Pure Appl. Biol.,13(3):328-334, September, 2024
http://dx.doi.org/10.19045/bspab.2024.130029

Review Article

A short review on the impacts of evolving and adapted yellow rust strains in wheat

Jameel Ahmad Bhatti[1*], Armghan Shahzad[1], Waqar Ahmad Bhatti[1], Haider Ali[1], Safdar Hussain[1], Muhammad Arif[1], Danish Abbasi[1], Muhammad Ismail Bhatti[2] and Muhammad Ishaque Mastoi[3]

1. National Institute for Genomics and Advanced Biotechnology, Islamabad, Pakistan
2. Pakistan Museum of Natural History, Islamabad, Pakistan
3. Pakistan Agricultural Research Council, Islamabad, Pakistan

**Corresponding author's email: jameelahmadbhatti@gmail.com*

Citation

Jameel Ahmad Bhatti, Armghan Shahzad, Waqar Ahmad Bhatti, Haider Ali, Safdar Hussain, Muhammad Arif, Danish Abbasi, Muhammad Ismail Bhatti and Muhammad Ishaque Mastoi. A short review on the impacts of evolving and adapted yellow rust strains in wheat. Pure and Applied Biology. Vol. 13, Issue 3, pp328-334.
http://dx.doi.org/10.19045/bspab.2024.130029

Received: 29/11/2023 Revised: 12/01/2024 Accepted: 22/01/2024 Online First: 30/01/2024

Abstract

Wheat (*Triticum aestivum* L.) is a good source of protein and calories in developing countries. Its production plays a key role in the food security of the globe and in bridging the gap between developing countries. However, wheat production was decreased due to it is host-specific pathogen *Puccinia striiformis* Westend f. sp. *tritici* (*Pst*). There are number of environmental factors such as temperature, humidity, and wind involved in yellow rust disease development in wheat crops. Yellow or stripe rust has the capability to evolve into new strains and made susceptible to resistant wheat cultivars. Therefore, cultivated wheat varieties could be unable to produce maximum yield. In past there were several genetically diverse *Pst* races has been evolved. Recently, it has begun to replace increasingly earlier clonally propagated and slowly enhance their chances for the creation of endemic populations. These circumstances will decrease the yield and ultimately damaged the economy of the country. However, parallely comes rapid advances in genomics application for wheat germplasm against the slowly evolving genetically divergent Pst races such as genetic resistance approaches, cloning of yellow rust resistance gene, designing of yellow rust resistant genes and searching of new resource for genetic exploitation with the help of conventional breeding. So, it is needed to bring out the rational approach for the diverse yellow rust strains. This review paper summarized on the response of environment for the adaption diverse *Pst* strains in wheat and recorded damages of yellow rust and its management strategies respect to future perspective.

Keywords: Economy; Environmental factors; Pst strains; Wheat; Yellow rust

Introduction

Yellow rust is a major disease of wheat crops in the cooler regions of the world. Rusts disease (yellow rust, leave rust, and stem rust) are immensely devastating to affect the economic yield of wheat plants. There are a number of rust epidemics reported in wheat-cultivated areas of the world. Races of yellow rust continually to begun due to mutation and sexual recombine and badly affect the economy of developing countries as in (Fig. 1). Molecular studies and pathogenicity

