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Status and Challenges of Wheat Stem Rust (*Puccinia Graminis F.Sp.Tritici*) and Threats of New Races in Ethiopia

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Abstract: *Wheat stem rust, caused by Puccinia graminis f. sp. tritici, is the major biotic constraints for wheat production in the world and in the Eastern part of Africa particularly Ethiopia and Kenya.the objective of this paper is to review wheat stem rust and new races in Ethiopia as well as to review wheat stem rust recurrent epidemics and challenges. Yield loss of stem rust reaches 100% in conducive environment and susceptible varieties during year of epidemics. Countries such as Kenya and Ethiopia experience recurrent epidemics of stem rust due to evolution of new stem rust races. Wheat stem rust was not problem for the last three decades, but after the emergence of Ug99 in Uganda, the new race of stem rust Ug99 was subsequently shown to attack the stem rust resistance genes Sr31 and Sr38, which were previously effective resistance genes. Since that it affects east and North Africa and Middle East. Currently about 13 Ug99 lineage are recorded in thirteen countries. Ethiopia experience recurrent epidemics of stem rust due to migration and evolution of new stem rust races. In Ethiopia popular bread wheat varieties such as Enkoy (1994) and Digalu (2013-2015) were wiped out by stem rust with a yield loss of 58 and 100% respectively. Similarly variety Dashen, Kubsa and Galama was also devastated by yellow rust in 1988 and 2010. Variety Digalu was devastated by non Ug99 race which is known as TKTTF named Digalu race. Currently about 11 new races are recorded in Ethiopia (TTKSK, TTKTF, TTKTK, JRCQC, TKTTF, TTKSC, TRTTF, SRKSC RRKSF, TTTH, HKPPF and HKNTF). The reason why the recurrent epidemics and causes of virulent races occur in Ethiopia could be most likely due to ecological location and climatic conditions of the country as well as continuous cultivation of wheat during the year providing green bridge for survival of inoculum. The environmental condition prevailing in highlands of eastern Africa facilitates populations of stem rust to persist throughout the year and these conditions provide support to the evolution of new physiological strains. Currently there is no resistant wheat varieties known in Ethiopia to stem rust. Late and extended planting of wheat in vertisol area, use of widely adapted varieties in mega environment, absence of timely action or weak periodic assessments, monitoring, forecasting and absence of early warning of wheat stem rust are the reason for epidemics. Continues developing and supply of resistant varieties and incorporating diverse resistance genes and adult plant resistance genes into high-yielding, adapted varieties as well as working strongly with international organization to manage rust is advisable.*

Keywords: *Wheat, Rust, Pathogen, Puccinia, Ug99*

1. Introduction

1.1. Wheat Production

Wheat is among the first domesticated cereal food crops cultivated in many countries in the world. Globally, wheat is produced in different agro-ecological regions (Braun *et al*., 2010). Currently the productivity of wheat worldwide on the average reaches 3.3t/ha (Solh *et al*., 2012). Wheat is the most widely grown cereal crop in the world and one of the central pillars of global food security (FAO, 2014). Wheat plays an important role in everyday life of the world's population and provides over 21% of the food calories and 20% of the protein to more than 4.5 billion people, thereby playing a fundamental role in food security (Kumar *et. al*., 2011). Wheat was one of the miracle crops of the 20th Century playing a significant role in the Green Revolution led by Norman Borlaug, which dramatically reduced poverty, hunger and saved millions of lives worldwide (ICARDA and CIMMYT, 2012).

Ethiopia is the largest wheat producer in sub-Saharan Africa countries (FAOSTAT, 2014). Wheat is fourth among cereal crops after Tef, maize and sorghum in area coverage and second in production per hectare next to maize (CSA, 2016). The productivity of wheat has increased in the last few years in Ethiopia, but it is very low as compared to other wheat producing countries (Alemayehu et al, 2015). The national average productivity is estimated to 2.35 tons/ha (CSA, 2016), which is below the world's average. Low productivity of wheat in Ethiopia and other countries are affected by different factors such as climate change and disease. Due to these factors wheat production is expected to decrease by 20- 30% particularly in developing countries in the coming years (FAOSTAT, 2014).

