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Research Article

Reaction of Bread Wheat Cultivars to Recently Emerging, Virulent and Dominant Races of Stem Rust (*Puccinia graminis f.sp.tritici*) in Ethiopiam

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ABSTRACT

Wheat is a top ranked stable food crops among many cereals in Ethiopia. Being important crop in the country, it is constrained by abiotic and biotic factors across many of production areas. Among biotic factor, stem rust is a major disease of wheat crops. Hence, periodic outbreak of new races and loss of resistance deployed in cultivars of the country is a bottle neck for wheat producer. This study was conducted to evaluate 22 bread wheat cultivars against dominant races for examination of major gene contained in the materials. Evaluation of cultivars was done by artificial inoculation at seedling stage against dominant stem rust races in the greenhouse. Twenty two cultivars were evaluated for stem rust seedling resistance gene against 6 races. The virulent and being dominant races assessed from western and south-western Ethiopia, TTKTT, TTKTF, TKTTF, TTRTF, TKKTF and TTKSK race were used for evaluation of cultivars. The Hierarchical cluster Analysis was done to classify cultivar based on infection types using SAS 9.3 version. Frequency and percentage of cultivar resistance to each 6 races was done by IBM SPSS statistics 20. There was no complete resistance observed among the bread wheat Cultivars evaluated at seedling stage as all cultivars allowed lesion formation by the pathogen. Infection type ranged from fleck 1 to 3+ were observed revealing that different genes in both the pathogens and hosts. The percentage and frequency result indicates, >60% of cultivars were showed resistant reaction to TKKTF race than other races. The most virulent and frequently infecting cultivar in current study to 50% of evaluated cultivars was TTKTF race than rest of strains. Moreover, Cluster analysis result indicates, cultivar Huluka, Lemu, Shorima, Hogana, Wane, Millennium, Honqolo and Biqa was classified to moderately resistant to resistance class. Among which cultivars Shorima, Huluka, Millennium and Wane showed stem rust seedling resistance reactions to all races. These bread wheat cultivars tested showed resistance reaction implying the presence of seedling resistance gene and can be used as the potential sources of resistance in the wheat breeding program. Further research should be conducted with the same cultivars against those emerging and remerging races for their polygenic resistance, which is additional indicator of crops reaction at a field.

Keywords: Bread wheat; Cultivar; Evaluation; Seedling resistance; Stem rust

INTRODUCTION

Ethiopia is known as the center of diversity for two of the cultivated tetraploid wheat, viz durum wheat (*Triticum durum*) and cultivated emmer wheat (*T. diccocum*). Bread wheat (*T. aestivum*) on the other hand, is an introduced species [1]. The low wheat yield on farmers' field could be attributed to biotic, abiotic and socioeconomic constraints. Among the biotic factors, diseases are economically important, causing the major yield losses on the crop. Stem rust of wheat caused by the fungus *Puccinia graminis f.sp.tritici* is the most destructive disease causing heavy damages particularly, at altitudes below 2300 meter above sea level.

Various control options are available for combating stem rust. The use of resistant varieties has been the most effective means in low input agriculture [2]. Until recently, stem rust of wheat has been

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successfully controlled through genetic resistance [3]. However, the emergence of a new race, TTKSK had been threatened wheat production globally [4,5] and currently new races like TKKTF, TTKTF, TKTTF, TTRTF and TTKTT being threatened wheat production in Ethiopia [6,7]. The common cultivars currently grown in Ethiopia as well as majority of advanced breeding germplasm of Ethiopia are succumbing to most races currently emerging [8]. Most of Ethiopian wheat cultivars were known to have *SrTmp*, *Sr38*, *Sr24* and Sr31 genes [8]. However *Sr24* gene, a known resistance gene in Ethiopia is being reported to susceptible to TTKTT race [7]. The presence of virulent race to 19 of *Sr* gene and additional report virulence on all of *Sr* in Ethiopia including *Sr24* makes a need of evaluating Ethiopian wheat cultivars to emerging and reemerged race. In addition searching for such stem rust resistance genes in commercial cultivars is advantageous, as it could quickly be transferred into other adapted wheat backgrounds without any undesired traits. Thus, the evaluation of commercial wheat is an important step in breeding for wheat stem rust resistance and identification of sources of resistance in current wheat breeding programs and eventually for sustainable production of the crop. Hence, the present study is aimed to evaluate the reaction of wheat genotypes against the virulent dominant races of stem rust for their major gene resistance and sustain wheat production in the western and southwestern zones of Ethiopia.