surveys have been conducted in central wheat-producing regions of America, Europe, and Australia. The reported *Puccini striformis tritici* (*Pst*), populations in these regions were shown that low number of genetic variations, clonal nature, and pathotypes very similar to each other which means that it is predominantly controlled by single step-wise mutations [1]. The yellow rust wheat-resistant gene was broken down by clonally derived *Pst* mutations which caused a number of epidemics. Here, highly reported yellow rust resistant genes, such as *Yr17* in Northern Europe [2], *Yr27* in Ethiopia [3], and *Yr9* in America, the Middle East, and the Indian subcontinent [4], became susceptible due to *Pst* mutations, increasing the likelihood of epidemics in developed countries. The low *Pst* genetic variation was observed in samples that were taken from Pakistan, Nepal, and China near to Himalayan regions since 2000. These were found showing varying amounts of genetic diversity, the maximum ability for sexual reproduction, and greater genetic recombination [5]. Past to till now these countries were famous for *Pst* origin [6]. In the last two decades, the world became susceptible to this strain due to aggressive and sudden changes in pathogen profiles. A remarkable event occurred that identify the two strains such as *PstS1* and *PstS2* that covered the whole United States of America [7], Europe [8] and Australia [9] within a very short time. The worldwide study was conducted about pre- and post-2000 *Pst* races with the help of DNA fingerprinting and virulence pathotyping and the study proved that *PstS1* and *PstS2* strains were genetically very close to relatedness. However, these strains were divergent from the rest of the previous races [10]. Both of them were spread more quickly because of adapting to high temperatures, the high ability of spore production, and speedily disease development which was elaborated in the comprehensive study [11]. In Northern France, the *Pst* population was specified the maximum level of genetic difference and clonal specific to South France [12]. It was surprising that these single pathotypes remained to stay for a long time in Northern and Southern *Pst* populations regardless of gene flow in these regions. Later it was found that this isolate is more similar to *Pst* populations of Central Asian-Mediterranean [13]. Likewise, in North-Western Europe high genetic divergence was also reported [14]. Three to four times more genetic variety was seen in two groups of distinct pathotypes from the ancient North-Western European population [15]. Two brand-new *Pst* races hurt the European agricultural sector in 2011. The two cultivated varieties were named 'Warrior' and 'Kranich' in Europe affected by these two novels' *Pst* races. Later it was called *PstS7* and *PstS8* races [16]. The *PstS7* and *PstS8* races were highly divergent from previous races which were present across Europe. They produced the maximum number of teliospores [17]. Collectively genetic diversity and observations were made that new genetically distinct *Pst* races reported in Europe since the 19th century. Furthermore, it was several severe yellow rust epidemics occurred in Central Asia, and North and East Africa due to rapid changes in the *Pst* population.

Environmental factors

Yellow rust compromises the ability of the wheat plant or part of the plant to carry out one or more essential functions. Being a causal agent wants to extract nutrients from it for their regeneration. Although yellow rust is a pathogen but did not produce disease until and unless gets productive environmental factors such as temperature, humidity, and wind [18]. When all of these factors are in one place, yellow rust will be able to recognize the presence of the right host by using unique genes. Those genes

produce proteins with a specific structure for detecting chemicals emitted by the host [19].