Currently, wheat production is constrained by various wheat diseases caused by fungal, bacterial, and viral pathogens. Of these, diseases caused by the rust fungi have since long been a major concern and problem for breeders, farmers and commercial seed companies in the world. Rust diseases of wheat are among the oldest known diseases and are important worldwide (Singh et al., 2005). Globally, yellow rust (*Puccinia striiformis* f *tritici*), stem rust (*Puccinia graminis* f. sp. *tritici*) and leaf rust (*Puccinia triticina*) are the most damaging diseases of wheat at different epidemics and years (Milus *et al*., 2009).

Wheat stem or black rust (SR), which is caused by *Puccinia graminis f.sp. tritici Erikss. &Henn* is a big threat to the production of wheat all over the world (Kanti *et al*, 2016). Stem rust occurs mainly in warm weather regions and can cause severe losses when epidemics occur (Leonard and Szabo 2005). Stem rust attacks many grasses, including the economically important cereals wheat, barley, oats and rye. Stem rust is favored by humid conditions and warmer temperatures of 15 to 35°C. Wheat stem rust is one of the most feared plant diseases, at times causing total crop failure. Recent studies of Recombinant DNA, or rDNA sequence data have confirmed the long-held belief that *P. graminis* is a genetically variable and complex species (Abbasi *et al*. 2005). It comprises variants known as formae speciales (special forms; f. sp.), which are morphologically identical, but are specialized to different host species. The disease is wide spread throughout the world and causes significant yield reduction in tropical Africa in years of epidemics (Kolmer, 2013).

Under suitable conditions, yield losses reach 70% - 100% when epidemics appear (Punam *et al*., 2014). Stem rust is highly mobile, spreading over large distances by wind or via accidental human transmission. Wheat stem rust has largely been under control for over three decades due to the widespread use of resistant cultivars (Belayeneh *et al*., 2010). The risk of a stem rust epiphytotic has increased in recent years following the evolution in East Africa of race Ug99. In 1999, a new virulent race of stem rust was identified from wheat fields in Uganda popularly known as Ug99 after the year and country of discovery (Singh *et al*, 2008).

The new race of stem rust Ug99 was subsequently shown to attack the stem rust resistance genes Sr31 and Sr38, which were previously effective resistance genes. Since then, similar virulence's have been confirmed in Kenya, Ethiopia, Yemen, and Iran, indicating that this new race, or its derivatives, has spread within North Africa and into the Middle East (Pretorius et al., 2012; Singh et al., 2011). Kenya and Ethiopia are the more victim countries by this new race variants, majorities of the variants are found in Kenya and Ethiopia (Pretorius *et al*., 2012). Hence, this review paper is initiated to review wheat stem rust diseases and new races in Ethiopia as well as to review and document wheat stem rust recurrent epidemics and challenges

2. WHEAT STEM RUST IN ETHIOPIA

Stem rust, caused by *Puccinia graminis* f. sp. *tritici,* is the major constraints for wheat production in the world, and in the Eastern part of Africa in particular. Countries such as Kenya and Ethiopia experience recurrent epidemics of stem rust due to evolution of new stem rust races (Admassu *et al*., 2009). Yield loss due to stem rust in Ethiopia was estimated to reach up to 100% on susceptible wheat varieties at times of disease epidemics (Bechere, *et al*., 2000). According to Singh *et al*.(2006) the highland of Ethiopia is considered as a hot spot for the development of stem rust races diversity.

The recent detection of the widely virulent race Ug99 in Uganda in 1998 challenged the misconception that stem rust was a conquered disease in the world (Singh et al., 2008). Now, about 90% of world's wheat cultivars are considered stem rust susceptible and the disease is threatening 120 million tons or 20% of the world's wheat in Central and North Africa, the Middle East and Asia, with a population of more than one billion people (Singh *et al*., 2011). Ethiopia is one of the country victim by Ug99 and other different races and recurrent epidemics.

