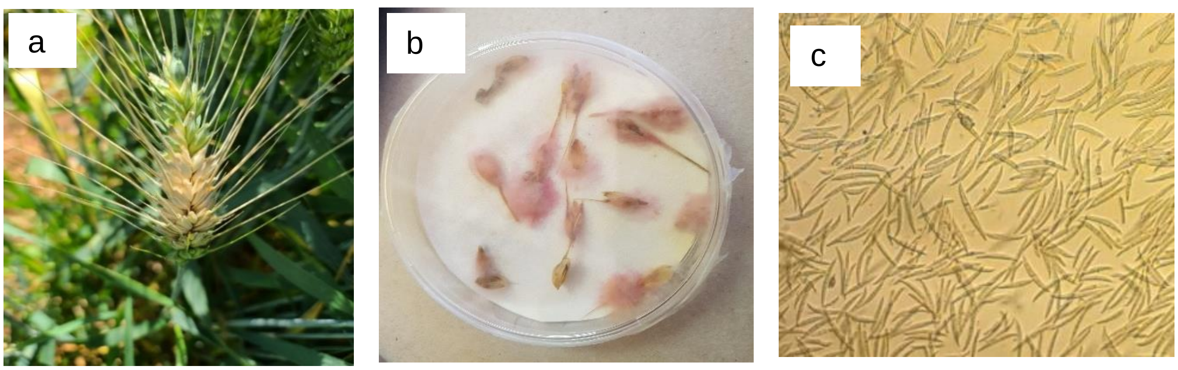

**Figure 3:** Fusarium head blight a) Infected wheat spike b) Plates plated with FHB, c) *Fusarium graminearum* isolated from infected wheat heads in irrigated wheat fields.

thrives in wet and warm weather (16°C and 30°C) with high relative humidity (>90%) (Lenc, 2015). Furthermore, high incidences of FHB were also observed on commercial farms which practice maize–wheat cropping system. Despite blast not being present in the irrigated season, two irrigated wheat genotypes that have the 2NS segment that confer resistance to blast are in the pipeline for release by ZARI-Wheat team. These could be used for the irrigated season in case that wheat blast happens during the cool and dry season.

Other diseases of importance observed with low incidence and severity during irrigated season were powdery mildew, bacterial leaf strike, smut, tan spot, take all and yellow rust. The analysis of yellow rust observed in Zambia by GRRC of Denmark revealed that it belongs to PST genetic group PstS1_2 which are “aggressive” and adapted to warmer temperatures compared to many other isolate groups. Though with low incidences and severity, the aforementioned diseases are of serious concern that require attention in terms of developing resistant germplasm.

A rain-fed wheat variety Coucal which is susceptible to wheat blast during rainy season showed no blast symptoms in all sites during the irrigated winter season but was highly susceptible to powdery mildew. This also gave an indication that wheat blast might not be present during the aforementioned 2021-2024 surveillance years in the irrigated season. However, under the climate change scenario, there is a big chance that the wheat blast pathogen might spread to areas and seasons where the disease is not currently present. Therefore, continued monitoring of wheat blast in the irrigated wheat fields is strongly recommended. Additionally, since wheat is grown under 2 agroclimatic systems rainfed (November - April) and irrigated (May- September) it is therefore important to avoid planting irrigated wheat in March or

**Figure 9:** Yellow rust observed during the 2024 irrigated season.

April to control the green bridge in between cropping seasons.

## Conclusion

Wheat blast was observed in Mpongwe, Mt. Makulu and Mpika during rain season throughout the 4 year period of wheat blast surveillance. Disease incidences and severity was higher in years with favourable weather conditions (2021/2022, 2022/2023) and less in years with less favourable weather condtions such as the 2023-24 season. Morphological analysis on the infected spikes sampled during rainy season confirmed the presence of *Magnaporthe oryzae* pathotype *Triticum* (MoT) pathogen. Furthermore, molecular analysis using PCR amplification with MoT3 primer confirmed the presence of MoT in the infetecd samples. On the other hand, no blast was detected in wheat grown under cool and dry irrigated season in all the years (2021 to 2024). The absence of the disease in irrigated wheat is an indication that the disease has not yet reach the season. Even the most susceptible variety Coucal was asymptomiatic of blast during the cool and dry irrigated season in all the aforementioned years. However, with the issue of climate change at hand continued monitoring of wheat blast in the irrigated wheat fields is strongly recommended as the disease might be detected in the presently cool and dry season. Green bridge management is key to control wheat blast pathogen to protect irrigated wheat since wheat is grown under 2 agroclimatic systems rainfed (November -April) and irrigated (May-September). Wheat blast is a new disease in Zambia and Africa at large and a threat to wheat production. As such, continued surveillance is critical to tracking disease distribution and limit its introduction into new areas and neighbouring countries.

**Author contribution:** All authors made substantial contribution to the concept, design of the work, preparation, analysis and data interpretation and all have approved the publication of the manuscript.

### Conflicts of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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