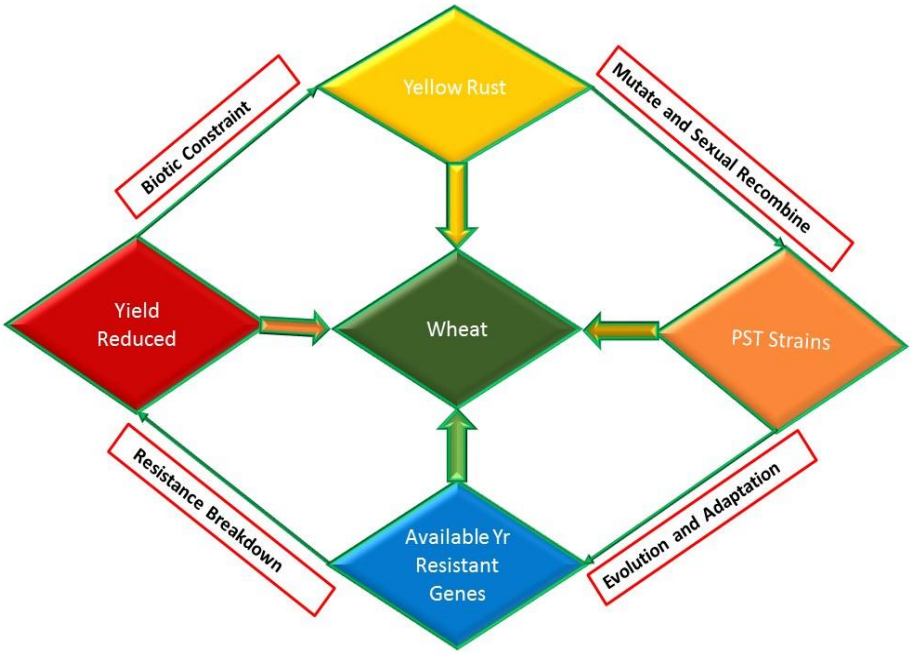

Figure 1. Impacts of evolving and adapted yellow rust strains in wheat

Therefore, yellow rust needs right host for disease development as host plant contains such types of chemicals, which can trigger its virulence, so the presence of such particular chemicals made it virulent for the wheat crop. However, these chemicals are released in response to specific environmental factors, which are interconnected in the case of yellow rust disease [20]. For example, yellow rust susceptible wheat variety planted in areas where the available temperature is greater than 40°C, as well as artificially dusting the rust spore on it, yet no disease is formed at this temperature. Because right host and pathogen are not enough unless get an optimum environment as in (Fig. 2) and also explain in tabulated form (Table 1).

Damages of yellow rust

Not only yellow rust but the rest of all rust (stem and leaf) caused epidemics in form of low wheat yield production worldwide. However, in the current situation yellow rust became more popular in sense of reducing yield per hectare per year as compared to stem and leaf rust in wheat. It has now become a critical issue for the economies of developing nations like Pakistan. Review of global YR epidemics shows most wheat growing regions document recurrent crop losses of 5–10 %, with occasional losses of up to 25 % [21]. Due to the motherland's major agricultural areas' rust susceptibility, wheat yield losses typically ranged from 0.1 % to 25 % [22]. [23] reported that increase in disease, 88 % of the world's wheat production is now prone to yellow rust constraint whereas the status of rust in Pakistan was ranged 10-70 % [24]. The loss of yield is increased by up to 100 % depending upon the earliness of infection and susceptibility of cultivated cultivars [25]. The reported loss was 5.47 million tons of yield due to yellow rust. According to estimates, there were 979 million dollars in losses, and when yield

losses were matched to the price of creating yellow rust-resistant types, it was found that US$32 million was needed per year for ongoing research on the yellow rust disease. In order to boost the production of wheat, the world is now asking that plant breeders perform certain actions.