2.1. Distribution of Ug99 Variants

The new race of wheat stem rust, Ug99 after it identified in Uganda it is named using North American scientific nomenclature and known as race TTKSK (Joshi *et al*., 2011). Ug99 (Race TTKSK) is a cause for concern as it exhibits unique virulence patterns (Pretorius, 2012). No other race of stem rust except Ug99 which has been observed to overcome so many wheat resistance genes, including the very important gene Sr31 and now Sr24 & Sr36 have been defeated by variants of Ug99. Wheat cultivars carrying the Sr31 gene typically have broad agronomic adaptability, as well as carry resistance to stem rust, leaf rust, stripe rust and powdery mildew (Sharma *et al*., 2012. After it characterized in Uganda in 1999 it has been detected in Kenya, Ethiopia, Eritria, Sudan, Yemen, Iran, Uganda, Tanzania, Mozambique, Zimbabwe, South Africa, and Egypt (Olivera *et al.*, 2015). Currently, about 13 known races of Ug99 lineage are found in 13 countries (Olivera *et al.*, 2015; Singh, 2015). All exhibit an identical DNA fingerprint, but differ in virulence patterns. They are all closely related and are believed to have evolved from a common ancestor, but differ in their virulence/avirulence profiles and the countries in which they have been detected (Singh *et al*., 2011). Ug99 or variants are considered a major threat to wheat production because an estimated of 80-90% of all global wheat cultivars growing in farmer's fields are now susceptible to Ug99 or variants (Jin *et al*., 2007). Ug99 has virulence against most of the resistance genes of wheat origin and other resistance genes from related species. Generally Ug99 race group is present in 13 countries (Singh, 2015).

2.2. Stem Rust Epidemics in Ethiopia

Ethiopia experienced severe yellow rust epidemics in 1988 and 2010 on three varieties Dashen, Kubsa and Galema with a yield loss of 58, 50 and 100% respectively. Stem rust epidemics in 1994 against variety Enkoy (58% yield loss) and in the Southern wheat production region during 2013, 2014 and 2015 for three consecutive years on variety Digalu with a yield loss of 100% in main wheat growing areas (David, 2016). The epidemic caused on variety Digalu for three consecutive years was by a non-Ug99 group patho type of *Puccinia graminis tritici*, designated as TKTTF (Hailu et al 2015). Pathotype TKTTF is virulent to Digalu variety in Ethiopia carrying resistance gene *SrTmp* that was effective to the known variants of the Ug99 group in Ethiopia (Work u et al., 2016).

Race TKTTF was first detected from Ethiopia in August 2012, but remained at a low frequency until October 2013 when it caused grain loss up to 100% in more than 10,000 ha area. A severe stem rust epidemic occurred in southern Ethiopia during 2013- 2015, with greater yield losses on the most widely grown wheat cultivar, 'Digalu'. Sixty-four stem rust samples collected from the regions were analyzed and a meteorological model for airborne spore dispersal was used to identify which regions were most likely to have been infected from postulated sites of initial infection (Worku *et al*., 2016). Based on the analyses of 106 single-pustule isolates derived from these samples, four races of *Puccinia graminis f. sp. tritici* were identified: TKTTF, TTKSK, RRTTF, and JRCQC. Race TKTTF was found to be the primary cause of the epidemic in the southeastern zones of Bale and Arsi. Isolates of race TKTTF were first identified and confirmed in samples collected from West Arsi. It was the sole or predominant race in 31 samples collected from Bale and Arsi zones after the stem rust epidemic was established. Race TTKSK was recorded from 15 samples collected from Bale and Arsi zones at low frequencies (David, 2016).

