Yellow Rust (puccinia striiformis.f.sp.tritici) on Bread Wheat (Triticum aestivum L.): Effect and Managements Methods-A Review

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Summary
Yellow rust is caused by Puccinia striiformis f. sp. tritici, is one of the known pathogens of wheat. This rust usually occurs at early in the growth season of wheat, when temperature ranges between 2 and 15 °C; but it may occur to a maximum temperature of 23 °C. High humidity and rainfall are conducive for increasing the infection (disease) on both leaf blade and leaf sheath, even on spikes when the disease occurred as epidemic form. Stunted and weakened plants, shriveled grains, and fewer spikes are among the symptoms of the disease. Therefore the objective of this paper is to review Effect of yellow rust (puccinia striiformis.f.sp.tritici) on wheat production and their management options. Yellow rust yield losses can be 50%, but in severe situations 100% is vulnerable. In countries where wheat is grown in winters or at high altitudes, stripe rust is a common threat, but not more significant than *wheat leaf rust* and *stem rust*, which are continuous threats in all wheat-growing seasons up to maturity of the crops. Epidemics of yellow rust have become more frequent and widespread at higher altitudes in south-eastern Ethiopia due to frequent production of mega cultivars, varietal susceptibility, expansion of wheat mono cropping, development and introduction of new virulent races and conducive environmental factors prevailing rust development. There are many methods of yellow rust (puccinia striiformis) management like bio control, chemical, cultural control and breeding for diseases resistance, among this, breeding resistant varieties is the most cost-effective method to control this rust. Fungicides are available but vary in ability to control this rust depending on their registration restrictions by state or national governments in addition they are not recommended more due environmentally unfavorable.
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Introduction

Wheat is one of the first domesticated food crops and for more than 80 countries has been the primary food staple of major civilizations of world, also its significant cereal stable food crop in the world, both in terms of food production and for proving the total amount of food diet and protein calorie in human diet (Gupta *et al.,* 2008). According to FAO (2018), ~749.5 Tg of wheat were produced globally in 2017 on ~220 million ha with a grain yield level of 3.4 t ha−1. In 2050, the world's population is expected to reach 9 billion and the demand for wheat will increase to >900 Tg. China is currently the world‘s leading wheat producer, accounting for approximately 15% of the world‘s total production (FAOSTAT, 2016)**.** Ethiopia is first producer of wheat in east and South Africa, In Ethiopia, about 60% of the area is covered by bread wheat and 40% by durum wheat production (Badebo *et al*., 2009). But in 1967 about 15% of the wheat production in Ethiopia is bread wheat and around 85% is durum wheat (Hailu, 1991). Wheat as one of the very important food crops is used worldwide for human and animal consumption and as a source for carbohydrate. Now a day, one of the most important aspects of wheat production is wheat yield and quality that includes biological traits such as the content of Proteins, carbohydrate, minerals, vitamins, Lipids etc. Since most quality and quantity traits are genetically controlled, breeding for resistance can successfully meet the needs of a changing and demanding world (Esfahani *et al*., 2009). According to (Guush *et al*., 2011) reported that wheat contributes an estimated 12.5% to the daily per capital calorie intake, making it the third most important contributor to national calorie intake, after maize and sorghum.

Production of wheat for future is threatened and challenged by the word population growth rate, global climate changes, various biotic and abiotic stresses (Dixon et al., 2009). Among biotic stress of; Stem rust *(puccinia grammis*. f.sp.*tritici*), leaf rust(*puccinia rodentina.*f.sp.*tritici*) and yellow rust *(Puccinia striiformisis* f.sp *tritici) diseases are* importance for bread wheat production. Yellow rust is cause heavy economic losses around the globe. This is mainly due to the pathogens multiply rapidly; ability to mutate and use its air-borne dispersal mechanism from one field to another (one country to other) and even over long distances (Singh *et al.,* 2005). According to (Chen, 2005) Wheat production is currently threaded with the local cultivar growth by farmers are highly susceptible to yellow rust, in some farmers complete loss of crops has been reported. Yellow rust *(Puccinia striiformis f.sp. tritici)* is one of the economically important fungal diseases of bread wheat producing regions of Ethiopia at the range of 2150 - 2850 msl (Ayele et al., 2008).