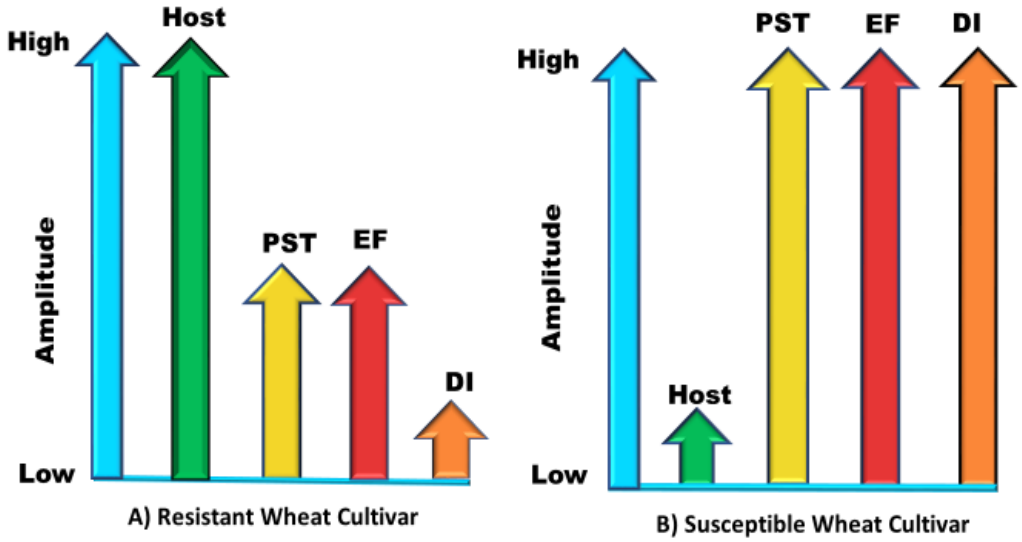

Figure 2: A) Interaction of resistance wheat cultivar as host with *Puccinia striiformis* Westend f. sp. *tritici* (*PST)* in presence low favorable Environmental Factors (EF). As result shown that low Disease Incidence (DI). B) Interaction of susceptible wheat cultivar with presence of maximum level of PST and EF. As results shown that maximum level of DI

Table 1: Interactions of yellow rust with environmental factors

Yellow Rust	Specific Host	Productive Environment	Disease Rate
High Rate	Wheat	Optimum	High Amount of Disease
Low Rate	Wheat	Low	Low Amount of Disease
Low rate	Wheat	Optimum	Low Amount of Disease
High Rate	Wheat	Absent	No Disease Occurred
Low Rate	Wheat	Absent	No Disease Occurred
Absent	Wheat	Optimum	No Disease Occurred

Strategies for yellow rust disease

The wheat growers' community across the globe has two main options to reduce the constraints of yellow rust on wheat production. One is chemical control and the other is genetic resistance. The use of systematic fungicides for plants started in the 1980s and then became part of integrated control measures against yellow rust [26]. Currently, several products of fungicides are used for yellow rust with different trade names by different companies [27]. Timely use of fungicide application to prevent significant losses during the epidemic time in the USA [28]. However, the permanent use of chemicals for yellow rust control caused negative impacts on the ecosystem and directly or indirectly increase the annual cost

of farmers. It was reported that Australia spent $ 359 million per year on fungicides for yellow rust control [29]. Secondly, new diverse strains of *Pst* became resistant against the two most resistant families of fungicides like demethylation inhibitors, succinate dehydrogenase inhibitors, and quinone outside inhibitors [30]. Now it is needed to bring out fungicide exposure time optimization as well as improved fungicide application technologies in areas where more research and development are required [31]. As a result, regular fungicide resistance monitoring for several *Pst* races should be implemented. The yellow rust resistance has been reported more than 300 wheat genomic regions [32]. Out of 300 genomic regions approximately 80 were permanently named YR resistance genes [33]. Genes for resistance should divided into two categories. The first is called All Stage Resistance (ASR), it means that conferring qualitative yellow rust resistance. Other one known as Adult Plant Resistance (APR) which conferring the quantitative resistance.

Conclusion

Yellow rust now became a burning issue in many developing and developed countries. It is a biotic constraint for the wheat crop. The wheat crop is its specific host which means that yellow rust completes its life cycle on it. There is a number of *Yr* resistance genes were identified against yellow rust, however, manipulated genetic resistance, and deployed resistance in cultivated varieties is insufficient and easily broken down by the diverse strains of *Pst*. It is imperative to bring out modern genetic approaches for diverse *Pst* races which appear after every two years such as advanced genetics approaches, cloning of yellow rust resistance genes, and designing of resistance genes for future perspective against yellow rust. Therefore, the development of a wheat variety should be resistant to this disease otherwise, the disease will prevail. A suitable approach, such as the use of genetic resources, should be used to keep one step ahead of yellow rust in order to win this race. It needs to focus on the rational approach which is to remain one step forward against pathogens.

Authors' contributions

Conceived idea/funding: JA Bhatti & A Shahzad, Wrote the paper: S Hussein, M Arif, D Ali & H Ali, Analysis /tools: MI Bhatti, MI Mastoi & WA Bhatti.