Genotyping indicated that isolates of race TKTTF belongs to a genetic lineage that is different from the Ug99 race group and is composed of two distinct genetic types. Results from evaluation of selected germplasm indicated that some cultivars and breeding lines resistant to the Ug99 race group are susceptible to race TKTTF. Appearance of race TKTTF and the ensuing epidemic underlines the continuing threats and challenges posed by stem rust not only in Ethiopia, but also to wider-scale wheat production (Olivera et al., 2015). Over 300,000 wheat germplasm from wheat-producing countries of Asia, Africa and other parts of the world, have been screened for resistance to virulent stem rust pathotypes belonging to theUg99 lineage at Njoro (Kenya), Kulumsa and Debre Zeit (Ethiopia) during 2005–2011, to combat the risk of stem rust epidemics. Of these, about 15% of materials from various countries was found resistant to the patho types of Ug99 group (Singh *et al*., 2011). These germplasms can be used in the Ug99-infected and bordering areas, so that further multiplication and spread of the patho types could be minimized. Robin (*SrTmp*), a wheat cultivar in Kenya was popular due to its high yield potential and resistance to the then known patho types of Ug99 lineage. But during the 2014 crop season, it faced severe damage in some farmers' fields. The patho type infecting this variety was identified as a new variant in the Ug99 group with virulence to stem rust resistance gene *SrTmp* (Singh *et al*., 2015).

It is predicted that most of the wheat growing regions of the world will suffer more and more in the future because of existing favorable environmental conditions for stem rust outbreak and unavailability of suitable resistant wheat germplasm to Ug99 pathotypes, which could lead to an epidemic build-up. In 2005-2011 more than 1000 Indian germplasms screened against the pathotypes of Ug99 group in Kenya and Ethiopia, variety HW 1085, FLW 2 (PBW 343 + *Sr24*), FLW 6 (HP 1633 +*Sr24*) and FLW 8 (HI 1077 + *Sr25*), were found resistant against the pathotypes under natural conditions in Kenya, but not immune in Ethiopia (Pretorius, 2012).

2.3. Wheat Stem Rust Races in Ethiopia

In Ethiopia Ug99 was first detected in 2003 at six dispersed sites (Singh et al., 2006) followed by Digalu race. Ug99 has been devastating many released varieties in Ethiopia and Kenya at different epidemics in both countries, this has been confirmed by the evolution of new stem rust races with additional virulence to the deployed stem rust resistance genes in wheat cultivars. For instance, variants with virulence for Sr24 (Jin *et al*., 2008) and Sr36 (Jin *et al*., 2009) genes were detected in Kenya. Similarly, virulence to SrTmp gene was detected from stem rust samples collected during the 2012, and 2013 season epidemics that wiped out Digalu (race TKTTF) in Bale zone of Ethiopia (Olivera *et al*., 2015). However, the race responsible for the loss of effectiveness of SrTmp gene in Digalu was reported in Turkey, prior to its discovery in Ethiopia (Zafer *et al*., 2012).

Currently, race Ug99 (TTKSK) is continuously evolving and undergoing stepwise mutations, to bear additional virulence. There are more than 13 variants of this race reported across many parts of Africa and its migration and spread to other parts of Africa, Asia and other parts of the world is inevitable (Singh *et al*., 2015). In view of the recurrent epidemics of stem rust in Ethiopia and Kenya, an internationally aggressive breeding strategy was followed and resistant cultivars were released in countries most vulnerable to the new races. For instance, in Kenya two bread wheat cultivars, Eagle-10 and Robin, were released in 2009 and 2011, in Ethiopia, Kakaba and Danda'a were released in 2010 as resistant cultivars to Ug99, but the varieties are not immune (Worku, 2014).

Although the release of resistant cultivars to Ug99 has paramount importance for those countries that were at immediate risk of the pathogen, the continuous evolution of new races and/or variants of the same race requires sustainable efforts to deal with epidemics of Ug99 or the one that wiped out mega bread wheat cultivar Digalu in Ethiopia by the race TKTTF (Worku et al., 2016). All varieties released in both countries are now break down by different variants of Ug99. In 2003, 2007 and 2010 Ug99 race and its variants recognized in Ethiopia are TTKSK, TTTSK, PTKSK and PTKST (Singh et al., 2015).