Different management options or methods are used to reduce its effect on quantity as well as quality losses. Cultural disease management methods such as crop rotation with non-host crops, field sanitations, late planting and inter cropping of wheat with other crops can reduce the incidence and severity of yellow rust, by reducing available inoculum to initiate infections. Biological control such as *Bacillus subtilis* strain QST 713 suspension concentrate (Serenade®ASO) was investigated for its potential for yellow rust control in winter wheat field trials (Reiss,A and Jørgensen, L. 2016**).**

Geographical distribution and importance of bread wheat (*Triticuma estivum L.*)

Wheat was cultivated cereal in the south western Asia is geographical center of origin, many wild species of *Triticum* are found in Lebanon, Syria, Northern Israel, Iraq and Eastern Turkey (ICARDA, 2011). Near East Mediterranean areas, Central Asia and Ethiopian regions are the world's most important centers of diversity of wheat and its related species (Kundu and Nagarajan, 1996). Recently, this cereal has been the object of renewed interest, because of its valuable production and adaptation to low rainfall, mid rainfall and semi-arid environments. More than half of the durum acreage lies in the Mediterranean Basin, mainly Italy, Spain, France, Greece and the West Asian and North African (WANA) countries, where through history this cereal has received special attention as an important commodity for humans as well as animal feeds (Royo et al., 2000).

Bread wheat (*Triticum aestivum* L.) is one of the world‛s leading cereal grains used by more than one-third of its population as a staple food. It is grown from below sea level to elevations exceeding 3000 m above sea level and at latitudes ranging from 30° and 60°N to 27° and 40°S. Wheat is used for food and many industrial purposes. It is the most important staple food of about two billion people (36 % of the world population). It exceeds in acreage and production every other grain crop (including rice, maize, teff, etc.) in Ethiopia and is therefore, the most important cereal crop of the world, which is produced over a wide range of climatic conditions and the understanding of genetics and genome organization using molecular markers is of great value for genetic and plant breeding purpose. Wheat has good nutrition value with 12.1% protein, 1.8 % lipids, 1.8 % ash, 2 % reducing sugars, 6.7 % pentosans, 59.2 % starch, 70 % total carbohydrates and provides 314 k cal/100g of food. It is also a good source of minerals and **7** vitamins *Viz*, calcium (37mg/100g), iron (4.1mg/100g), thiamine (0.45mg/100g), riboflavin (0.13mg /100g) and nicotinic acid (5.4mg/100mg) (Alemu, 2013).

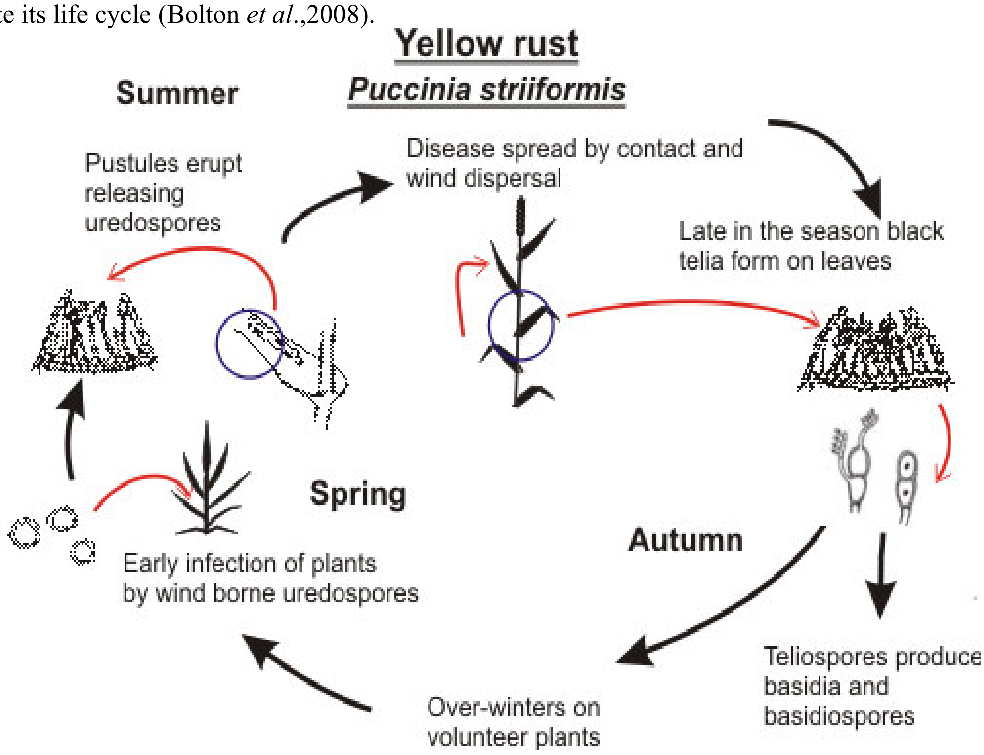
***Puccinia striiformis* of bread wheat**