MATERIALS AND METHODS

Description of the study site

The evaluations of bread wheat cultivars were done at Ambo Agricultural Research Center. It is located at 08°96' 885"N latitude and 37°85'923"E longitudes and at an altitude of 2147 m.a.s.l. The annual average temperature and rainfall are 27.54°C and 1077.68 mm respectively.

Raising seedling

The test materials included 22 bread wheat varieties selected from cultivars released periodically from Kulumsa and Holeta Agricultural Research Centers. These cultivars are grown in several wheat growing areas including western and southwestern Ethiopia [9]. Susceptible variety McNair was also included for comparison as a check and for determining the viability of spores inoculated on the wheat cultivars. Seeds of twenty two cultivars and a check McNair were planted in plastic pots of 5 cm diameters filled with soil, sand and farmyard manure mixed in proportion of 2:1:1, respectively, in three replicates. The materials were evaluated in Complete Randomized Design by three replications in the greenhouse (Figure 1).

Inoculation

The urediospores of virulent dominant stem rust races previously identified in Ethiopia; TTKSK and those detected in the present race analysis study; TKKTF, TTKTF, TKTTF, TTRTF and TTKTT were multiplied on the susceptible variety and maintained in separate test tubes for inoculation. Urediospores of the races were inoculated on to seven-day-old seedlings, when on the first leaf fully expanded and the second leaf just emerged at the rate of 4-5 mg spores per 1 ml lightweight mineral oil suspension. Then, inoculated plants were moistened with fine droplets of distilled water using atomizer [10].

After 30 minutes of inoculation, seedlings were placed in a dew chamber for 18 hrs dark periods at 18-22°C and 98%-100% Relative Humidity (RH) followed by exposure to light for 4 hrs to provide a favorable condition for stem rust infection. Seedlings were then allowed to dry/remove dew/moisture for about 1-2 hrs. Following this, the seedlings were transferred from dew chamber to glass compartments in the greenhouse where conditions was regulated at 12 hrs photoperiod, and a temperature range of 18-25°C and RH of 60%-70%.

Infection and resistance classification

Fourteen days after inoculation, the reaction of cultivars was evaluated and classified according to scale described by as indicated in Table 1 below. In cultivar selection, IT score against single race cannot always guarantee the selection of that material for further breeding program, the overall response is crucial [10]. Based on the IT score against overall six race of stem rust, cultivars were classified into cluster group in the range of resistant to susceptible reaction (Table 2).

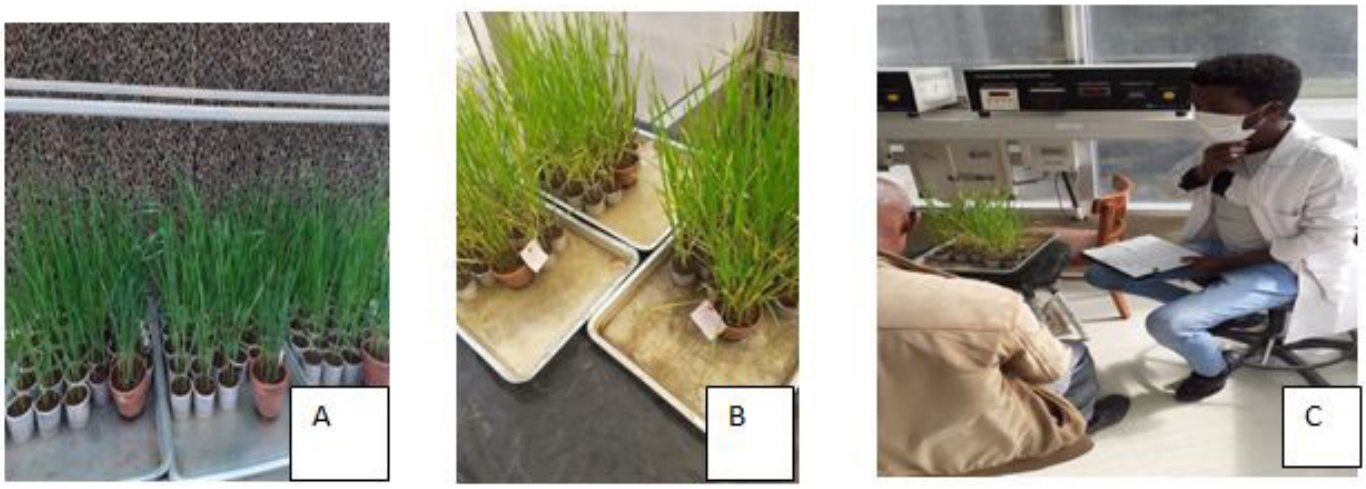

Figure 1: (A) Inoculated bread wheat cultivars against dominant *Puccinia graminis f.sp.tritici* races; (B) Developed IT by *Puccinia graminis f.sp.tritici* after 14 days of inoculation; (C) Scoring of infection type on seedling.