For over a decade the Ug99 race group has dominated in both Ethiopia and Kenya, however the latest results indicate that this situation is now changing. A total of 214 stem rust samples collected from Ethiopia in 2015 were analyzed by the 3 different laboratories. The results indicated that the original Digalu race (TKTTF) dominated throughout the country, with 86% (David, 2016). Three hundred and six elite breeding lines, selected and advanced at the Wheat Regional Centre of Excellence (WRCoE) in Ethiopia, were planted in stem rust hot spot areas of the country (Arsi-Robe) and Kenya (Njoro) under natural infections. Stem rust scores of 18, 25.8 and 56.2% of lines at Arsi-Robe; and 35, 49 and 16.7% of lines at Njoro were resistant to moderately resistant, intermediate and moderately susceptible to susceptible category, respectively. Overall coefficient of infection (ACI) at Arsi-Robe (24) was greater than that of Njoro (13), indicating higher disease pressure in Ethiopia than Kenya (Worku *et al*., 2016).

2.4. Stem Rust Assessments in Ethiopia

Studies that were carried out in Ethiopia showed that most previously identified stem rust races were virulent on most of varieties grown in the country (Belayenh and Embet, 2005; Belayneh *et al*., 2009).

Seasonal race assessments help to generate information regarding the virulence of races and their frequency and distribution patterns across regions and over time (Belayenh et al., 2009). In addition, race monitoring and assessment is important to study occurrences of new races and determine virulence shifts in a population (Hailu *et al*., 2015).

Wheat stem rust differentials with known resistance genes including Sr31, Sr36, Sr38, Sr24, and SrTmp, were tested in Ethiopia for sample collected from three region (Hailu et al., 2015). Nine races were identified, which includes TTKSK, TTKTF, TTKTK, JRCQC, TKTTF, TTKSC, TRTTF, SRKSC and RRKSF. The result confirmed that race TTKSK was predominant against the tested differentials and widely distributed in the country with 52% (Hailu et al., 2015). Alemayehu et al., (2015) also reported in central Ethiopia five races, namely, TKTTF, TTKSK, TTTTH, HKPPF and HKNTF and confirmed the presence of high virulence spectrum along the five identified wheat stem rust races. This indicated that, wheat growing areas of Ethiopia particularly Amhara, Oromia and Southern Ethiopia are hot spot areas for appearance of virulent genetic diversity of stem rust races. Around 11 non Ug99 races are reported in Ethiopia. According to Hailu et al (2015) report the most dominant and virulent races in Ethiopia were TTKSK and TKTTF. Most of the genes were ineffective except Sr36, SrTmp and Sr24 against TTKSK race (Hailu et al., 2015). The discovery of the race Ug99 with Virulence to Sr31 in Uganda in 1999 (Pretorius et al, 2000) represented a real threat to wheat production in the world, including Ethiopia where stem rust epidemics did not occur since the resistant cultivar 'Enkoy, lost its resistance in 1993/4.

Likewise, the second most dominant race TKTTF which is known as Digelu race was virulent on 17 stem rust resistant gene and widely distributed in the central and southern eastern part of the country. Digalu race is for the first time reported in Ethiopia and cause localized stem rust endemics in Bale and Arsi zones of Oromia region since 2013 (Hailu *et al*., 2015; Worku *et al*., 2016). Stem rust resistance gene in Digalu variety SrTmp gene was broken and most farmers grow Digalu variety were highly affected (Oliver *et al*., 2015). Stem rust resistance gene sr24 was effective against all of the isolates tested in Ethiopia. Admassu et.al., (2009) also indicated that no virulent race was detected against Sr24 gene in Ethiopia. Use of this gene (Sr24) for breeding in Ethiopia is pertinent (Tekly *et.al*, 2012).

3. CAUSES OF VIRULENT RACES

Due to a wide variability of stem rust pathogen, there are continuously emerging new virulent races which overcome resistant genes of wheat (Andrii *et al*., 2014). Because of the airborne nature of urediniospores and the capacity to produce large number of spores, the pathogen can be transferred by wind to adjacent and distant wheat growing areas (Kolmer, 2005). The greater is the area under the cultivars which have the same mono gene of resistance, the faster pathogen overcomes host resistance. Traditional monoculture cropping systems apply significant selection pressure on the pathogen to cause rapid shifts in patho types in race specific resistance. Limitation of diversity of resistance genes creates favorable conditions for development of epiphytoty (Chaves *et al*., 2013). It is also the ability to change genetically, thereby producing new races with increased aggressiveness on resistant wheat cultivars (Abbasi *et al*., 2005). The high virulence diversity and evolution rate of the pathogen and mutation makes considerable reasons (Punam *et al*., 2014; Hailu *et al*., 2015). Virulent patho types could emerge in a population via changes in pathogen's genome (sexual recombination or mutation).