The yellow rust pathogen, *Puccinia striiformis Westend. Pst*, is classified in kingdom Fungi, phylum Basidiomycota, class Urediniomycetes, order Uredinales, family *Pucciniaceae*, genus *Puccinia. Pts* is separated below the species level by host specialization on various grass genera, comprising up to nine formae specials (Cortazar, 1985). Uredinial/telial hosts: *Puccinia striiformis* mainly infects common wheat (*Triticum aestivum* L.), durum wheat (*T. turgidum var. durum* L.), cultivated emmer wheat (*T. dicoccum Schrank*), wild emmer wheat (*T. dicoccoides Korn*) and triticale (*Triticosecale*). The minimum, optimum and maximum temperatures for urediniospore germination are 0 °C, 7–12 °C and 20–26 °C, respectively. Of the three wheat rusts (yellow rust, leaf rust and stem rust), yellow rust appears to be the most sensitive to environmental factors, such as air pollution and UV light, which reduce the germination of urediniospores. Resistance of the host is also influenced by temperature and light, which, in turn, influences disease assessment of the infected plant. Increasing day length or light intensity lowers the infection type (Wellings *et al*., 1988).

Several yellow rust epidemics in many wheat-growing areas of Iran have reported over 30% yield loss and estimated grain losses were 1.6 million tons in 1993 and 1 million ton in 1995. Yield losses arise due to leaf tissue damaged by the infection, reduced number and size of flowering spikes, shriveled grain, and damaged tillers, especially when the infection occurs in early growth stages (Wellings, 2010). Yellow rust can cause 100% yield loss when infection occurs at early time and the disease continues to develop during all the growing season provided the susceptible cultivars (Afzal *et al*., 2007) are grown. Wheat yellow rust remains the most important disease of wheat worldwide, This is mainly due to pathogen multiply rapidly and use air-borne dispersal mechanism from one field to another and even over long distances because of its wide distribution, its capacity to form new races that can attack previously resistant cultivars, its potential to develop rapidly under optimal environmental conditions that result in serious yield loss (Singh *et al*., 2005). Yellow or stripe rust is an important disease of bread wheat in the highlands of Ethiopia at altitudes ranging from 2150 to 2850 m above sea level. In south-eastern part of Ethiopia, yellow rust is one of the major constraint to wheat production resulting in high varieties ‘yellow rust resistance and yield performance are directly proportional to each other‛s (Mengistu *et al.,* 1991).The majority of farmers in Ethiopia still use susceptible landrace varieties; though large number of improved cultivars of wheat has been released (Mamluk *et al*., 2000). In the Balea nd Arsi highlands, wheat is produced twice a year, favoring the continuous occurrences of the yellow rust pathogen year round. High yield loss is associated with the main cropping season because yellow rust is more important in the main cropping season than in the short season (Bekele *et al*., 2002).

Disease cycle, Symptoms and Epidemiology of Yellow rust

Yellow rust is caused by *Pst* is one of the oldest known pathogens of wheat. It is a heteroecious pathogen, requiring a telial host (wheat or one of several grass species including wild relatives of wheat) and a pycnial host to complete its life cycle (Bolton *et al*.,2008).



(Jin *et al*. 2010).