Table 1: Description of infection types used in classifying the reactions to stem rust (*Puccinia graminis f.sp.tritici*).

Class	IT	Description of symptom
Immune	0	No sign of infection to the naked eye
Very resistant	0;	No uredia, but distinct flakes of varying sizes, usually a chlorotic yellow but occasionally necrotic
Resistant	1	Small uredia surrounded by yellow chlorotic and necrotic area
Moderately resistant	2	Small to medium sized uredia, typically in a dark green island surrounded by a chlorotic area
Mesothentic/heterogeneous	X	A range of infection type from resistant to susceptible scattered randomly on a single leaf caused by a single isolate not a minute
Moderately susceptible	3	Medium sized uredia, usually surrounded by a light green chlorotic
Susceptible	4	Large uredia with limited amount of chlorotic; may be diamond shaped
	Modified character	
Lower uredinia	=	Uredia much smaller than typical and at the lower limit of the IT
Small uredinia	_	Uredia smaller than normal
Larger uredinia	+	Uredia larger than normal
Largest uredinia	++	Uredia much larger than typical and at the upper limit for the IT

Note: *IT=Infection Type, Where: The IT readings of 3 (medium-size uredia with/without chlorosis) and 4 (large uredia without chlorosis or necrosis) were regarded as susceptible. Other readings, i.e., 0 (immune or fleck), 1 (small uredia with necrosis) and 2 (small to medium uredia with chlorosis or necrosis) were resistant.

Table 2: List of bread wheat cultivars evaluated for their monogenic resistance.

Cultivars name	Year of release	Breeder/ Maintainer	Pedigree
Daka	2018	KARC/EIAR	NA
Balcha	2018	KARC/EIAR	NA
Shorima	2011	KARC/EIAR	UTQE96/3/PYN/BAU//Milan
Hidassie	2012	KARC/EIAR	YANAC/3/PRL/SARA//TSI/VEE#5/4/CROC 1/AE.SQUAROSA(224)//OPATTA
Huluka	2011	KARC/EIAR	UTQE96/3/PYN/BAU//Milan
Digalu	2005	KARC/EIAR	Sha 7 / Kauz
Hogana	2011	KARC/EIAR	PYN/BAU//MILAN
Ogolcho	2012	KARC/EIAR	WORRAKATTA/2*PASTOR
Alidoro	2007	HARC/EIAR	HK-14-R251
Wane	NA	NA	NA
Hawi	1999	KARC/EIAR	CHIL/PRL
Danda'a	2010	KARC/EIAR	Kiritati//2*PBW65/2*Seri.1B

Kakaba	2010	KARC/EIAR	Kititati//Seri/Rayon
Honqolo	2014	NA	NA
Biqa	2014	NA	NA
Lemu	NA	NA	NA
Kubsa	1995	KARC/EIAR	NDG9144//KAL/BB/YAC"S"/4VEE#5"S"
Millennium	2007	KARC/EIAR	ALD/CEP75630//CEP75234/PT7219/3/BUC/BIY/4/
Kingbird	2015	KARC/EIAR	TAM-200/TUI/6/PABON-F 76//CARIANC A422/ANAH UAC75/5/BOBWHITE/CROW// BUCKBUCK/PAVON
Sulla	NA	NA	NA
ET-13A2	1981	KARC/EIAR	UQ 105 SEL. X ENKOY
Mitike	1994	KARC/EIAR	(FSYR20.6/87BOW28) X (RBC (ET1297))
McNair	NA	AARC/EIAR	NA

Note: NA=Not Available, Source: Kulumsa Agricultural Research Center (KARC/EIAR).

Statistical analysis

Descriptive statistics analysis were done for qualitative data like frequency of infection and percentage reaction of cultivars by using SPSS and Cluster analysis were done based on IT score using SAS software version 9.3 [11,12].