Generally, susceptible host, virulent pathogen and conducive environment contribute for disease epidemics in different countries (Braun *et al*., 2010). Why Eastern Africa particularly the two countries, Ethiopia and Kenya are critically affected by stem rust constantly, most likely due to ecological location and climatic conditions of the region, and the continuous cultivation of wheat during the year providing green bridge for survival of inoculum. The environmental condition prevailing in highlands of eastern Africa facilitates populations of stem rust to persist throughout the year and these conditions provide support to the evolution of new physiological strains (Amir *et al*., 2015).

The high virulence diversity and evolution rate of the pathogen, makes a considerable proportion of wheat germplasm at risk (Admassu, 2009). The highland of Ethiopia is considered as a hot spot for the development of stem rust diversity and favorable environment both for the pathogen and the host.

Late planting is also suitable for stem rust occurrence. In addition, vast area wheat based mono-cropping system and the continuous release and extensive cultivation of CIMMYT originated bread wheat genotypes with similar genetic background (commonality in parentage) which could serve as the breeding ground/reemergence for new physiological races of stem rust that can attack previously resistant cultivars or evolution or migration of new races. Furthermore, studies that were carried out in Ethiopia showed that most previously identified races were virulent on most of varieties grown in the country (Admassu and Fekadu, 2005). Wheat stem rust races in Ethiopia attacks most of the known resistance gene which are found in 20 stem rust differential lines used for race analysis in America, only sr24 are effective, but this R gene is overcome the resistance at Kenya.

4. Developing Wheat Stem Rust Resistant Varieties

In the past, wheat stem rust was the most feared plant disease capable of devastating epidemics and crop losses. For 2-3 decades, widespread use of resistant cultivars had reduced disease incidence to non significant levels worldwide. Stem rust research and resistance breeding ceased to be a priority activity (Netsanet, 2017). The emergence of a new virulent stem rust race lineage in Uganda in 1999, popularly named Ug99, and subsequent variants have rendered 80- 90% global wheat varieties stem rust susceptible. Emergence and spread of the Ug99 lineage have put wheat stem rust firmly back on the agenda of wheat scientists worldwide (David, 2016).

Identification and deployment of genetic sources of resistance is an opportunity to get resistance variety. The best control strategy of rust diseases of wheat for resource poor farmers in the developing world and the most environmentally friendly and profitable strategy for commercial farmers everywhere is to grow genetically resistant varieties using different resistance genes (McIntosh *et al*., 2009). In order to prevent losses by wheat rust, it is necessary to widen the genetic variability of wheat. Wild species which in co-evolution during thousands of years evolved genes of resistance against pathogens are valuable sources of resistance. They contain a broad pool of genetic variation, which carries resistance against the majority of biotic and a biotic stresses. Disease resistance genes, transferred from wild species, support wheat production on a global level (Davoyan *et al*., 2011).

More than 50 resistance genes are identified for stem rust so far and about 18 resistance gene have been introgressed from wild progenitor and non-progenitor species in developed countries (McIntosh *et al*., 2007). Most of the commercially exploited genes condition hypersensitive reaction and interact with the pathogens in gene-for-gene fashion. Deployment of such genes over large areas leads to the development of new virulence in the pathogen. A large number of these genes have been rendered ineffective due to the emergence of virulent races of the pathogens necessitating the constant search and transfer of new and effective sources of rust resistance to counter balance the continuous evolution of rust populations (Singh et al., 2007).

Even though numerous resistance genes and several quantitative trait loci (QTL) have been identified majority of them are overcome by the new races because they are race specific resistance gene (McIntosh *et al*. 2016; Philomin *et al*. 2017). Generally new sources of resistance genes can be obtained from various sources wheat gene pool and wild relatives. Ethiopia is the largest wheat producer in sub-Saharan Africa countries (FAOSTAT, 2014). The country is known as wheat research center of Excellency in east Africa. In Ethiopia, stem and yellow rust severely occur every year at different distribution. Few farmers use fungicides to protect their crop from rusts. Use of the chemical fungicides is not economical and unaffordable for small scale farmers. So, continues supply of resistance varieties is needed to avoid wheat rust epidemics in the country (Hailu *et al*., 2015).