Figure: 1. Life cycle of *puccinia striiformis*

Symptoms

The first sign is the appearance of small, yellow pustules in stripe on the leaf. When the pustules mature, they break open and release a yellow-orange mass of spores. Stripe rust goes by the name of yellow rust because it is a slightly lighter color than leaf rust or stem rust. Mature pustules will break open and release yellow-orange masses of urediniospores. In many varieties of wheat, long, narrow yellow stripes will develop on leaves due to that American said stripe rust. The diseased tissues may become brown and dry as the plant matures or becomes stressed and reduce the ability of crop to photosynthesize. Severe early infection can result in plant stunting (Stephen, 2012).

Figure: 2.Spring bread wheat reactions to yellow rust under natural field conditions at in Ethiopia**,** 2017 main cropping season.

Epidemiology of yellow rust

Yellow rust is a serious problem on many wheat varieties in regions like the Pacific Northwest where cool temperatures prevail through the wheat growing season. Mild, open winters followed by unusually cool, wet springs can greatly enhance its spread (Hovmoller *et al*., 2008; Milus *et al*., 2009). This particular yellow rust can develop at lower temperatures than when we compare with other rusts and, therefore, infect wheat at earlier in the spring and acts upon the host plant for a longer period of time. Spores develop and disseminate rapidly when temperatures are between 50 to 70 ^{0}F and when intermittent rain falls present. In 2016, some cultivars were hit very hard by this disease. Because of the consistent occurrence of stripe rust over the last two seasons, it is reasonable to expect continued pressure from this disease in 2017 (Brain *et al;* 2017).

Epidemics of yellow rust have become more frequent and widespread at higher altitudes in south eastern Ethiopia due to variety susceptibility and favorable weather conditions. Arsi and Bale highlands in south eastern Ethiopia are the major common (bread) wheat producing provinces and are considered the wheat belts of East Africa. Bale zone alone contributes about 11% of the country's wheat production (FDRE, Federal Democratic Republic of Ethiopia, 2002). The Arsi-Bale highlands are also a hot spot for the *Triticum Puccinia* system (Mulugeta *et al*; 1986). It was reported that the mean minimum (9.4°C) and maximum (24°C) temperatures during the main season are within the optimum (11°C) for stripe rust epidemic development at Sinana (Bekele *et al*., 2002).

Management Practices of Yellow rust of bread wheat

Different management practices are being used to minimize the effects of yellow rust, although many have their own disadvantages so that the disease remained difficult until to date, although climate change play a great role for making conductive environment for pathogens, dispersal of inoculum and reduce effectiveness of management options. Disease management including using resistance cultivars, crop rotations, seed treatment, different cropping and tillage systems ,biological control ,fungicides have been and are being used by growers.

Resistant cultivars

Use of resistant varieties is the best methods to control wheat losses to yellow rust. Two types of genetic resistance to yellow rust are known: i) seedling resistance and ii) adult plant resistance. Seedling resistance, which is controlled by a single gene or monogenic, is highly effective and lasts throughout the wheat life cycle but it's easy for pathogens to break resistance because it have only a single to control a single pathogen. *Puccinia striiformis f. sp. tritici* is a highly variable pathogen and new pathotypes are continually being discovered. The development of wheat varieties resistant to yellow rust makes use of resistant genes termed yellow rust. There are more than 70 yellow rust genes designated so far (Lolandze A, 2006). Expression of resistance gene can occur at different growth stages ranging from boot to early head emergence, depending on the wheat variety and pathogen races. Because new races of the fungus pathogen can develop, it is important to know the susceptibility or resistance of a given wheat variety (Feyissa *et al*., 2005). More genes are needed to increase the diversity of resistance used in breeding programs and for monitoring virulence changes in the stripe rust population. Gene pyramiding, or combining several resistance genes into one genotype, is one strategy for developing durable resistance that the pathogen may not be able to overcome. For this reason, a constant search for new genes for resistance is required, and wild relatives of wheat may be a rich resource for identifying novel resistance genes for stripe rust. Many of wheat relatives contain important disease resistance genes, which have already been transferred into bread and durum wheat cultivars (Jiang *et al*., 1994).