RESULTS

A Greenhouse screening at seedling stage showed that bread wheat cultivars differed in their reaction to stem rust races; TTKTT, TTKTF, TKTTF, TKKTF, TTKSK and TTRTF (Table 3). No cultivars gave complete resistance. Resistant cultivars had infection types ranging from fleck one (1-2+) with frequently occurring infection of "2+". Of 22 tested cultivars; Daka, Balcha, Huluka, Shorima, Ogolcho, Wane, Kakaba, Honqolo, Biqa, Millennium, kingbird and Mitike exhibited resistance to TTKTT virulent races 1 to 2+. About half of tested cultivars were susceptible to TTKTT race i.e., infection type 3- to 3.

TTKTF race was virulent to 50% of cultivars; Shorima, Huluka, Hogana, Hawi, Honqolo, Biqa, Lemu, Millennium, Kingbird and Sulla cultivars were resistant to TTKTF race with infection type of ;1 to 2+. While rest of cultivars were susceptible to TTKTF race with different degree of reaction ranging from 3- to 3.

A Digalu race, TKTTF was virulent to 40.9% of cultivar including Digalu variety while Genotypes like Balcha, Shorima, Huluka, Hogana, Ogolcho, Wane, Hawi, Kakaba, Biqa, Lemu, Millennium, Sulla and ET-13A2 showed resistant reaction which accounts 59.1% of cultivars. Thirteen wheat cultivars which is more than half (59.1%) of cultivars under test namely, Daka, Balcha, Digalu, Shorima, Huluka, Hogana, Wane, Ogolcho, Hawi, Honqolo, Lemu, Millennium, and kingbird showed resistant reaction to TTKSK (IT=;1 to 2+) races but a known high yielding cultivars like Hidase, Danda'a, Kakaba, Kubsa and other cultivars were susceptible to TTKSK (Ug99) race (IT=3-).

TKKTF race was virulent to 32.46% of cultivars and avirulent on 63.64% of cultivars; Balcha, Shorima, Huluka, Hogana, Ogolcho, Wane, Danda'a, Kakaba, Honqolo, Lemu, Kubsa, Millennium, Sulla and ET-13A2 with variable resistant infection type (;1 to 2+). TTRTF had a virulence pattern similar to TKKTF race. However, more number of cultivars was susceptible (45.46%) to TTRTF races than TKKTF. Of 22 genotypes, Shorima, Huluka, Hogana, Alidoro, Wane, Danda'a, Honqolo, Biqa, Lemu, Kubsa, Millennium, and Sulla which account 54.54% of cultivars were resistant to TTRTF race.

The frequency and Percentage of resistance and susceptibility of cultivars to race were not similar. Out of total 22 bread wheat cultivars evaluated; 54.54%, 50%, 59.1%, 63.6%, 54.54% and 54.54% were resistant to TTKTT, TTKTF, TKTTF, TKKTF, TTKSK and TTRTF races, respectively (Figure 2). Infection type coding resistance was ranging from (;1- flecks) to (2+) whereby- the frequent infection type mostly displayed was "2+" on the primary leaves of the seedling.

On the other hand; 45.46%, 50%, 40.9%, 36.4%, 45.46% and 45.46% varieties were susceptible to TTKTT, TTKTF, TKTTF, TKKTF, TTKSK and TTRTF races respectively. Moreover, high frequency of 63.6% and 59.09% of bread wheat varieties were resistance to TKKTF and TKTTF races respectively, with low infection types ranging from (flecks) to (2+). The high frequency of susceptibility was 50% for TTKTF followed by TTKSK, TTRTF and TTKTT which 45.45% of the evaluated varieties susceptible.

Beyond evaluation of cultivars to single race, the overall classifications of cultivars reaction to 6 races of stem rust were exhibited below by (Figure 3) cluster analysis.

Table 3: Reactions of bread wheat cultivars to dominant stem rust races at seedling stage, Ambo Agricultural Research Center, rust laboratory.