In Ethiopia there is an opportunity that a large number of germplasm from CIMMYT and ICARDA are tested for stem rust resistance gene. Borlaug Global Rust Initiative is working to alleviate the potential of epidemics, mainly on monitoring the spread of race Ug99, identification of resistant sources through screening of existing germplasm mainly in Kenya and Ethiopia, distributing selected material for breeding or to utilize as varieties directly and incorporation of resistance from diverse sources into high yielding through breeding. There was also large germplasm (over 470,000) screening for wheat rust resistance conducted from 2005-2014 in Ethiopia and Kenya giving few diverse race specific and adult plant resistance that needs further exploitation and developing resistance varieties through breeding program (Prasad *et al*., 2016).

Currently, wheat rust trap nurseries is conducted in all wheat growing areas of Ethiopia carried out each year. There are also many activities conducted in Ethiopia with collaborative organization and countries. There are also wheat rust survey activity carried out every year by research centers and testing collected rust sample at Ambo greenhouse on selected differentials. It is through these trap nurseries and monitoring the spread of race Ug99 is well known. Quality green house were also established and there are also short and long term training of manpower from the international budget. Hence, many breeding efforts focus on horizontal, non-race-specific, quantitative or slow rusting resistance which is the widely preferred mechanism to achieve durability, defined as the ability of a widely deployed resistance gene to provide an economic level of protection over an extended period of time (Cantu *et al*., 2013).

Utilization of resistant cultivars is the most effective, economical, and environmentally friendly approach to control rusts. Therefore, it is critical to identify new rust resistance genes and to use more effective and durable resistance genes in wheat breeding programs. Molecular markers are appreciable tools to speed up the development of resistant wheat cultivars in pyramiding of resistance genes (Cantu *et al*., 2013). Pyramiding of several genes into one cultivar can be an effective strategy to use resistance genes to enhance durability of wheat resistance to stem rust (Leonardo and Szabo, 2005). All this activities are also some of the approaches in Borlaug global rust initiative which is working in hot spot area in east Africa mainly in Ethiopia and Kenya, so it is time to take the advantages. Any effort made to developing wheat stem rust resistant varieties in east Africa is an opportunity to Ethiopia.

5. Challenges of Stem Rust in Ethiopia

Stem rust, also called 'polio of agriculture', has caused several severe epidemics in the past throughout the world (Prasad *et al*., 2016). Climate change and crop diseases always threaten the production of wheat in Ethiopia. In Ethiopia there is a recurrent epidemic of stem rust by locally evolved or migrated wheat stem rust races from the neighboring countries. The nature of the pathogen producing and dispersing large amount of spore in long distance and diversity of races contribute for a big challenge in wheat production. The highland of Ethiopia favor both the host and the pathogen (Admassu *et al*., 2009).

Late and different sowing date in the vertisol also expose the crop to disease. Deployment of few mega cultivars with major genes all contribute for the occurrence of epidemics. Another main challenge in Ethiopia is absence or weak periodic assessments, monitoring, forecasting and early warning of wheat stem rust. The presence of bimodal rainfall at different regions and green bridge to the pathogen to survival all over the year is also another problem. Currently the resistance wheat varieties are almost susceptible to different races of stem rust including Ug99 variants. There is no immune wheat varieties in the country. Non Ug99 wheat stem rust race which was identified in 2012 and devastated widely adapted variety Digalu about 10,000ha only in 2013 is another challenge (Parasad *et al*., 2016; Singh *et al*., 2015).

Wheat breeding is conducted through conventional method. Today in many countries even though plant breeders strive to stay ahead of the evolving pathogens by releasing new crop genotypes with new rust resistance genes or gene combinations the challenge of new races of rusts are not alleviated. Owing to the limited number of known resistance genes and the lack of molecular understanding of the plant pathogen interaction, even in the developed countries rusts remain challenging organisms to study, both at organismal and molecular level (Craig and John, 2006). Understanding the host and pathogen genetic should be the priority concern for the challenges.