Chemical control

Fungicides have been used to control wheat rusts; however new strain frequently develop resistance to commonly used fungicides, complicating the control of these diseases (Figlan S et *a*l., 2020). In the absence of resistant varieties, the use of fungicides becomes necessary. Adequate rust control could be attained by application of fungicides before the rust starts and frequent application thereafter throughout the growing season (Peterson, 2001). A number of fungicides are highly effective against yellow rust and have been used to control the disease. These include triadimefon (Baylaton and Noble) 25% WP at 0.5 l/ha, and propiconazole (Tilt and Bumper) 250 EC at 0.5 l/ha (Bekele, 2003). State farms in Bale use large amount of fungicides for the control of stem and yellow rust. During 2002-2004, the farms used a total of 2683, 2695 kg and 1940 kg of fungicides, respectively, to control these diseases (Bekele, 2003). Fungicides have not, however, been widely used for the control of cereal rust by subsistence farmers. There are several reasons for this, the cost of fungicides is high and is a direct cost to the producer. Chemical control is usually considered only where losses are expected to be very high and where grain prices are highly subsidized and yields are high. Repeated applications of fungicides are necessary under heavy epidemic conditions, increasing costs further. Lack of knowledge and awareness about appropriate fungicides and unavailability of the chemicals is also the main limitation particularly to the small scale farmers. Early disease detection and immediate application of fungicides should be considered in the control of stem rust with fungicides (Beard *et al.,* 2004).

Cultural control

Cultural measures can reduce the loss caused by yellow rust to some degree; however, wind dispersal of spores up to hundreds of miles can initiate seasonal epidemics of the disease. Several cultural methods can be used to reduce the intensity of an epidemic or provide long term partial control. The date of disease onset is directly related to the development of an epidemic (Hamilton and Stakman, 1967). Planting as early as possible and planting early maturing cultivars help to reduce the time of exposure of the crop to the pathogen and hence reduce yield loss. The success of implementing this method depends on sufficient knowledge of the epidemiology of yellow rust in a particular area. It is only feasible where inoculum is exogenous and arrives well into the cropping season.

Bio control

Yellow rust (***Pst***) is an important disease in wheat causing significant yield reductions, if not effectively controlled. The bio fungicide *Bacillus subtilis* strain QST 713 suspension concentrate (Serenade®ASO) was investigated for its potential for yellow rust control in winter wheat field trials (Reiss,A and Jørgensen, L. 2016).

Integrated Management of pathogen (IMP)

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Molecular markers and their use in breeding for disease resistance in yellow rust.

DNA-based molecular markers have many advantages over the traditional phenotypic selection and their potential benefits as marker-assisted selection (MAS) have been widely discussed (Anderson, 2003; Varshney and Tuberosa, 2007), especially to provide solutions to overcome some of the problems faced by phenotypic screening approaches in plant breeding programs that easy for pathogen to break. Molecular markers can be used to tag rust resistance genes and further their use can serve for the improvement of the efficiency of selection in plant breeding by MAS. Marker-assisted selection can be used at early stage of plant to development when many or multiple DNA markers are used to screen a segregating population for one or more genes simultaneously.

Several techniques have been used to develop molecular markers for resistance to yellow rust. Widely used marker techniques include random amplified polymorphic DNA (RAPD), simple sequence repeats (SSR), and amplified fragment length polymorphism (AFLP). The RAPD technique employs 10 base pair random primers to amplify random segments of genomic DNA to reveal polymorphisms. The DNA is hybridized by the primers at specific sites and amplified into many specific-length segments that can be separated by gel electrophoresis (Williams *et a*l. 1990). The SSR technique employs primers designed based on short sequences of nucleotides (2-6 units in length) that are repeated in tandem among the genome (Jacob *et al.* 1991). AFLP uses restriction enzymes to cut genomic DNA, followed by ligation of complementary double stranded adaptors to the ends of the restriction fragments (Vos *et al.* 1995). A subset of the restriction fragments are then amplified using two primers complementary to the adaptor and restriction site sequences. The resulting fragments are visualized on denaturing polyacrylamide gels either through autoradiography or fluorescence methodologies. With conventional methods in wheat breeding programs, the continuous pyramiding of genes in a single genotype will become difficult or even impossible when one or more genes in the background are effective against many races of the pathogen and also when different resistance genes produce similar infection types. In this case, identification of molecular markers linked to disease resistance genes facilitates MAS for pyramiding resistant alleles (Sharp *et al.,* 2001; Babu *et al*., 2004; Haile *et al.,* 2012; Miedaner and Korzun, 2012).

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