Cultivars	**Sr-genes	Host reaction (IT) to races					
		TTKTT	TTKTF	TKTTF	TKKTF	TTKSK	TTRTF
Daka	*Sr?*	2	3	3-	3-	2+	3-
Balcha	*Sr?*	2-	3-	2+	2+	2	3-
Shorima	*Sr24*	2-	2-	;1	2-	;1	2-
Hidase	*SrTmp*	3	3-	3	3	3-	3-
Huluka	*Sr24*	2	2	;1+	2	2-	2-
Digalu	*SrTmp*,Sr38	3-	3-	3-	3-	2+	3-
Hogana	*Sr24*	3-	2	2-	2	2	;1
Ogolcho	*Sr24*	2+	3-	2-	2+	2	3-
Alidoro	*Sr24*	3-	3-	3-	3-	3-	;1
Wane	*Sr?*	2-	2-	2	2	2	2+
Hawi	*Sr30+/31*	3-	2-	2+	3-	2+	3-
Danda'a	*APR*	3-	3-	3-	2+	3-	2+
Kakaba	*APR*	;1+	3	2+	2+	3-	3-
Honqolo	*Sr24*	;1+	2	3-	2+	2	2
Biqa	*Sr?*	;1	2	2+	3-	3-	;1
Lemu	*Sr?*	3-	2	;1+	2-	2-	2+
Kubsa	*APR*	3-	3-	3	2+	3-	2+
Millennium	*Sr24*	2+	2-	2	2	2	2
Kingbird	*Sr2,Sr57/L4*	2+	2+	3-	3-	2+	3-
Sulla	*Sr?*	3-	2+	2+	2+	3-	2+
ET-13A2	*Sr?*	3	3-	2	2	3-	3-
Mitike	*Sr?*	;1	3-	3-	3-	3-	3-
McNair	*McN*	3	3-	3+	3	3	3

Note: *The scale described with ITs=; 1, 2 considered resistant and 3, 4 considered susceptible. Negative (-)=smaller uredinia than the normal size and+larger than the normal uredinia. Sr?=unknown resistant gene **.

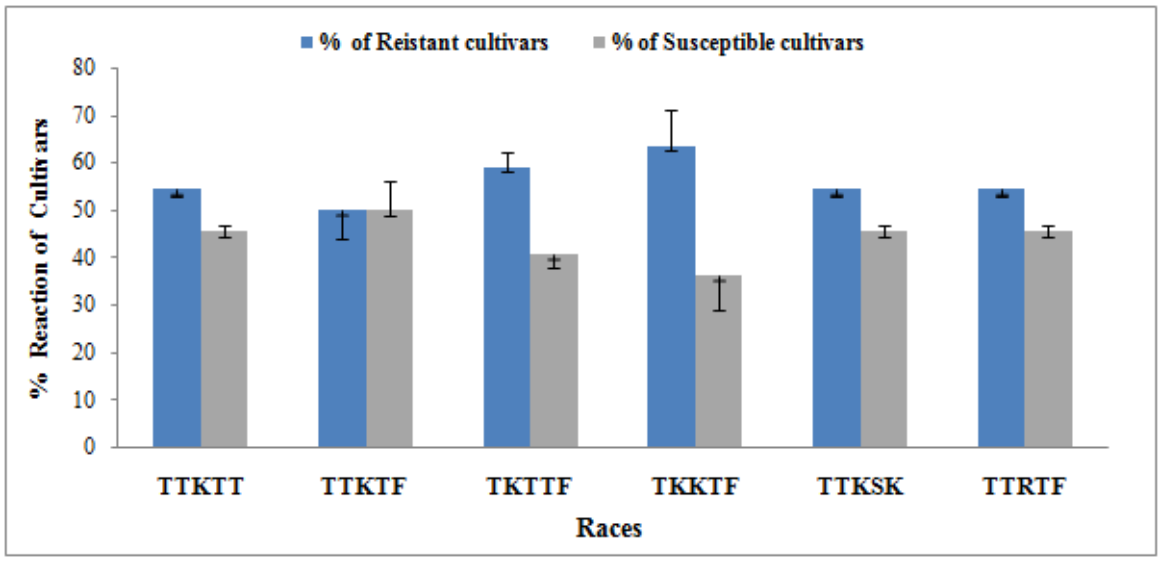

Figure 2: Percentage number of cultivars exhibiting a resistant and susceptible reaction.

