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A Review on Yellow Rust (Stripe Rust) of Wheat, Identification, its Spread, and Management

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Abstract—*Wheat is one of the primary staple foods throughout the planet, having a protein content of about 13%. India was the second largest wheat producing country in the world after China with production level of 97.44 mt during the year 2016-17. India's share in global wheat production was recorded at 11.78% in the year 2015-16. The production can further be enhanced from the current levels by minimizing the yield losses owing to fungal diseases. In recent years, stripe rust has emerged as a major threat to wheat crop due to emergence of new pathogen variants. Stripe rust also known as yellow rust of wheat is caused by Puccinia striiformis f. sp. tritici, which is one of the most important diseases of wheat worldwide as well as amongst the most studied of the plant diseases. This review describes its spread, identification and management in wheat crop. In the recent years, new races of stripe rust have been emerged and its incidence has increased to such an extent that many high yielding varieties which were found to be susceptible to yellow rust have been replaced by new resistant varieties. Although stripe rust has mainly been endemic only in cool climate regions but lately it has also spread to areas previously unaffected. Efforts have been carried out worldwide to minimize the losses and to develop new varieties that can confer resistance to yellow rust.*

Keywords*: Puccinia striiformis, stripe rust, resistance, wheat.*

1. INTRODUCTION

The stripe or yellow rust caused by *Puccinia striiformis* Westend f. sp. *tritici* is the most commonly occurring fungal disease in wheat. In northern India, it is locally known as yellow rust. It affects the productivity and quality of wheat throughout the world. Yellow rust appeared in severe form in plain areas in J & K, foot hills of Punjab and Himachal Pradesh, parts of Haryana, Tarai region of Uttarakhand (Sharma and Saharan, 2011). It is an excellent air traveller and can spread to long distances under favourable climatic conditions because of proliferating attribute (Chen, 2005). The pathotypes with virulence for *Yr9* and *Yr27* currently predominate in India (Sharma and Saharan, 2011). Although stripe rust is considered to be a disease of regions with lower temperature, its recent introduction to South Africa and Australia suggests a wider level of adaptation. The new genotypes have undergone mutational changes and provide capability for adapting to higher temperatures which can easily overcome a number of specific resistance genes deployed in wheat (*Solh et al., 2012*). The wheat cultivars become susceptible to rusts due to their narrow genetic base and the rapid rate of evolution of the pathogen, making it necessary to search for new source(s) of resistance. Amongst all the three rusts of wheat, viz., stem (black) rust *(Puccinia graminis* Pers. f. sp. Tritici Eriks. & E. Henn), leaf (brown) rust *(P. triticina* Eriks.) and stripe (yellow) rust *(P. striiformis* Westend f. sp. tritici) is the most damaging in reducing the grain yield (Singh *et al*., 2000). Till now, nearly 76 major genes conferring resistance to stripe rust (*Yr1* to *Yr76*) have been identified (Dracatos *et al*., 2016; Xiang *et al.*, 2016). Although chemical control and wheat cultivation measures can minimize the losses caused by yellow rust at some extent, the most economic and environmental friendly way to control the yellow rust is through deployment of genetic resistance (Line and Chen, 1995; Uauy *et al*., 2005). Stripe rust disease has remained a constant threat to sustainable wheat production in wheat growing countries of the world that need to be managed properly for securing higher yields.

2. STRIPE RUST SPREAD AND ITS IDENTIFICATION AT FIELD LEVEL

The causal agent infects the green tissues of wheat. Infection can take place anytime from one leaf stage to mature plant. Symptoms would appear about a week after infection. Sporulation starts about two weeks post-infection. The fungus usually forms long and narrow stripes, appearing as yellow-to orange discoloration between veins and on leaf sheaths, spikes, spikelets, glumes and awns on susceptible plants progressing into yellow rust symptoms. Mature pustules will break open and release yellow-orange masses of uredinospores. The infected tissue may becomes brown and dry as the plant matures or becomes stressed. Severe early infection can result in plant stunting. The three most important features of weather i. e. moisture, temperature and wind affect