References

1. Hovmiller MS, Walter S, Bayles RA, Hubbard A, Flath K, Sommerfeldt N, Leconte M, Czembor P, Rodriguez-Algaba J, Thach T, Hansen JG, Lassen P, Justesen AF, Ali S, & de Vallavieille-Pope C (2016). Replacement of the European wheat yellow rust population by new races from the centre of diversity in the near-Himalayan region. *Plant Pathol* 65: 402–411.
2. Bayles R, Flath K, Hovmøller M & de Vallavieille-Pope C (2000). Breakdown of the *Yr17* resistance to yellow rust of wheat in northern Europe. *Agronomie* 20(7): 805-811.
3. Solh M, Nazari K, Tadesse W & Wellings CR (2012). The growing threat of stripe rust worldwide. In Borlaug Global Rust Initiative (BGRI) conference, Beijing, China. pp. 1-4.
4. Chen X, Penman L, Wan A & Cheng P (2010). Virulence races of *Puccinia striiformis* f. sp. tritici in 2006 and 2007 and development of wheat stripe rust and distributions, dynamics, and evolutionary relationships of races from 2000 to 2007 in the United States. *Canadian J of Plant Pathol* 32(3): 315-333.
5. Duan X, Tellier A, Wan A, Leconte M, de Vallavieille-Pope C, & Enjalbert J (2010). *Puccinia striiformis* f.sp. tritici presents high diversity and recombination in the over-summering zone of Gansu. *China Mycol* 102: 44–53.
6. Ali S, Leconte M, Rahman H, Saqib MS,

Gladieux P, Enjalbert J, & de Vallavieille-Pope C (2014). A high virulence and pathotype diversity of *Puccinia striiformis* f.sp. tritici at its centre of diversity, the Himalayan region of Pakistan. *Eur J Plant Pathol* 140: 275–290.
7. Markell SG & Milus EA (2008). Emergence of a novel population of *Puccinia striiformis* f. sp. tritici in Eastern United States. *Phytopathol* 98: 632–639.
8. Hovmøller MS & Justesen AF (2007a). Appearance of atypical *Puccinia striiformis* f. sp. tritici phenotypes in north-western Europe. *Aust J Agric Res* 58: 518–524.
9. Wellings CR (2007). *Puccinia striiformis* in Australia: A review of the incursion, evolution, and adaptation of stripe rust in the period 1979–2006. *Aust J Agric Res* 58: 567.
10. Hovmøller MS, Yahyaoui AH, Milus EA & Justesen AF (2008). Rapid global spread of two aggressive strains of a wheat rust fungus. *Mol Ecol* 17: 3818–3826.
11. Milus EA, Kristensen K & Hovmøller MS (2009). Evidence for increased aggressiveness in a recent widespread strain of *Puccina striiformis* f. sp. tritici causing stripe rust of wheat. *Phytopathol* 99: 89–94.
12. Enjalbert J, Duan X, Leconte M, Hovmøller MS, & DE VALLAVIEILLE-POPE C (2005). Genetic evidence of local adaptation of wheat yellow rust (*Puccinia striiformis* f. sp. tritici) within France. *Mol Ecol* 14(7): 2065-2073.
13. Ali S, Gladieux P, Leconte M, Gautier A, Justesen AF, Hovmøller MS, Enjalbert J, & de Vallavieille-Pope C (2014a). Origin, migration routes and worldwide population genetic structure of the wheat yellow rust pathogen *Puccinia striiformis* f.sp. tritici. *PLoS Pathogens* 10: e1003903.
14. Hovmøller MS & Justesen AF (2007). Appearance of atypical *Puccinia striiformis* f. sp. tritici phenotypes in north-western Europe. *Aust J Agric Res* 58: 518–524.
15. Hovmøller (2007). Appearance of atypical *Puccinia striiformis* f. sp. tritici phenotypes in north-western Europe. *Aust J Agric Res* 58: 518–524.
16. Ali S, Gladieux P, Leconte M, Gautier A, Justesen AF, Hovmøller MS, Enjalbert J, & de Vallavieille-Pope C (2017). Origin, migration routes and worldwide population genetic structure of the wheat yellow rust pathogen Puccinia striiformis f.sp. tritici. *PLoS Pathogens* 10:e1003903.
17. Hubbard A, Lewis C, Yoshida K, Ramirez-Gonzalez R, de VallavieillePope C & Thomas J (2015). Field pathogenomics reveals the emergence of a diverse wheat yellow rust population. *Genome Biol* 16: 23.
18. Wan AM, Chen XM & He Z (2007). Wheat stripe rust in China. *Aust J Agric Res* 58: 605–619.
19. Flor HH (1971). Current status of the gene-for-gene concept. *Ann Rev of Phytopathol* 9(1): 275-296.
20. Jones JD & Dangl JL (2006). The plant immune system. *Nature* 444(7117): 323-329.
21. Wellings CR (2007). Puccinia striiformis in Australia: A review of the incursion, evolution, and adaptation of stripe rust in the period 1979–2006. *Aust J Agric Res* 58: 567.
22. Ibrahim M, Shah SJA, Hussain S & Ahmad M (2017). Yellow rust surveillance and deployment of wheat cultivars in the region of pathogen diversity in Pakistan. *Sarhad J of Agric* 33(3).
23. Beddow JM, Pardey PG, Chai Y, Hurley TM, Kriticos DJ, Braun HJ, & Yonow T