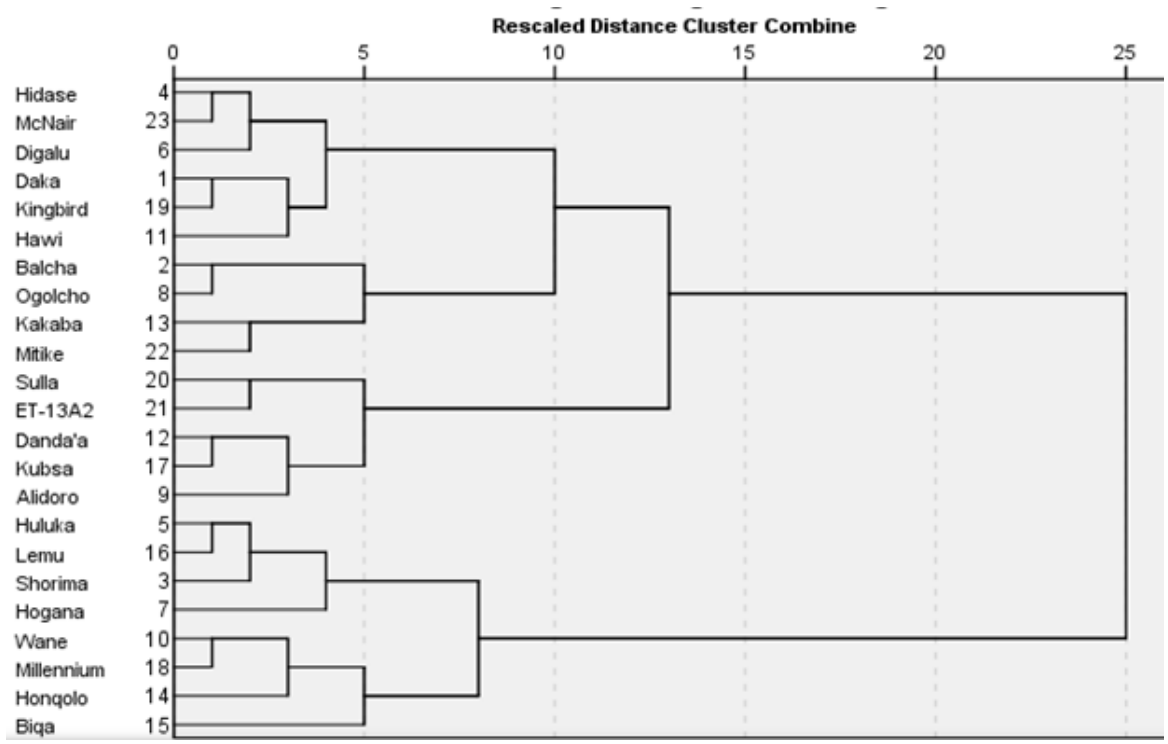

Figure 3: Hierarchical clusters of 22 wheat cultivars and 1 Universal susceptible McNair based on host reaction (IT) to races of wheat stem rust.

DISCUSSION

Among tested Cultivars Shorima, Huluka, Wane, Millennium, Hogana, Alidoro and Honqolo were postulated to have *Sr24* gene while Hidase (*SrTmp*), Digalu (*SrTmp*), Kingbird (APR), Danda'a (APR) and Kakaba have Adult plant resistance genes [8].

Susceptible cultivars, Digalu was introduced in 2005 to provide protection against the Ug99 race [13] and serve as resistant genotype since the outbreak report of TKTTF race [14]. However, Digalu (carrying *SrTmp*) was susceptible to race TKTTF that first detected in Ethiopia in 2013. The susceptibility of currently high yielding bread wheat cultivars such as Digalu, Kakaba and Kubsa to TKTTF indicated the potential threat of this race in wheat production in the country. Danda'a and Kakaba showed susceptibility to TTKSK (3- to 3) in the greenhouse evaluation [15]. It was confirmed that Danda'a and Kakaba, a stem rust resistant cultivars that their demand by farmers and seed producer increased throughout the country featuring adult plant resistance or minor gene resistance to stem rust. Moreover seedling infection types (3 to 3+) by Danda'a and Kubsa cultivars in response to TTKSK races of Pgt is also clear indication of increased in susceptibility of the two cultivars [8].

TKKTF race had low virulence spectrum with low frequency of virulence to universal gene of differential set in current study. As a result most cultivars in evaluation were resistant to TKKTF race. The resistant cultivars tested against this race contain either of *Sr11*, *Sr24*, *Sr31* and *Sr36* genes [8]. Four cultivars namely Huluka, Shorima, Wane and Millennium had resistance infections represented by infection ranging from ";" or fleck to 2+ to all races, indicating that the presence of seedling resistance genes in these host cultivars to effectively manage these virulent races. Two Cultivars, namely Lemu and Hogana exhibited resistance to all virulent races except to TTKTT race.

Cultivars, Hogana and Lemu were resistant (IT;1 to 2+) to all races except TKTTF and Digalu (*SrTmp*) was susceptible to all race except TTKSK, whereas Cultivar Hidassie (*SrTmp*) showed susceptible reaction as high as 3- to 3 to all used races. In this study, Danda'a and Kakaba cultivars were susceptible to TTKSK (Ug99) which is in line with [15] who reported susceptibility of both Danda'a and Kakaba to TTKSK races with a reaction of 3- to 3.