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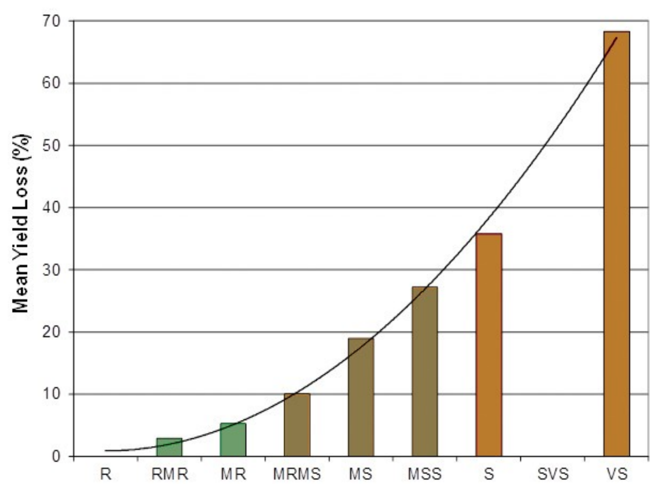
the epidemics of stripe rust. Moisture affects spore. High moisture flourishes disease by favouring rust development (Chen, 2005). Temperature affects spore germination, infection, latent period, sporulation, spore survival and host resistance. Germination of uredinospores is at highest rate at 9.7^{o} C, even though it is capable of germinating at 2.8- spore germination. Humid regions with frequent dew formation during the growing season provide optimal conditions for stripe rust development (Chen, 2005). Temperature affects spore germination, infection, latent period, sporulation, spore survival and host resistance. Germination of uredinospores is at highest rate at 9.7^{o}C, even though it is capable of germinating at 2.8- 21.7^{o}C (Rapilly, 1979). Yellow rust, although potentially a damaging disease in cool climates, has spread in new areas due to climatic changes and adaptation of pathogen to higher temperatures (Johnson, 1988). Wind plays a major role in dispersing the spores (Roelfs *et al*., 1992; Brown and Hovmoller, 2002; Chen, 2005). Long distance dispersion of stripe rust by air resulting in reintroduction and recolonization has also been reported (Nagarajan and Singh, 1990; Hovmoller *et al*., 2011; Chen *et al*., 2014). In addition to features described above, yellow rust epidemics are also influenced by host resistance characteristics (Johnson,1984; Johnson, 1992), host nutritional status (Neumann *et al*., 2004), host density (Garrett and Mundt, 2000) and the time of initial infection in relation to the phenology of the host (Zadoks, 1961). Furthermore, increase in commercial exchange, travel and improper quarantine activities may increase the possibility of moving urediniospore from other countries as foreign pathogen; incursion that has been witnessed by countries like Australia (Wellings and McIntosh, 1990; Wellings *et al*., 2003) South Africa (Boshoff *et al*., 2002). Yellow rust can be easily identified by rubbing fingers over the leaf blade and looking at for yellowish powdery residues. Fields to be checked periodically and early in the season for disease symptoms. Yellow rust should not be confused with any yellowish discoloration on wheat leaves. The usual yellow discoloration may be attributed to temperature especially in early maturing varieties that lead to tip burn and yellowing of leaves (Shroyer *et al*., 1995). The other causes of yellowing on wheat leaves are poor root growth, nitrogen and sulphur deficiencies along with low organic matter (Shroyer, 2011). Waterlogging would also cause lower leaves of wheat to turn pale yellow through nitrogen shortage. Herbicide phytotoxicity especially when applied in frost conditions could result in yellowing of leaves (Simpfendorfer, 2013). Leaves infected with streak mosaic display a bright yellow streaking that resembles yellow rust of wheat. Generally, plants infected with this virus also are infected with other diseases (Wolf *et al*., 2011).

Severe yellow rust on wheat leaf



Yield loss due to stripe rust in wheat cultivars with differing resistance/susceptibility to stripe rust

3. MANAGEMENT AND CONTROL MEASURES OF YELLOW RUST

Stripe rust can cause significant loss to wheat yield and grain quality, given appropriate environmental conditions and susceptible varieties. However, farmers have shown that by planning to manage this disease they can effectively minimise its effects. The most appropriate stripe rust management strategy for a given farm will vary from one farm to another, from region to region and from season to season. Field inspection is quite helpful in timely identification and control of stripe rust. Growers are encouraged to be educated with stripe rust symptoms and anticipate environmental conditions that are conducive for the disease. Constitution of surveillance team by government or other organizations can keep tabs on any occurrence and subsequent spread of the disease. It is advisable to refrain from monoculture of single variety as the chances of an individual variety to become prone to a specific

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strain of pathogen is higher than growing number of resistant varieties on different fields. Removal of the “Green Bridge”; that is to remove volunteer wheat plants that support stripe rust infection, six weeks prior to sowing the seed can minimize the impact of stripe rust. Moreover, ensure to procure certified or registered seed with high degree of resistance and maintain corresponding data for each variety to determine the rate of susceptibility (Murray *et al*., 2005). Adaptation of new varieties which are proven to be resistant to stripe rust and cultivation of these resistance varieties is the best approach to control wheat losses to stripe rust (Line, 1972; Konzak *et al*., 1977; Robbelen and Sharp, 1978; Line and Chen, 1995; Wan *et al*., 2007). Australia alone saves about A$124 million annually by using resistant cultivars (Brennan and Murray, 1988). A good seed in good soil yields abundantly. Therefore, seed treatment is an alternate to this which reduces disease severity. Sowing seeds should be done after treating the seeds with bio-agent Trichoderma viride @ 4.0 g/kg seeds plus tebuconazole 2 DS (Raxil) @ 0.1 g/kg of seeds (Ahanger *et al*., 2014). Application of fungicide solution of propiconazole 25 EC (Tilt), tebuconazole 250 EC (folicur) or triadimefon 25 WP (Bayleton) is recommended to control the spread of yellow rust. Strobilurinsis a fungicide which provides excellent control of yellow rust and is most effective when applied before infection, and if stripe rust is already present, it is better to apply the triazoles (Eddy, 2009). There are many ways to develop resistant varieties. Marker-Assisted-Selection (MAS) is an approach where genes can be accumulated to ensure durable resistance (Khan *et al*., 2013). Use of multiline cultivars and gene pyramiding to expand the life span of all-stage resistance, have been successfully used to control stripe rust (Chen, 2007; Allan *et al*., 1993; Chen, 2005). Growing mixtures of wheat cultivars in yellow rust infested area yields higher than the pure strand of all the mixtures (Knott and Mundt, 1990; Finckh and Mundt, 1992). Wheat scientists have recognised the temperature effects on resistance which was described as high-temperature-adult-plant (HTAP) resistance (Sharp, 1965; Lewellen *et al*., 1967; Brown and Sharp, 1969; Line et al., 1974; Qayoum and Line, 1985). HTAP resistance has been incorporated through molecular markers. Use of HTAP cultivars is another approach in fighting with yellow rust. A combination of HTAP resistance and effective all-stage resistance is the best approach to develop durable and high-level resistance (Chen, 2013). Incorporation of resistance based on additive slow rusting genes by the use of single backcross approach has shown 5-15% of higher yield potential than the original cultivar and many varieties have also been developed by this methodology (Singh *et al*., 2005).

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