(2015). Research investment implications of shifts in the global geography of wheat stripe rust. *Nat Plants* 1(10): 1-5.

24. Afzal SN, Haque MI, Ahmedani MS, Rauf A, Munir M, Firdous SS & Ahmad I (2008). Impact of stripe rust on kernel weight of wheat varieties sown in rainfed areas of Pakistan. *Pak J Bot* 40(2): 923-929.
25. Chen XM (2005). Epidemiology and control of stripe rust [*Puccinia striiformis* f. sp. tritici] on wheat. *Canadian J of Plant Pathol* 27(3): 314-337.
26. Chen XM (2005). Epidemiology and control of stripe rust [*Puccinia striiformis* f. sp. tritici] on wheat. *Canadian J of Plant Pathol* 27(3): 314-337.
27. Chen X & Kang Z (2017). Introduction: history of research, symptoms, taxonomy of the pathogen, host range, distribution, and impact of stripe rust. *In Stripe rust*. pp. 1-33.
28. Line RF (2002). Stripe rust of wheat and barley in North America: A retrospective historical review. *Ann Rev Phytopathol* 40: 75–118.
29. Murray GM & Brennan JP (2009). Estimating disease losses to the Australian wheat industry. *Aust Plant Pathol* 38(6): 558-570.
30. Cook NM, Chng S, Woodman TL, Warren R, Oliver RP, & Saunders DGO (2021). High frequency of fungicide resistance-associated mutations in the wheat yellow rust pathogen *Puccinia striiformis* f. sp. tritici. *Pest Manag Sci* https://doi.org/10.1002/ ps.6380.
31. Carmona M, Sautua F, Pérez-Hérnandez O, & Reis EM (2020). Role of fungicide applications on the integrated management of wheat stripe rust. *Frontiers in Plant Sci* 11: 733.
32. Wang MN & Chen XM (2017). First report of Oregon Grape (*Mahonia aquifolium*) as an alternate host for the wheat stripe rust pathogen (*Puccinia striiformis* f. sp. tritici) under artifcial inoculation. *Plant Dis* 97: 839.
33. Jamil S, Shahzad R, Ahmad S, Fatima R, Zahid R, Anwar M, Iqbal MZ, Wang X (2020). Role of genetics, genomics and breeding approaches to combat stripe rust of wheat. *Frontiers Nut* 7: 580715.