Hawi was susceptible to TTKTT, TKKTF, TTKSK and TTRTF races showing reaction type (3- to 3). Resistance gene postulation studies have suggested that cultivar seedling stem rust resistance gene(s), *Sr30+/Sr31* [8], Hawi has not been effective to the virulent stem rust races in the major wheat growing regions of Ethiopia [16-18]. According to the report Danda'a and Kakaba are the two stem rust resistant cultivars that are characterized by adult plant resistance and are highly demanded by farmers and seed producers throughout the country. The two cultivars are currently sustaining increased disease pressure under field conditions, most probably because of low level of adult plant genetic resistance and weather variability influencing the efficacy of adult plant resistances.

Other report also indicated that Digalu (currently known to have *SrTmp* and *Sr38*) variety was resistant to TTKSK race at seedling stage due to the presence of *SrTmp* and *Sr38* resistance genes [16,17]. Eleven wheat cultivars namely, Daka, Balcha, Shorima (*Sr24*), Huluka (*Sr24*), Wane, Ogolcho (*Sr24*), Hawi, Honqolo (*Sr24*), Lemu, Millennium (*Sr24*), and kingbird (APR) showed resistant reaction to TTKSK (Ug99) races whereas Digalu and Hidase showed susceptible to TTKSK race. Digalu cultivar was introduced in 2005 to provide protection against the Ug99 (TTKSK) race [15]. Four of these cultivars have possessed *Sr24* an effective resistance gene to all races except TTKTT prevailing in Ethiopia.

Cultivar released to farmer with seedling or whole stage resistance stay under production commonly for few years since its adaptation

to newly evolving virulent races in the pathogen population. Likewise, Digalu carrying *SrTmp* and sustained wheat production in Ethiopia for some years has become susceptible to new virulent race TKTTF that first detected in 2013 and damaged significant wheat production both in 2013 and 2014 [14]. *SrTmp* is also ineffective to UG99 [19]. The susceptibility of currently high yielding bread wheat varieties such as Digalu, Kakaba and Kubsa to race TKTTF justify the need for removal of these cultivars from production and introducing TKTTF resistant cultivars to farmers and sustain wheat productions.

Cultivars Hidassie, Digalu, Alidoro, Danda'a, Kubsa, Sulla and ET-13A2 were susceptible to TTKTT and TTKSK races (3- to 3). Nevertheless, cultivars like Alidoro, Danda'a, Kubsa, Sulla and ET-13A2 also susceptible to TTRTF race. Mitike was susceptible to five virulent races i.e., TKTTF, TTKSK, TTRTF, TTKTF and TKKTF but resistance to TTKTT races whereas ET-13A2 cultivar was susceptible to all virulent races tested but resistant to TKKTF and TKTTF races and this cultivar is also susceptible to TTKSK race at the seedling stage [16,18]. Balcha and Daka, recently released cultivars were susceptible to TTKTF and TTRTF races, but resistant to TTKTT and TTKSK races. Ogolcho, one of the widely grown cultivars revealed resistance to all virulent races, but susceptible to TTKTF and TTRTF races.

The seedling evaluation result indicated that most cultivars were susceptible to TTKTF race indicating that these cultivars lack sufficient all seedling resistance that withstand this virulent race. Honqolo was resistant to all virulent races except to TKTTF race with infection level of 3-. Biqa cultivar showed resistance to TTKTT, TTKTF, TKTTF and TTRTF and susceptible to TKKTF and TTKSK races. Kubsa was susceptible to all races except to TTKSK and TTRTF races whereas Kingbird, a cultivar possessing adult plant resistance was susceptible to TKTTF, TKKTF and TTRTF [8] whereas resistant to rest of races used in this study indicating that this cultivar may have all stage resistance to some races used in present study like TTKTT, TTKSK and TTKTF.

Moreover, cluster analysis result indicates, cultivars was classified to three cluster Class, where Hidase, Mcnair, Digalu, Daka, kingbird, Hawi, Balcha, Ogolcho, Kakaba, Mitike classified to Moderately susceptible to susceptible reaction class; Sulla, ET-13A2, Danda'a, Kubsa, Alidoro to Moderatey susceptible to moderately resistant class and cultivar Huluka, Lemu, Shorima, Hogana, Wane, Millennium, Honqolo and Biqa was classified to Moderately resistant to resistance class.

Thus, Cultivars Huluka, Shorima, Wane and Millennium was found in 3rd cluster class which is resistant to all of 6 wheat stem rust race (TTKTT,TKKTF,TTTTF,TTRTF, TKTTF TTKTF and TTKSK races) showing hypersensitive reaction.