6. Summary and Conclusion

Wheat plays an important role in everyday life of the world's population, but disease threat the production of wheat worldwide. Rust fungi are plant pathogens that pose a particularly high bio security threat because they can travel large distances, build up rapidly and attack wheat, which is economically important plant species. The ability of rust pathogens to spread and build up rapidly also makes them extremely difficult to eradicate once established. Application of fungicides, may be one means of controlling the disease, but could not be profitable and safe to the environment as well as to the society.

Plant disease resistance (R) genes have the ability to detect a pathogen attack and facilitate a counter attack against the pathogen. Numerous plant R-genes have been used with varying degree of success in crop improvement programs in the past and many of them are being continuously exploited. With the onset of recent genomic, bioinformatics and molecular biology techniques, it is quite possible to tame the R-genes for efficiently controlling the plant diseases caused by pathogens. Genetic resistance is the principal means of controlling wheat rust diseases. Selection and development of wheat cultivars with effective and durable rust resistance gene should be a global concern in wheat breeding.

Therefore, the identification of resistance genes in modern wheat cultivars and breeding lines, and then selection of the best resistance genes combination(s) are the first steps for a successful breeding program. Strategically planning and deploying cultivars with combination of two or more race specific genes, deploying cultivars with race non specific genes and many minor gens with smaller additive effects collectively contribute to resistance and each of these genes is equally effective against all races. In adult plant resistance cultivars, will not be affected by new races easily. Race specific and non race specific gene combination is also best method to get durable resistance. Pyramiding of several genes into one cultivar can be an effective strategy to use resistance genes and to enhance durability of wheat resistance. Primarily the pathogen and the host- interaction should be well studied and known. Marker assisted selection is a powerful alternative to facilitate new gene deployment and gene pyramiding for quick release of rust-resistant cultivars and to manage rust diseases including Ug99. However phenomenon of sexual recombination, mutation or somatic hybridization followed by selection whenever the new race has a selective advantage due to frequent evolution and selection of virulence in pathogen arise new strains of rust pathogens. New races of wheat rusts complicate the struggle of wheat scientists to breed rust resistant wheat cultivars. New races may also be introduced into a new area through migration. Resistance could be conquered with the appearance of new races of the stem rust pathogen. Wheat breeding for disease control is not complete unless breeders encompass all aspects of global pathogen variability and epidemiology, resistance discovery and genetic characterization, germplasm development (pre-breeding), and capture of resistance in competitive high-yielding, high quality varieties with sufficient adaptability for adoption in agriculture. CIMMYT, ICARDA, BGRI and others are working to alleviate wheat rust problem.

As a challenge in Ethiopia, there is a recurrent epidemic of stem rust by locally evolved or migrated wheat stem races from the neighboring countries. The highland of Ethiopia favor both the host and the pathogen. Late and different sowing date in the vertisol also expose the crop to disease. Deployment of few mega cultivars with major genes all contribute for the occurrence of epidemics. Another main challenges in Ethiopia is that periodic assessments, monitoring, forecasting and early warning are not conducted in the country. Currently the resistance wheat varieties are almost susceptible to different races of stem rust including Ug99 variants and Digalu race. Ethiopia wheat breeding program is conducted through conventional method.

As an opportunity, Borlaug Global Rust Initiative is working to alleviate the potential of epidemics, mainly on monitoring the spread of race Ug99, identification of resistant sources through screening of existing germplasm mainly in Kenya and Ethiopia, distributing selected material for breeding or to utilize as varieties directly and incorporation of resistance from diverse sources into high yielding through breeding. Currently there is also a wheat rust trap nurseries in all wheat growing areas of the country conducted each year. So, continues supply of resistance varieties is needed to avoid wheat rust epidemics in the country. Hence, it is important to be aware of the nature of resistance in the cultivars and the pathogen genetics. Further sources of the potential genetic resistance need to be classified and exploit with the support of international organization working in Ethiopia on wheat research.

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