A Susceptible, McNair being found under 3rd cluster class was heavily infected and exhibited the expected compatible IT's ranging from 3- to 3+ for all stem rust races. This infection type indicated successful inoculation and high level of infection in experiment. This in turn allowed for the reliable scoring of IT's in all wheat cultivars. McNair 701 (*SrMcN*) was susceptible to all of the races identified and it was universal susceptible cultivar [17].

Most of the released bread wheat varieties in country become susceptible to stem rust, commonly in some years after their release. This is caused by either introduction of exotic races or newly and locally evolved virulent races to commercial cultivars in production under favorable environmental factors [13,20]. Modernizing a breeding science to develop stem rust-resistant wheat varieties is valuable and can definitely contribute to the increment of wheat production in Ethiopia.

Changing temperature and rainfall patterns in other way have encouraged the emergence of new stem rust races that overcome the currently resistant and popularly grown wheat varieties remain at constant stake of losing their resistance to it [21]. They also report that pressures on food security, across the globe are being made worse by plant diseases that are emerging more frequently and spreading very rapidly. Among such disease, wheat stem rust or black rust take the first rank.

None of the tested genotypes were immune to stem rust infection. Out of the tested bread wheat genotypes, some varieties recorded low infection types (fleck (;) to 2+). These could be emanated from genotypes carry effective race-specific or seedling stem rust resistance genes to the virulent races. Seedling resistance called *R* genes, are pathogen race specific in their action, effective at all plant growth stages and probably mostly encode immune receptors of the nucleotide binding leucine rich repeat class [22]. This resistance can be responsible for a large amount of the resistance to a particular race of a pathogen in their action and effective through all plant growth stages, it functions against certain stem rust races or biotypes but not against others [23,24].

Monogenic resistance can be very helpful and can sometimes offer the plant near immunity against a specific race of the pathogen. This is the reason that seedling type of resistance can offers complete resistance against specific pathogen and has been used for years and is frequently very successful. However, in almost all cases the pathogen overcome effectiveness of the genes because of once a seedling resistance gene is discovered it is often deployed over a broad area, which exposes the gene to incredible amounts of inoculums [25].

Low infection types scored on some of the varieties evaluated against virulent races in current study could be due to the presence of one or more major stem rust genes. This result is in agreement with low infection types at seedling stage could be either due to one or more of the stem rust genes or a combination that had similar infection type pattern towards the races [26]. Major gene resistance/seedling resistance can offer complete protection and significant economic benefits to farmers. Therefore, such like varieties can be used as sources of stem rust resistance when the aim of the breeding program is for the major gene.

Contrary to the use of seedling resistance, a weakness with the use of *R* genes is the difficulty in assuring that the best and most durable combination of *R* genes ("gene stewardship") are deployed effectively across international frontiers which new rust pathogen races can easily spread by wind [22]. Additionally stem rust resistance at the seedling stage may not be indicative of the reaction at the adult plant stage because some genes are effective only at specific growth stages [26] and cultivars that exhibited high infection type may display minor gene resistance at adult plant stage. Despite this seedling resistance has been easy to evaluate on a large scale under environment-controlled conditions and is highly correlated with stem rust resistance at the adult plant stage; the method has been widely used to evaluate stem rust resistance of wheat materials. Moreover, Priority materials to be used for developing cultivars were combining non-race specific and race specific genes which is more durable than cultivars with major resistance gene effect [8].

CONCLUSION

A wheat rust, stem rust in particular is emerging and re-emerging diseases. The nature of rust disease, having two alternatives host and its high evolution rate makes a series wheat pathogen. Therefore the loss of resistance gene in wheat cultivars over time and evolution of avirulent gene in existed stem rust race through time requires periodical evaluation of resistance materials. Inspite, out of evaluated materials in current study about four wheat cultivars were non compatible to all of race implies those material can be used for production and it can also serve as source of resistance for further breeding program. In conclusion, stem rust resistance breeding programs working with parents' of known stem rust resistance gene is more efficient in stacking known *Sr* resistance genes into a single cultivar. Therefore, Shorima, Huluka, Wane and millennium were moderately resistance to resistance to all races in current study and can be used as source of resistance in combating the problem of wheat stem rust. Being resistance at present does not mean they can be resistance forever; it needs periodical evaluation to escape of new race epidemics.

SUPPLEMENTARY INFORMATION

The supplementary Information supporting current work is available upon reasonable requesting of authors.

AUTHOR CONTRIBUTIONS

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CONFLICTS OF INTEREST

There is no conflict of interest.

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